Safe Sink Tectonics

Towards a Metabolism of the Built Environment Within Planetary Capacities

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SAFE

SiNK TECTONICS

Towards a
Metabolism
of the Built Environment
within Planetary Capacities

~ *by* ~

. KU .

Kemo USTO

Dissertation Submitted 2023

AALBORG UNIVERSITETSFORLAG

Aalborg University,
Department of Architecture Design & Media technology

To
my family
and their patience.

Dissertation submitted:	24-5-2023
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Dissertation submitted May 2023

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DENMARK

Abstract

This PhD thesis is a theory-building exploration that attempts to build a material-centered and metabolic architectural theory based on two complementary disciplinary frameworks, i.e., that of industrial ecology and tectonic design theory.

Material flows in the built environment are a large and complex dynamic, containing certain paradoxical mechanisms where intentions and material manifestations are sometimes not aligned as intended (Jevons Paradox). As an extension of this, we can observe that the practical and material dimensions of theory building are lacking in architectural theoretical discourse. Specifically, even in cases where architectural theory explicitly centralizes matter, it does not really integrate actual (metabolic) material concerns but only uses matter as a stepping-stone for the legitimization of more and more creative endeavors (and subsequent material flows). To deal with these discrepancies, this doctoral study hypothesized the potentials of juxtaposing industrial ecology (social metabolism) theory and tectonic theory towards the development of a metabolic theory informed by industrial ecology. The questions are thus how such a theory can be built, and what its subsequent analytic and design capacities could bring in terms of new insights and critical reflections?

To explore this, this doctoral thesis structures a systematic interdisciplinary research design by way of a mixed method abductive research approach. It uses a multitude of relevant methods – both in the written papers as well as the dissertation chapters (of building and testing of the theory) – to systematize the exploration and theory development methods are needed: case study, research-by-design, method, literary reviews, and several other methods for working with interdisciplinarity.

The findings resulted in a theory called (im)material metabolism which centralizes the notion of Urban Sink and its nuanced spectrum of five key constructs of material and immaterial considerations which are inter-relational and causal. The application and testing of said theory also brought about new *metabolic* insights. In the instance of an analytic application, the key finding was that of the (im)material surplus which potential performs as a material investment. In the instance of the design application, the theory permitted an exploration of large-scale urban systems of storage sites as a way to deal with large amounts of construction waste. Both the analytic and design capacities allowed for a further linking of other fields to define what is a seemingly abstract "metabolic" understanding of the built environment could entail through the notion of the Urban Sink.

While the theory promoted significant considerations, reflections, and findings concerning material use in the built environment, further research should be done to either explore new facets and trajectories as well as further qualify and substantiate the found considerations and other variants they may have. The theory cannot replace other theories and methods but acts supplementarily to both design theories, methods, and tools.

Abstract (Danish)

Denne ph.d.-afhandling er en udforskning af teori, der forsøger at opbygge en materiale-centreret og metabolisk arkitekturteori baseret på to komplimenterende disciplinære rammer; nemlig den industrielle økologi og tektonik design teori. Materialestrømme i det byggede miljø er en stor og kompleks dynamik, der også indeholder visse paradoksale mekanismer, hvor intentioner og materielle manifestationer ikke altid er i overensstemmelse, (Jevons Paradox). I forlængelse af dette kan vi i den arkitektoniske teoretiske diskurs observere, at den praktiske og materielle dimension af teoriopbygning mangler, selv i tilfælde hvor arkitektonisk teori eksplicit centreres omkring materie, integreres der ikke reelle (metaboliske) materiale hensyn, men anvender blot materie som et springbræt for at legitimere flere og flere kreative initiativer (og efterfølgende materielle strømme). For at imødegå disse diskrepanser, udvikledes en hypotese PhD studiet om potentialet i at sammenstille industriøkologisk (social metabolisme) teori og tektonik teori mod udvikling af en metabolisk teori informeret af industriel økologi. Spørgsmålet er derfor, hvordan en sådan teori kan opbygges, og hvad dens efterfølgende analytiske og designmæssige kapaciteter kan bringe af nye indsigter og kritiske refleksioner? For at udforske dette struktureres PhD undersøgelsen systematiseres med et tværfagligt forskningsdesign ved hjælp af en mixed-method, abduktiv forskningsmetode. Denne PhD undersøgelse bruger en række relevante metoder, både i de skrevne artikler og i afhandlingskapitlerne (til opbygning og test af teorien) til at strukturere og systematisere udforskningen og teoriudviklingen. Dette er gjort ved casestudier, forskning gennem design, metode, litteraturstudier og flere metoder til arbejde med tværfaglighed.

Dette resulterede i teorien, den (im)materiel metabolisme, som centraliserer begrebet Urban Sink, sammen med dens nuancerede spektrum af fem centrale bestanddele af materielle og immaterielle overvejelser, der er indbyrdes afhængige og kausale. Yderligere resulterede anvendelsen og testen af denne teori også i nye metaboliske indsigt. I tilfælde af analytisk anvendelse var den centrale indsigt af det (im)materielle "overskud", som potentielt fungerer som en materiel investering. I tilfælde af designanvendelse tillod teorien en udforskning af storskala urbane systemer af opbevaringssteder som en måde at håndtere store mængder bygningsaffald på. Både de analytiske og designmæssige kapaciteter gjorde det muligt at skabe forbindelse til andre felter for at definere, hvad en tilsyneladende abstrakt "metabolisk" forståelse af det byggede miljø kunne indebære gennem begrebet Urban Sink. Mens teorien fremmede betydelige overvejelser, refleksioner og fund med hensyn til materiale brug i det byggede miljø, bør yderligere forskning udføres for at undersøge nye facetter og retninger og for at yderligere kvalificere og underbygge de fundne overvejelser og undersøge hvilke andre varianter, de kan have. Teorien kan heller ikke erstatte andre teorier, men fungerer som supplement til både teorier, metoder og værktøjer.

Structure and Content: A Reader's Guide

This PhD dissertation is structured in a slightly unusual way given its explorative interdisciplinary trajectory, as it aims to build theory based on two very different theoretical frameworks. Each chapter is thus structured in a dual manner by first elaborating material flow considerations and then correlating the considerations with architectural thinking (theory).

The dissertation starts with an introduction (chapter 1)which maps the challenges and inherent issues regarding the ways the built environment consumes and moves materials. The chapter then maps the tendencies which may be at fault (at least partially) for the lack of insight and challenges of material flows in the practice of architectural theory/theorizing. The chapter ends with a hypothesis that a further reading into industrial ecology and tectonic design theory is pertinent to explore the potential consequence for architecture when juxtaposed with industrial ecology.

Based on the above hypothesis (chapter 1), chapter 2 proceeds to map respectively the state-of-the-art: first industrial ecology theory and then tectonic design theory. With an eye on the theoretical building, the aims of this chapter (2) are to find a middle ground (i.e., of *metabolism*) between the two different theoretical frameworks which would allow a systematic approach to the theory building. After having insight into the disciplines' potentials and key points, it is possible for chapter 2 to end with a Research Question along with two sub-questions that deal with the building and testing of theory in its analysis and design capacities, respectively.

Chapter 3 deals with the methodological systematization of working with two complex disciplines, necessitating a range of interdisciplinary methods—i.e., metaphor, add, adjust, connect – among others.

Chapter 4 deals with the building of theory. While having insight into the state-of-art (chapter 2), this chapter initiates the theory development of this concept by disassembling the two theoretical frameworks to permit a systemic building process. Prior to the testing/application of the developed theory, said theory was of a lesser and more speculative nature. For the sake of effective communication, Chapter 4 of this dissertation presents the "completed" built theory, incorporating the insights gained from testing and applications discussed in Chapters 5 and 6. This approach avoids the need for separate chapters on theory development before and after application. However, Chapters 5 and 6 extensively elaborate on the lessons learned during the process of theory development.

Chapter 5 deals with the analytical testing of the theory and continues as a case study, anachronistic analysis, and critique, respectively.

Chapter 6 deals with the testing of built theory's design capacities. This trajectory proceeds as a Research-by-Design exploration, links with other relevant design trajectories and concludes with a set of normative design considerations.

Chapter 7 is the final and concluding chapter and provides a synthetic overview of theory-building exploration, reflections on methodology and possible future explorations.

Acknowledgments

This PhD study must acknowledge the many people who have made this it possible and have influenced its process of becoming.

Firstly, I must thank the department of Architecture, Design & Media, Technology at Aalborg University for giving me the tremendous opportunity to do research. In particular, I want to thank the staff of this department who have helped and facilitated the many aspects surrounding my research. I am immensely appreciative for the opportunity to work in this environment.

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I thank my former supervisors who had to leave for different reasons. Thanks to Camilla Brunsgaard, who was particularity influential on all things technical concerning sustainability and likewise methodological aspects. Thank you to Marwa Dabaieh with whom I had many great talks and who initially inspired me to dive into industrial metabolic studies.

I did a digital stay-abroad (due to COVID-19) at the Weitzman School of Design at the University of Pennsylvania as part of my stay-abroad during my PhD studies. Franca Trubiano took me in and inspired me. Thank you, Franca, for your impeccable and thorough feedback, inspiring talks, and for providing the space to engage in activities with PhD students at UPenn. I am immensely grateful.

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Though it was just before my PhD studies, I also must thank Anne-Catrin Schultz for whom I contributed a book-chapter. During the development of the said chapter, the many talks with her about architecture served as guidance for me and shifted my own understanding of the architectural discipline which influenced the trajectory of my PhD studies.

Lastly, I must thank my family for their support, sacrifices and patience. Thanks to my mother, my wife, my daughter, my brother – and more generally family and friends who have provided support from close and from afar. Thank you all. Thank God.

Kemo Usto, May 2023

Contents

Chapter 1.
Introduction

This PhD thesis explores the possibility of building theory across disciplines with a focus on challenges of material consumption in the built environment. As the city is behaving as a large-scale organism that has its own metabolic rates of material consumption, the challenge is understanding how such dynamics can be reconsidered concerning limited resources (and planetary capacities) through a critical tectonic design approach to safely handle materials. While this is a brief look into what is to come in later chapters. the purpose of this chapter is to explore the background conditions and possibilities of relevant disciplinary challenges and insights that can be used in the subsequent theory-building efforts.

Chapter 1 gives the background of the dual challenge of material considerations and architectural thinking. The chapter elaborates on the key tendencies of the building industry concerning materials use. Additionally, it juxtaposes the material flows conditions with the "nature" of architectural thinking, allowing for the discernment of discrepancies within architectural theory in terms of material flows concerns. The chapter finally outlines the relevant disciplines and their theoretical frameworks for the later theory development: industrial ecology and tectonic design theory.

1.1. Motivation: Matter vs. Thinking

With modernization and technological development, everything around us seems more and more complex and interconnected. This is also the case for the built environment and is especially true in the face of resource scarcity and climate change. What otherwise should have been a simple profession of "four walls and a roof" (De Graaf 2017), architecture is becoming more and more complex as a result of having to integrate multiple knowledge forms from multiple disciplines while facing social, economic and environmental challenges. The difficulty of such integration also increases because architecture as a profession has branched out into many "sub-professions" such an urban design, building design, planning etc., and architecture.

1.1.1. The Backdrop

Considering these frustrations, the first seed planted for this PhD thesis is rooted in a book chapter I wrote before my PhD study. The book chapter "Real Architecture – the object (cause) of desire" (Usto 2020)—is a philosophical and speculative/polemical paper on the complex ontological nature of architecture which attempts to consider empirical conditions of architecture as well as metaphysical legitimizations as a whole. This chapter, along with another paper (Usto 2019) was a kind of "shots in the dark" although they did have their own legitimacy. Unknown at the time, both of the papers had significant metabolic implications and potentials but lacked rigor regarding becoming an applicable theory and framework relevant for architects, designers, and engineers.

A significant part of my motivation is the interdisciplinary challenges of the built environment. The complexity and difficulty of the built environment contribute to the fact that architecture is a complex entity with many disciplines, professions, and fields. This complexity is why I remain fascinated by it. Architecture is a kind of slippery Thing which can trick you into thinking you have finally understood it but something always eludes your grasp of it. The building industry or building culture (architecture included) can be considered by what in System Theory and Complexity Science is categorized as a Complex Adaptive System (CAS). This categorization is in and of itself a part of a larger network of socio-economic, cultural, and natural conditions. As scholars have indicated, CAS is "at the heart of many contemporary problems" (Holland 2006) – i.e., be anything from ecosystems, cities, markets etc., – and thus constitutes what scholars in interdisciplinary research have categorized as a "wicked problem" (Keestra et al 2016). Even in this push toward system-thinking in architecture and planning, some potentially essential aspects of the building industry are slipping through the grasp of the *system* such as *architecture-itself* (spatial character, experience, spatial quality etc.) (Autrup 2021).

It is difficult to change the building industry, as it is a complex phenomenon involving market forces, legislation, demographic shifts, trends etc. Perhaps a modest contribution can be made by juxtaposing architecture with an engineering discipline to try to re-actualize the importance of architectural design thinking and hopefully provide theoretical simplicity to the vast complexity.

1.1.2. Architecture With Engineering – or Apollon et Medusa

Keeping in mind the challenges of complexity and integration of disciplines within architectural discourse, we have seen historical and ongoing examples of both practice and theory integrating technical engineering considerations with architectural ones. Historically one could perhaps argue that the field of "engineer" was inherent to the position of the architect, but in modern times these fields became separate professions and disciplines which again would overlap and be integrated. The most significant, and perhaps familiar, has been the integration of structural engineering and architectural design. This has not only been done by taking into account structural aspects in solving spatial problems. There are good examples where designers have actively generated spatial configurations and phenomenological effects grounded in an understanding of material properties aligned with structural geometries to "push the envelope" of what is possible in architecture. Examples of this could be the works by Santiago Calatrava (Tzonis 2007), or the collaborations between Cecil Balmond and OMA (Balmond et al 2007) among others.

There have been other types of integration of engineering into architecture, and indoor climate and MEP/HVAC engineering should be a significant example. Integrating such approaches into architecture can be done by attempting to accommodate technical installations to a predefined spatial setup and its indoor climatic challenges. Importantly, there are examples of how a fundamental understanding of the dynamics of the indoor climate and energy performance allows for spatial configurations which contain unique architectural qualities. This is exemplified in the works and research of Phillipe Rahm (Clement, Rahm 2006) and Isak Worre Foged (2014; 2019) (among others) who apply micro and macro climatic considerations as design drivers.

The integration of engineering considerations with architectural design has become more and more common. The integration of engineering is pertinent given the many challenges that come with the climate and sustainability. It is thus timely to explore yet another engineering field – an engineering field that is highly relevant for the hegemonic dynamics of the building industry and how it consumes materials (its material flows). With all the current emphasis on sustainability, life cycles, circular economies, and material consumption, the very first steps of this doctoral study were concerned with exploring different applied sciences, looking for theoretical and/or methodical frameworks which were pertinent to consider. This search arrived at the theoretical and methodological framework of industrial ecology from chemical engineering. In the following, this will be elaborated on why and how.

1.1.3. Issues of Matter and Thinking

While the current material flows tendencies of societies are manifested through our actions and practices, if we are to make a shift in said patterns of material consumption the challenge is approaching the mental structures and thinking which have manifested said practices. With the abovementioned in mind, the issues in general can be circumscribed into categories of materials and material movement (how building materials are made, constructed, dismantled or demolished in the relations between city and natural environment and generally concerning material finitude and scarcity) and patterns of thinking in societal, aesthetical, cultural aspects which tend to "steer" the movement of physical matter through demand for consumption. Thus, in relation to the built environment and building industry, the fundamental challenge is situating the building industry in material and immaterial beings and relations and conceptualizing such conditions within an architectural discourse in meaningful ways to apply in the architecture and engineering of the built environment.

Nonetheless, materials are understood differently and a variety of epistemological and disciplinary approaches create differences in how materials are either analyzed and observed as well as how they are treated, transformed, and applied. This means the challenges and issues of matter are paired with the need to understand matter from different and relevant disciplines and epistemological positions: the shifting from an understanding of the material being infinite and endlessly malleable to an understanding of material finitude within planetary scarcity.

Unlike the water of a river which flows irrespective of humans, the material flows of society are dependent on their cultures of consumption. Since we are interested in the issues of matter, one should of course acquire a mapping of the flows of materials in the built environment and additionally get an idea of how the mental/ideological inclinations should govern them. While there can be many different cultural facets that sustain material consumption, this thesis is limited to architectural theory as the point of attack/critique. Before we can change anything in practice, we have to change how we think and theorize. Specifically, what is missing in the current theoretical discourse which could address such uncritical use of materials? The assumption is to thus attempt a contribution that may not make a significant dent in the current modes of operation and practice in the building industry but at least lay grounds for different perspectives and considerations and discussions.

There are many different tools, methods and theories which have or could have immense consequences for architectural thinking. Firstly, the realm of material consumption and material flows are in themselves very complex, and there is more and more literature being written on what architecture and design has to implement to be more sustainable path. Needless to say, it can sometimes be difficult to wrap one's head around the many different theories, tools, and methods and how they influence material consumption. While more and more data and scientific findings on climate change (IPCC 2022) and material consumption (European Commission 2021) is coming to light, it can be difficult to absorb and "architecturalize" such data and knowledge and understand the architectural consequences of it. Generally speaking, architects and designers/thinkers within built environments disciplines and professions need their own architectural way of thinking which is inherently sensitive to material (pre)conditions. To do this, we need an overview of material consumptions juxtaposed with the structures of architectural thinking (theory) to first find gaps and discrepancies before initiating the theory building.

1.2. Pertinent Currents in Material flows

This section has a dual purpose. Firstly, the key mechanism and tendencies in material flows are mapped. Secondly, tendencies in architectural theory development and what kind of misalignments are present in architectural theory are compared which could prevent adopting a more ecological way of thinking the built environment. Starting with the materials flows, the section outlines the general material flows tendencies

(1.2.1), the shift to circular thinking and the challenges linked with that shift (1.2.2). Finally, the section concludes by emphasizing the immense risk of different forms of entanglement and the so-called "take-back-effect" (or Jevons Paradox), which can be a problematic phenomenon in the built environment (1.2.3).

1.2.1. Material Flows in the Built Environment

Chemical engineering literature elaborates that a modern city compared to a medieval city (which have the same size) consumes materials by an order of magnitude (Brunner et al 1994), and since 1970 those material flows have almost tripled (IRP, 2019). This increase in material flows means that there is a larger accumulation of materials within societal infrastructure, and it is projected to increase (possibly double) by 2050 (from approximately 80 Giga-tons to 167 Giga-tons) (OECD 2018; European Commission 2021, UNEP 2022). This is transpiring while consumption of non-renewable materials is growing (IRP 2017; European Union 2019).

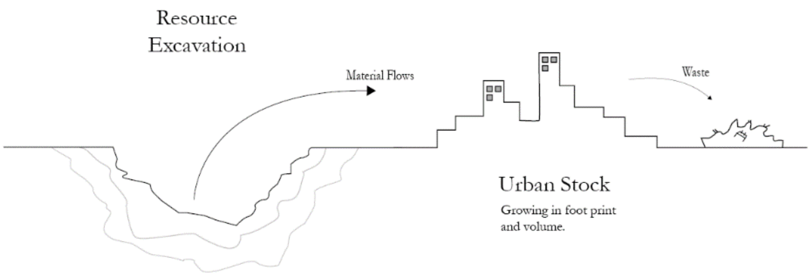

Figure 1. Principle diagram of material flows which increase the building stock in the current "linear" fashion.

Generation of waste is estimated to increase by 70% by 2050 (Kaza et al 2018). Buildings use approximately 40% of extracted recourses (in volumetric amounts) and make up 40% of solid waste in developed countries (IPCC 2018). This puts great pressure on how professionals within the building industry (architects, engineers, etc.) transform and apply these materials more sustainably. Scholars who focus on the aspect of "demolition" in architecture point out that demolition of buildings occurs partially due to buildings being outdated and undesirable in the social and cultural context (Cairns, Jacobs 2013) and not always as a result of material failure and tear. This dimension of demolition is further complicated as authors speculate on the inherence of "demolition" within the building industry. This speculation can create a "circular" dialectic for a dynamic building market. In this regard, Jeremy Till –

architectural practitioner and scholar – shows that the market is indeed not interested in creating flexible housing and is much more interested in demolishing and building to maintain a high activity rate (Till, Schneider, 2005; Goodbun et al 2014). This activity embodies the “planned obsolescence” (or “creative destruction”) of market dynamics where the desire for consumption goes beyond actual material needs (McGowan 2016; Jonsson, Wennerlind 2023).

The aspect of the high activity rates is an indication of the predominant functioning of the building industry and its dependence on demolition which further necessities service and materials/products along with building activity (Cairns, Jacobs 2014; Till 2009). We can thus hypothesize that the current market dynamics define the space (or frame) within which problems can be solved. As Elenora Eberhardt—a researcher on circularity and LCA from an engineering perspective—has indicated, industrial ecology may be too radical as it does not permit an opportunity for profit (Eberhardt 2020). The problem field, as it seems to be defined today, is that we are looking for solutions which will permit the building industry to maintain a high level of dynamic flows and material consumption while being sustainable. It is my assumption that there is an unspoken understanding of the building industry which has almost an implicit “fantasy”, i.e., what we *have to design* a circular building industry where more and more building activity *will* be more sustainable than a slow (and considerate) building industry (and it subsequent material consumption). While this may seem impossible, it is my claim that the general understanding (of the industry) is that this is indeed possible in a circular economy. Design-for-disassembly (DfD), among other strategies, could simply permit the continued input of more and more material and thus the continued growth of the building stock. Both Cairns & Jacobs’ and Till’s elaborations on the central function of demolition in the built environment permit us to develop a hypothesis of the building industry having an implicit yet very systematic agenda of a self-perpetuating loop of “bad circularity.” This “bad circularity” is materialized when we design buildings, they are to some extent poorly made. This could be due to a lack of experiential quality, poor material quality or poor reuse value. Such buildings are usually cheap and fast and get “easily” demolished with little or no outcry from the public. When buildings get demolished, new ones are built which meet the new demands; however, they are at risk of being poorly made and demolished. The high dynamic of the building industry is thus maintained which is reflected by the end goal not being good, flexible, long-lasting buildings which people love and care for, but the very “circular” dynamic of the industry of building/demolishing which maintains profit opportunity and the need for professional services.

Architects are more and more under pressure to deliver projects with less and less time allocated for meeting client and developer needs. This is happening while urbanization continues (Baeumler et al 2021), population increases (UNDESAPD 2022) and there is a rise in floor area pr. capita (International Energy Agency, 2019; Bierwirth, Thomas 2019, pp. 15; EU Buildings Database 2023). All of these tendencies amplify the material increase in building stock and are among other factors that cause an increase in CO_2 emissions which in turn continue to increase global temperature (IPCC 2022). On the "other side" of the great material accumulation within the cities and overall building stock is the degradation of soil and thwarting of biodiversity (IPCC 2019) which partially occurs due to deforestation (ibid), excavations for materials (ibid), and the increasing footprint of urban areas (Du, Mahendra 2019). Environmental literature highlights the importance of land use as crucial (IPCC 2019; IPCC 2019b) which in turn creates pertinence to architectural design and urban planning in possibly limiting the expansion of urban footprint without limiting the lived quality of architectural and recreative spaces.

Figure 2. The growing urban stock and covered area due to urbanization, increase in population and increase in floor area pr. Capita among other parameters.

This means that the structure of the market, given its many agencies, i.e., architects, engineering stakeholders, different material and product manufacturers, all constitute a complicated system which allows for the self-building of new smart cities in the middle of deserts which lay as ruins (Easterling 2016; Wang et al 2019) and uncoordinated building activity beyond actual demand in existing cities (Kjær 2022) which are driven by concerns to increase profit (Love et al, 2012).

Given the increase in urban footprint, increase in population in urban areas, overall population growth, and the increase in floor area pr. capita (Bierwirth, Thomas 2019), the architectural character of the built environment is to be criticized and questioned. There is a great deal being built –whether it is self-built, speculative investment construction or buildings designed by architects (even by so-called starchitects) – and there has been critique of such works due to their overemphasis on creating spectacles without providing meaningful phenomenological and lived quality for people (Buchanan 2015). While recent neuro-aesthetical and brain science has elaborated the potential of aesthetics and heterogenous designs (Chatterjee et al 2021), a recent study elaborates on (lay) people mostly taking a liking to old and classical aesthetics while predominantly disliking bland modern buildings (Mouratidis, Hassan 2020). In other words, there is simply great dissatisfaction among the public regarding different aspects of the contemporary design of the built environment due to the cities lacking varied and meaningful (Kristensen 2020) spaces in engaging human scales (Christiansen 2020; Svenborg 2019).

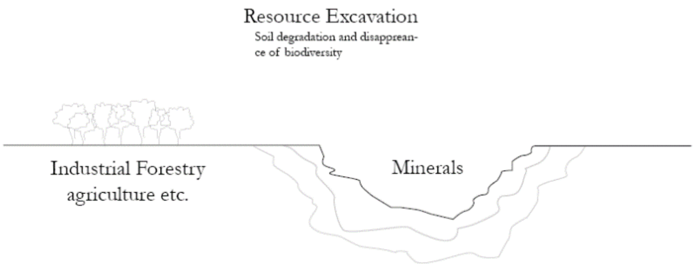

Figure 3. The degradation of soils and biodiversity, and aggressive excavation of hinterlands.

With the tendency to increase building stock, there is little emphasis on the built architectural character (Kristensen 20220; Svenborg 2019) which as we have seen increases the likely hood of demolition and the contribution to construction waste of non-renewable materials. The above-mentioned, although not only constituted by these tendencies, characterizes what is conceptualized as the age of the "Anthropocene" which means that human activity is the factor that is geologically the cause of the greatest flows of matter (Elhacham et al 2020). To this point, the building industry is largely linear (as material consumption is expected to increase), which maintains it within a growth paradigm (Schmelzer 2015).

Material scarcity is also an important issue. This issue is so important that leading researchers are elaborating on the primary future recourse for new buildings being the existing building stock and not virgin material sources. These researchers are exploring different ways to map current building stock for such a scenario (Kleemann et al 2017; Lederer et al, 2021; Honic et al 2023). This means that even if the carbon footprints of any process related to the building would become minuscule compared to now, material capacities and scarcity will remain an issue.

1.2.2. The Shift to Circular ways of thinking

Given these tendencies of the material flows – which have been oncoming for some time – what is to be done to accommodate these challenges? We are seeing a grand shift from a linear to a circular way of thinking from both a scholastic and practice-based perspective as well as a political legislative perspective (Dansk Industri 2023). Awareness is being raised of the circular way of thinking; however, analytical and critical literature has indicated some issues in this transition towards circularity.

Scientific literature on CE has shown that there are (at the time of the paper) 114 different definitions of how CE is conceptualized (Kirchherr et al 2017) and that there are still great challenges to a serious transition to circular ways due to a "lack of business case illustrating possible revenue" (Ritzén, Sandström 2017). It has been noted that the complex disarray of the many conceptualizations of CE makes CE prone to misinterpretation and misuse being conceptualized (Kirchherr, et al, 2017). This prompts the speculation that complex and seemingly well-argued opportunistic "greenwashing" endeavors can fall under the umbrella of CE as well. As Kirchherr et al elaborated, the variety of understandings and conceptualizations of CE "collapse" and end up in a "conceptual deadlock (Kirchherr et al 2017). In this deadlocked situation, there is a great lack of emphasis on the social dimension (Kirchherr et al 2017). While CE possess the ability to attract business opportunities, it needs to strengthen their scientific base regarding achieving sustainability (Korhonen et al 2018).

When it comes to the buildings industry disciplines, architects and architectural engineers have been familiar with working with energy-optimizing designs such as the Passive House concepts, Zero-Energy and other approaches of building operational aspects (Malmqvist, et al 2018) which have been part of a "green" and "sustainable" agenda but – given the great amounts of material flows from natural resources to societal building stock – now is being replaced with a greater emphasis on transitioning to a circular way of thinking and Circular Economy (EU Sustainable Development Goals).

This shift towards circular thinking has come to mean an inclusion of aspects from production, use to waste (Harris et al 2023) and circular economy conceptualization in the building industry which is considered as "restorative" and "regenerative" via principles of "slowing", "narrowing" and "closing" of the circle (Bocken et al 2016; Geissdoerfer et al, 2017) and thus seeks to preserve material resources and stock (Ellen MacArthur Foundation, 2012, 2015a; European Commission, 2020a). Thus, a focus on re-loops (Reike et al., 2018), can create multiple loops potentially inside and outside of a building (Rehberger, Hiete, 2020). The shift towards circular thinking in the building industry is immense, and there is a growing number of conceptualizations and contributions to this end. However, there is still no streamlined and commonly accepted way to conceptualize CE in building (Hart et al, 2019). Contemporary literature on Circular Economy in the building industry by "alignment" with LCA (Life Cycle Assessment) and the predominant model of circular conceptualization is based on the cascading model of the Ellen McArthur Foundation (Ellen Macarthur Foundation 2013; 2015). A recent state-of-the-art paper illustrates a predominant focus on "design for disassembly" (Hvejsel, Beim 2019) along with mapping a number of other different CE design principles (Eberhardt et al 2020). When we CEs applications in the building industry. Concerning life cycles, there has been a clear emphasis on "down-cycling" (Di Maria, et al 2018) which also sees a lesser emphasis on the assessment of environmental performance (Andersen et al 2020). Furthermore, on account of the currently limited approach of mostly single-cycle assessments (Malmquist et al, 2018), there is a need for a more "ambitious" multi-cycle perspective as recently attempted via an alignment of LCA with CE (Eberhardt 2020). Eberhardt et al conducted a literature review, mapping out all the current working CE principles in the building industry (Eberhardt et al 2020). Even so, the authors did not consider the explicit potential of the architectural and tectonic character and its proteins in relation to material flows. The Danish Ministry of Environment postulates that the main strategy for minimizing waste is the "prevention of waste generation" (Miljøministeriet 2021, pp: 25). It is thus possible to postulate that architectural and tectonic character could help with the prevention of waste generation. If this is the case, what are the particular conditions and relations between material aspects and the experiential ones? In extension of this, scholars from a metabolic study circle argue for a need for a trajectory towards working and theorizing of social-natural "hybrids" (Fischer-Kowalski 2003).

The architectural profession is attempting to implement and apply these considerations. Examples such as the Circular House by Danish architects 3XN/GXN (Circular House 2019; Circular House Lab 2020) remaking of waste materials and growth of organic materials (Hebel 2014; 2017) and the Resource Rows, among other projects (Lendager, Pedersen 2020), are precedents of "proof of concept" that it is indeed possible to make circular considerations and reuse waste materials. Such principles, however, are not applied on an industry-wide scale. Rather, when having to reuse waste materials, it is often the case that they are used in the new building. It is however not the practice to apply waste material in an outdoor urban design setting as a recreational space. There is likewise an attempt to make co-called reduction roadmaps which centralize total carbon emissions but not material flows and resources capacities (Reduction Roadmap 2023; Petersen et al 2022), implying that material volumes can circulate "conventionally" as long as their carbon footprint is lowered through a shift to more organic (wood, straw etc.,) construction materials. Perhaps more radically, scholar and urbanist Charlotte Malterre-Barthes suggested construction moratoriums where selective and strategic ceases of the halt of construction could both limit material use and increase social justice (Malterre-Barthes 2023).

Research on clean organic materials is perhaps best epitomized by scholars such as Anne Beim and the research group CINARK at the Copenhagen Art Academy. At the forefront of this particular research is an emphasis on phenomenological quality along with advocacy of less use of highly polluting materials (such as concrete which is non-renewable and becoming scarce) (CINARK 2019) and the advocacy of more clean organic materials such as wood and straw (CINARK 2019). Other Tectonic design literature also engaged with the question of circularity and circular economy which approaches the question of matter from a critical approach (Hvejsel, Beim 2019) but also examines more opportunistic "enabling" conceptualizations by linking and transferring tectonic principles of detailing (assembling) to CE in the building industry (Ejstrup, Munch-Petersen 2019).

General observations and concerns regarding material flows

While circularity is a complex concept and there is still a long way to go to implement circular principles at the core of the design of products and services, many companies are already using circular principles which limits waste, work hours, and saves costs on making, transporting etc. Despite this, there has been a "reluctance" to implement a circular economy due to the lack of possibility of increased revenue which is significantly linked to the current capitalist dynamics of linear material consumption. This is important as within the many and intertwined social, economic, and environmental challenges, there is a significant shift towards more considered use of materials relying on the literature of Circular Economy and life cycle thinking.

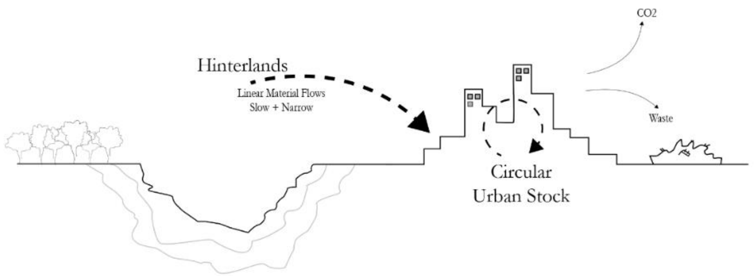

Figure 4. Diagram showing that "circularity" is largely a metaphor, and a need safe handling of end-of-life is still needed.

At the same time, circularity is perhaps not a "radical" enough concept that could provide a different trajectory outside of the current growth and consumption paradigm. The prospect of transferring the omitted/suppressed industrial ecology thinking into architectural discourse could nevertheless hold pertinent potential. An industrial ecology approach may have to demand that we accept that material flows are ultimately linear and that the quest is first and foremost to slow down the flux of materials. Keeping that in mind, one of the ways to do that is to circulate elements and materials.

Figure 5. Linear, despite re-strategies and thus needing safe handling of materials.

CE in its current iterations lacks what is needed to propose significant shifts in its relations to nature (Bianchi, Cordella 2023), and perhaps more radically, the concept of circularity "…will not be able to decisively reduce environmental impacts as it operates in and supports economic growth" (Weidmann 2023). In relation to the above, material consumption is intertwined with the conditions of the social, cultural, and economic "addiction-to-growth" mentality (Constanza 2022). The use of "circular" strategies and design is ideologically a call for a sustainable relationship with nature while practically privileging economic circularity and thus risking the manifestation of continued addiction to growth. This further indicates that even if circularity can exist in some form, it is only partial and mainly operational within the social spheres (cities etc.,), and the circular cascading system is still confined to the "use" phase. Even if the use phase has more and more cascading loops, at some point, a product or parts of it will fail or get demolished thus requiring safe handling (a safe sink). It is thus pertinent to acknowledge that material flows between society and nature will probably forever remain linear, regardless of how many cascading loops are introduced. For this reason, the challenge is to slow down the "metabolic rate" of society. We can introduce material loops which can ultimately minimize the material input into society, but the material flows are still mainly linear. As we currently see, the city (with its current physical, socio-economic, and ideological manifestations) acts mostly as a facilitator which maintains and increases material input into itself (and thus increases waste generation) thus necessitating a re-conceptualization of what the building stock functions are and could be.

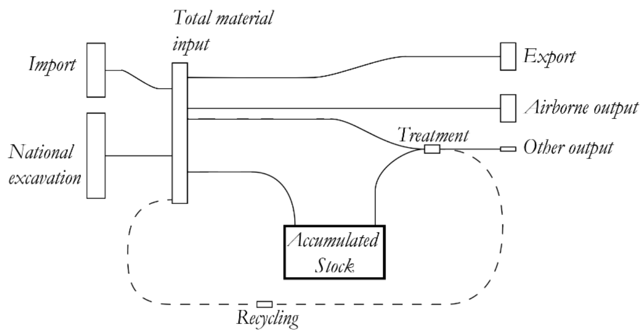

Figure 6. Own redrawing of diagrammatic distribution of material flows from a Danish national perspective (Miljøsyrelsen Affaldsrapporten 2019).

Recent CE literature speculates that hegemonic discourse has "deliberately" moved away from the "industrial ecology" concept due to the lack of the economic dimension while CE is more attuned to business opportunity (Eberhart 2020, pp.23). This simply means that there is an inherent antagonism between making sustainable material flows and making money (at least from the current cultural and social predispositions perspective). The reason for "industrial ecology" being low-key "controversial" is because it approaches the mapping and design of material and energy exchanges between society and nature (*hinterlands)* on metabolic concepts as seen in chemical engineering literature in Material Flow Analysis approaches which possibly prohibits "freedom" for profit-oriented dynamics which are dependent on material use. Furthermore, CE literature points out that there is great risk involved in planning for buildings that are supposed to last for over 200 years (Eberhart 2020) while the risk is lowered for strategies aimed at 30-50 years. The same authors also acknowledge that there is no guarantee that the circular design principles will be realized in the future as they are currently intended (Eberhart 2020). Studying the case of a +200 years life span, it is very clear that phenomenological value and overall architectural character are not part of the estimate. Many such estimations of carbon footprints (or other toxins) are not only here-and-now footprints but also estimates which include considerations of the possible/potential lifespans of buildings and elements within the estimate (Eberhardt et al 2020), indicating an initial footprint can "appropriate" itself over time given a prolonged life span, reusability, circulatory etc.
Since then, and in parallel, more radical ideas are being brought forth from outside the building industry professionals and scholars. These include ideas such as degrowth and decoupling (Hickel 2022; Schmelzer et al 2022) along with pushing for the need to develop an understanding of planetary boundaries and what kind of influence and consequence this could have for the design and building of cities.

Other scholars have attempted to deal with the phenomena of material consumption in the building industry. Specifically, there have also been attempts to systematize the challenges of consumption through theories and models on planetary boundaries

(Habert et al 2020), i.e., the efficient categorization and management of building industry components as systemized into a global carbon budgeting system. The argument is thus, since it is not possible to "budget" architectural character, carbon budgets are not necessarily a guarantee of architectural longevity through multiple uses, architectural character. and appreciated phenomenological characteristics.

However, just as well as systematizing management models and normative systems of organization can hold efficacy, there is likewise a well-documented critique of efficiency optimizations and as such efforts can in turn have non-intended material realizations and consequences which seem paradoxical in relation to the initial intentions.

1.2.3. Challenges of Entanglement and Jevon's Paradox

Related to the above conditions and challenges, the building industry is not a simple system that can easily be straightened out and changed without having grave effects on other conditions. In general, this issue is related to *entangled* conditions (Hodder 2012, 2018; Harman 2014) of not only material resources and their effects on natural environments but also entanglements in the societal, economic and cultural realms.

Jevon's paradox (Polimeni et al. 2009; Sorrell 2009), sometimes called the "take-back effect" or "rebound" (Mavropoulos, Nilsen 2020, pp.9), posits that an optimization/effectivization of a technique/technology will lead to more material use and not less. There have already been observed phenomena in the built environments where questions of improved efficacy have increased consumption empirically. An example of this is the case observed between 1990-2009 where the energy efficiency of European households increased but the final energy consumption also increased instead of decreasing (McGranahan 2015). The literature indicates that these kinds of "optimization" or new technologies tend to create new markets which promote new growth dynamics (Schneider 2012, p.5) which, in turn, necessitates a shift away from a linear economic growth paradigm which challenges the current ideological presuppositions surrounding new optimized technologies. Another exemplification is that of the seemingly irrational tendency that the "worst" projects are the ones that get built (Flyvbjerg 2009). This tendency is connected to many social aspects of the business as usual and the inherent behaviors distortions (*biases*) when acting within the building industry as a decision maker (Flyvbjerg 2021). These aspects, among others, manifest an immense waste of resources over time and the antithetical consideration to this "business as usual" would be a modular system approach (Flyvbjerg, Gardner 2023) in order to attempt to contain both monetary waste and waste of resources.

"Circularity" is becoming a buzzword in the sense that CE strategies are mostly implemented into industry insofar as they optimize production dynamics which make production more efficient in order to increase profit. Similarly, literature on CE also acknowledges that CE-strategies could perhaps not be utilized in the future as intended. It is unclear what incentive profit-oriented agencies will have to reuse old

materials/elements. For this reason, the main function these agencies have now is to optimize material processes which minimize costs while legitimizing more and more material consumption and building activity through a "circular" narrative. In doing so there is a risk of materializing the Jevons Paradox. An example of that could be the Nakagin Capsule Tower (Gardini 2022) which holds architectural and historical value and can in certain ways be considered a proto-circular manifestation where modules can be added and changed. There was no clear incentive to add to and change the building and as such it got demolished.
Another important type of entanglement is the already mentioned notion of the "bad circularity". This hinges on the economic dynamics of the building industry where poorly designed buildings are built and will followingly require either extensive renovation or demolition. This then loops back to more demand for new buildings (which again are built quickly in poor quality) - thus maintaining the economic circular model of supply and demand by design (Cairns, Jacobs 2014). Jeremy Till describes this phenomenon as architecture being dependent on demolition. He also characterizes demolition as effectively inherent to architecture (Till 2009). Apart from already having entangled in natural processes and resources, there are clear aspects to criticize in this economic loop. The fact is that the building sector is a large industry that employs many individuals thus entangling economic growth with growth in building stock (Næss et al. 2019, pp. 2-3).

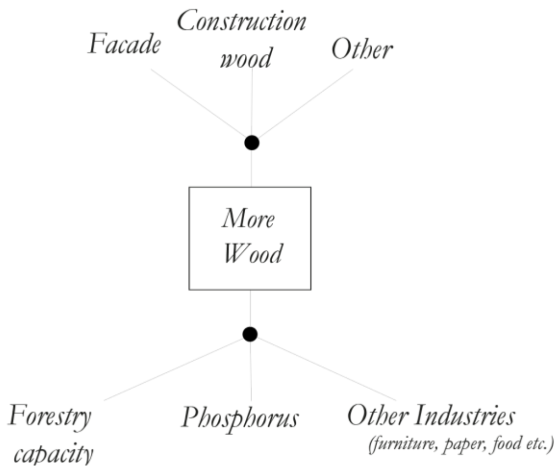

Figure 7. The prospect of building more in wood is "strung-up", or entangled with many factors, and probably many more than listed here.

If we consider the current popular trajectory of "building more in wood" then such a trajectory is already problematized from several perspectives by taking on an industrial ecology point of view. A particularly pertinent example of entanglement across industries in relation to the well-being of both the natural environment and perhaps in particular of human survival is the compound of phosphorus. This compound is non-renewable but crucial for the cultivation of plants (meaning both food needs and growth of trees for construction (Baccini 1997)). We should already be careful about our phosphorous consumption according to t leading science (Rockström 2009) which is why food waste is already a pressing issue. Likewise, wood is also needed in other industries such as furniture and different sorts of paper products (A4, paper cups etc.,). Since the capacity of forestry is limited, we cannot simply build endless amounts of wooden buildings or replace all new buildings, now and in the future, with wooden structures. There is already scientific research on how large-scale application of forestry would greatly deteriorate soils and biodiversity (Osman 2014). There are many instances of "shifts" in which one solution of a local metabolic problem is simply transposed elsewhere for grave consequences (Magadoff, van Es 2010; Goldenberg 2014) – while locally there is less pollution. There is thus a need for dialogue and strategic balancing of different factors nationally and internationally.

Entanglement is a complex phenomenon that could contain many more parameters which have not yet been mapped out. The significance of Jevon's Paradox is the discrepancy between what is intended and what is materialized. One can have certain intentions in architecture and design, but the physical manifestations can have a reverse consequence This means that one can start with good intentions (i.e., minimizing effects on nature) but the result ends in an increase in negative impacts on the natural environment. Many variants of "greenwashing" (where supposed good intentions are either knowingly or unknowingly impossible to achieve or never the goal) can be seen (Willis et al 2023). More radically, it is not that some external circumstances skewed the process into undesirable effects. Rather, the intentions were flawed to begin with, and the lack of the proper scope of the outcome led to the opposite effect of those intentions. One could also add that no architect directly has negative or bad intentions when building (i.e., "naturally" our intentions are "good). Nonetheless, it is not enough to have good intentions. As the above indicates, there is need for a critical reversal, a kind of "negative" perspective, of the current conditions if we are to create a "sustainable" relationship between societal consumption and natural environment as this requires shifts in ideological presuppositions regard the "eternal" emphasis on "growth" to be able to make a significant dent in the material flows from nature to society. This shift is perhaps best illustrated by Kate Raworth's work. Raworth maps a set of different industries and political agencies, where she conceptualizes the need to shift away from linear, growth-oriented design thinking towards a distributive network design orientation (Raworth 2017, pp 26-28). Such a "network" oriented design could move away from an expansive ideology without losing life quality.

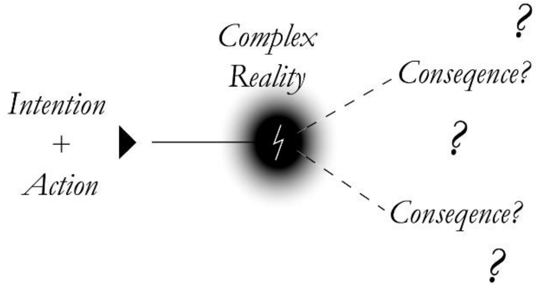

Figure 8. An experience of a paradoxical "disconnection" between action/intention and consequence (cause and effect) due to the complex nature of material flows?

Jevon's paradox is significant because it urges us to consider that "good intentions", along with their tactics and strategies, are not enough, as the "good" intent can have unintended ("paradoxical") consequences. We could postulate, that if we fail to adopt a wider, holistic ("multi-cycle") industrial ecology approach in the built environment, we may indeed end up mobilizing (limited applications of) LCA and CE strategies which risk not warding off but possibly achieving increased material consumption.

There might be too great an emphasis on short-term mitigation of carbon footprints (which have manifested as the imperatives on more and more carbon construction). While this is of course needed, there is also a need for wider temporal long-term scope because an overly emphasized short-term approach could bring about unintended and unforeseeable consequences long-term. If these tools and strategies allow for a certain market optimism and remain applied on a single-building level, we may indeed either achieve or overshoot the expected doubling of the building stock.

Not that we have some insight into the challenges of the material conditions, what are the current corresponding lines of thought in architectural theory which allow it or fail to question it? How does architecture theory consider such paradoxical discrepancies between intention and manifestations, if at all?

1.3. Pertinent Currents in Architectural Thinking

When we have gained a fundamental overview of the many challenges of material flows, we can perceive that phenomenon like Jevon's Paradox (the take-back effect) is a serious discrepancy between what is intended and the final consequences, how are we as architects/engineers to understand our disciplinary material predicaments? Specifically, what are the limitations of those ideas and ways of perceiving our reality? How do architects conceptualize and theorize issues of matter/materiality? When we observe and formulate the challenges and problems of material flows, how we formulate the problem is also part of the problem. This means that the way we perceive our conditions structures the (sometimes wrongful) approach to the problem.

There can certainly be many different social, cultural, and economic considerations for this wrongfully defining problem field across any industry. However, in the case of architecture, such a "defining of problems" could be structured by something more fundamental, i.e., theoretical framing, which can steer our mental capacities in certain directions rather than others. What are the common structuring logics of architectural theory? Even with the vastness of theoretical variety in architecture, can we observe some challenges and omissions in how theory is generally structured in architecture?

Stuck in the Growth Paradigm with our Problems

Different professions may seem to have different ontological positions which as a consequence can have different presuppositions and assumptions regarding what problems to approach and what solutions are viable for said problems. Technically inclined professions (hard-fact engineering etc.,) may privilege technocratic definitions of the problem field which implies "only" technocratic solutions, while humanities and the arts are not necessarily inclined towards problem-solving in an equally "rigorous" manner. In relation to architecture, we have seen the critique by Jeremy Till (Till 2009, pp. 154) in reference to Reyner Banham of how professionalism manifests itself in relation to problem-thinking:

> "A professional is a man with an interest, a continuing interest, in the existence of problems." – Reyner Banham (Till 2005).

In the same spirit, the now famous Danish architect, Dorte Mandrup once proclaimed in relation to a talk regarding loneliness in modern society, that we "should be able to 'build' it away" (Raun 2019) which would most likely be categorized in industry terms as "optimism bias" (Flyvbjerg 2021). Loneliness is a complex issue and cannot merely be solved through spatial arrangements. Nonetheless, architects can tend to cling to problems and make them architectural thus making architectural services their (seemingly only) solution. Jeremy Till further elaborates on how a problem-solving agenda allows for a profession to strengthen and perpetuate itself (Till 2005).

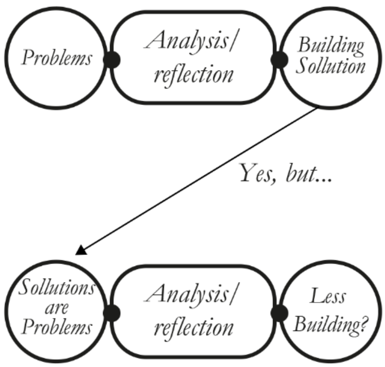

Figure 9. Problem-solution dialectics: conventional vs. alternative.

Conventionally, we perceive the built environment and observe pressing challenges and issues. On account of this, we reflect and propose a solution. However, in such a process the problem and the solution seem to be overlayed because of the way we *think* we are solving the problem in truth perpetuates the existence of problems. The very problem field has been conceived of as the conventional dialectic of problem/solution which prompts us to question what a "solution" really entails and what the scopes of the problem and solution are.

An example seen in today's predominant analytical approach is the "culture" or norm of how we define problem privileges as a growth-oriented outlook. This means that we approach the space of the problem field and its possible solution by recognizing they are confined within a certain capitalist realist framework. Architects and designers as professionals in the building industry tend to construe problems in a way where our services and subsequent building activity are the solution. Even in the critique of circular economy, which seems to privilege the economic aspect of the circular trident (omitting social and environmental), my reading here is that the main implicit problem-defining and problem-solving agenda of the predominant modus operandi of CE at a more fundamental level is how to "design" a (pseudo-) circular edifice without it impeding on or even accelerating growth. In such a condition, we see that the market is already defining the frame of the problem within which research and innovation can contribute. These challenges are not only visible in practice but in academia as well. While it is difficult to generalize the many different pockets of research agendas there are many examples of industrial PhDs and practice-oriented research which fundamentally act as an aid (or mere consultancy) for the industry to solve their challenges at more complex and informed levels, while the industrial norms are very difficult to shift in relation to the social and environmental challenges of today.

The tendency of industrial PhD is in and of itself not necessarily negative, but it leaves many dimensions towards who and how a problem field is defined. I think it is important to explicitly speak of and critique this *a priori* definition of what and who pre-defines what types of solutions and research is "meaningful" and useful to society. By choosing impossible *idée fixe* (green, sustainable, circular), it overtime develops and materializes an edifice which in a "circular" manner allows for incessant building activity which "fails" to solve the problem by creating new problems – rather than materializing "slow" and "narrow" design which stand the test of time while providing functional, aesthetical and cultural meaning for the city and its population. As such also fails to question the very space of the problem-definition. The maintaining of a high rate of building activity for economic reasons fits very well with an emphasis on DfD-concepts (Hvejsel, Beim 2019) because even if it fails to work as intended in the future (of building materials and elements actually being reused) the general notion of circularity functions here and now as a legitimization to maintain the continued need for material use. What also complicates this challenge is that different professions and disciplines have very different theoretical foundations and ontological understandings of the built environment which implicates how they engage with it. Since we find ourselves "stuck" within the growth paradigm, what are the theoretical structures which allow this tendency from an architectural perspective?

1.3.1. General characteristics of Architectural Theory

Architectural theory is a seemingly complex edifice which itself can be written in a complex language to a lesser or greater degree and at times necessitates a large amount of knowledge and familiarity with philosophy, social critique, politics etc. While there are many theoretical contributions with very different characteristics, a smaller number of scholars have attempted to map the structures (or structuring principles) of architectural theory and theorize them as such (meta-theory). Simply asking the question "what is a theory" is almost *faux pas*. Few have attempted to discern the structures along with providing much-needed critical reflections on practices of theory-making. Architectural scholar, Karen Cordes Spence, argues that we have to do away with this opaqueness of architectural theory (Spence 2017).

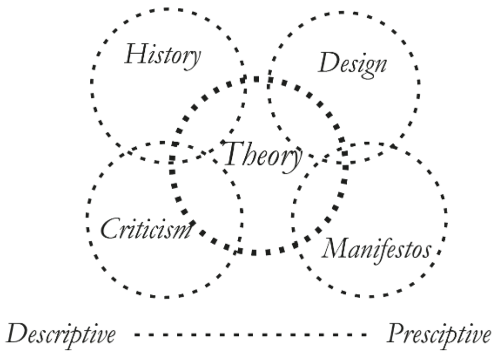

Figure 10. Different types of writings in architecture (own redrawing of Spence's diagram) (Spence 2017, pp.86).

Spence conceptualizes different variants of architectural writing (Figure 10), which both overlap and are to be distinguished. This could be compared to distinguishing theory as one of three main categories in architecture: explanatory, normative and design-polemical theory (Groat, Wang 2013, pp:111-120). Spence also elaborates that different written contributions that theorize on the subject of architectural theory either comes in the categorization of types (i.e., all theory that emphasizes matter through history is one type) and groups through time (where theories are grouped together through their historical chronology (Spence 2017, pp. 4). Spence also elaborates that every theory is guided by ontological, epistemological and methodological considerations which are likewise guided by four main types of world-views (Spence 2017, pp. 50-62).

Franca Trubiano, an architect and researcher, in her magnum opus on theory in architecture articulates the crucial missing dimensions in contemporary architectural theorizing: those being the question of matter and the question of (the act of) building (Trubiano 2022). Trubiano furthermore elaborates on the painstakingly simple fact that architectural theorizing poorly acknowledges: its origins in the acts of building. It is as if architects consider this aspect of building a pedestrian and common dimension that they thoroughly understand to the point that they do not even have to bother with it. In extension of this omission, the dimension of matter and its role in creating and thinking of architecture equally is not unfolded.

Erik Nygaard, an architectural scholar and theoretician, elaborates very comprehensively on how theory in architecture is very complex with a wide range of categories and sub-categorization of theory types (Nygaard 2011). He describes how architectural theory has developed throughout history and categorizes theory into four main groups of how architecture is ontologically construed: form, emergence, reception, and social/cultural product (Nygaard 2011) (figure 11). Nygaard also highlights a significant distinction within the architectural theory, i.e., that of the normative and descriptive (also sometimes called *prescriptive* (design) and *descriptive* (analysis)). Within both of these categories, architectural theory axiomatically hinges on either perceiving architecture as art or (merely) building activity. Nygaard also goes on to theorize on the architectural theory as either being more of an “objective” nature or more personal and subjective filled with values and opinions (ibid., pp:43), meaning that it is more systematic and problem-solving or driven by personal desires for expression and exploration. Furthermore, Nygaard highlights that architectural theory is a vast and complex (open even) entity which is made up of “…written architecture systems, whole or partial…” (ibid, pp:43). He claims that architectural theory has been developed by architects, philosophers, theologians etc., but also claims that architects’ own theory development tends to be more “pragmatic” due to is the inclination of physical synthesis in the built form related to the “nature” of the profession (ibid., pp:43).

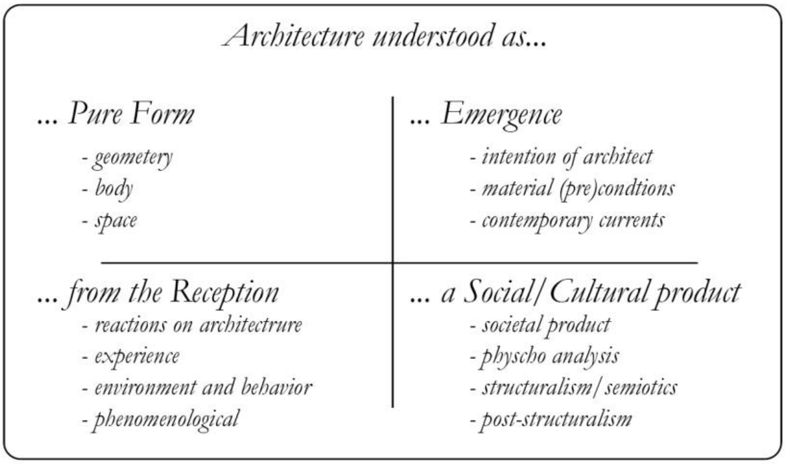

Figure 11. A redrawing of Nygaard’s 4 categories of architectural theory (Nygaard 2011).

While Nygaard delineates the analytic and design capacities of each theory in the introductory chapter before actually he elaborates on them in the book, he writes that he describes the different theoretical positions (of understanding architecture) in a way where he does not systematically differentiate analysis and design (Nygaard. 2011, pp: 68). While this can be perceived as lack, it can also be seen as an ode to the integral nature of descriptive and prescriptive capacities of many (if not all) architectural theories.

When it comes to architectural analysis, Nygaard differentiates two types, i.e., making and understanding, and offers analysis regarding which is related to the *making* of architecture as building science (i.e., energy consumption, temperature, lux, etc.) and architectural analysis (as more usual spatial, phenomenological, etc.). Furthermore, there are analyses which are aimed at *understanding* a historical analysis and history of ideas (Nygaard 2011; pp.57) all of which have their methodologies and method. Nygaard differentiates theory and analysis and does so by indicating a theory consisting of core elements (constructs like in Norberg-Schulz trinity of *assignment*, *form,* and *technique*), and the architectural analysis brings forth the relations between the elements (Nygaard 2011, pp:61). The core elements or components of a theory are according to Nyggard *not* the components of the building (brick, bolt, insulation, etc.) as theoretical components are often more general (Nyggard 2011, pp:28) While this seems to be the case in architecture, generally a scientific theory also includes the relations between constructs. An interesting example of an analytical "construct" is that of the *type*, which according to Nygaard is also easily translated to applied design (Nygaard 2011, pp.62).

Constructs (Elements) in Architecture

Beneath the general categorization of theory groups, theories are often constituted by their "first principles," also often called elements or constructs. The use of such can be considered central to theoretical endeavors and has spanned all theoretical groups through the architectural history of theorizing. These groups can be termed differently: principles (Groat, Wang 2013), constituents (Nyggard 2011), concepts (constructs) (Colquitt, Zapata-Phelan 2007; Bhattacherjee 2012), or elements (Semper et al 1989). Nygaard goes through a brief yet compelling history of constructs from different theoretical efforts and starts with Vitruvius and his well-known constructs of *vensustas, firmitias,* and *utilitas*. Vitruvius also proposed a set of sub-constructs, where each had tridents of their own, i.e., venustas was comprised of the sub-constructs *ordinatio, eurythmia,* and *symmetria.* This was a dominant lens into architecture which was later challenged by Claude Perrault (in the early 1700s) who proposed two constructs in his theory – the *positive* and the *arbitrary* –which occurred at a time where beauty (venustas) was starting to get relativized (Nygaard 2011, pp.30). Without going into much detail on all contributions throughout architectural history, Nygaard elaborates on the history of components/constituents, emphasizing the key founding texts of the different discursive shifts up to the late 20th century. More recently, the same tendency continues, and we can observe that architectural thinking is widespread. Scholar Alejandro Zaera-Polo attempted to map and theorize the different dogmas, approaches, and styles of contemporary times in a kind of architectural compass (Zaera-Polo 2016). More than anything, this indicates that there is no one clear way or style which is currently dominant. Some more recent examples of theoretical construct in contemporary theory are Turko & Hensel's *grounds* and *envelopes* (Hensel, Turko 2015) and Aksamija's and Iordanova's trident of *issue, concept,* and *form* (Aksamija, Irdanova 2010). These too can be argued to be too immediately pragmatic and professionally inclined as they mostly deal with design tasks where the problem-solving is an *a prior* frame, and the challenge is to solve the specific design problem at the given site, while potentially minimizing carbon impacts and energy consumption,n etc.

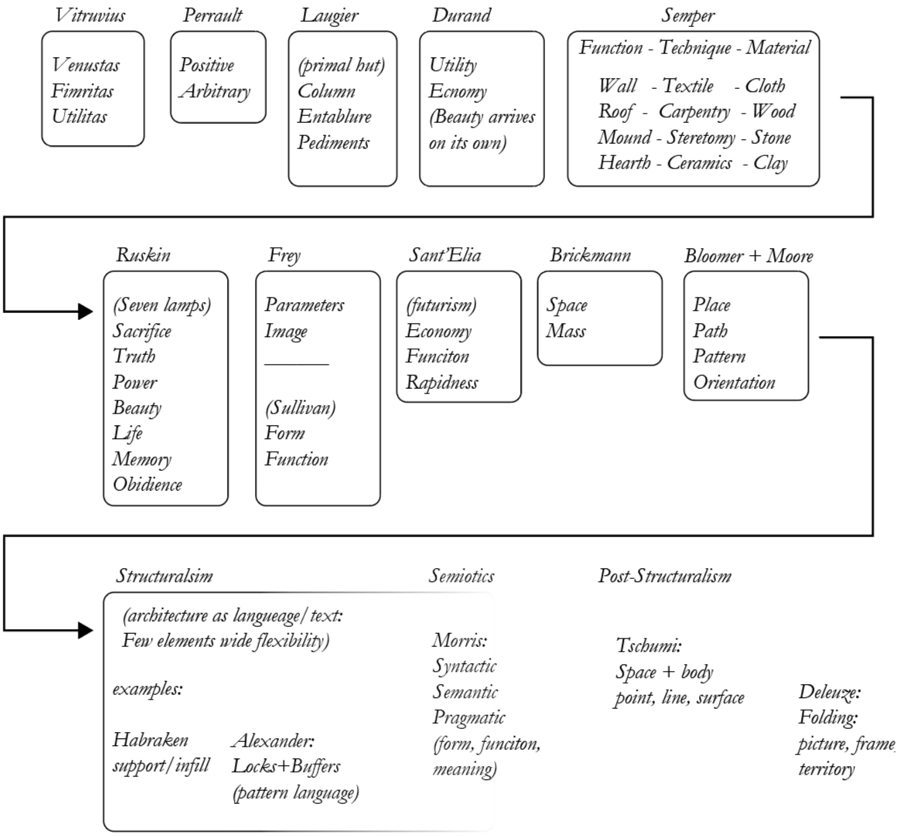

Figure 12. A brief history of the evolution of architectural constructs (based on Nygaard's account) (Nygaard 2011) with the inclusion of Ruskin.

With regard to the theorizing with constructs/elements, we can observe a tendency of theories often have few key constructs or elements (Figure 12), and it is highly unusual that a theory has ten or fifteen elements (to maintain a level of simplicity and comprehensibility) although such high numbers of constructs do exist (Spence 2017, 45-47). The quest is not to choose "all" constructs/elements but to balance a limited set of constructs that implicates a certain dialectic between them which followingly prompts critical consideration.

1.3.2. The Materialist Discourse in Architectural theory

Since we are interested in material consumption and material flows, the theoretical category of “architecture emergent from material (pre)conditions” is relevant to consider. What are the tendencies of emphasis, approaches, and ways of constructing architectural thinking structures? Materialism in architecture was initially and still mainly concerned with materiality, tactility (Pallasmaa 2012; Böhme 2018), material properties in relation to architectural performance (Hensel 2013; Hensel, Turko 2015), whether structural (Gramazio, Kohler 2008) or microclimatic (Foged 2018). But materialism as an architectural discourse can also imply several other considerations. Here, I rely on the mapping of the materialist discourse in architecture provided by Erik Nygaard.

Erik Nygaard postulates that, historically, the understanding of architecture as “emergent from material conditions” is in sharp contrast to the category of architecture as the “architect’s intention” (free creative *will,* etc.) (Nygaard 2011, pp 132). He goes further to claim that the “old” perception of emphasizing the architect’s “free will” was characteristic of “grand” architecture (large venues, religious complexes, etc.), while materially emergent architecture was characteristic of approaches, especially during industrialization, where more “common” architecture was to be built, e.g., housing, factories, offices (ibid). Nygaard also highlights that such an architecture was more “earth-bound” – i.e., inspired by a Marxian approach - as it focused on aspects of function, technique/technology, materials, economy, and legislation (ibid). Nygaard designates a number of foci characteristic of the materialist approach in architecture: function (housing especially), type, typology, climate, topography, resources, construction, technique/technology, economy, politics, and legislation (Nygaard 2011, pp. 133-153). Within these, there can be a range from hardline material-realists such as Viollet-le-Duc (ibid, pp. 135), to more “loosened” materialists who include many considerations on interiority and function such as Gottfried Semper (ibid) and later variants of Marxist materialism in architecture where general social and political conditions of buildings, cities and their social consequences are subject to analysis and critique.

It can thus be claimed that there is a spectrum of materialist approaches from hardline reductionist realism where everything *has* to be explained from material properties to wider environmental and social conditions that influence how buildings and cities are formed. This fundamentally hints at the differing philosophical nature of the two types where one (the formal/structural strain) is concerned with material properties and is the Analytical philosophical tradition (“old” conventional materialism), while the other is more general and critique-oriented regarding tendencies of social and political conditions which is foundational in Continental philosophical tradition (dialectical or historical materialism). Materialist discourse in architecture is thus a practical and pragmatic approach which deals with every day “socio-material” existence of buildings and cities which largely deals with tectonic concerns. One could even go so far as to claim that a "materialist" approach to architecture more or less equals the tectonic discourse.

Black Boxes of Architectural Thinking

In extension of the fact that architecture is becoming more and more "practical" with its problems at hand, there are tendencies in line with this which amplify the issue. What seems to complicate things is that there is currently a "post-critical" dogma in the architectural discipline (Spencer 2021; Trubiano 2022, pp.51-56) which is in a way *anti-theory*. That is to say, some movements and practices in architecture are convinced that theory (and criticality) is of little use, and we need only to be "practical", "pragmatic", and action-oriented instead of still pondering theory. If we do not rely on theory, what values of thought (epistemology, ontology, worldview) then guide our actions? Simply being "practical" and "pragmatic" towards the problems at hand does not automatically imply that one is acting in some profound or ethical way. Rather one solves "real" problems for "real" people because one has no concern for some grand, "pompous" abstraction. This also implies two crucial things. Firstly, the reality is knowable and "rational", and secondly, we know fully the extent of our actions and intentions when we engage with reality so much so that theory is not needed. However, as we have seen with the Jevons Paradox (paragraph 1.2.3.), that is not the case. Just because we now know of the Jevons Paradox (take-back effect) does not mean that it will stop from occurring. We are prone to repeat it given the market dynamics and its "optimism bias" (Flyvbjerg 2021) among other reasons. In our attempts to be "pragmatic", one may indeed be subject to embodying ideological constructions, without knowing it, within a "frame" defined elsewhere (i.e., market dynamics, growth paradigm, etc.).

That is not to say that this design ideology only occurs when one is practicing (without theory). Rather, it can likewise occur within a theoretical edifice which has been "distorted".

Architectural theory does not always stand on its own in the form of constructs, and there can be some governing logics and assumptions which can "steer" how such seemingly approachable elements of a theory can be used one way rather than another. Historically, we have seen grand references of architectural production to God, Nature, Music, etc., and we can perhaps thus claim that there is a kind of "secularization" (Hartoonian 1994) of creative processes in architectural production. I, however, would claim that creativity[1] is not yet fully demystified as even in modern and contemporary times, there are new variants of such mystery boxes in architectural creativity where creativity "ex nihilo" is rationalized through this spectral *idée fixe*. These are not always explicitly written within the architectural theory, but they are

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[1] I do not mean the common instrumental creativity of solving simple or complex tasks efficiently, but an "architectural creativity" which necessitates a reference to history, norms etc. and their subversions.

there, or in their absence, something else is imposed (personal or societal values). Architectural discourses and dogmas are filled with *a priori* and presuppositions that knowingly or unknowingly steer the architectural production in certain rather than other directions. Such discourses usually fail to challenge the stuck-ness of architectural production within the linear growth paradigm or even allow for an opportunistic amplification of material consumption.

Even in modern times, there is still much effort to grasp the mysterious and mythical genesis of architecture which is almost on par with fantasies of Abbe Laugier's primordial hut. Such texts usually deal with "truth" and "essence", i.e., genesis and roots (Bech-Danielsen 2014). Even if the purpose of these analyses was to deconstruct such mental constructions, they somehow seem to have a grip on architectural creativity. Architects can tend to fixate on these impossible (mental) objects which are impossible to discern empirically as a minimal cognitive legitimization of the design activity. Jeremy Till elaborates on the notion of *ex nihilo*, i.e., the architects' creative urge to create "from nothing" as it were (Till 2009). Dominant or not, the use of spectral objects (ex nihilo) is still a tendency both in academia and practice, where non-scientific argumentation and design development is at the forefront. A reason for this axiom (of the *ex nihilo*) may be that architectural production is axiomatically stuck within the growth paradigm and one may need a simplified argumentation for why and what to build. With reference to Frank Lloyd Wright, Alvar Aalto once proclaimed:

> "Architecture is the transformation of a worthless brick into something worth its weight in gold" (Strasnick 2017)

On the surface level, this may seem a simple statement. At the same time, it reveals a kind of architectural "magic," a modern alchemy on which we remain fixated, permitting us to transform finite, banal matter into a vibrant material. Another famous example is Louis Khan who can "speak" with bricks. Such a mental construing of material productions becomes an ideological edifice of "magic" and material animism which "opens" (for better or worse) the creative frame, i.e., an edifice that can nullify actual empirical facts and assert its creative *will*. Architect and researcher, Andrew Benjamin, also theorized of a tectonic (or a kind of formal-materialist) ideology within architectural design, where a seemingly materialist approach is fundamentally disconnected from actual material concerns (Benjamin 2007) and where architectural thinking becomes a kind of willful ignorance of actual, empirical material conditions. Jeremy Till also (in a slightly simplified yet convincing critique of tectonic discourse) elaborates how a theoretical discourse can "flatten" itself to what he calls a "phony ethics" (Till 2009) where critical thought is replaced with a kind of "modest" way of designing as the highest moral goal. Ultimately, this itself can turn into a kind of arrogance where critical thought is pushed aside by a stern certainty of a design style due to its supposed modesty. This tendency is not only characteristic of tectonic discourse but a wider tendency which constitutes the ideological structures of architectural thinking and production at large as a proper need to invent and narrativize new ways to legitimize itself.

Whether it is a failure to know or an unwillingness to know, we assert a narrative into this gap (Usto 2020). Given the vast complexity of both architectural production and the building industry, as architects, we seem entangled (both materially and meta-physically) in the current modes of production, and since we are unable to propose a "way out" of the current mode of production we create ideological constructs as a way in which we seemingly either follow or subvert the hegemonic coordinates, all of which allow material consumption to continue or even increase.

Even in contemporary times with the most recent agendas in architecture and design, something similar can arise. Especially regarding material consumption, we can see how we conceptualize certain edifices to strive for something impossible like the Sublime Circularity, (which will never be achieved because it is physically/thermodynamically impossible). As such endless activity is "permitted" and guaranteed. Current sustainable and ecological edifices can thus become equally ideological, where ecological concerns can be argued to be entirely "cut off" from actual empirical ecological facts and concerns and have everything to do with ecological virtue-signaling. This is a sublime fascination with ecology (as ideology) instead of the actual practice of ecological concerns. As such, and precisely because we are stuck in the growth paradigm, circularity has to be an "endless" (suspended) circularity that can be detached from actual material facts.

1.3.3. Overview: Observations and Challenges Regarding Theory

From Nygaard's categorizations' perspective, there is a shift away from architecture being understood as a form to being understood as a relational, social system in motion. This shift also tells of an epistemological clash and shift, which also indicated that reality in its true complexity is unknown or even unknowable. Both ontological positions of reading reality as either an object or a set of relations imply two theoretical positions which allow certain ways of relating to reality. The question is whether they are different enough to allow for a thoroughly different way of relating to reality and whether will there be a need to consider both?

A theoretical position is ultimately a simplification of the true complexity of architecture and hence the different variants/types of architectural theory according to Nygaard (2011). The Thing of architecture ultimately eludes our cognitive abilities and epistemological structures, making it evident that one single individual cannot explain or discern the full empirical nor meta-physical complexity of architecture. So too is the limit of the materialist approaches in the architectural discipline.

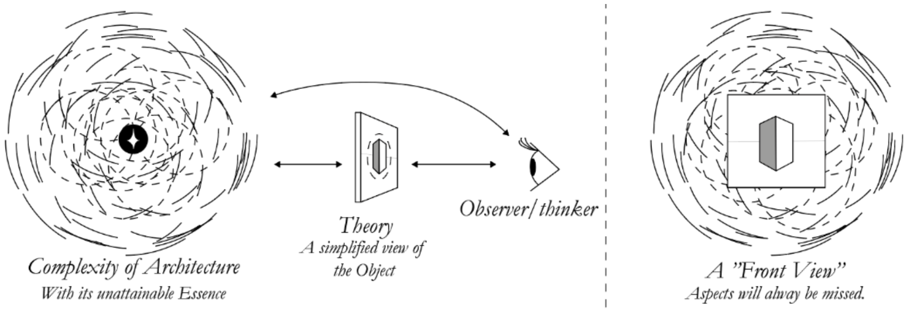

Figure 13. An abstract diagram showing how one must simplify architecture within the theory.

Generally, regarding theory, we see a development from a form- and object-fixated approaches, and through the relativization of aesthetics, architectural theory becomes more and more "open", complex, relativized, and relational (Nygaard 2011). At the same time, the architectural theory structure remains familiar and consists of a few central constructs, which can have several sub-constructs that indicate the relations between the constructs.

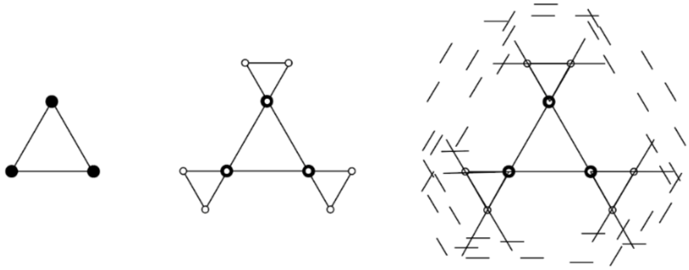

Figure 14. A general example: few core constructs/elements, along with sub-constructs - possibly with branching complexity expanding into relation?

Sub-constructs are often isolated from other constructs or sub-constructs (like in the case of Vitruvius mentioned in 1.3.2). We can see that architectural theory has clear emphasis on the main constructs of a theory, i.e., well-known elements which are sometimes the "outward" appearance of a theory. Sometimes a discourse or theory is even simply referred to as its constructs directly: Semper's *four elements* or Ruskin's *seven lamps*. We also see that most architectural theories can be mobilized both for analytical purposes and design purposes.

The materialist approach

According to Nygaard, there are several approaches within materialist thinking which emphasize different aspects of architecture and thus indicate that there is a spectrum of the materialist position spanning from ontic material-realist (empirical) concerns to a kind of expanded materialism (meta-material patterns) of the conditions of everyday life (Nygaard 2011, pp. 133-155). Architectural materialism is thus a spectrum of both stern ontic facts and immaterial considerations of social and political considerations which nevertheless have material conditions and manifestations in everyday life.

While Nygaard is very critical of the materialists' ability to explain or account for *everything*, I do not think that this is the strength of the materialist approach. Instead of merely listing the materialist approach as one among many others, what is more important to observe is that the "material" conditions should be conceptualized to provide a framework (whether monetary budget or environmental limitations etc.) within which certain artistic freedoms, among other considerations, are possible. These conditions could be seen as setting the boundaries or framework for what types are solutions are feasible/possible/desirable from said perspectives. Something similar can be said also of research and academia as we see more and more industrial PhDs and collaborations across fields, industries and academia. Research is becoming "industrialized" as to "serve society" more and more (Horst, Irwin 2018). Many types of research can have pertinence but what kinds of research gets funded and prioritized is up to the different stakeholders and agencies with monetary capacity. In cases where for example "the intentions" were to protrude the frame from within (proposing too costly or materially consuming designs etc.) it would simply not be chosen, or the architects would be asked to simplify and minimize costs (depending on if it is a competition or client situation).

While Nygaard conceives of the "material conditions" as one of many other theoretical understandings for architecture, it should be expanded to "contain" the other ones.

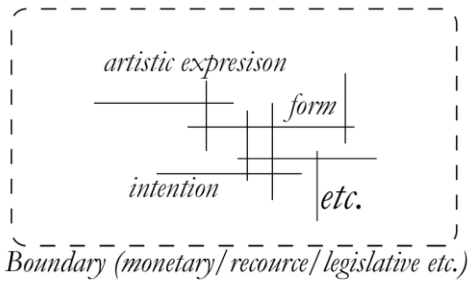

Figure 15. The material (pre)conditions provide the frame in which maneuvering is possible.

The materialist position could hold potential if it were considered as a frame within which there still is some leeway. In relation to today, given the current "plasticity" of modern technology, many considerations on limits and capacity have seemed unnecessary for a long time. We can see this where, regardless of site-specific conditions, one can accommodate any comfort level and modern standard of living. How could architecture be conceptualized as “emergent from material conditions” but the “material conditions” be conceptualized in ecologically relevant ways? The challenge is then how to re-actualize and modernize this idea of making architecture form within material boundaries? There are theories written outside of architectural thinking which is relevant such as Kate Raworth’s donut model (Raworth 2017), and Schmelzer’s concepts of degrowth (Schmelzer et al 2020). Given the complexity of understanding and thinking about planetary scarcity or limits, it becomes very difficult to conceptualize this in architectural terms in ways where it is both abstract (meta-physical) and also both rigid and empirical to have specific approaches and normative tactics. Nygaard does not explicitly conflate the materialist theoretical discourse with tectonics as such, despite the chapter being initiated regarding Gottfried Semper. Nevertheless, general concerns regarding the materialist approach (making, production, function, climate, and resources) are today easily associated with the tectonic discourse, and since the tectonic discourse generally circumscribes these concerns, tectonics is of pertinent interest for the progression of this doctoral study.

Considerations for later theory building effort

Nygaard mentioned that architectural theory refrained from speculating on universal and metaphysical aspects and instead concerns itself with being practical and problem-oriented. Having this in mind, it is not necessary for us to revert to the outdated classical theoretical mindset. Instead, it is essential to recognize that certain architectural theories exhibit a "problem-solution bias," wherein specific architectural problems and their solutions are assumed *a priori*, requiring architects and their theories to devise means (tools and methods) of addressing them. However, it becomes challenging to critically examine this inherent (axiomatic) process. When it comes to the aspect of architectural constituents (constructs/elements) there are also a few things to take note of. There exists a general inclination in theories to consist of a few simple constructs, often adopting a "bottom-up" and "open-ended" approach (Figure 11). This openness implies that architects have the freedom to shape these constructs according to their own imaginative and creative aspirations. Ultimately, this tendency perpetuates architectural productions within the frame of a linear growth paradigm. Nygaard hypothesizes that all architects have some form of theory that helps them make (design) decisions (Nygaard 2011, pp.42). These types of loose theories are not often explicitly called architectural theories because they are usually “...implicit and part of the ‘silent knowledge’ of the profession…”2 (ibid. pp: 42) in architectural discourses. At the same time, we can observe that there can be other “governing” aspects to a theory which may or may not be put forth explicitly: “logics” and “boundaries” (Colquitt, Zapata-Phelan 2007; Bhattacherjee 2012) (more on this later; 3.2.2.).

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[2] Own translation of the original Danish text.

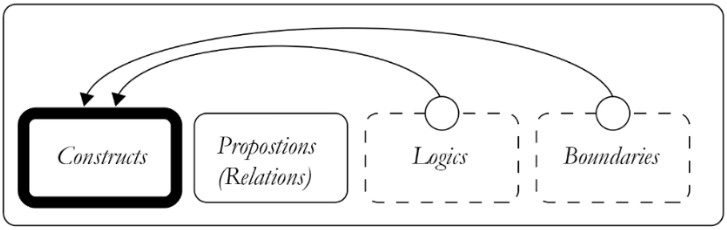


Figure 16. Constructs are the most "visible" elements of a theory.

These aspects of a theory are often implicit and are often more of a “philosophical” nature containing elaboration of how and why some key assumptions are made and for what purpose. If architecture is to be positioned within material (pre)conditions, the “boundary” considerations must in some way be present among the constructs. What we are thus in need of is a theoretical position where within the set of constructs, there is a “representative” of the material conditions. The perhaps “common” way of constructing a theory would have been to create a set of constructs and elaborate on the “logic” and “boundaries” that they are located within planetary boundaries (physical boundaries) and the ontological and world-view axioms and assumption (immaterial boundaries), with certain accompanying epistemological and ontological considerations. Instead, there should be an insistence that the key component of the theory (situating architectural production within planetary boundaries) is represented within the construct already, however abstract and general that may be.

Architects have no ill intentions. Yet, we can observe that how our mental faculties are steered (at least partially) by architectural theory or ideology can materialize unintended or downright bad consequences.

1.4. The Pertinent Disciplines and their Theoretical Frameworks

When we consider the juxtaposition of challenges regarding material consumption and material flows with how architectural theory develops thinking regarding material conditions, we can see the radical potential of thinking about material boundaries (as seen in the industrial ecology field and discipline of chemical engineering) has to be coupled with architectural thinking. Followingly, the tradition or discourse of materialist thinking is also vast, spanning from empirical approaches of material properties to socio-material conditions on large-scale structures and infrastructure (which could be designated as meta-material conditions).
As Nygaard conceptualized, there are several strains within materialist thinking, but it can be observed that tectonic discourse holds considerable potential as it too concerns itself with material production as well as social and cultural aspects.

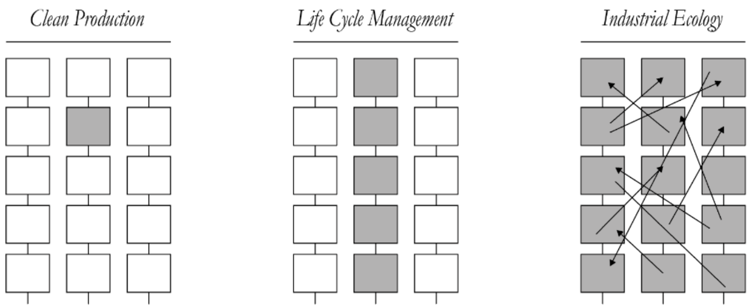


Figure 17. Redrawing of illustration inspired by "From Cleaner Production to Industrial Ecology", Hanssen and Abrahamsen (2012).

It can thus be said that while industrial ecology discerns and maps material flows, tectonic discourse is the architectural "poetization" of how the built environment consumes and moves/transforms materials. However, given the environmental challenges of today, there is a need for a more complex and nuanced approach to material flows. Industrial ecology, sometimes called metabolism, holds the potential to rigorously mobilize a "multi-cycle" way of thinking. Thus, the Tectonic theory and industrial ecology (metabolic studies) are pertinent for the proceeding of this doctoral study.

The reason to proceed with these two key disciplines is due to them both having an impetus in "matter" – although from very different epistemological and ontological positions – some of which are explicit and some of which are more implicit. Another crucial aspect, as per the given complexity of issues of material flows in society in relation to nature, is that an approach is required which can include many scales simultaneously. The span from the small scale (elements and buildings) to the larger societal scale would permit critical positioning in relation to materials and how they flow in relation to their ideological justification.

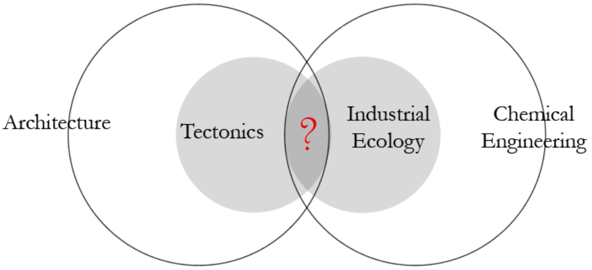


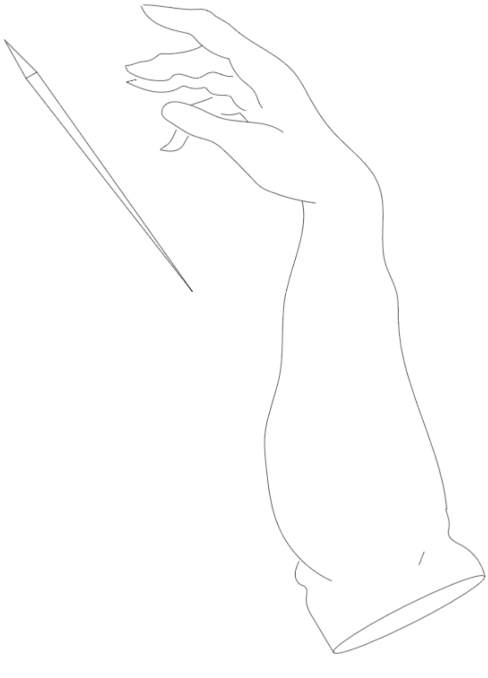
Figure 18. Juxtaposing of the key disciplines and their subsequent theoretical frames.

How can we outline the contours of the tectonic field and industrial ecology? What are their strengths and how, if at all, do they theoretically overlap? Is it possible to discern something "common" between the two theoretical frameworks which can help construct an inter-disciplinary theoretical position in which material conditions are at the forefront?

1.4.1. A Hypothesis

We have observed challenges in the patterns of material flows. Within these patterns of how materials are applied in the built environment, we can also see that said materials are used in great volume but very often in poorly designed conditions which emphasizes optimization/efficiency within a capitalist realist framework of minimizing cost, etc. Ultimately such a dynamic can seem minimally alienating to the people who are supposed to use these buildings. In a sense one could say that there is a triple challenge: consideration of the use of materials, the architectural character of buildings and urban spaces, and the fact that the two above-mentioned are inherently disconnected and should of course be considered in unity. There have been here many efforts in the built environments, from scholars and practitioners, to provide design tools, methods and approaches (of a normative and practical nature). As such we are seeing a more and more practical approach to design (from immediate problem to solution) whereas a refreshed reproach with critical thinking and theory could open the scope of material consumption in the built environment which could link the material and immaterial. Putting it in a slightly risky fashion, we know what we must do (with tools, methods, normative imperatives, etc.,), but we may also need adjusted ways of thinking (theory) to accompany the practical and pragmatic. Two very different yet material-oriented theoretical frameworks become pertinent to consider: tectonic theory from architecture and industrial ecology from chemical engineering.

Hypothesis
The hypothesis of this PhD study is thus that pertinent insights can potentially be made by the connecting and juxtaposing of knowledge from chemical engineering and architecture. More specifically the theoretical frameworks of industrial ecology and tectonic theory can give us pertinent insights which we can use as we develop architecture in the future. These two theoretical frameworks deal with material flows in very different ways yet hold significance to each other in their juxtaposition to potentially challenge how we currently understand the role of material thinking and design in built environments. In the trajectory of juxtaposing these theoretical frameworks, delving into the state-of-the-art of the two disciplines is necessary to further specify the research questions and corresponding theory-building exploration.



Chapter 2. State of the Art and Research Question

In this chapter the two pertinent theoretical frameworks will be opened up: the tectonic theoretical discourse and industrial ecology (metabolic studies) field. These frameworks offer relevant ways to conceive material flow conditions from different perspectives. The purpose of this chapter is to map and discern a potential middle ground as a possible way for proceeding to theory-building purposes later. The chapter starts by mapping industrial ecology and laying out its theoretical, methodological aspects, and applications. The tectonic theoretical discourse is then fleshed out into distinctive approaches and understandings. The chapter concludes by focusing on commonalities between these approaches and understanding along with challenges and objectives. It ends with the research question(s).

2.1. Industrial Ecology

Given that crucial observations and ways of working empirically with material flows can be found in industrial ecology, what is the state-of-the-art in both methods and theory and what key aspects could be considered in the later theory development? With an eye on challenging these architectural axioms *a priori* and ideological fixtures in tectonic theory and practice, industrial ecology and in general metabolic studies allow for a wide variety of approaches that have a rigorous and critical understanding of material conditions. In this chapter, the metabolic studies will be mapped out, highlighting relevant aspects needed for later theory development purposes.

2.1.1. General Overview

Metabolism, whether societal metabolism or industrial ecology, is a field in chemical engineering. Industrial ecology is most known as an applied method for mapping material flows (Jelinski et al 1992; Baccini, Brunner 2012), but industrial metabolism is also a theory which is both descriptive and prescriptive (Korhonen 2004; Graedel, Allenby 1995) meaning that it can be used to both explain (analysis) and design metabolic constellations

The term metabolism stems from biology and has become a metaphor used in practice, albeit criticized (Graedel 1996), given the fact that cities are not exactly living organisms or natural ecosystems. Despite the challenges and limitations of the analogy and its application, it is nevertheless useful to conceive of the city (or anthroposphere at large) as an organism (or eco-system) that metabolizes (moves and transforms) materials in an exchange with nature. Theoretical development thus has been made based on this metaphor in mapping input and output. At this level, industrial ecology is the applied theory and methodology of metabolic "discourse". Deeper within the discourse, is material flow analysis which is a more specific method that contains several steps in which evaluation of the material flow system can be done through LCA as a tool.

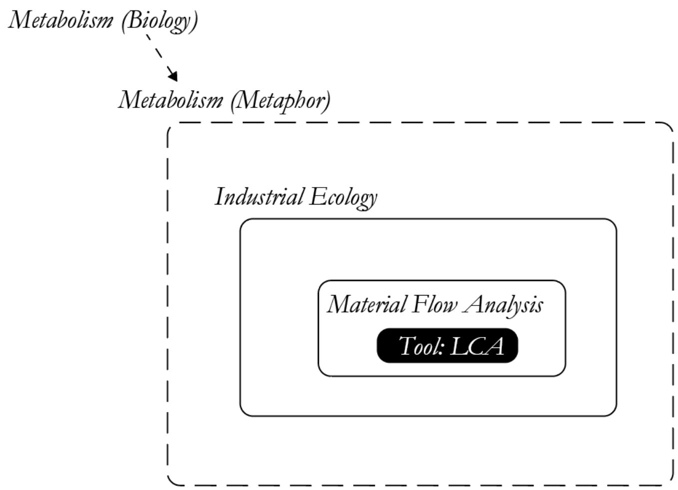


Figure 19. From metaphor to the theoretical frame to methodology.

When it comes to metabolism and the terminology, theory, and method of the concept, things can become a bit confusing for people who are not familiar with the metabolism/industrial ecology. Architects are mostly familiar with the notion of metabolism from the Japanese Metabolist architectural Avant Garde which does not contain chemical engineering considerations. Industrial ecology deals with "metabolism" differently. Industrial Ecology is a field within chemical engineering that is often interchangeably called "metabolism", "societal metabolism", "industrial metabolism", or "industrial ecology". At this broad level of the framework in this disciplinary field, we are dealing with the theoretical framework. Deeper within the field's framework is the method of material flow analysis which also (very often) is interchangeably called "metabolism." In "shoptalk", both the theory and method are referred to as "metabolism". While there are differences, my speculation on the reason for the “interchangeability” is that the theory and method are very closely linked.[7], This slight confusion or ambiguity is also present in the application of metabolism. As the literature on the theory of industrial ecology (metabolism) indicates, industrial ecology using a *descriptive* or *prescriptive* approach (meaning analysis or design-oriented proposing designs) has been unclear. (Korhonen 2004) –). As an extension, this approach to metabolism is merely a framework. The question is does it simply map and explain conditions, or can it also be used to prescribe conditions, meaning design and manifest desired conditions and not only explain/observe.

Metabolic studies have evolved greatly over time. It started entirely on the metabolism of human beings in the 16th century (Baccini, Brunner 2012, pp. 22). Later, the invention of *mass balance* (Lavoisier in the 18th century) and *input-output* (Brunner, Rechberger 2017, pp.9), among other inventions, would permit for empirical mapping of metabolic exchanges of multiple individuals, households and cities, regions, etc. (Ibid, pp.21-43). Marx’s theories regarding the metabolic exchanges between society and nature (while initially very abstract) served as important inspiration for the formation of metabolic studies and made the discipline more rigorous over time (Fishcer-Kowalski 2003).

The notion of metabolism doesn’t hinge on one scholar or researcher but on many who have contributed to the building and refining of the metabolic way of thinking both in theory and method. From developing *mass balance* and *input/output* principles to later eco-philosophical elaborations (Bourg 2003) on the metaphysical potentials of metabolic thinking for how human existence is situated in relation to nature – proposing a new metabolic “spirit” in being with nature.

2.1.2. Uses and applications

A very common method(ology) in metabolic studies is the use of material flow analysis (MFA) which be used for analyzing/explaining and changing/designing in different fields of societal material and energy considerations: i.e., environmental management and engineering, industrial ecology, resource management, waste management, and anthropogenic metabolism studies (Brunner, Rechberger 2017, pp.19-39). While they are here listed as separate fields (to help limit, simplify, and introduce rigor in analysis and findings), the methodologies are thoroughly interconnected, and the notion of the “anthropogenic metabolism” (which can be considered a type of expansion of the notion of industrial ecology as the large scale society’s relation to the natural environment) can be said to contain all of the above (Baccini, Brunner 2012).

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[7] For the sake of comparison, one could compare this to social sciences and the well know contribution of Actor Network Theory by Bruno Latour (Latour 2005). In this case, ANT can be both a theory and method/methodology which theoretically (generally) explains phenomena as actors in a network. It is also easily applied as a methodical approach which needs particular methods and tools to discern chosen actors and their relation in particular (empirical) situations.

As the base methodology is that of MFA, there may be a need for supplementary tools and methods to acquire data and knowledge (ibid, pp. 40) to map and assess the impacts of the material flows.
The general objectives of metabolic studies (material flow thinking) are many and broad. They span everything from aspects of understanding better material flow conditions to be able to design better products (ibid, pp. 46-47). While the focus is normally on materials and substances, the usage of MFA for energy flows is possible (Baccini, Brunner 2012; Brunner, Rechberger 2017).
In broad terms, mobilizing metabolic studies (through MFA) allows for the empirical mapping of material flows. A specific aspect in this regard is related to Jevon's paradox (chapter 1.2.3) in which designers or policymakers can have certain intentions and then mobilize certain techniques, technologies, and legislation through a seemingly rational, pragmatic approach which amounts to certain consequences that end up being opportunistic, unexpected, etc. Approaching the challenges of material flows allows, among other things, MFA to permit discernment if the intentions correlate with the materialized reality.

2.1.3. Different approaches and evaluations

There are a number of different approaches when conducting metabolic studies. These differences span a range from the mapping of material flows to what is assessed and how the mapping gets synthesized and presented/disseminated. And ultimately having differing purposes of consulting and informing the public, private stakeholders, policymakers, etc.
The main set of different approaches can be laid out as territorial vs. consumption (Athanassiadis et al 2018), top-down vs. bottom-up, spatial, and temporal. All of these have pros and cons in relation to what kind of data and knowledge is relevant and needed to extract from a metabolic study. The territorial approach is generally less precise and more appropriate for urban scale mappings, while consumption takes into account indirect impacts and flows preceding the use stage of a product (Athanassiadis et al 2018). The top-down/bottom-up approaches are used when providing aggregate value for a city and estimating data for large constellations, while the bottom-up requires on-field measures and surveys and is thus more precise but time-consuming (ibid). The temporal approach considers several temporal situations in order to discern a general pattern of a chosen system (city etc.). These can span from hourly to monthly to yearly to up to 100 years (ibid; Krausmann, 2013). The spatial approach (unlike the temporal which generalizes the entire boundary of a city) allows for the nuancing of the spatial conditions within a city to map which parts of the city have higher consumption than others (ibid).
There are likewise different methodologies to "measure" the metabolism of cities, i.e., data collection, material flow accounting, input-output analysis, and life cycle assessment.
The general data collection approach is a broad approach of utilizing any available

data (papers, national and international statistics, reports, etc.) which requires many additional data sets, tools, and methods, etc. (Kennedy, Hoornweg 2012). The accounting methodology is that of material flow accounting. While there are several different methodologies, perhaps the most common was developed by Eurostat (Eurostat 2001) and sets a standard for which compounds and materials are important to consider and under which input/output norms. Material flows accounting also uses certain indicators to assess the material economy of a city (Matthews et al. 2000). The material flow account approach is a thorough, tested, and developed method (Brunner, Rechberger 2004; 2017; Baccini, Brunner 2012). The input-output table (IOA) allows for the mapping of materials from one sector to another (Murray, Wood, 2010) or on a larger scale between regions (Kanemoto, Murray, 2013). Another way to assess material flows is the use of LCA (life cycle assessment). LCA typically takes into consideration all inputs and outputs, ideally from all phases from extraction, to use to end of life (EPA 1993; ISO 2006). LCA is a widely used and acknowledged tool but is difficult to use on a large urban scale, as such a constellation holds many products and materials.

When conducting urban metabolism studies, there are standardized indicators that can facilitate the comparison of cities and/or strategic actions. The standards set are ISO 37120 (ISO 37120, 2018). Other standard cities can follow the ones developed by GPC, which helps these cities meet their goals regarding emissions etc. (GPC 2023).

Some later supplementary approaches have been developed. Among them is the method of assessing material flows systems through entropy (Brunner, Rechberger 2017) which later also uses "indicator materials" as a way to assess larger metabolic systems (Roithner et al 2022).

In the current predicament of circular thinking, there is much theory and practice on LCA. Nonetheless, LCA without the MFA dimension of designing material flows risks keeping the current modus operandi of the building industry with incremental optimization in footprint, cost, and time management. As an extension of this, life cycle thinking is greatly hindered. While it does contain immense importance and potential to map and analyze life cycles (also allowing to optimize them), life cycle thinking does not directly include the design of material flows as chemical engineering (MFA) which considers it pertinent. MFA methodology contains LCA as a 7^{th} phase out of 8, while emphasizing the importance of the overall material flow scheme and necessitates interdisciplinary collaboration towards nurturing and creating "metabolic designers" (Baccini Brunner 2012). Only relying on the combination of CE with LCA on a methodical and tool-level is not sufficient, since the LCA approach allows for too much linger space which can be filled with personal and socially contingent beliefs and values (Cays 2021) as LCA is "qualitative" tool to assess particular life cycles but not analyze and design metabolic systems at a more fundamental level. Furthermore, given that the conducting of an assessment is the 7^{th} step of the metabolic approach implicates a great deal of mapping (or designing) of material flows before assessing their effects; however, if we remain too focused on the LCA as a design tool, this could hint at the fundamental acceptance of the current

material flows of the building industry and that we are merely optimizing and making more efficient the current paths and cycle by way of LCA without redesigning at a metabolic level.
The omission of a metabolic understanding in architecture (and in general the built environment) should be taken seriously because of the immense possibility of designing interconnected metabolic systems.

Metabolism in different scales and different fields/professions
Metabolic studies are useful if one's aim is to map and assess single products and materials/substances. It has additionally allowed for the mapping of households to provide a general look into the material consumption of citizens, on average, while mapping whole cities and potentially bio-regional cities to planetary scales (Allenby 1999; Baccini, Brunner 2012). It could be useful to segment the metabolic systems of the anthropogenic boundaries (cities) into four main categories of activities—nourish, clean, live/work, and transportation (Baccini, Brunner 2012, pp: 87; Brunner Rechburger 2017) – as these largely make up for the main metabolic dynamics and material consumption patterns.

Another important contribution in relation to material flows has been that of the NetStadt (Oswald, Baccini, 2003). This was an initial interdisciplinary methodology between chemical engineering (MFA and metabolic thinking) and architecture (in the broad sense without emphasis on Tectonic) which ultimately seemed like a strategic planning method. Given its complexity, it didn't make itself approachable for architects in spatial and phenomenological terms. Other architects and designers can be said to have touched upon the notion of metabolism. Among them is Weinstock, who has worked with "metabolism" but this was largely reduced to bio-mimicry and branching systems (Weinstock 2008) in computational design (Weinstock et all 2010) and does not consider "metabolism" as chemical engineering and urban metabolism studies. Other architects have been working with designing "metabolic" flows such as landscape architects Dirk Sijmons and Julie Marin, among others (Designing with Flows 2017). The approaches of these landscape designers/architects are to a large degree confined to landscape design and are mostly practical applications in practice without developing the theoretical and methodological framework for their "metabolic" approaches. In another significant contribution, the concept of "Sustainable Urban Metabolism" further conceptualizes how to position different disciplines and professions in relation to societal material flows in relation to the natural environment by building upon the concept of "Industrial Ecology" (Ferrao, Fernandez 2013). Ferrao and Fernandez also describe the position of architecture as a discipline/profession in relation to a spectrum of being analytical (observational) or synthetical (active/engaging) thus placing architecture as a heavily synthesis-oriented discipline indicating that it is a dynamic and active profession which aims to "do" (design, build and real-life problem-solving) and to a much lesser degree analyze and understand, respectively compared to other disciplines/professions relevant to the built environment (Ferrao, Fernandez 2013: pp. 50). Perhaps even the analysis which *is* performed is mostly used as new form-giving knowledge. Hypothetically, exactly this "synthetic" nature of architecture is what makes it prone to the risks of Jevon's paradox phenomena and thus remains within the growth paradigm.

2.1.4. A Planetary Approach through the Safe Sink

Another important contribution was the "Metabolism of the Anthroposphere" which solutionitical approach to the organizing manifestation of material flows within society in relation to the *hinterlands* (natural resources) ican bealanced way grounded in crucial substances and their importance to maintaining the quality of life (Baccini, Brunner 2012; pp. 107).

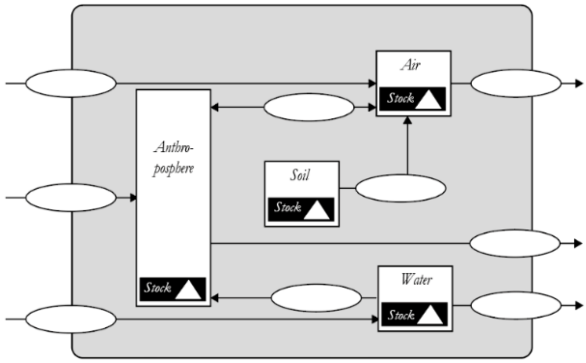


Figure 20. The planetary system boundary of the planet, air, soil, and water in relation to each other and the anthroposphere (society) (redrawn diagram) (Baccini, Brunner 2012).

Thereunderstandingother contemporary contributiof planetary thinking, and thinking in terms of planetary limitations with regard to any kind of consumption and industry (Rockström et al 2009; Raworth 2017; Jackson 2019; Schmelzer et al 2020). Even so, it has been difficult to situate architectural theory and practice in such lines of thought which takes into account challenges of complex material flows, entanglements, and Jevons paradox phenomena. Here, the chemical engineering field may have the potential to provide some rignecessitateatic thinking regarding this challenge, and what radically new consequence it would have for thinking in terms of planetary boundaries. A metabolic approach is thus inherently "planetary" as its fundamental functioning is that of mapping resource availability, capacity, and scarcity at different spatial and temporal scales.

Chemical engineering fundamentally provides a methodology: the Material Flow Analysis. This is the basic methodical approach to understanding (and thereby changing) patterns of material flows in society. While the method of MFA is at its core a part of the material flows practice and method, there are different fields and approaches within chemical engineering. One of the most significant being the theory of industrial ecology or industrial metabolism. Chemical Engineering thus provides a rigorous way to conceive and conceptualize this challenge with the key concept of "Metabolism of the Anthroposphere" (Baccini, Brunner 2012) via the methodology of Material Flow Analysis (MFA also often using the metaphor/metonymy of 'metabolism' as in the above tittle) which hypothesizes that an:

> "...essential part of a strategy to achieve sustainable development on a global scale is the early recognition of metabolic processes and their potential effects such as resource scarcity, environmental effects, and socioeconomic implications." (Baccini, Brunner 2012, pp: 16)

While metabolic studies deal with materials and substances, it is widely accepted that social and individual aspects of people in cities are crucial in explaining the currents of the material flows. This aspect cannot, however, be taken into consideration for chemical engineering methodology and urban metabolic studies (Baccini, Brunner 2012: pp. 285). It is thus crucial to consider and juxtapose social aspects with material concerns. A way to proceed, at least in the material path, towards a planetary way of thinking is to map out the so-called bio-region and thus create networks across several bio-regions globally (Ferrao, Fernedez 2013; Baccini Brunner 2012). As there is more and more new data and knowledge, it can seem confusing to think in those terms and absorb such trajectories within any architectural *ethos*. An important emphasis regarding metabolic studies is the centralization of the key concepts of "sinks" as scholars argue for an increased focus on facilitating and/or *designing* "safe sinks" for materials and products (Kral et al 2019; Brunner, Rechberger 2017: pp. 395). This concept seemingly holds a certain potential if we are, from metabolic perspective, to architecturally theorize what the city is, what its role is etc. If the city can be conceptualized as a "safe sink" (safe storage) of materials in its designed manifestations, it would potentially, regardless of future developments in tools and data, slow material consumptions and minimize its impact on natural environments.

Can we find any "metabolic" tendencies in tectonic design thinking which would allow for such a metabolic re-conceptualization of architecture?

2.2. Tectonic Theory

Having the above insight in mind, what is the state-of-the-art of tectonics - what are the general characteristics of tectonic theory, and can we also discern some of these above-mentioned tendencies or potential for metabolic thinking in tectonic discourse as well?

Although this PhD study is concerned with two disciplines, i.e. architectural tectonics and industrial ecology, the aim is nevertheless to implement the metabolic lines of thought from industrial ecology into architectural theory through tectonics. If we are to transfer some of the circular metabolic considerations and concepts from industrial ecology, what ideas, notions, and concepts would be necessary to consider in such an endeavor? This chapter will attempt to map tectonic theory with particular regard to material flows and metabolic considerations.

2.2.1. A Dualist Ontology: Material and Immaterial

The tectonic theoretical tradition, as we are currently familiar with, was brought into being in the 1800s by Karl Bötticher, and further developed by Gottfried Semper (Frampton 1995). The tradition however builds upon the Greek ancient history of the *tekton* (meaning builder) (Holst 2017) which was more concerned with the craft and making of built structures as a kind of proto-architectural immediate making or craft (not yet architecture). This proto-architectural notion of making is termed *techne* (Holst 2017) and is a kind of “organic” or balanced dualist idea of being artistic through technical means (Holst 2017, Christiansen 2014). Followingly, the *techne* discourse is wholly concerned with poetics and a kind of immediate/inward and “organic” approach to making (Hartoonian 1994) where poetics (or styles, etc.) concerns are at the forefront. Likewise, it is important to note that tectonic theory has been subject to scalar stretch, as there have been developments regarding material considerations, details (Frascari 1981), interiors, and buildings (Semper among many others), and likewise urban design considerations with an impetus in Sekler’s writing (Christiansen 2020).

As mentioned above, it was Karl Bötticher who attempted to intellectualize and modernize (in his time) the “organic” idea of *techne* into a tectonic theory. Tectonics in the modernized form was fundamentally brought into the intellectual sphere by Karl Bötticher who proposed a fundamental distinction between *kunstform* and *kernform* – *kunst* being linked with the beautifying and delicate applications, while *kernform* is a rigid structural frame (Bötticher 1852). Bötticher, in his division/dualism (of the *kern* and *kunstform*), argued that the two were inherently integral to each other. Regardless of how thoroughly he develops the arguments for this, later (modern) understandings are used in a segregated and split manner where the *kern* (material) concerns form at the front. With these founding contributions, an ontological split was introduced between material and immaterial considerations – even if their original authors thought of them as inherently connected – which led to early examples of the formal (structural) focus in architecture in the work of Viollet-le-Duc (Nygaard 2011) as well as several other throughout later architectural epochs which usually emphasizes the formal aspect through material performance and material properties.

Gottfried Semper proposed a radical shift away from an object-fixated approach to that of (the activity of) making and thus veiling interiority in his stoffwechsel theory (Semper et al 1989; 2004). Semper emphasized the "knot" as the primordial motif (and not the Primordial Hut as was the norm at the time). This emphasis on the knot paired with his *stoffwhcsel* ("metabolic") way of thinking, allowed for a critical deconstruction of the creative processes which further brought to light some of the hidden "organic" (instinctual) processes of creativity (*techne*) - a kind of attempt to "secularize" (or demystify) architectural production (Hartoonian 1994). Semper too conceptualized a dualist ontology of *structural-symbolic* and *structural-technical* (Semper et al 1989) with the first concept dealing with cultural aspects and the second with the material-technical aspects.

Over the centuries, several architects have made their contribution to the dualist "nature" of architectural thinking a production. While we see the material-immaterial dualism historically, we also see more contemporary iterations of it. Edward Sekler also makes a similar contribution but his contribution is more in line with Semper's founding axiom of "knitting" (as the essence of artistic and architectural production). Sekler emphasizes the dual processes of *constructing* (concerned with the formal and material aspects of making) and *construing* (concerned with immaterial aspects of telling a story of the making) (Sekler 1965).
Theoretician Kenneth Frampton later conceptualized a similar ontological split in his "poetics of construction"— a split of what he calls the *ontological* and the *representational* with one being the true and authentic and the other being theatrical or posing appearance (Frampton 1995). Framptom thus also introduces, as per Sekler, the distinction between the *tectonic* and the *atectonic*, highlighting a difference in the motif of whether an element follows its material-structural logic and the expression of such (ibid, pp.20-21).

There are similarly more contemporary variants of such material-immaterial dualist ways in tectonic thinking. While more a method than a theory, the contribution of *gestures* and *principles* (Hvejsel 2018) is similarly a way to create a dualism of material, formal, ontic concerns juxtaposed with the immaterial, phenomenal feelings (of interiority, etc.). Sometimes material and immaterial dualism can be practiced but perhaps misunderstood. As exemplified in a paper on insulation and tectonics, the author equates ontological considerations with that of *kern-form* (Ejstrup 2019). As it becomes clear in this article, the use of ontology (supposedly as opposed to cosmogony) is not "ontological" but merely ontic, meaning that it deals with "mere" material and/or technical aspects, while the terms "ontology" is much more encompassing and includes the material and immaterial within the same edifice. Ontology can furthermore not be put in opposition to the representational aspects, as the representational are inherent to the tectonic discourse. Using the same logic, Frampton's split of *tectonic/atectonic* can also be considered false as the *atectonic* is already inherent to the *tectonic, i.e.,* it is not possible to have mere ontic (material) being without its consequential expression, as "honesty" and "truth" in design is its own theatricality (Usto 2020). As Paolo Tombesi indicated with an analysis of a particular structural element in the Sydney Opera House (Tombesi et al 2022), there may be no "true" continuity between technique, making, and the final "Tectonic" expression. Tectonic is thus its theatricality and theatricality is inherent to tectonics, albeit a theatricality which is to be taken as seriously as possible.

As such, through the dualist way of thinking—usually comprised of two main constructs—tectonic discusses remaining as a kind of "conventional" mode of production (where the old *techne* is split into a tectonic dualist discourse of material and immaterial concerns) which fails to acknowledge some the inherent antinomies and deadlocks of tectonic discourse. This results in these antinomies and deadlocks remaining within the poetics of making circumscribed by the frame of growth and material consumption paradigm.
For this reason, a more radical critical tradition in tectonic discourse is to be brought forth along with the mapping of later (critical) ecological theorization. In proceeding with doctoral study, it will be necessary to map the "critical tecotnics" as it tries to deconstruct the instinctual, "organic poetics" of making as well as the "ecological" in the coming paragraphs.

2.2.2. The "Critical" Tectonics

One could naively assume that all architecture theory is ultimately supposedly "critical" either explicitly or implicitly because the premise of a theory can often be that there are existing conditions that are not "good", and a new perspective offers a different way of looking at things. The use of *critical* thinking in architecture distinguishes itself from this way of thought as criticality has been transferred from the critical continental philosophical tradition (i.e., Hegel, Marx, and later Hanna Arendt, Walter Benjamin, Adorno and Frankfurt School, to the later radical French thinkers in psychoanalysis etc.). Perhaps the great popularizer of *criticality* in tectonic discourse is Kenneth Frampton starting with his essay on *critical regionalism* with the "critical" aspect containing reference to Adorno and Arendt (Mallgrave, Goodman 2011, pp. 101). Later there are variants such as "critical tectonics" (Hvejsel 2018) and "circular tectonics" which certainly still contained the critical dimension. Nonetheless, these authors along with Frampton would better be designated as a kind of "applied-criticality" (as a counter against characterless opportunism) while the *critical* tradition in architecture and tectonics in their more "radical" forms are spearheaded elsewhere. While the *critical* trajectory in architecture goes beyond the tectonic discourse (Rendell ed. 2007), there have also been iterations of radical criticality in tectonic discourse which digs "deeper" into the ontology of making, bringing forth some *unpleasant* truths or "cracks" in tectonic discourse and architecture as such.

Gevork Hartoonian contributes in this regard, as he considers Semper's theory a

significant break with the "conventional" poetics of *techne*. Hartoonian indicates that much of architectural discourse is concerned with construction but that this is framed by a number of aspects whether implicitly or explicitly; one of them being *techne* (Greek word for technology or "art of making") which is already an integral way of making with an understanding of aesthetics and technical norms (Hartoonian 1994). He furthermore suggests that it was already Semper who introduced a significant distinction between meaning (immaterial aspects) and construction (and material/ontic considerations). Furthermore, Hartoonian's conviction is that this distinction of Semper's introduced a "break" into the "organic" and immediate application of *techne* – a founding critical break in the canon of tectonic (perhaps architectural as such) theory as it was a new direction compared to the aestheticisms and "historicisms" of his time towards "secularization" or demystification of construction. This, Hartoonian calls *montage*, i.e., a bringing together or seemingly disparate and fragmented pieces that do not form an "organic whole" and for this reason opens up an artistic space in the seam (joint or rather "dis-joint") between them. According to Hartoonian, the whole arises from these fragments, indicating a kind of oncological "unfinishedness." Hartoonian's elaboration on the "dis-joint", the Negative entity of the seam which is not in coherence with the "organic whole." This would be like when Luis Khan famously asked his bricks what they wanted to be. One of them might say that *it* does not want any of those things. The dis-joint is not just a new aesthetic for the design of joints but more fundamentally a manifestation of the problematization of architectural conception and humanist myths and subjective expressions of architects (Hartoonian 1994).
Another important distinction Hartoonian makes in reference to Semper is the dialectic of intention versus construction. Without refuting the poetic potentials of such a dialectic, it can be further expanded in comparison to material flows studies with which intentions and material manifestations are radically discrepant. Both within the realm of architectural and aesthetic intention (people experiencing the work completely differently than the architect intended) and in the current ecological challenges this could demonstrate a Jevon's paradox where the "sustainable" intentions materialize opposite effects. As Hartoonian notes, the modern twist is laid out by tectonics, as the radical disruption of old organic *techne* and that new epoch of *suspicion* is born where *montage* "…drains the metaphysics of tectonics and unfolds a new way of being." (Hartoonian 1994). Metaphysics in this context means the implicit ideological presuppositions, axioms, and aesthetic tautologies which have accompanied architectural production in pre-modernity which now must be disrupted by modern, critical thought.

Tectonics has, according to Hartooninan's arguments, acting as a counter to pre-modern "organic wholesome" architectural theory and practice in the sense that it introduced a modern and critical self-reflective moment in the canon of architectural theory and practice. One should here risk the possibility that within the tectonic theory itself arises a kind of repetition of "organic wholesomeness" as well with its ever-returning emphasis on making and poetics of transformative process into a final product that tells its own story. In extension of this, architectural ideological presuppositions remain in place even if a tectonic theory explicitly claims to be critical. In extension of this, one could be inclined to agree with Jeremy Till who also strongly criticizes tectonic discourse as an almost pompous discourse whose goal is to search for “tectonic effects” from higher moral grounds, while thinking all other works are of lower value (Till 2009, pp.177; pp.183). Even if these tendencies may be present in tectonic discourses - where ideological modes of operation continue (where architects instinctively know what is good, moral, wholesome, etc.) – I would still argue that there is an inherent potential for radical critical thought within tectonic discourse, since Till tends to slightly flatten the meaning of tectonics (ibid., pp.27). Some theories and methods are simply there to enable more creative production, while others require a critical introspective dissecting of architectural ideological presuppositions along with material and transformational processes which cause intellectual stagnation and as a consequence cause poor-quality in-built environs and relations with nature. It can thus be surmised that, within tectonic discourse, there are two traditions (the Positive and the Negative). On the one hand, is its very own continuation of pre-modern poetic organicism (Positive) and on the other a radical cut of critical reflectivity and introspection (Negative). The first instance is a kind of Kantian field of Things, which is largely concerned with formal constellations and structures and the poetics of such in which “tectonic designs” have an impetus in realness and truth is at the front, while the other is a Hegelian field of Negativity in which new ways of production are *not* proposed by arguing for a complex ontologically and contingent view on the architectural production through the lens of tectonics. The first is a positive, normative field while the other is not a direct opposite but rather a Negative self-critical entity within the first. Sometimes, even the “positive” strain describes itself as “critical” but in its applied reality it means that it is merely critical of other theories and built works which are *atectonic*, un-real, untruthful, or (according to its discourse) lack integrity. In opposition, the second field can also be critical of other theories and practices but is centrally concerned with being critical of itself through the dismantling its own meaningless fantasies, myths, and ontological and world-view preconceptions which may be faulty and as a consequence manifest undesirable physical effect as well as problematic ideological discourses.

After Hartoonian significant contribution in the 1990s, something new yet familiar emerged in the early ’00s. Specifically, it was as if the radical critical gesture of Hartoonian was too abysmal. Neil Leach et al. argued for a “structural turn” along with the development of CAD (in the 1990s and 2000s) in what he and his co-authors called “digital tectonics” (Leach et. al 2004). This argument returns us to the “usual” poetics of form-making and the structural capacities of architecture and tectonics of permanence. Critical of this tendency, Mari Hvattum, conceived of the mythical (axiomatically founding logic) search of origins in architecture and considered that perhaps it is not the permanent which deals with architectural essence but rather the ephemeral and fleeting feelings of interiority and their “hazes of carnival candles” (Hvattum 2001). In extension of this, according to Hvattum, it is the ephemeral and not the long-lasting which is more essential to architecture, and the origin of architecture is not in permanence but rather “…in the urges and acts that call forth such form.” (ibid)

Even more radically critical introspective, is the contribution of Mark Rakatansky on the tectonic acts of desire and doubt (Rakatansky 2012). He further inflicts architectural and tectonic discourse with Negativity by way of inscribing desire and its inevitable backside, doubt, alongside the founding principles of architectural concept and production. What he fundamentally illustrates is how not only the desires of the inhabitants, but equally, and perhaps more importantly how the desires of the architects affect (distort even) the architectural production and his/her accompanied doubts become discernable in the work. Perhaps formally comparable to the primordial search for origins, Rakantsky too elaborates how a search for identity is ultimately a failure, not in spite but because of this failure, desire persists, and the incessant self-revolving activity to search for "identity" perpetuates itself in designed/built physical manifestations.

The "critical" dimension is in a way the diametrical opposite of the poetic *techne*, as it is not a creating force but a *negating* force. The radical potential of the "critical" tectonics is thus to acknowledge that the edifice is filled with logical and ontological deadlocks where wholesome (organic) poetics of making is not only a profound aspect of architectural production but likewise filled with personal and ideological construction which in way risks of maintaining architectural thinking within the "usual" growth paradigm. While it can be difficult to arise at a kind of "final critical tectonics", along the way it is always needed not only that we are critical of other practices, but also question how we reason, why we reason the way we do, and what axioms and *a prioi* structure our reasoning.

2.2.3. The "Ecological" Tectonics

As the pressing issue of climate change along with material consumption are ever-more pertinent, and while the "critical" strain of tectonic is needed, it is likewise important to consider the tectonic theory concerned with the issue of ecology.

In this regard, David Leatherbarrow's elaboration of architecture being oriented *otherwise* (Leatherbarrow 2008) holds potential. This theoretical contribution implicates an ecological approach to design that was antithetical to the fetishes of the object-fashion (and its crisis). This "otherwise" architecture, is an architecture that embeds itself in the "web of life" as Leatherbarrow puts it (Leatherbarrow 2013). Architecture should be considered a multifaceted entity with a large mixture of affordances related to people, sites, terrains, and animal life potentially all at the same time. This is a way of understanding architecture as playing along with the many "points" in a complex network that does not pompously elevate itself into a supposed ideal, grand aesthetic (empty) gesture. While very sympathetic, the challenge remains of how to conceive of this so-called integration into the "web of life" and how rigorously this integration could occur.
In a similar vein, Claus Bech-Danielsen argues for the need to reconstruct our understanding of first nature to construct a new position of construction and architectural making as well as thinking which is connected with a more sober understanding of nature (Beck-Danielsen 2014). Among other issues, a way to

approach this challenge was the shift away from "..essence to assemblages…." (Stylsvig Madsen 2014) – fundamentally mirroring the ongoing shift from discursive objects to relations/processes. Stylsvig Madsen argues for a refreshed view of parts and wholes in which he mobilizes Manuel DeLanda's theoretical elaborations on the assemblage (Delanda 2016), i.e, a complex object which is constituted by several similar and/or disparate entities in a network (ibid).

Perhaps epitomized by Anne Beim, tectonic theory also started to engage with ecological concerns, not unlike the abovementioned, i.e., Leatherbarrow's intentions, Beim envisioned a more rigorous, normative approach to material practices in editing a book on tectonic and ecology (Beim, Madsen ed. 2014) and later developed ideas regarding circular tectonics (Hvejsel, Beim 2019). She, along with the research group CINARK, has helped develop significant contributions such as the material pyramid (CINARK 2019). Given that the circular economy was starting to pose a challenge for how tectonics are conceptualized, contributions emerged. Decoupling material consumption from economic growth was also considered important, and tectonics holds potential in this regard (Kjær Frederiksen, Munch-Petersen 2019). Furthermore, as design-for-disassembly started to become a dominant agenda, contributions were made to conceptualize tectonics and tectonic detailing for assembling and disassembling purposes (Ejstrup, Munch-Petersen 2019). On the other hand, similar contributions on circularity and tectonics have argued for the inclusion of aesthetics and beauty in particular (Andersen 2019) and other immaterial considerations (Usto 2019) in circular practice and theory as there has been a predominant emphasis on design-for-disassembly (Hvejsel, Beim 2019) in architectural practice. Currently, we also see an emphasis on the need to build more with wood and other organic materials (as per the material pyramid (CINARK 2019)). The challenge with this is that without the "metabolic" dimension (as seen in chemical engineering) there will be an advocacy of "building more with wood" without the understanding of its wider entanglements and need for a "safe sink". Likewise, the capacity of forestry is also limited and entangled with other industries (food, furniture, paper, etc.), and there is a need for a "metabolic" dimension within tectonic discourse.

As the theme of this doctoral study is materials and their transformation in different forms, Gottfried Semper's key notion of the stoffwechsel (sometimes translated as metamorphism, but translated as metabolism) is of importance. Akos Moravanszky, perhaps more than any other contemporary thinker, has re-actualized Semper's ideas on material changes/exchanges, making the relevancy given the current predicaments of climate change and material consumption more prevalent. Semper's application of this theoretical notion aims to explain the different phases of how a material goes from its original form to being transformed to finally becoming a built work (Semper 2004). With reference to Semper, Stine Sundahl mentions that there is a higher metabolism of skeuomorphism (of culturally relevant transformation of the form) and a "mere" material transformation (lower metabolism). Sundahl deliberately differentiates the notions of metamorphism and metabolism, where metabolism is more of a design and formal consideration, as mentioned above, but the metabolism is a literal material transformation, such as burning processes (Sundahl 2019, pp.88), which claims that

metamorphism is related to the metaphysical world while metabolism is an "ontic" material process which is not concerned with immaterial properties of the transformations. In pushing back on this division, Semper's definition of the stoffwechsel is equally immaterial and material (see chapter 4) and it may be unnecessary to distinguish two types of "metabolisms" terminologically as metabolism can be sufficient in containing both types of transformations (material and immaterial). Recently, perhaps the most elaborate of the contributions to Semper's stoffwechsel has been the contribution of Akos Moravanszky simply titled Metamorphism (2018). Moravanszky elaborates in detail Semper's metamorphism (stoffwechsel) and its different variants but fundamentally acknowledges that Tectonic theory and stoffwechsel could be much more radically aligned with ecological concerns in regards to positions architectural material exchanges/transformations (metabolism) between society and natural environment (Moravanszky 2018, pp. 212) and not remain at the same level of metaphorical thinking concerned with the creative process as seen to this point.
Isak Worre Foged also develops, with direct reference to Semper's stoffweshsel, his own "stoffwechsel II" (Foged 2018), but this is more of a micro and macro climatic "metabolic" exchange between materials and (material-atmospheric, if you will) environment and does not conceive stoffwechsel (metabolism) in a large (industrial ecology and societal) scale. Foged argues that Semper's stoffwechsel is merely a visual transformation, but I would argue that it may be indeed more than that and Foged does not consider the material (wider industrial metabolic) potentials of such a "immaterial" metabolism. Stoffwechsel II could be seen as an example where a "metabolism" is conceived in the literal sense as chemical reactions (climate and weathering reacting with the surface of the material) which change the (surface) expression of an element/material. As such, an example where being literal (a la the Analytical Philosophical Tradition) proves limiting in comparison to chemical engineers' field of societal metabolic studies (which knowingly utilizes the metaphor for a large-scale application despite challenges of the metaphor).

While Semper's theoretical writings are complex, and the precise outlook of the notion of metabolism not outlined by him, later scholars have elaborated on the centrality of stoffwechsel to Semper's writings (Chestnova 2018) to Akos Moravánszky indicating that all of Semper's theoretical contributions on practical aesthetics is fundamentally covered and encapsulated by the overarching notion of stoffwechsel (or *metamorphism* as Moravanszky insists) (Moravanszky 2018).

2.2.4. An Overview: A Prolegomena to a "Critical-Metabolic" Tectonics

Tectonic is not just *one* theory. Rather it is a theoretical discourse that has spanned centuries and continues to receive new contributions and is needed to somehow make sense of the different strains of theoretical contributions as the conditions and aims are different to the point of being contradictory or antinomic.

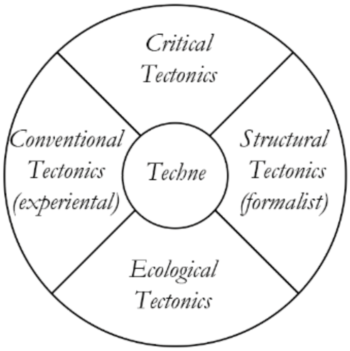


Figure 21. The four-leaf structure of tectonic discourses.

Generally, we can claim that there is a branching of the tectonic approach – all of which spurs from the center that is *making.* It could be proposed that there are four main strains of tectonic thinking: the "conventional", the structural, the ecological, and the critical. These overlap and contain elements of each other; however, all relate to the central dimensions of *making,* as it either drives the tectonic strain or criticizes and deconstructs it. The "conventional" and "formal" are mostly extensions of the poetics of making, while the "critical" (Hartoonian) and "ecological" (Bech-Danielsen) try to deconstruct and reconsider the essential dimensions of architectural making.

Though I would argue for the four main discourses, it is also very difficult to divide them as each scholar or practitioner within tectonic mobilizes more often than not all four while arguing that certain considerations can have higher priority than others (i.e. the priority of climatic and environmental relations in Isak Worre Foged's works, or the radical critical dimension of Hartoonian and Rakatansky, etc.). Semper's stoffweshsel has here a particularly almost universal status, as it potentially covers all four discourses simultaneously and equally.
Furthermore, throughout the history of tectonic theory, the discourse of a dual nature can be laid out as containing both material and immaterial aspects. Remaining at this "conventional" dualism nevertheless allows for modern iterations of the pre-modern mechanism of *techne.* Likewise, the crucial aspect to expand is the material preconditions of architectural production. While there are developments in this direction, we are yet to see an architectural theory that is ontologically imbued with a critical metabolic understanding of processes as developed in chemical engineering. In this trajectory, Semper's idea of stoffwechsel holds the potential to be coupled with the urban metabolic (chemical engineering) notion of societal material flows. As Hartoonian elaborated, Semper intended to attempt to "secularize" architectural production with inspiration from natural sciences, and the idea of metabolic transformation was used to "segment" architectural production phases.

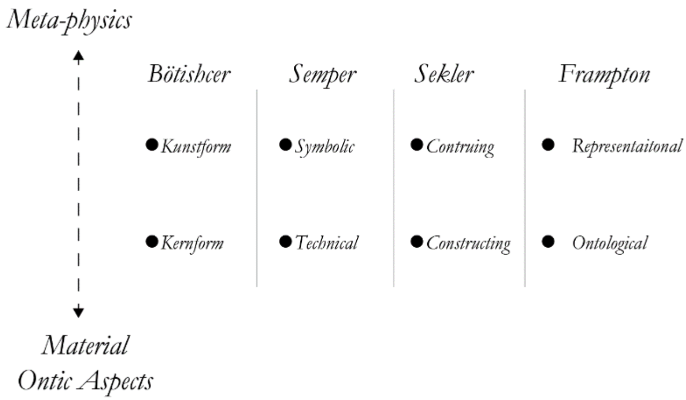


Figure 22. The material-immaterial dualisms (though not the only ones) of tectonic discourse.

That is not to say that it would be pertinent to do away with the material-immaterial distinction and return (reenchant/mystify) to a pre-modern organic unity of poetic *techne* into a contemporary fetishism of the act of *building*, but rather provide more nuance to the spectrum of the material-immaterial dualism. That is to say that regarding material aspects, the material dimensions were conventionally limited to meaning material availability and material properties, and recently we are becoming aware of the need to also consider material consequences or limitations/boundaries. Another missing aspect in explicit terms is a tectonic category which is perhaps that of “function”. While this is indeed a difficult category (also indicated by Nygaard), for the most part, we accept that function is often “fixed” to a form (Nygaard 2011). Even so, function is and should be seen as important, as it is conceived in metabolic studies (see chapter 4). Literature on material flows and metabolic studies also furthermore highlight how “use-intensity” is an important factor to minimize material consumption, meaning that there is a need to minimize buildings being empty and make the most of every facility for any function it may house (IRP 2020, pp 90-94). While it may be nonsensical to conceive of a “Functional Tectonics” (next to all the different strains of tectonic discourse) as *use* inherent to the design, it may hold the potential to consider functionality/flexibility in its own (metabolic) right.

Tectonic discourse can also develop its own “ideology” in which arguments (or even critical thinking) can be flattened to a kind of automated mechanism of simply calling something “true” or “authentic” tectonic and thus of higher morality. Given the many implicit assumptions, axioms, and pompous ideological fixations in architectural theory, the very notion of so-called (proverbial almost) Capital A Architecture (usually the very opposite of mere building) gets sublimated into “mere architecture”. The reason for this is that the very ontological being of architectural production has become automated, where arguments of something once profound get flattened to facilitate any design. Tectonics is guilty of this with its usual arguments that something is “true” and “honest”; arguments which have given birth to lazy and “phony” moralism (Till 2009) that fail to provide meaningful cognitive coordinates on how to engage with reality. An important critique of the tectonic discourse is provided by Andrew Benjamin who demonstrated that the materialist approach can be entirely disconnected from empirical material conditions and concerns into a kind of material/tectonic ideology (Benjamin 2007). Ultimately such a disconnectedness/suspension may perpetuate the current hegemonic modes of production within the linear growth paradigm, as it merely serves as mental inspiration for creative endeavors and subsequent material consumption.

The “ecological” strain is in limited scope when it comes to tectonics. While it is indeed a discourse that deals with materials and making (and the narrativization of such), there is still a possibility to develop a tectonic theory which situates architectural production within the wider material conditions and planetary boundaries from an industrial metabolic way of understanding.

The best iteration of ecological tectonics is currently the theoretical (as well as practical/normative) contributions to the notion of “circular tectonics.” This is a late shift in a tectonic discourse which is fused with the ideas and strategies of circular economy (Ejstrup, Munch-Petersen 2019) and has an extenuated emphasis on “design for disassembly” (Hvejsel, Beim 2019). Since then, there has also been a movement towards developing “radical tectonics” (Trubiano, Beim, Meister 2022) which is not to be confused with the book on “radical tectonics” from 2001 (LeCuyver 2001). The authors attempt to conceptualize a so-called “absolute sustainability” through a multi-scalar approach (Trubiano, Beim, Meister 2022). While that paper argues for social inclusion as well as material conditions, there are no explicit and immediate conceptualizations of planetary boundaries and limitations, potentially in the ways that we have familiarized ourselves with in the former chapter and paragraphs (chapter 1.2 and 2.1.).

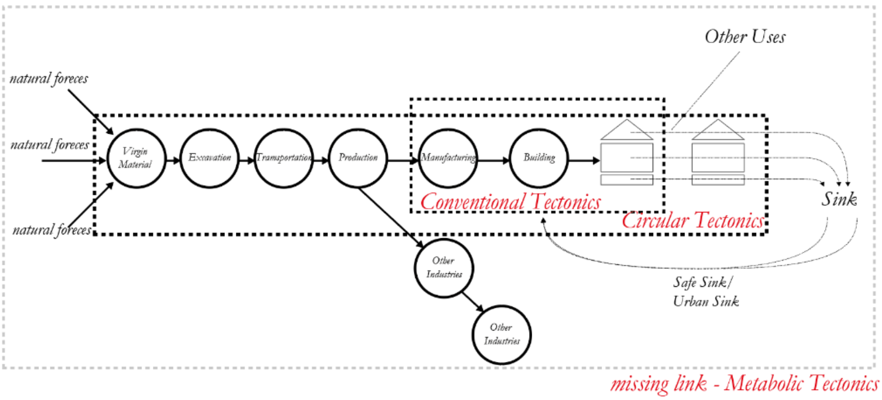


Figure 23. The scopes of Ecological Tectonics.

But the contributions on both circular and radical tectonics are not yet fleshed-out theories but more normative indications of possibilities, i.e.., material pyramids (Munch-Petersen, Beim 2022; CINARK 2019), critiques (Hvejsel, Beim 2019) and explorative texts on the similarities between circular economy and tectonic thinking (Much, Frederiksen 2019), all of which lack the metabolic understanding as seen in chemical engineering. That is to say that current tectonic fused with only "circular" thinking cannot account for phenomena such as Jevon's Paradox and may even be at risk of repeating such phenomenon (e.g., increasing accumulated material consumption across the industry while minimizing material use for a single building). This is because researchers on CE and LCA argue that there is no guarantee that any circular design strategy will be used in the future as intended (and calculated) when designed and built today (Eberhardt et al 2020). Perhaps a different variant of tectonic theory can be forged if it translated some of the key aspects of the chemical engineering understanding of metabolism.

As Jonas Holst has reified in his historical analysis on the ecological potentials and implicit connotations of antient Tectonic thinking, conceptualizing the proto-architectural notion of Tectonics in its own right has tremendous potential and an actuality of its own (Holst 2019) and could even be seen a pretext for metabolic thinking in tectonic discourse. Metabolism can be considered a central notion in Tectonic thinking, as scholars have brought renewed focus on this idea, and perhaps the best known contribution is Akos Moaranvaksy's on Semper's stoffweshcsel (Moravanszky 2018). As Hartoonian elaborated, Semper's theory was a significant break in architectural thinking as it tried at deconstruct the creative process and attempted to demystify it. This is certainly relevant to this day, as it is important to explore and highlight how the architectural creative process "construes" questions of materials which allows for perpetuation of ever increasing material consumption within the linear growth paradigm and beyond of planetary limits and boundaries. Not only for purposes of deconstruction and critique, Semper's stoffweshsel is also of relevance as a foundation for a new tectonic theory which situates itself within planetary boundaries as developed in urban metabolic literature.

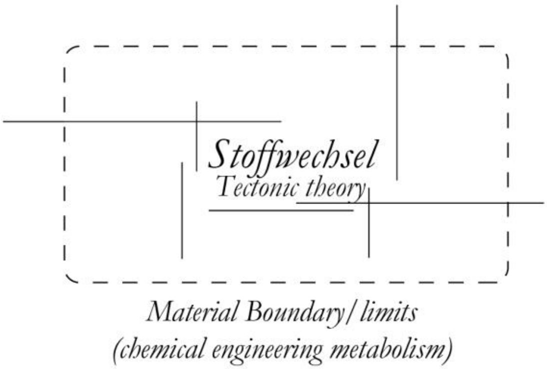


Figure 24. Coupling planetary boundaries with tectonic metabolism.

There is currently no architectural theory that can include something like the phenomenon of the Jevons paradox. It is a crucial phenomenon to consider regarding material consumption and architecture theory is mostly confined to theorizing the design of singular objects (buildings, urban spaces, districts, etc.). Even when architecture attempts to be “sustainable”, it has no way of thinking about how “good intentions” can be materialized in negative ways to increase, and not decrease, materials consumed and impacts on natural environments. Architects obviously would not claim to have “ill intentions”, so why are that good intentions materialize as their opposites, we need a critical architectural way of also thinking in these terms. Aspects such as planetary boundaries are mainly developed in natural sciences or applied sciences among other research fields, and architects are indeed attempting to implement these considerations in methods and tools and ultimately try to envision what kind of architecture would fit such a “planetary” trajectory.

In the coming years, there will certainly be different attempts to “architectural” planetary boundaries, and thus integration into architectural theory and practice, but the challenge remains of how to do so. How can this be achieved in rigorous ways so that we do not conceptualize too loosely in a way which will allow for many future examples of materialization of Jevon’s paradox (we intend good things and we manifest increased not decreased carbon footprint and material consumption etc.)?

It is in this relation that my hypothesis of the juxtaposition of tectonic theory with that of metabolic studies (as seen in chemical engineering and industrial ecology) could provide crucial insights.

2.3. Conclusion of SoA: Metabolism in the Middle

With tectonics and industrial ecology being two separate fields within two different disciplines, they nevertheless hold immense potential when juxtaposed. The commonality that they nevertheless potentially share is that of “metabolism” and “metabolic” thinking. Concludingly in this section of this chapter, the challenges and objectives will be laid out in relation which have a “metabolic” impetus.

2.3.1. Metabolism as common denominator

Given the many challenges regarding material consumption in the building industry (as reified in chapter 1.2), we can observe that tectonic theoretical discourse holds potential as a way to implement metabolic and planetary thinking regarding material consumption in the built environment. Industrial ecology is solely concerned with materials but does acknowledge that social and economic aspects greatly influence material consumption. Rather, it is not something that is empirically mapped and included in material flows analysis. Tectonics, on the other hand, includes social and cultural considerations regarding the design of the built environment, and despite having ecological trajectories is still limited in comparison to industrial ecological ways of thinking about cities and material construction.
Both (tectonics and industrial ecology/metabolism) have their strength and limitations as there are wider sociopolitical aspects to consider which are not included in either of the two. We have seen that tectonics has width regarding scales and design challenges, while metabolic studies allow for a similar cross-scalar approach making it possible to freely choose both the temporal and spatial system boundaries of any chosen of interest. Tectonics is a wide field, with built theory across scales from material (on micro levels) (Foged, 2015) to detailing (Frascari 1981)   to urban design scale (Christiansen 2020). All of these approaches have impetus in material understanding in relation to immaterial aspects while demonstrating a width of approach in scales. Material Flow Analysis (also known as ‘metabolism’) has thus been considered a good supplement due to its flexibility over scale (from a single household to an entire city or even region) while having an impetus in materials (Oswald, Baccini 2003; Baccini, Bruner 2012). The scientific disciplines and fields of ecology and natural environment are many. There is anything from environmental sciences to ecological sciences all of which overlap to a greater and lesser degree. But chemical engineering is an applied science that relies on the knowledge and findings of natural and environmental sciences and the theory of industrial ecology (and MFA methodology) which can act as a lens or filter for making findings in other fields meaningful and applicable.

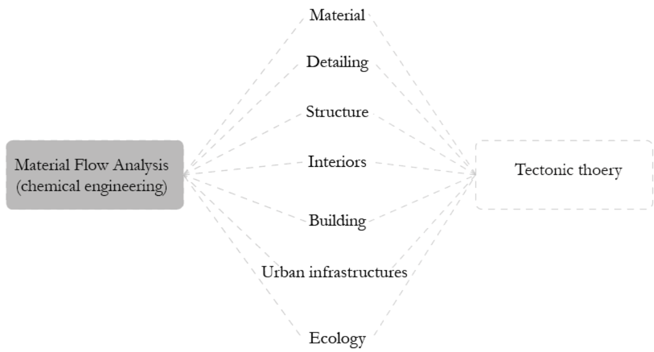


Figure 25. The potential links of industrial metabolism with tectonics.

Regarding the challenges of being within a linear growth paradigm, even with the latest developments regarding the circular economy and circular tectonics, it may not be certain that material consumption will be minimized or slowed as there is always a risk that curricular strategies will not be implemented and used by future generations as intended.

While this issue and its challenges are = expansive regarding dealing with many other aspects of the economy and social and political realms, from an architectural perspective it would be pertinent to deconstruct and reposition how we think about design. That is not to say that we *are* stuck in the linear growth paradigm because tectonic theories are not critical enough, but we have to make ourselves aware of some of the gaps in theoretical ways of thinking and the application of theoretical positions in practice. Even if the industry currently finds itself within a shift from a linear to a circular economy, such a shift would still be linear, and if the "economic" aspect of circular economy is overly emphasized and the application of circular thinking in practice is limited to "design-for-disassembly", there is a risk that the industry will perpetuate or even increase material consumption and not slow and narrow the flows. For these reasons, the "crucial" and "ecological" strains of tectonic discourse are to be coupled with industrial ecology (metabolism). As an extension, Gottfried Semper's theory of stoffwechsel (metabolism) could, in an extension of Hartoonian's reading, be conceptualized as a critical-ecological theory as it attempts to deconstruct (materially and immaterially) the anatomic and ontological structures of architecture design and creativity. Juxtaposing tectonic (metabolism) with industrial ecology (metabolism) could prove fruitful in providing potentially new ways of thinking and insights. However, as they are two separate disciplines having their immense complexity, a way to proceed is to centralize the notion of "metabolism" as a commonality between the two.

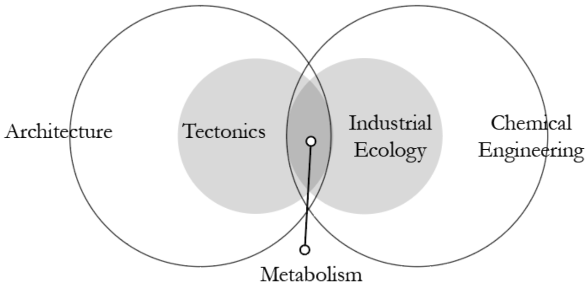


Figure 26. Metabolism in the middle.

Metabolism is mobilized very differently in the two disciplines, as they help to explain two different "flows" of material (and immaterial) aspects. Specifically, one can deal with entire cities in terms of how materials move through society, and the other can be described as a kind of breakdown of architectural constituents and how the creative process takes place with impetus in materials. Both are metaphors. A city is neither directly an organism that has its metabolism, nor is the creative design process a literal metabolism. There here is however utility in being aware of the uses as metaphors. With these theoretical frameworks, theory building will proceed in chapter 4 by way of a more precise "breaking" down of theoretical constituents in correlations to presented methods and methodology (chapter 3.).

2.3.2. Key Challenges and Objectives

There are certainly many challenges and issues persisting regarding material flows, especially regarding mapping and redesigning of these flows. This doctoral study has observed a missing link for architectural theory to attain a different "materialist" understanding informed by the chemical engineering discipline. As such, this doctoral study is concerned with building an interdisciplinary architectural theory that integrates consideration from the industrial ecology framework. The challenges are laid out in relation to missing aspects of the currently available theory and the inner structures of the theory.

Generally, it can be described in parallel to the conventional modes of production (Figure 17, chapter 1.4) where each mode of production can be paired with a similar "tectonic" tradition. The classical, or conventional, dualist tectonics tend to isolate a single object, while stoffwechsel is a procedural cycle that comes from the transforming material for usage, etc. The missing link is to be explored in this doctoral study, *metabolic* tectonics.

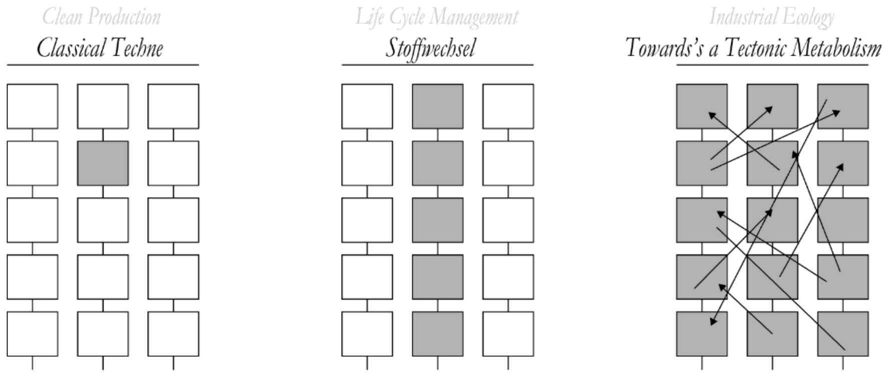


Figure 27. Regarding Figure. 17, there is corresponding "tectonics" to the different ways of making /producing.

With Jevon's Paradox as a starting point, we could hypothesize a discrepancy between what is being said/intended and what material consequences manifest, i.e., a discrepancy between theory and practice. Tectonic theory in its current state does not have a way to consider how and theoretically conceptualize that "good intentions" can manifest materially entirely outside of our intentions and control.

Tectonic theory is missing the "metabolic" dimension, as it is known in chemical engineering because such a perspective could potentially require rethinking ways of design and creativity.
We also see a dualist ontology of the material-immaterial spectrum mostly made up of two constructs. It could be of importance to nuance further this material-immaterial spectrum and how it aligns and correlates the critical mechanisms (constructs) of architectural thinking with material limits and conditions. This spectrum implicitly contains both the Analytical and Continental traditions. The reason for this is that something like planetary boundaries has to be dealt with Analytically (empirically) while the challenges of deconstruction inner axioms and problematic "ideological" construction within the tectonic theoretical edifice require a Continental thinking (more on this in chapter 3).
One could argue that the predominant mode of research today is the Analytical tradition, but the reason to also include the continental is due to its critical tradition. Why? Because phenomena and notions such as *techne* and poetics are core dynamic mechanisms, which can spur new "myths" at any time. Theoretically, we have to be aware and focused on critical reflection and deconstructing of such constructs to understand what we are "really" doing (what material consequences are there of our ideological preconceptions). Just because we experience ourselves as rational, it does not mean that our actions and their material consequences are equally rational.

Theoretical constructs (e.g. *issue, concept,* and *form* (Aksamija, Irdanova 2010), see chapter 1.3.1) are too open, lacking a kind of material culpability, and open for endless iterative variation. As Nygaard elaborated, they are too much inclined towards "practical" problem-solving and do not allow critical issues such as a "problem-solving" approach. While there is certainly another aspect that also cements the architectural discipline within the current linear growth paradigm, the architectural culture of making few and "open-ended" constructs does not allow for a critical challenge of the current hegemonic ways of thinking.

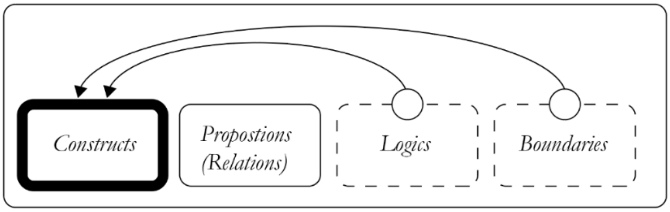


Figure 28. Construct and boundaries.

Given the creatively inclined openness of architectural constructs, a newly built set of constructs would need to contain considerations of both material and immaterial "boundaries" – meaning that aspect of philosophical and ontological foundations (critical theory) as well as empirical-material limitations (planetary boundaries through metabolic thinking) of the theory should "represented" among the constructs.

Objective

This doctoral study's main aim is to build a metabolic tectonic theory that could act as an anchor when dealing with issues of life cycles, new tools, and technologies/techniques in the building industry. The building of a theory needs to contain both explanatory and observational capacity (analysis) and at the same time – with the same theoretical framework – it should have the capacity to prescribe actions normatively (design). Metabolic thinking can be very complex and in the future, more and more data, knowledge, methods, and tools will be developed which means professionals linked with the built environment (architects, engineers, urban designers) will be required to utilize any of these as well have an understanding of material consequences. Currently, such knowledge and tools are external to architecture, but with an actualized metabolic theory for architects, designers, and engineers, these professionals could be better versed for the challenges of any future tools or conditions.

2.4. Research Question

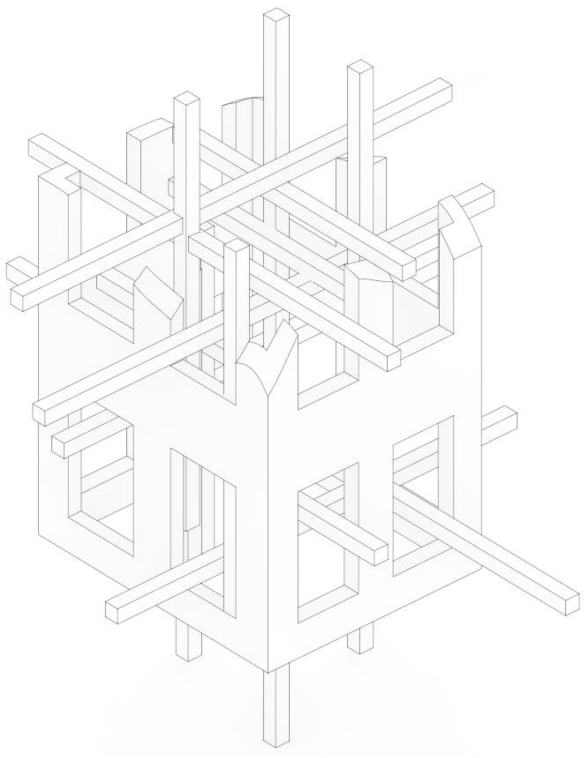
Given the aforementioned challenges – and in the context of this doctoral study's aim to build a theory – this doctoral study proceeds to develop a theory through the juxtaposition of tectonics and industrial ecology. Since theory development generally deals with both theory building and theory testing, the overarching research question of theory development, along with the sub-questions which are concerned with the testing of theory in both analytic and design capacities are discussed below.

Research Question(s):

Main Question:
1. How can a joint tectonic-metabolic theory be developed, which is *metabolic* through the centralization and transformation of the notion of "safe sink" into architectural and design discipline, and to what degree can such a *metabolic* approach provide pertinent insights, reflections, and understandings on material consumption in the built environment? (chapter 4)

Sub-Questions:
2. How and to what degree can such a theory introduce a combined material and immaterial (metabolic) understanding of construction in architectural *analysis*?
(paper 1 + chapter 5)

3. How and to what degree can such theory introduce a combined material and immaterial (metabolic) understanding of construction in architectural *design*?
(paper 2 + chapter 6)



Chapter 3.
Methodology and Research Design

Towards the development of theory, this chapter gives an initial overview of the research strategy and subsequent research methods for theory development as well as the building and testing of theory. This chapter elaborates on the chosen methodologies respectively for the building and the testing of the theory. Afterward, the chapter delineates the ontological and epistemological assumptions of the doctoral study and its endeavor toward theory development. Finally, the chapter concludes with a research design and provides an overview of how the theory-building and testing efforts are to take place.

3.1. Research Strategy

As theory development involves both the building and testing of theory, the doctoral study is initiated by the need to first build an initial theory and then test it. The testing of theory occurs on two main levels when it comes to architecture and design: analysis and design. In this doctoral study, the Initial theory is built through reference to other theories, but the testing occurs both about other theories as well as empirical inquiry.

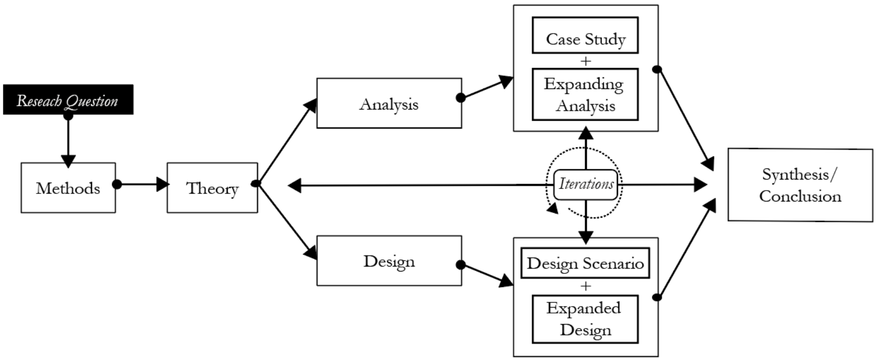


Figure 29. Overview of the research endeavor.

3.1.1. Scientific Research Logic

The research logic which provides rigor to this iterative process is Karl Popper's circular logic for scientific research inquiry (Popper 1959). Popper elaborates on the importance of developing hypotheses (or theories) which one then attempts to apply and falsify (ibid). This aspect is of importance for this doctoral study as the initial hypothesis of a joint tectonic-metabolic theory can be assumed to provide new insights but requires applications and thus attempts of falsifications to both tests the limits of said theory and subsequently adjust it in accordance to both other existing theories and the findings of the testing efforts.

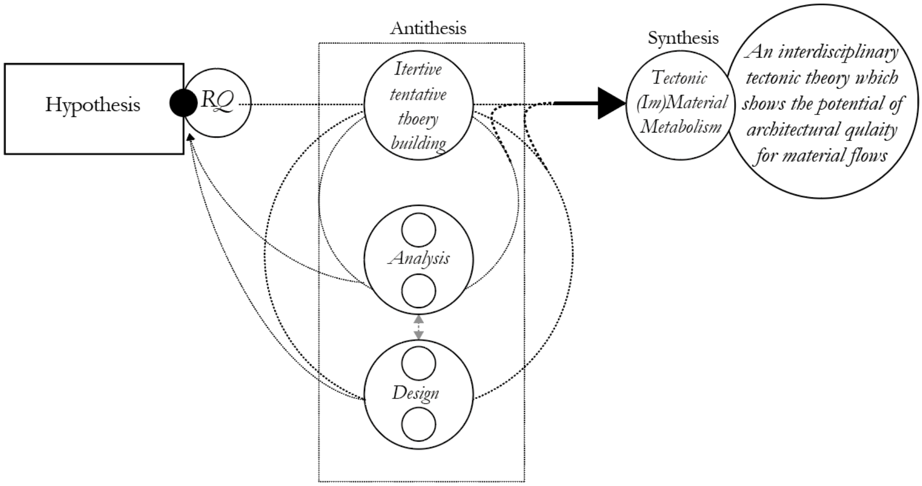


Figure 30. Iterative loops of testing and building.

Fundamentally, the research strategy is an abductive approach. Abduction is the "…logical operation which introduces new ideas.." (Groat Wang 2013, pp.34), and as this doctoral study is concerned with building a theory by way of building and testing the theory, it will proceed as such.

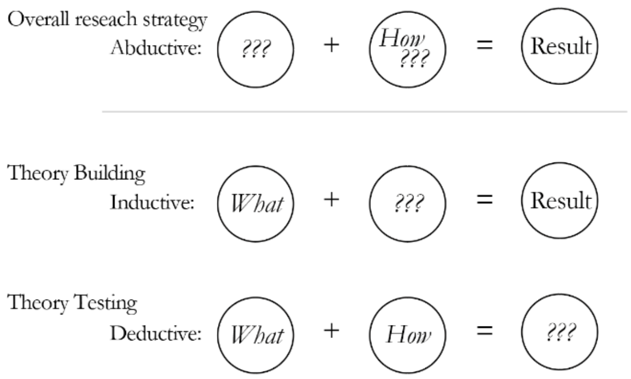


Figure 31. Abductive research strategy - along with inductive (building) and deductive (testing).

The research strategy is thus an explorative mixed-method strategy initiated by a deductive approach of building a hypothesis and a theory. It then tests the research empirically to inform inductively the initially theory building.
Furthermore, the research relies on both qualitative and quantitative data as the research question is concerned with reifying how immaterial aspects can play a part in slowing and narrowing of material flows. The conducted research of this doctoral study is mostly qualitative, though it was also initially intended to do LCA calculations (i.e., in the case study paper) but this proved difficult due to lack of access to (historical) data regarding where materials of said cases actually went.

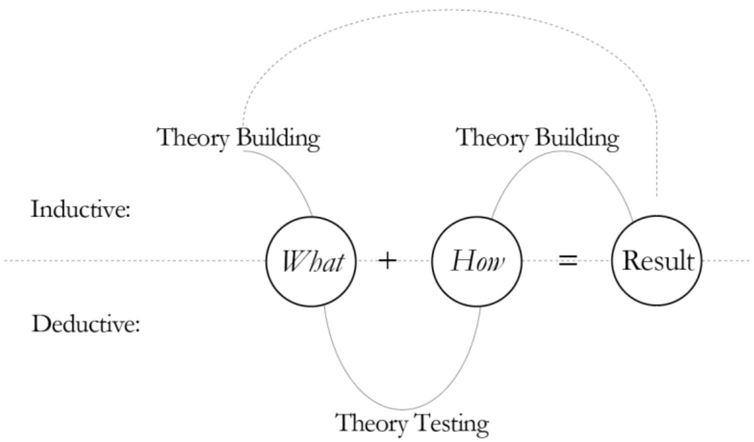


Figure 32. The dual process of abductive approach: inductive and deductive.

Towards building of a theory, there is an initial pre-synthesis of the theory, which is in way a "specter from the future" (inductive process) that then needs to be applied and thus tested (deductive). This is then an iterative process, as the testing of the theory provides insight which allows for refinement and nuance of the initial theory.

3.2. Theory Building

In the following section, a mapping of the theoretical framework and methodological considerations regarding theory development are laid out. Firstly, there is an elaboration regarding the general scope which is an interdisciplinary approach due to dealing with architectural (tectonics) and chemical engineering (industrial ecology). There is then the theoretical elaborations on the development of theory and what particular methodological considerations are crucial to structure the theory building efforts of this doctoral study.

This paragraph will give a slightly complex account of the methodology as we are indeed dealing with an interdisciplinary theory building exploration. While the overall scope is to develop a theory which hinges on the use of metaphor (as method), it also requires other sub-strategies, as method (of metabolism) is not enough on its own to provide specific direction regarding how to explore the "safe sink" in tectonic terms.

3.2.1. Interdisciplinary Research

The premise for theory development of this doctoral study is that of interdisciplinarity. While we are seeing more and more segmenting of different professions across all markets (architecture diving into landscape, building architects, urbanist, planners, interior designers etc.), the built environment includes the problems we are attempting to tackle occurring and requiring being dealt with from a multi- or interdisciplinary way of thinking, as one particular problem can span many fields and disciplines. Along with a developing and more interconnected global society, approaching different issues and problems often requires more nuance and insight from different perspectives, both separately and from an integrated, interdisciplinary point of view.

Karl Popper famously proclaimed that:

> "We are not students of some subject matter, but students of problems. And problems may cut right across the boundaries of any subject matter or discipline." (Popper 1963)

The above is a statement is becoming more and more relevant today given the fact that issues and challenges of contemporary society are intertwined (within itself and nature) and perform as complex adaptive system (CAS) which are "at the heart of many contemporary problems" (Holland 2006). Furthermore, when a problem is so complicated that it is fundamentally hard to establish what the problem is to begin with, they are categorized as "wicked problems because they "lack a definitive formulation or solution" (Keestra et al. 2016). The overall issue of material flows (from the perspective of architecture and the built environment) can be conceived as such a "wicked" problem, since it is fused with social, economic and environmental concerns in a complex array or web of agencies and actors.

There are different ways to define what a discipline is, and when we are dealing with the dual nature of this doctoral study, generally accepted definitions from a scientific understanding defines architecture as part of wider scope of disciplines (Keestra et al. 2016, pp:29) while, some architects themselves speculate and argue that architecture is its own discipline (Leatherbarrow 2001). This doctoral study relies on the provided definitions of two main groups of disciplines, i.e., natural sciences, social sciences and humanities (Keestra et al. 2016, pp:29). As metabolic understanding from chemical engineering necessitates an "multi-cycle" approach, it would be fruitful to conceive of architecture as part of a larger scheme or network. At the same time, these two opposing views are not entirely incompatible. Given the proclivity of this doctoral study and its interest in an interdisciplinary approach to material flows, the his thesis relies on the interdisplinary literature's definition (ibid) to use the main disciplinary groups. The firstly being "Geography and Urban Planning" from social sciences which concerns itself with the built environment (which contain architecture and tectonics); secondly, "Chemistry" from natural sciences which contains chemical engineering (MFA and industrial ecology).

There are a number of reasons why this categorization and definition of disciplines is pertinent to consider. Firstly, although it may appear superficial, the fact that this doctoral study has a foot in the two main groups is important for considering it a thoroughly interdisciplinary endeavor. Secondly, unlike the notion that architecture is its own discipline, positioning architecture within a larger disciplinary context not only demands an overview for potentially and critically positioning professions within the built environment in a larger perspective internally within the discipline but also externally towards to two sciences and the humanities.

With the two pertinently chosen disciplines, the doctoral study proceeds by relying on the interdisciplinary research model "IIS" (Keestra et al. 2016, pp:52) which is made up of the following phases: Identify the problem field or topic, formulate preliminary research question, develop theoretical platform, finalize research problem, formulate sub-question, develop research design and method, collect and analyze data, interpret results, and conclude and reflect (ibid) (figure 33). This doctoral study and its chapters are thus guided by the interdisciplinary research structure of the IIS-model in which the introduction chapter (1) accounts for the problem field or topic which is the issue of material flows within the built environment. The second chapter outlines the current theory and practice along with a state-of-the-art (of the two disciplines of this doctoral study) of the relevant two disciplines, i.e., finishing the chapter with the final research question Chapter two accounts for the interdisciplinary reasoning and the research design which oriented around theory building and a design scenario. Chapter four develops a greater perspective of the theoretical background of the two disciplines and build theory through an iterative process of conducting a design scenario in chapter 5. Following this, chapter 6 presents the resulting theory of the (im)material metabolism. The dissertation concludes and reflects upon the research in chapter 7.

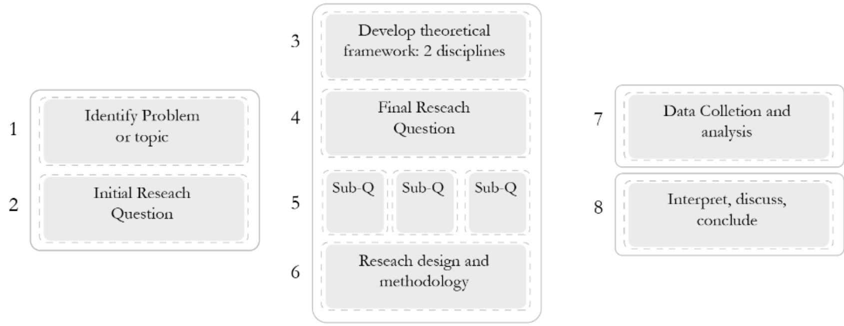


Figure 33. The IIS-model (Keestra et al 2016) for interdisciplinary research provides the working structure for this doctoral study.

The crucial initial step (step 1 in figure 33) is to define a problem with this methodology (done in chapters 1 and 2). To do this one applies the Mind-map method (Keestra et al. 2016, pp:61) (see appendix A) which isused prior to the mapping of the state-of-the-art in order to create a methodical approach to map the problem (of linear, growth-oriented material flows) and enables the choosing which disciplines and their frameworks are relevant for the chosen problem and as such used as the background for the writing of the introduction (chapter 1) in this doctoral study - concluding with a hypothesis of the potential of juxtaposing two disciplines (step 2 in figure 33). Subsequently (step 3), once the two disciplines and their theoretical frameworks are chosen, it is pertinent to map them systemically via the tools of "data management table" (see appendix B). This is a way to further map chosen frameworks and map how these frameworks conceive of the chosen problem. Potential significance regarding the mapping of the two disciplines according to the elaborated parameters of theory, concept and method (Keestra et al. 2016; Repko, 2008) which outlines and constitutes the state-of-the-art of the two disciplines for the purpose of finalizing the research question in chapter 2 (step 4 and 5) can also be mapped. Within this chapter (3.2.5.), methods of connecting the two disciplines will be laid out (step 6) regarding the particularities of building theory and that of testing the theory, respectively. The testing of the theory will occur in chapters 5 and 6 (steps 7 and 8) respectively with partial discussion and conclusions within each chapter as well as a final conclusion and discussion in chapter 7.

3.2.2. Theory Development

What is a theory, and how can it be built and tested? There are obviously very different uses of theory in the wide spectrum sciences and disciplines. Perhaps the architectural discipline in particular has a very broad understanding of what a theory can be and what is necessary for a theory to be considered a theory (Nygaard 2011; Spence 2017). As Nygaard indicates, theory has a certain structure and can be guide by “invisible” aspects (Nygaard 2011). As such, Nygaard vaguely emulated in his own writing the widely acceptable (scientific) definition of what a theory is: a theory uses a system of constructs (concepts), propositions (relations between concepts) to explain a phenomenon (Colquitt, Zapata-Phelan 2007; Bhattacherjee 2012). This doctoral study relies on this definition due to the fact that it is an interdisciplinary endeavor mixing architecture (social science) and industrial ecology (natural/applied science). A theory mainly consists of four elements (abovementioned constructs, propositions/relations, logics, boundaries). All theories consist of these 4 main elements, but not all theories make them explicitly clear and are very often implicitly present in case where it is missing explicitly. If we observe architectural theory from this perspective, architectural theories do not fall outside of these proposed structures though these theories occur in implicit aspects and are “hidden” within architectural thinking.

Theory can act at either a micro (idiographic) level, where it explains a single specific phenomenon or macro (Nomothetical) level where it acts as a generalizable theory for different situations (Colquitt, Zapata-Phelan 2007; Bhattacherjee 2012). Some of the benefits of theory include providing the logic of phenomena and the sense-making system for the found empirical data while having the capacity to identify other constructs further exploration and testing.

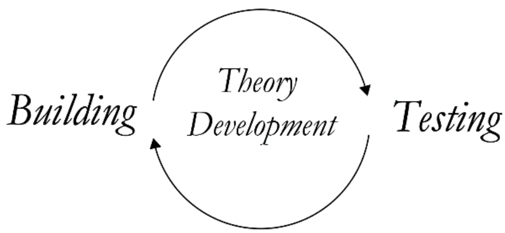


Figure 34. Theory development is an iterative dialogue between building and testing- often spanning long periods of time – sometimes decades (Spence 2017).

Theory development consists of two main aspects: building and testing. Testing of a theory occurs in four ways with the first being the logical consistency which tests the logic that brings together system of concepts, propositions and boundary conditions (assumptions). The second is to test for explanatory power to see how much theory can predict in which it better explains something compared to other theories. The third is to test for falsifiable, where you test if some data goes against the theory and thus avoid tautologies and requires rival explanations via explanatory power. Fourth, parsimony considers how simple an explanation is in order to be considered the good/understandable theory that contains as few as possible variables and assumptions. (Colquitt, Zapata-Phelan 2007; Bhattacherjee 2012).
There are 5 degrees to testing a theory. Firstly, it should be determined whether it is inductive or does it ground predictions with logical speculation (Colquitt, Zapata-Phelan 2007; Bhattacherjee 2012). Secondly, it should to ground predictions with reference to past findings (comparing to past theories) should be considered. Thirdly, ground predictions with existing conceptual arguments as part of the logic should be contemplated. Fourthly, grounding predictions with existing models, diagrams, or figures should be examined, and finally, grounding predictions with existing theory should be acknowledged (ibid).

Theory building requires the synthesis of a range of literature and studies to provide evidence confirming an explanation to a given phenomenon and is thus an attempt to plausibly explain a phenomenon in different way than done by previous theory. This requires a knowledge of current theories which attempt to explain the same phenomenon and how they are currently used.
Building theory occurs in four main ways. Firstly, grounded theory which builds theory inductively on observed patterns and requires consistent explanations from the researcher. Secondly, the Bottum-up conceptual analysis (inductive in nature) in which is conducted to identify different sets of predictors regarding the phenomenon by using a predefined framework. Thirdly, it is possible to build a theory by extending or modifying existing theory which is a deductive approach. Finally, the application of existing theory in a new context which is also a deductive approach (Colquitt, Zapata-Phelan 2007; Bhattacherjee 2012). This PhD study thus combines exploration of theory building and the use of existing theory as well as empirical findings.

Theory Development in this PhD

In continuing of this doctoral study, initial theory development was initiated by using the literary review following the methodology of the IIS-model along with mapping the two disciplinary frameworks done in chapter 2. As the purpose of this PhD is to build theory, the literature on theory development categories four main elements that constitute a theory: concept or constructs (the what), propositions (how concepts relate), logic (why the concept are related), and boundary conditions (the assumptions and circumstances for the efficacy of the theory) (Colquitt, Zapata-Phelan 2007;

Bhattacherjee 2012). These are in the context of this PhD segmented into two categories: 1. constructs and propositions and 2. logics and boundaries. The first set is the more immediately approachable aspects of a theory, while the second is usually “more difficult” and philosophical in nature. All four elements overlap and are integral but for the purpose of proceeding the doctoral exploration, the four elements are segmented into two which can be explored separately though not independently of each other.

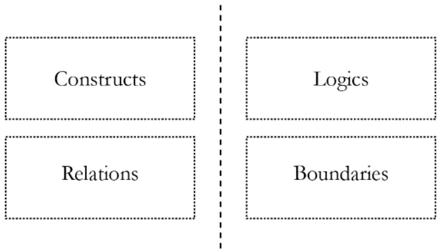


Figure 35. Four elements of theory as two segments.

Initially, the first segment was built (constructs) and, with vague ideas of the relations, the purpose was to explore the relations between constructs. Secondly, the building of the second segment was informed by both the application of theory (analysis and design) as well as by referring to existing theories and philosophical positions pertinent to a “metabolic” shift in architectural theory.

3.2.3. Logical Argumentation

When one of the key intentions of a research endeavor is that of theory building, it is of importance to engage with logical argumentation. The first aspect of this research strategy is to construct *first principles* (Groat, Wang 2013, pp: 379) or, as has been established that *principles* corelate to the notion of “constructs” in theory development sub-chapter (3.2.2.).

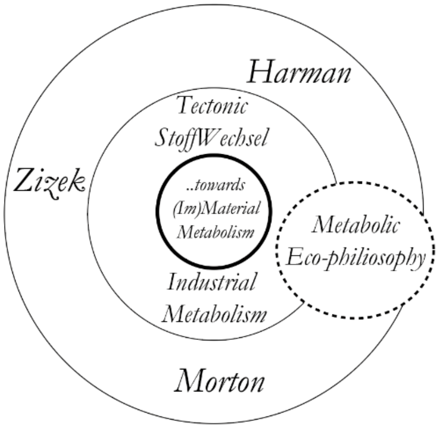


Figure 36. Approach for logical argumentation for building of theory.

Working towards the building of a theory, the inner most layer is that of the theoretical frameworks of the chosen disciplines and their "metabolic" elaborations. The inner layer is mostly concerned with proposing and developing the main constructs of the theory along with their relations (segment 1). The outer layer is mostly concerned with providing insight for the structure for the logic and philosophical assumptions and boundaries of the theory-to-be-built (segment 2). While this is the case for the most part, the categories overlap as the inner layer also holds significance for the logics and boundaries, and likewise the outer layer also holds significance for the proposal of constructs and what relations they develop.

The inner layer deals with the given theoretical frameworks from architectural tectonics (stoffwechsel or metabolism) and chemical engineering metabolic studies. This juxtaposition creates both certain frictions and the bringing together of crucial ideas. Thus, the need for an understanding of complexity and phenomena, such as "multi-cycle" networks, and of paradoxical phenomenam such as the Jevon's Paradox, three key authors with overlapping ideas are crucial: Graham Harman, an object-philosopher par excellence, (who shares similarities with) Timothy Morton, a prominent eco-philosopher, and lastly Slavoj Žižek, a philosopher of ideology and sublime objects. Harman and Morton share many similarities as their founding philosophical onset is that of object-oriented-ontology, while Morton is much more eco-philosophically inclined. Žižek's relevance is pertinent as the dealing with ecology and relations in general between subject and object (people and nature) can turn out to have a complex, complicated and even paradoxical relations.

When developing theory through logical argumentation, one has to also take into account what type of arguments and theory is to be developed and the literature that elaborates a spectrum spanning from formal/mathematical to cultural/discursive (ibid, pp: 385). In relation to Groat and Wang's definition, the development of theory in this doctoral study - while containing formal constructs - contain discursive elements introduced through critical materialist thinking.

As the above diagram indicates, given the fact that the theory building of this PhD study is rooted in two disciplines but is shaped by the ontological positions of the eco-ontological materialist views, the theory intends to develop a set of constructs that are in the *primary* category (groat Wang 2013. Pp: 389). The *secondary* category occurs on a "deeper" level than that of the *primary*, an example being Stewart Brand's six elements (site, structure, service, space plan, stuff) which are directly applied in the OPEN building concept (ibid). Similarly, in this doctoral study, the *primary* constructs are developed to conceptualize the *secondary* notion of the Urban Sink. Furthermore, as the theory development is tasked to nuance the tectonic material-immaterial spectrum, we are dealing with *spectrum* category of constructs (first principles) (ibid, pp: 408)

Groat and Wang further elaborate that logical argumentation tend to be interdisciplinary as their founding constructs (first principles) tend to contain a certain openness for differentiated applicability (ibid, pp: 388). These first principles (the *primary* category) can have different "natures", being that of principles of quantity (as with Vitruvius' firmitas, utilitas, venustas) or quality (i.e., the Greek *eudaimonia* or "the good"), or principles of origin (as in the theory of Marc Antoine Laugier's Primitive Hut) (ibid. pp.393-395). While constructs are general an overarching concept, in the context of this doctoral study, the constructs (or first principles) would need to be made empirical in order to be juxtaposed and correlated to discover specific relations for the purpose of critical assessment. The relations of these are to be mapped and tested in the application of the theory.

Proceeding in developing logical argumentation is with the *tactic* of analogy (Groat, Wang 2013, pp: 401) which is mobilized in this doctoral study as the main (founding) tectonic/method but other sub methods are also needed as we are dealing with two complex and very different disciplinary theoretical frameworks (tectonics and industrial ecology) (more on this below in 3.2.5).

3.2.4. Methods in Building Theory

Given the overall scope of the research design (theory building) there is need for supplementary methods that will structure and systematize the theory development. As an interdisciplinary exploration of two very different disciplinary frameworks can prove complex, multiple methods will be needed.

State-of-the-Art

For the purpose of informing the theory building and testing efforts as well as the need to map existing theory (which is crucial for theory building), this doctoral study proceeds by conducting a state-of-the-art (theoretical framing) on the chosen two disciplines using “data management tables” (Repko, 2008; Keestra et al. 2016) which will act as the “backbone” for the final research question (Keestra et al. 2016, pp:70). Multiple “data management tables” will be needed to gain a proper understanding of the state-of-the-art of the relevant disciplines and should “offer critical overview of academic literature” in relation to problem field/topic, be based on the perspectives and theories from the selected disciplines, and finally be a “coherent story” and not just collections of concepts and theories etc. (Ibid, pp:71). The state-of-the-art literary review is used in this doctoral study both in the introductory chapters but also in the initial paragraphs of the theory building chapter (chapter 4) where a more in-depth mapping of the two chosen theoretical frameworks is explored while they are deconstructed critically for theory building purposes.

In mapping the state-of-the-art of two chosen disciplines (as done in chapter 2), the “data management table” lists the categories of the table: discipline, theory/hypothesis, concept, assumptions/methodology, and insight into problem/topic (Keestra et al. 2016; Repko 2008). The first category simply names the disciplines and relevant sub-disciplines. The second category is that of the theory or hypothesis which broadly consist of mapping the key theoretical notion that are relevant to the disciplines and its potential contribution to the doctoral study. The third category are (key) concepts that constitute the theory. The fourth, is an analysis into the “behind the scene” ontological, epistemological assumptions and methodological considerations which often are unspoken or implicit in a text that govern an approach. Finally, the fifth category holds key insights the disciplines contributions regarding the chosen problem/topic (ibid; ibid).

There are many important considerations to consider. . One of them is to be critical with the above mentioned categories especially regarding one’s own disciplinary precondition since “all researchers operate with implicit assumptions based on personal values and guided by their discipline...” (Lélé, Norgaard, 2005; Keestra et al. 2016).

Object-Oriented Ontology as Method

While object oriented ontology (ooo) is usually a theoretical effort to comprise a philosophical description of realty as both material and immaterial objects, in the context of this PhD study, Graham Harman quadruple structure of objects (Harman 2011) and provides the structural foundation for the theory building. Harman’s theory’s (as will be elaborated further in the coming paragraph 3.4.2) fundamental axiom is to be considered on equal footing with material and immaterial objects, whether material thing of meta-physical ideas, as these assert effect onto each other. Harman’s quadruple structure is applied to the theory building effort of this PhD, as the "core" spectrum to form material and immaterial entities of tectonic thinking and practice.

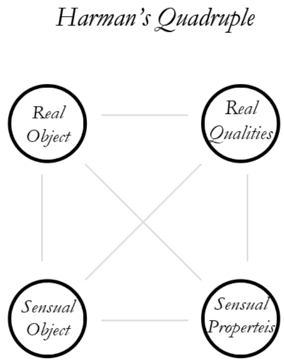


Figure 37. Graham Harman's quadruple of objects (Harman 2011).

Harmon asserts that both material and immaterial objects *and* processes (effects/properties though he calls them qualities) can be objectified as a way to comprehend them. As such in the theory building effort, this logic of ontologically considering such disparate objects as potentially equally important and at the same footing is what provides the "structuring" of the theoretical development. Harman's elaboration that objects can change properties/effects due to changing circumstances etc. is a useful aspect which seems very similar to *affordances* (Gibson 2015), as an object (a building) can function as something very different due to its characteristics and imbued potentiality (affordance).

Žižekian Dialectics as Method

In addition to Harman's structure, Žižek is perfect countermeasure from critical theory. Žižek theoretical elaborations do not perhaps span as wide as Harman's (Haramn theorizies on *everything*, all objects (Harman 2018)). Žižek's instead has clear emphasis on the "immaterial" especially in human relations. If I could put it so, objects of everyday life allows us to see how ideological presuppositions of any kind (social and cultural positions, economic, political, personal taste etc.) allows for the "construction" of narratives which can steer or "distort" reality in one way rather than the other. Slavoj Žižek's notion of the *objet a* is used as a dialectical mechanism to explore and narrativize certain conditions and relations. The *objet a* is explained by Žižek as a "positivization of a lack" (Žižek 2012) in which one's inability to properly map empirical circumstances forces you to provide a narrative to nevertheless make sense of the situation. A very good way to explain Žižekian thinking is through a very simplified and even banal example. For example, Santa Claus, which Žižek uses often at lectures to explain *objet a* and ideology. Paraphrasing Žižek, we thus have phantasmatic figure (Santa Claus), who supposedly brings presents for Christmas. The children (at a certain age) do not believe that Santa brings the presents, but at times they pretend they do as not to disappoint their parents. The parents in turn also pretend to believe in Santa as to not disappoint their children. Thus, no one believes, but the specter remains, and the acts of buying gift continue as as if everyone believed in Santa despite the lack of actual belief in Santa. So how is this relevant to materials flows? Žižek is of course not interested in carbon footprints nor does he make life cycle assessment of all the "gifts". He *is*, however, interested in the "Santa Clauses" of different societal edifices. Namely the ideological (immaterial) objects which ideologically maintain, legitimize, or fail to address the edifices' mental structures and their subsequent material flows.

While the *objet* a can be used to critically reflect the ideological objects of architecture thinking, it can also be used as a sense making mechanism as well. As we are dealing with ecological concerns, the many different material flows and material behavior, it can very easily become difficult to wrap one's comprehension around such many different and seemingly not connected data points and knowledge. By wrapping it all under one term, i.e., metabolism, things suddenly start to become understandable. Even if this PhD also uses chemical engineering to build theory, the theory-to-be-built is first and foremost intended for architects and designers, while chemical engineering could also use it in multi and interdisciplinary efforts, it is perhaps of lesser significant for them. Given this fact, there is a challenge in how to properly "translate" pertinent consideration from industrial ecology (metabolism) to architecture through tectonics. The analysis of Semper's theory is thus done by differentiating between "form and content" (Žižek 2012, pp. 176, 374) of this theory in the quest to re-actualize Semper in modern chemical engineering metabolic fashion. Žižek also elaborates when having to translate any author or work, one has to be true to the original. But in what way? Merely copying his content (using the exact same 4 elements (Semper et al 1989) perhaps with one new addition) would flatten the effort of Semper. The proper way to be faithful to Semper is to equally consider his content while being true to his "form." This would implicate that one ought to repeat what and how Semper did it (i.e., the form, meaning that he studied other sciences and attempted to address pertinent societal issues) and not only reconfigure the content (i.e. add another element to the existing four). One should thus speculatively ask the question what would a Semper-figure do if he had all knowledge available of today (from environmental and chemical engineering sciences etc.), and if he was put in the current predicament of climate change etc. - what would that have done to his theory? Formally, what we also have to consider, in extension of this question, is the fact that (as we will see in chapter 4.2.1) Semper was greatly inspired by the natural sciences of his time in constructing a kind architectural "chemistry." What would a new stoffwechsel look like if he delved into industrial ecology and chemical engineering?

Metaphor as Method

Before the prevalent uses of metabolism as metaphors in chemical engineering and architecture, the notion was used in biology and the metabolic systems of living organism - but has since then been applied in very different ways in the two disciplines of interest. In architecture, there has been several uses of metabolism with perhaps the most dominant and ongoing being continued use of metabolism in architecture and in particular tectonic discourses (Moravanszky 2018). Here we see the metaphor of metabolism translated/transferred to poetically explain the process of becoming from making to the finished manifest in use in architectural discourse. In industrial ecology, literature has even been developed which puts into question the very use of the metaphor and its "efficacy" while nevertheless showing the immense potentials in taking a serious and critical approach to conceptualizing society as an metabolic organism.

Given the fact that the notion of "metabolism" as a metaphor is quite central to tectonic discourse as well as the chemical engineering field of material flows, both disciplines demonstrate there is significant efficacy in mobilizing the metaphor. This metaphorically links to the how metabolic rates of different size organism vary, where a small entity has high metallic rate, and thus a city being a very large entity should have a very slow metabolic rate.

There are different definitions of *metaphor* (Black 1955). Metaphors implement a similarity and difference: when one claims that architecture is a metabolism, there is already a similarity (architecture transforms materially) and a difference (architecture is not a metabolism in biological terms). Max Black hypothesizes (with the *substitution theory)* that the differences do not make a distinction for the meaning of the metaphor and can easily substitute actual words, while a thinker such as Chaïm Perelman, distinguishes metaphor and analogy, claiming that the difference does make a distinction (Perelman 1979). Perelman believes this in the sense that one can be confused about what is exactly meant when one says "architecture is a metabolism" as association within language playing a big part in reifying the underlying meaning. Daniel Rigney later conceptualizes "root metaphors" which according to him are like that of "society", i.e.,no one has ever directly touched "society" but it *is* like something else (a forest, organism etc.) (Rigney 2001). In this sense industrial ecology (metabolism) uses metaphors, since we cannot directly know it (e.g., the city), we conceptualize it (the city) as a metabolism.

There is Here, there is a discrepancy between the two metabolisms in architecture and chemical engineering, respectively. It is my position that the challenge is for architecture and tectonic discourse to introduce a shift in how we conceptualize the term metabolism to allow the metaphor to manifest more pertinent material effects. One could here refer to Darbellay's *nomadic concepts* (metaphors) (Darbellay 2012) which circulates and swerves through different disciplines and fields. The challenge for this PhD is to attempt to repeat the logic of metaphor in the architectural discourse of tectonics. But how? Well, the challenge is to translate the metaphor in a more "literal" way as seen in industrial ecology and metabolic study norms.

Metaphor Use and Architecture

Before simply explaining how the uses of metaphor will manifest in this research, it is important to gain quick overview of how metaphors are already used in architectural discourse as this will guide which type of metaphor mobilization would be relevant for this study (as there are different metaphor mobilizations). While what is discussed below is not comprehensive and is in no way an exhaustive inquiry into the uses of metaphors in architecture, it uses the Žižekian notion of *objet a* (or as he conceptualizes it dialectically: "a postivization of a lack"(Žižek 2012, pp.175) to attempt to bring forth the roles metaphors have. Here Žižek explains how *objet a* works by categorizing the *signified* and the *signifier* (Žižek 2012), i.e., in the sense that a phenomenon may appear complex and complicated and by asserting a analogy or metaphorical narrative of said phenomenon, it suddenly appear understandable and approachable. While this has positive implications, it also has negative ones, as it is possible to mobilize a narrative without a thorough analysis an understanding of a phenomenon and the use of narrative becomes ideologically effective.

Architectural discourses have over time been keen on implementing other sciences and types of thinking as ways to revive or reinvigorate itself, and architecture has a very long and wide history of this. Relevant to this doctoral study is that some of the early uses of metaphors and inspiration comes from biology and human body (Nygaard 2011). These were initially mostly concerned with the proportions of the body, and how to translate anatomic ratios into architectural ones to achieve appearances of great sublimity and beauty. Sempers practical aesthetic approach in *Style* (Semper 2004) of stoffwechsel (*metabolism)* was initially inspired by biology, chemistry of his time. Post WWII, the Japanese Metabolist Avant Garde movement also employed this metaphor/metonymy, and while there were some interesting developments there in terms of interchangeable module systems which provide flexibility (Koolhaas, Obrist 2011), the movement was not metabolic in the industrial ecological sense. This movement was also aesthetically fixed on designing a metabolism which was dynamic and accelerated (which perhaps reflected the economic developing era of Japan at the time). It can be considered as an aesthetic (architectural) acceleration of the metaphor of metabolism which did not contain the critical understanding of planetary boundaries. To this day, we see "green" and "ecological" designs which aesthetically emulate wetlands, quagmires, lush forests but ultimately require high maintenance and do not significantly contribute to biodiversity.

Considering the above, the use of metaphors in architecture, at least in the tradition of referring to body/anatomy/metabolism, gets translated in ways which allow architecture to revolve around itself. Žižek would designate the role of metaphor as an *objet-a* in such cases which would act as a legitimizing/propelling entity and allow for a continuation of ones' activity while lacking proper cognitive coordinates of the challenges and problems at hand. At the same time, the challenge is to consider some metaphors as perhaps more useful than others, and at the same time attempt to take them as seriously as possible on their own terms. To this point, the metaphor of metabolism, as seen in chemical engineering, does hold much more potential than mere alluding aesthetically in architectural terms to an appearance of rich ecosystem.

Method of Add – Adjust -Connect

But how to continue to transform the metaphor of metabolism in tectonics in the "spirit" of the industrial metabolism? The crucial step is to take a notion from industrial metabolism and introduce it into tectonic discourse: that of the "safe sink". Following and relying on interdisciplinary research literature and its methods for integrating disciplinary insight, this doctoral study uses the overarching method of "metaphor" but also mobilizes the methods of "adding", "adjusting" and "connecting" (Keestra et al. 2016, pp: 44-46).

…Add

It is possible to add an existing element from one discipline into another (Keestra et al. 2016, pp: 44). The central aspect of this doctoral study is to add the element of "safe sink" into tectonic discourse and centralize it towards a new tectonic thinking of metabolism.

…Adjust

When there are commonalities in two disciplines, but they aren't perhaps immediately clear, adjusting a concept can be of use (Keestra et al. 2016, pp:45). After introducing (adding) the concept of the "safe sink", there are already some commonalities between tectonic metabolism and chemical engineering metabolism as they both construct notions of parts and wholes. The tectonic discourse will however require an adjustment based on the addition of the "safe sink".

…Connect

The method of connecting is used when there are concepts with that are similar but have different meanings. It can be of used to draw out their differences and connect them (Keestra et al. 2016, pp:45-46). This is precisely what is taking place at more general level with use of metaphor. The notion of metabolism is exactly such a notion which is present in both disciplines but has different uses and translations.

As the literature elaborates, one is not confined to having to use merely one of the above methods (add, adjust, connect) of translating/integration across disciplines (Keestra et al. 2016, pp: 46). Furthermore, this can also happen across three distinct categories: theory, method, result.

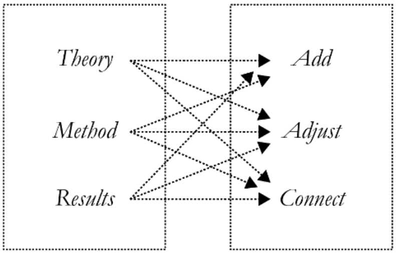


Figure 38. It is possible to connect on three key levels.
(Redrawing of diagram Keestra et al. 2016)

In what has come to this point in this PhD study, the key concept from the industrial metabolism (safe sink) is to traverse from the chemical engineering field into the tectonic framework in the spirit of metabolic thinking as seen in industrial ecology and thus attempt to introduce a shift in architectural/design theory of tectonics in order to be attuned to industrial metabolic thinking and metabolic meta-physics (more on this in chapter 4.2).

3.3. Theory Testing

In this section, the testing aspect of the overall theory development efforts will be laid out. The testing of theory occurs in two main strains: testing of the theory in analytical and design (prescriptive) capacities. These will require two main methodological considerations (case study and research-by-design) along with supplementary methods and tools which will structure and systematize the inquiries. The following methodical considerations are used both in the two written papers 1 and 2 (Usto et al, 2022; 2023) and in the expanded explorations in the chapter 5 and 6.

3.3.1. Overall Methodology for testing theory

As literature on theory development shows, there are several ways to test a theory and several degrees of theory testing (Colquitt, Zapata-Phelan 2007; Bhattacherjee 2012). When testing a theory, one has to test for logical consistency, explanatory power, falsifiability and parsimony (how ‘simple’ the theory is) (Colquitt, Zapata-Phelan 2007; Bhattacherjee 2012). In this doctoral study, the quest is to test theory through gathering of data. The theory to be tested will act as a methodological framework in the application of the theory where said theory will guide the methodology and the subsequent methods and tools.

3.3.2. Case Study (Analysis)

The testing is to take place through a case study, and the choice of the case study is applicability of the theory as framework and the constructs as parameters (units) within the case study. The case study is a known way to also provide data and findings which are useful for theory building (George, Bennet 2005).

The overall objective of the case study is to test the analytical applicability of the theory. In doing so, the case study will specifically attempt to explore how a set of "constructs" (spanning from material to immaterial) interrelate, and how immaterial ones could affect the material conditions (if experiential properties can help to minimize material consumption/flows)in particular. Specifically, the relationship to be explored is how phenomenological quality of a house, and what "social narrative" has gained over time have or could have affected material flows of the house (if there has been additional renovation, repair etc.). Case studies are widely accepted as ways to both test a theory and buildi upon a theory from findings from a conducted case study (George, Bennet 2005).

The case study is of an explorative research "nature" and has an inductive approach. This means that the case study proceeds to explore the relationship of the chosen embedded parameter of the chosen cases (units) by hypothesizing that there could be an intrinsic relationship between the material conditions and flows compared with the tectonic quality of a case. It is furthermore mixes both quantitative data (material conditions of the buildings such as structural system and history of renovation and repair) and qualitative data (analysis of functionality, phenomenological analysis of interiority gesture and social narrative of how the building is describe in society). The case study proceeds as a multiple case study which is *embedded* (Yin 2003), meaning that the study focuses on particular selected parameters (sub-units) which are to be compared. This is unlike a *holistic* case study which covers a much broader set of data to cover the case thoroughly (Yin 2003) with the latter being the more usual to the choice of a single case.

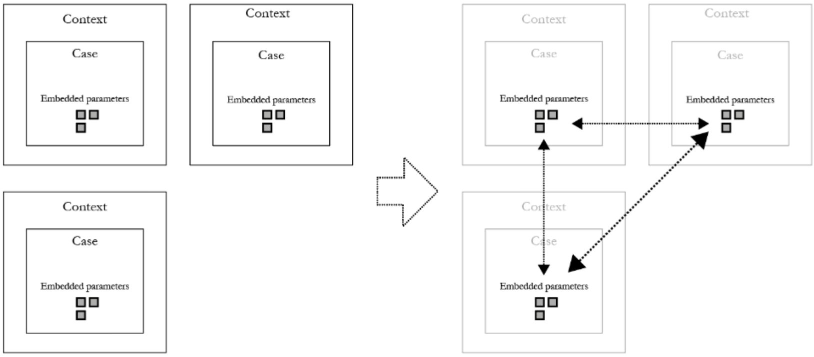


Figure 39. Showing the multiple cases of embedded study and exploring the relations between the sub-units (not to be confused with correlation research).

The *unit* of the case is thus a building, the surrounding buildings, and park area which act as the immediate *context* along with the urban constellation surrounding it. The *sub-unit* (embedded parameters) are the five constructs from the theory development. They constitute a spectrum from material to immaterial across the five constructs: "material flows", "structural principles", "use/functionality", "experiential conditions", and "narrative" (see chapter 4.4.4).

The case study transforms the five theoretical constructs into five sub-unit as point of inquiry, and furthermore hypothesizes that the immaterial conditions (spatial gesture and social narrative) could positively influence the slowing of material flows as it establishes links of data to proposition to explore that particular relationship (Yin 2003; pp. 26-27).
Towards establishing *internal validity* (Yin 2003; pp. 35), the case study chooses similar building typology and function in order to discuss their similarities and differences and thus discern more pertinent and nuanced findings.

3.3.3. Research By Design (Design)

For the purpose of testing the developed theory for design purposes, this PhD study employs the methodology of Research By Design as developed by Jørgen Hauberg (Hauberg 2011). In this relation, the PhD develops a Design Scenario in which to apply and test the potentials of the theory and provide feedback for subsequent theory building. Generally, experimentation is an accepted approach to testing and application of a theory but can also be mobilized for theory building purposes (Horváth 2016).

In the architectural profession—given the “creative” dimension of the discipline which can be both informed by methods as well as guided by intuition – an architectural researcher had to nevertheless develop a way in which it is possible to explore and research design endeavors. Jørgen Hauberg elaborates that a “research by design” methodology goes in the “opposite direction” in which you make the design and then explore the methods and rationalization to “extract the design rules” (Haubaeg 2011). This aspect of considering “design rules” (which can also be understood as applicable design parameters/principles) asks for the particular variant which Research By Design methodology of “research-into-design”. Hauberg furthermore elaborates that such an endeavor can be similar to conventional architectural production but differs in the fact that it is structured by use of methodology for the purpose of being able to explain the process and thus its quality. This methodology is relevant for this PhD as the methodology is intended to explore openly how a built theory applies in a design scenario, what considerations it prompts and what its lacks are in further development.

3.3.4. Methods for Testing Theory

While the above accounts for the methodologies as part of the research strategy, to be able to conduct an inquiry into knowledge gathering, a set of methods are used to gain insights. The method at the “meta-level” of this doctoral study is linked with interdisciplinary research and theory development is described in paragraphs 4.6 and 4.7 while in this section are the method of the empirical inquires of the theory testing qua case study and research-by-design.

Literature Review

While literature review is listed here, it was also earlier mentioned in relation to the mapping of the two key disciplines using the data management method (Keestra et al. 2016; Repko, 2008). The same method is also used but on a much “smaller” scale in mapping the literature written on the particular chosen cases in the case study. Here, the literature was chosen that had scholars deliberately and explicitly analyze the cases and give their takes on both the character of the architecture and how it embeds itself into a wider cultural setting. Similarly, the literary review was also used in the research-by-design endeavor (paper 2 and chapter 6) as it was necessary to found the experiment in an existing frame of knowledge and issues related to material flows, though it was not crucial for the conduction of the design scenario.

Document Analysis Method

When applied, the newly built theory as design application, archival material of drawings and detailed descriptions of the material build-up of each case which can provide an insight into buildings, their material build-up, what changes it has been subject to (demolition, additions etc.). There is a wide body of archival data stored in Danish municipal records on buildings (Filarkiv or Weblager). These contain building permits, applications for renovations, neighbor complaints etc. In inquiring into this data, the method of *document analysis* (Gross 2018) was used. Although this data is archived as documents in Danish municipality archives spanning back decades and centuries, the research methodology is a historical research strategy but the conducting of *embedded* case studies in which particular sub-units are to be compared. The literature distinguishes between primary and secondary sets of data in documents, making my case documents of dated drawings and applications for re-building/demolition are of interest (Gross 2018). This method is used both in the design scenario (research by design) and in the case study (but also to a lesser degree the design scenario)

Tectonics as Method
This method was used in the applications of theory in both analytical and design capacities a pedagogical/communicative way to synthesize the findings. A Tectonic Method analysis by way of Tectonic Gestures and Principles as developed by Marie Frier-Hvejsel allows for the description of how the principles of the material constellation provide (or does not provide) meaningful phenomenological gestures (Hvejsel 2018) in a tectonic way. This method fundamentally combines two methods (as one) where a phenomenological method is used to analyze and describe the spatial gestures of the analyzed object/phenomenon and principle is used to describe a set of material or ontic considerations such as material, structural system and as such already is a method of juxtaposing immaterial and material considerations in architecture. The researcher in this instance uses their own faculties in inquiring and analyzing the phenomenological properties of the cases.

3.4. Ontological and Epistemological considerations

It can be very difficult to get an overview of how to consider “ontology” and “epistemology” in relation to more comprehensive uses and references to methods and tools. When we consider these terms, it very quickly becomes clear that theory is both very complex and interconnected. Lack of clarity comes if an ontological position came to be from a certain way of “knowing” or vice versa. Even what methods and tools one uses, in relation to one’s goals and agenda, appropriate ideological and ontological position can be “constructed” along with what role knowledge plays in such an agenda. Before going further, I simply attempt to provide an overview for how I understand and use these terms.

So, what is ontology? Ontology is the learning of reality. However, there can be different understandings of what reality is and hence different ontological positions. If you are a materialist, then reality is all that is material while ideas and ideologies are not included as *real*. Since we are dealing with architecture, which is constituted by material reality and also the *immaterial*, i.e., ideas, desires and assumptions, that to lesser or greater degree incline us towards material reality in one way rather than another. As such, when we use the word ontology (reality) then reality is both material and immaterial aspects rolled into one study. The study of realty has a long history and follows different traditions, as these tradition have differing attitudes towards how to deal with reality, what it means to know etc.

In mapping the key terms of ontology, epistemology, methodology, methods, tools, I use the sociologist's, David James (James 2015) (figure 40), model of explaining these terms in relationship to an iceberg: where the notions are interlocked and some are more comprehensible (the visible tip over the surface of the water) while others are more hidden and withdrawn. As James elaborates, the deepest edges of the iceberg is a position of how one perceives the world. As often seen within research environments, it becomes very clear what one's analytic tools are but something like World-view can be implicitly present but into explicitly brought forth.

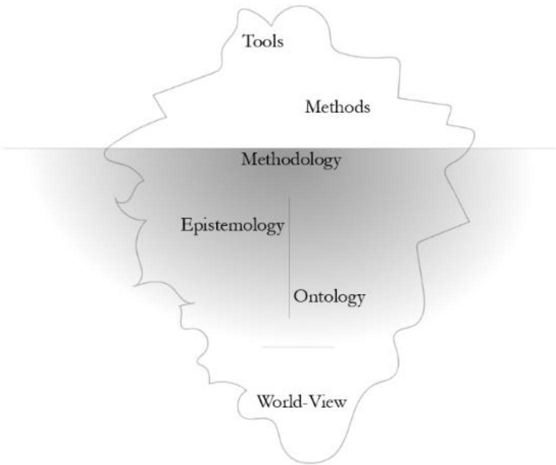


Figure 40. The Iceberg Model (inspired by David James 2015) where tools and methods are "visible" and the ones below the surface are "withdrawn" yet present.

The iceberg model can be compared to the of diagram of architectural theorists Groat & Wang's concentric model of System of Inquiry, School of Thought, Strategies, and finally tactics (Groat Wang 2013). These largely correspond to ontology, epistemology, methodology and method/tools, respectively but are missing a rather important point, i.e., World-View. The reason the importance of World-view is that even ontology isn't "neutral". Rather, it is already guided or predicated on a *Weltanschauung*, which *a priori* guides one's ontological positioning and steers ones understanding of what is knowledge and what is worth knowing. In relation to this doctoral study, this dimension is important to explicitly include as the with the current predicament of global warming there is need for a "new spirituality" in the fundamental attitudes and perspectives on how we approach and relate to our surroundings.

As we have seen in the State-of-the-art (Chapter 2), architectural discourse and chemical engineering can have a varied and mixed situation of ontological positions. Tectonic metabolism, as Moravanszky argues is both Materialist and Idealist. This implicates the ontlogical position and what kinds of knowledge are relevant or important for it. Whether a person who positions themselves opportunistically or critically in relation to reality, both can be contained within the same ontological position. Something similar can be said of chemical engineering. While chemical engineering ontology is more of a mechanistic with empirical data, it too can nevertheless be mobilized to opportunistically lower costs (for a company/industry) or more radically re-redesign material exchange between society and nature.
While these are the onto-epistemological tendencies of the two key disciplines which are of interest for this doctoral study, this doctoral study itself will need to make certain how it positions itself in proceeding, i.e., what to emphasize and include etc. In the following section, the positions of the abovementioned categories will be made explicit.

3.4.1. Philosophical Traditions

Given this doctoral study's research objective and the differing "nature" of two chosen disciplines, this section will attempt to highlight some important differences between the different research "cultures" or traditions as this doctoral study is dealing with chemical engineering (an applied science) and architecture and design (social science). These two "traditions" in approaches are the analytic and continental. The analytical tradition is usually in natural sciences and the continental is mostly exclusive to the humanities. Even this is slight over-simplification and over-generalization, as there can be crucial overlaps and shared traditions. Nevertheless, as philosopher Kile Jones indicates, there can be some truth to such over-generalizations (Jones 2009). Jones elaborates, with reference to Prado, that there are distinct differences, particularity in methodology in the two traditions, and further what they concern themselves with:

> "The heart of the analytic/Continental opposition is most evident in methodology, that is, in a focus on analysis or on synthesis. Analytic philosophers typically try to solve fairly delineated philosophical problems by reducing them to their parts and to the relations in which these parts stand. Continental philosophers typically address large questions in a synthetic or integrative way, and consider particular issues to be 'parts of the larger unities' and as properly understood and dealt with only when fitted into those unities." (Prado 2003, pp.10)

Neil Levy also notes that analytic philosophy is a "problem-solving activity" (or as Hans-Johan Glock puts it; "…uses specific techniques to tackle discrete problems with definite results (Jones 2009) while continental philosophy is closer to humanistic traditions and is politically engaged (ibid). In comparison to the research endeavor of this PhD, it can be observed that a problem-solving approach is not necessarily an exclusively a good or neutral activity, as the solving of problems, optimizing of technologies, and acquiring of knowledge can turn out to have a "negative" impact which opposes the initial intentions and as such fails to problematize the very way one conceives of problems. In the above quote by Prado, we see the potentials in the rift between the two traditions in face of the contemporary climatic challenges in the building industry. For far too long the building industry has been dominated by a kind of "divided" analytical approach lacking the "total" synthetic perspective.

Considering that today's global predicament finds itself within "wicked problems" this indicates that some issues/conditions are too complex and despite having knowledge and empirical data, it can be quite difficult to define what exactly the problem is. It is perhaps worth noting that this statement comes from an analytical tradition but links or opens up towards continental thought. Here a contemporary continental philosopher, Slavoj Žižek, elaborates that a problem is not *just* a problem, simply and immediately there for us to solve. Žižek believes that how we define the problem is already inherent to problem at hand. This hints at the possibility of many implicit ideological biases and axioms already inherent in the problem-definition which already invisibly guides how one attempts to solve the problem and under what criteria the solution is a solution at all. An example of this could be that the current "circular" ideology of the building industry is an implicit privilege for the circulation of elements and materials and where the amplified circulation "will solve all problems" because the market dynamics may prefer this type of solution over others. In academia there much infighting on who and what is to be taken as serious at all although science and academia is dominated by the analytical traditions (Vrahimis 2019) Of much more importance is the attempt to find a balance where the strong aspects of both can feed into each other (Samuel 2010). There are already few (and perhaps modest) examples of such crossings of traditions in relation to this doctoral study.

The Two Traditions in the Two Disciplines

On account of the state-of-the-art, a hypothesis is developed for need of shift in "spirit" for how we conceive of material consumption. While it can be easily claimed with little dispute that the chemical engineering disciplines, including the fields of MFA and industrial metabolism, are largely committed to an analytic tradition, inherent in the literature there are requests for a meta-physical shift towards a "new spirituality" as elaborated by eco-philosopher Dominique Bourg (Bourg 2003). This meta-physical shift, although elaborated to greater extent in philosophical terms, is also modestly requested in the writings of Baccini, Brunner, Rechberger as the need for more social and cultural awareness in society and shift people's consumption behavior which would then fit a shift towards a "slowing" of material consumptions and a more sustainable relationship between society and nature. Despite these tendencies, chemical engineering stems from and operates within an analytic tradition.

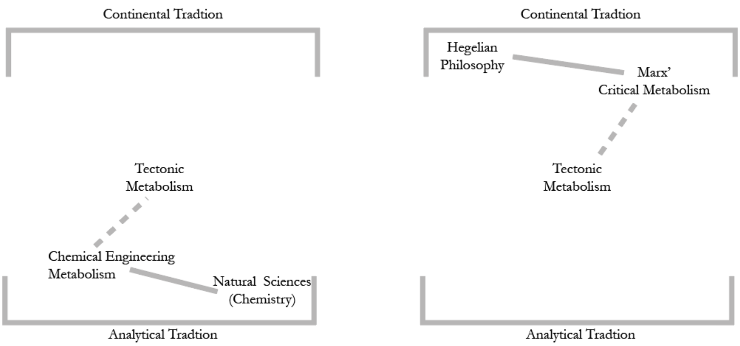


Figure 41. Approaching Metabolism and Tectonic from "above" and "below."

Architecture as a field is perhaps much more divided. Within architectural theory throughout the 20th century, and especially post-WWII, we have seen a use of continental philosophical thinking in theory development as well as analytical as structural engineering and HVAC and indoor climate engineering became integral to both theory and practice (materialist architecture). The entirety of architectural theory and practice would be simply too expansive to consider, and even if we attempted to circumscribe tectonic discourse, a wide variety of reference and approaches can be seen. Contemporary tectonic discourse has since the time of Gottfried Semper, and perhaps in the spirit of his writing, merged with the abovementioned engineering fields. There are examples of reductionist material concerns (a la material science) in tectonic discourse. We also have social and cultural concerns as well which often require the use of an analytic research methodology. As Moravanszky shows (Moravanszky 2018), even in Semper's theoretical writings, there is a kind of "struggle" of idealist and materialist lines of thought which very roughly can be translated into both continental and analytical traditional thinking. The fact that Semper as a theoretician was in some sense in the middle of idealism and materialism, allows for an openness in his *stoffwechsel* which today affords opportunity for a realignment relevant to the current ecological issues. Likewise, it is important to note that the contemporary metabolic studies in chemical and environmental engineering were initially inspired by Marx (Saito 2017; Pincetl et al, 2012).

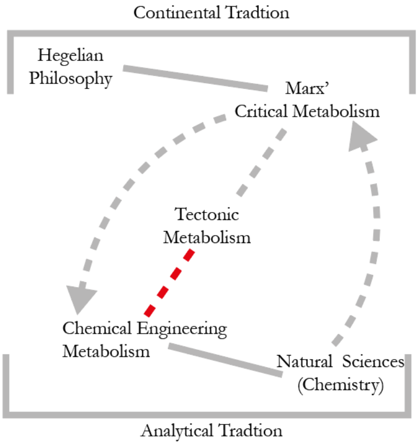


Figure 42. Illustrating the interloping link between the field and traditions.

Marx was greatly influenced by the leading natural and applied science of his own time when he developed the idea of the "metabolic rift" between society and nature (Saito 2017). It can thus be conceptualized in a complex circular way that these field and traditions interlink. The early chemical (alchemical) and ecological sciences influenced Marxian thought. This has had an immense effect on the development of material flow understanding and methodology (more in chapter 4). While Tectonic metabolism (metamorphism) does not directly contain critical industrial metabolic understanding, Moravanszky acknowledges the pertinence to a potential linkage between the two (Moravanszky 2018). Since the "new spirit" of metabolic thinking is already inherent in industrial metabolism, it is crucial to establish a link is between tectonic discourse and industrial metabolism (red line in Figure. 42).

This doctoral study also inherently relies on two traditions and attempts to follow a rigorous analytical tradition in developing arguments. It additionally integrates the radically critical questioning, speculation and conceptualization from the continental tradition as a guide to the analytical progress. This means that in the attempt to slow (lessen the consumption of materials) material consumption in societal metabolism, we have to radically rethink how we value the "solving" of problems, what problems we define, and not only privileged problem-solving endeavors that will guarantee more "problem-solving" activities.

3.4.2. Views from Dialectical Materialism and Object-Oriented Ontology

In proceeding with this doctoral study, there are two main schools of thought which are pertinent to include: those that connected with dialectical materialism and object-oriented ontology. These ontological positions are relevant to consider for different reasons. While both o have already been included in methods section earlier in this chapter, they also have ontological and epistemological implications for this doctoral study.

Why ooo? When dealing with theory building which delves into industrial ecology and material flow analysis (in quest of “thinking” about multiple-cycle networks), there are several aspects and a few crucial differences which makes Graham Harman’s object approach more pertinent that other assemblage (DeLanda 2016) and actor-networks (Latour) approaches. As Harman elaborates, Latour’s ANT conceptualized that something is only an object if it acts (Harman 2022), but this makes it difficult to conceptualize the facts that metabolic schemes can have both flows (transportation) and processes (of incineration of materials) but a “mere” process of storage is in some sense a process of nothing, non-activity. Safe sink is thus potentially better conceptualized from a ooo perspective as it allows for an acknowledgement of object which does not have immediate efficacy onto material reality. Ooo is furthermore present for its dual traditions and is indeed a continental theory greatly influenced by analytical tradition and as such embodies a crucial balance of the two traditions.

Why dialectical materialism? Žižek’s iteration of materialism is an interesting one as it ultimately concerns itself with immaterial considerations but emphasizes how such social and subjective constructs (regardless of how fake and delusional) can have severe material consequences. Furthermore, Žižek’s ontological conceptions allows for the consideration of “paradoxical” conditions, as he highlights that reflexivity is inconsistent meaning that there is no immediate and logical transfer from cause and effects and that is ultimately not possible to fully understand one’s intentions and how they fail in their material manifestation. This is relevant exactly due to the crucial material flow phenomenon of the Jevon’s Paradox. While Dialectical Materialism and Object-Oriented Ontology do have overlapping traits but also differ in how they construct their ontological positions.

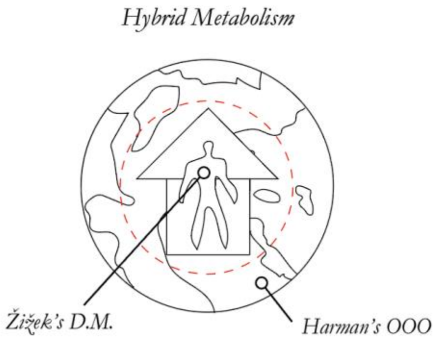


Figure 43. The "inner" and "outer" layers of the hybrid metabolism.

Generally speaking, as the metabolism is a hybrid entity, the two chosen ontological positions allow for the tackling of challenges and issues of said metabolism. Slavoj Žižek's dialectical materialism allows for a critical approach to the "inner" mechanisms of the metabolism, while Graham Harman's object-oriented approach allows for a hybrid way of thinking both the inner along with the "outer" perimeter (material conditions, planetary limitations etc.).

Object-Oriented Ontology

Object-Orient Ontology has already been introduced because its particular sub-strain (of quadruple objects (Harman 2011)) is to be used for initiating the theory building. Object-oriented ontology, however, also holds pertinent perspectives which are pertinent for the metabolic challenges of the built environment and theory building exploration of this doctoral study. Graham Harman's Object-Oriented Ontology is a way of perceiving the world which is strongly founded in Bruno Latour's Actor-Network-Theory (Harman 2018, pp.106-113). Harman pushes this logic and its potential to more radical directions where *actants* become both Real and Sensual Objects which have Real and Sensual qualities and properties (Harman 2011; 2018; 2022) but also allows (unlike ANT) for hybrid (compound) entities being considered new objects regardless of if they are passive or active (Harman 2018, pp. 113). Harman conceives of reality as one of indeterminacy and inability of knowing reality. There *is* reality out there. which is not a construction of human's minds—an in-itself—but it is withdrawn and unknowable which can materialize different appearance and effects over time. According to Harman, this stands in a slight contrast to Latour's *network*, as Harman's constellations of *actants* are put in in certain way which can explain a phenomenon at the time of observation but can also explain why and how the same entity/phenomenon which is comprised of the same elements develops new and unexpected effects over time. He goes further to developing a system of a quadrant of objects: Real Object (RO), Real Qualities (RQ), Sensual Objects (SQ) and Sensual Qualities (RQ) (Harman 2011; 2018). The immense potential of object-thinking in architecture is vast, and as Fischer-Kowalski (scholar on metabolic studies) sees it, industrial metabolic thinking would benefit greatly from a hybrid object thinking (Fischer-Kowalski 2003). Harman stresses that objects (things) are autonomous, and the true quest is to discern the inconsistencies and complexity between the being of the object and its properties effects as objects can seem to shift radically over time, in different situations and contexts (Harman 2022). This is a relevant ontological position assumption given the challenges of having to work with "multi-cycle" networks and social-natural hybrid objects, as the way to slow and narrow material flows is through objects (architectural works etc.). Given that the doctoral effort to building theory of the material-immaterial spectrum, Harman's quadruple structure fundamentally mimics such a spectrum from real objects and properties to immaterial (sensual) ones (Harman 2011).

Another key point of OOO is what Harman designates as "justified untrue belief" (Harman 2018, pp. 181). The implications of this notion in ontological terms is that reality cannot be known, so any theory/model of it is "untrue" (partial, limited, problematic etc.), but it can be justified if it is pertinently useful. This is a key consideration given the fact that the doctoral study uses the method of the metaphor (of metabolism) as wrongful yet useful *construing* of a city or building (because cities and buildings are not actual metabolisms).

Dialectical Materialism

So, what is reality according to Slavoj Žižek? Žižek is a thinker who positions his line of thought in the spirit of Hegel – which ultimately has the ontological view of reality as a Negative one (not bad but one of negation which a central concept/mechanism in Hegelian thought). Žižek perceives reality as one which is un-finished. It is not a Negative, anti-realist position which clams that reality simply does exist and that all is a mental/social construct. Of course, there is reality out there, but it is not self-contained, coherent reality as such which can be defined and mapped. Žižek here uses examples from both the social, political realms as well as quantum physics to elaborate how reality resists coherent conceptualization and thus knowability. Not unlike Hegel's shift from Kant, Žižek takes the step further from Harman (who says that reality cannot be known) into the direction that the property of unknowability is not only due to our finitude and lacking epistemological abilities, but rather an inherent property of reality. If one assumes such an ontological potion, it would necessitate an critical impassivity in how one engages with the world. As the logical conclusion of such a position would be that whenever one develops a thesis about reality, and attempts to change it, there is not always a clear link between cause and effect. An exemplification of this dialect is the many ways in which Jevon's Paradox has materialized itself. If we again take up the example of "wicked problems", an object can be too indeterminate and complex to be definable (but this does not stop people attempting to try). A Žižekian position would conversely take this very inability to be part of the object itself, meaning that it is ontologically open and undefinable (Žižek, 2012, pp. 741). Žižek emphasizes the Hegelian notion of the spirit being a bone (Žižek 2012) which has implications for tectonics and its material-immaterial spectrum. While it can be possible and useful to maintain some type of dualism (of material/immaterial, social/natural, mental/real etc.), Žižek fundamentally claims that it is not enough to say that there is material reality and appearance. Rather material reality already contains disturbance or irrationality which allows for the emergence of appearance and metaphysics. Thus, the spiritual (metaphysical, immaterial) aspects emerge from material reality. The immaterial does not freely float irrespective of the material conditions. The dualism of material and immaterial are not in opposition, but the one is contained within the other. Furthermore, as Žižek elaborates on ideology, he conceives that despite one's inability to articulate a clear view of reality through knowledge, this "lack" is supplemented by narrative. This dialectic is conceptualized by Žižek, as a "positivization of a lack" (Žižek 2012) in which people assert a narrative which propels activity even though one is unable to properly map a situation or phenomenon.

Hegel's elaboration of an entity or an idea follows the logic of going from In-Itself to For-Itself. (Žižek 2012, pp.231) This means given phenomena realizes itself in a particular context given particular conditions and reflexivity as responses of effect of these particular reasons, but at some point it becomes evident that even beyond its necessity for particular reasons, it starts to cause itself and self-perpetuate (Žižek 2012), i.e., "eppur si muove" (ibid, pp. 3-4) as Galileo proclaimed of objects which kept on moving beyond any seemingly logic reasoning. Such a phenomena is inherent within architectural creativity which is mirrored in Tectonic discourse where the perpetuation and continuation of physically manifesting the Drive or Will of the culture in new material transformation. Even further, this self-referential dimension is seen as the very manifestation (built designs) which in its aesthetical traits and *affordance* narrativizes its own process of its own becoming and making. Such a mechanism is thus a "circular" one in which Architecture is never finished, and the urge of "creativity" simply needs ways to manifest. Although there is the obviously the poetic and profound aspects and potential of this, this Driven-ness is inherent to any type of architectural discourse which renders creativity inherently ambiguous and not only good and poetics. This implies a virtual "circular" reflexivity, in which the need for "creative destruction" (McGowan 2016) does not embody the "pleasure" of designing and making beautiful objects and so on but a desire for constant building activity as such beyond any specific physical manifestation and as such serving the market dynamics via this reflexivity.

Finally, "Objet a" is the dimension which on account of the epistemological deadlock asserts a narrative or "fixates" on an object which acts a purpose-giving and sense-making entity. While Žižek develops several uses of this dialectical idea, it is strongly rooted in the Hegelian notion of *Aufhebung* (Žižek 2012; Žižek 2014). It is a mechanism as developed originally by Hegel which has been further developed and clarified by Žižek. This is a key fundamental dialectic mechanism taking place at many different levels. Žižek elaborations on "repetition" (Žižek 2012, pp. 455, 491) where a banal contingent phenomenon goes through a process of Sublimation and becomes aestheticized/idealized and uplifted into a higher sublime being through creative or ideological process. This particular dialectical "mechanism" also shows itself in the Chemical engineering discipline and is the way that it uses the metaphor or metonymy of "metabolism" as useful metaphor to proceed with gaining insight in a given problem. Tectonics too, along with general architectural discourse (Picon, Ponte, 2003; Gerber, Patterson 2013; Unwin 2019; Usto 2020), mobilizes metaphors, narratives and other "objet a" to both design and puts forwards a design but also explains it and makes sense of it in everyday life. Again, similar to the dimension of Drive, there is an ambiguity in the use of metaphors in the sense that they can provide cognitive reasoning to simply continue while lacking proper insight into the problems regardless of if the outcome is positive or negative. In architecture, we have seen much use of metaphors of nature etc., but they often get translated visually (sublimated) to appear nature-like without following the fundamental mechanism of nature (actual biodiversity, carbon storage etc.). The challenge becomes to take metaphors such as in the case of this doctoral study— metabolism—more seriously.

Nature vs. Society and hybrid objects

In the current predicament, philosopher Bruno Latour develops quite a pessimistic view on which discourses we currently have regarding planetary concerns. He conceptualized 7 fictional planets which largely correspond to different ideological predispositions and how they perceive the planet (Latour 2019). He elaborates that there is very little chance that the fictional planets would merge into one holistic form of thinking and that their existence influences both society and each other simultaneously in very complex ways. In Latour's seven "planets", one can basically discern the Worldview and implicit ontological positions of those seven views of planets whose attitudes materialize and accumulate very different effects and consequences for the one actual planet we live on. The most predominant attitude (World-View) on Nature has been one of modern enlightenment perhaps best depicted by Casper David Friedrich in *The Wanderer Above The Sea of Fog*, depicting Man or humanity triumphing over nature or aimin to do so. This attitude is one which continues to perpetuate itself within the current era of the Anthropocene—an era where human activity has surpassed nature in terms of material flows (Elhacham et al 2020).

As a kind of sign from the future for what kind of attitudes, ontological thinking and epistemological positioning we could assume, Timothy Morton attempts to develop and push to more radical conclusions the need for eco-critique and eco-philosophical thinking. Morton has built theory in reference to Žižek and New Materialism and has elaborated the need to approach ecology not only in the terms of hard-facts sciences but also integrate aesthetics – a critical and aesthetical way of Being ecological in the current challenges of climate change (Morton 2018). I find this rather refreshing. There is in contemporary times a certain amount of controversy attached to revitalizing aesthetics. Some simply brush aesthetics off—sometimes from a post-modernist position of relativizing subjective taste—while others consider it a reactionary return to traditional values. Those who criticize this and consider it deeply conservative revival which perhaps contains a secret perpetuation of Man-Master Worldview. On the other hand, there are people who from this neo-traditional revivalist position consider that a return to notions of Sublime and Beauty brings more value leading to buildings perhaps lasting longer. It can be thus said that today, it is largely the conservative, like Roger Scruton and his followers, who are or have been spearheading the debate on aesthetics and are thus given free space to "angle" the debate on aesthetics as inherently conservative. It is also here that Timothy Morton perceives an opening and perhaps even an space of antagonism. Specifically, Morton sees an opening for a way in which aesthetics, i.e., Beauty, is in tuned with an ecological way of Being. In the book *Ecology Without Nature*, Morton elaborates how the idea of Nature is already fused with many ideological aspects which problematize our dealings with it and thus needs to "wither away" for serious ecological state of human society (Morton 2007). This indicates that a rethinking of how we understand nature is needed before establishing new relationships with it. Morton even goes on to link the very name of "Ecology Without Nature" to Deleuze & Guattari (as they developed the notion of Body Without Organs, but I believe that is of more significant to link with Žižek's notion of Organ Without Body which explains much better Morton's own position. Žižek's notions allows for a conceptualization of, as he often puts it, freeing the "baby" from "dirty bathwater" - i.e. gaining a critical view of an entity without its ideological presuppositions (Žižek 2009; 2012). As I read it, what could hold immense potential in what Morton elaborates is not the manufacturing of some esoteric, complex and fused interrelationship with nature (man and nature in extension of each other) but] acknowledgment of the radical "otherness" of nature could bring about a new attitude which is not based on mastering, manipulating and exploiting of nature. In banal terms, one can perhaps easily conceptualize an esoteric and poetic blurring of lines between human and nature, but if you were to find yourself hiking in a mountain and a stone fell on your head, the distinguished of barriers are phenomenologically reconstituted. The pressing challenge is thus perhaps not to simply destroy and blur lines but shift in attitude.

This is basically what Morton elaborates as *ecomimesis* where the dualism of subject-nature is simply laid aside (forgotten even) (Morton 2007, pp: 151). If you are incessant in developing new relationships with an impetus in the subject-nature dualism, the reality of both is relativized into new an unforeseen form of exploitations. If we were here to compare with architecture, lets imagine a situation where an architect designed a building in the middle of a serene landscape. The natural surroundings have visual and aesthetic quality, and the architects have observed these. There is Something in that place, a *genus loci*, which is worth appreciating and respecting. On account of these observed qualities, the architect designs a house which is "integrated into nature", causing the house to leave a larger footprint thus increasing its carbon footprint among other things. In such an example, the architects have a certain understanding of what nature is, and the underlying ideology of design is to "extend" into nature or connect with nature which simply materializes effects which fundamentally are in contrast to the initial idea of "respecting nature" as the architects impress a larger footprint and leave larger devastation of the local soil and biodiversity etc. compared to if they design for compactness or simply did not build at all in such a remote place.

In relation to this *ecomimesis*, as a shift in attitude or way of being, Morten conceptualizes the HyperObject where one is simply within the "climate-object" whether ones likes it or not regardless of your ideological predispositions (Morton 2013).

Lastly, in a more recent book, Morton (in a way) already speaks in an ecological way as if sent to us from the future. He initially emphasizes that the book is not another "information dump" and thus focus on, among other things, aesthetics and beauty and its potential to ecological being. Beauty could play a big part in a shift towards ecological Being as the feeling of beauty is "...neither about putting a label on to things, nor of our being absolutely inert. Instead it's like finding something in me that isn't me." (Morton 2018, pp:178). This feeling of Beauty is what is acknowledgement of "otherness" within oneself which is already out there in "nature" or rather ecology. In such a way, Morton opens up for the possibility that that aesthetics as a cognition in relation to ecology could be mobilized into efficacy instead of bombarding people's (scientific/intellectual) cognitions with more "information dumps" Here it is of importance and relevance to note what Žižek elaborates as "fetishist disavowal" where people are able to cognitively understand a piece of information but nevertheless continue their behavior as if it weren't so. Thus, the challenge isn't perhaps only to inform people with ever-more scientific data and expect they will entirely shift their behavioral patterns but to perhaps include aesthetics cognition (Harman 2018, pp:59-103) with its potential for people to assume at a more deeper level the eco-ontological way of Being. In the quest of "de-materializing" of our consumption, the notions are that meta-physics (the *immaterial*) could make a dent in the current patterns of material consumption and flows between society and nature.

3.4.3. Epistemology

Perhaps in the most common use of the term epistemology, one simply refers to epistemological positions for how one understands what knowledge is. Those can be phenomenology, empiricism, pragmatism etc. naturally link to how one gathers knowledge and data and how one makes sense of the world in general. It also links "upwards" in how very often particular ontological positions and Worldviews are also greatly influenced, or at least have roots in, how ones perceive what knowledge is and what is worth knowing. At the same time, there is a certain openness in the very epistemologies which allows for different attitudes to manifest.
The above-mentioned ontological positions seem to be very pessimistic in terms of what can be known about reality – and it is of course not so that they simply mean that we cannot inquire into the world to gain knowledge. Rather, the above ontological views are more of guiding attuited when one finds oneself having to "angle" and choosing the epistemological positions as well as the choice of method and intention/goals. Here, the goal is not to provide new knowledge which will prompt ideas, methods, theory to increase material flows (which in line the current growth ideology) but rather to find ways to slow and narrow.

New Materialism

While the term of "New Materialism" is very wide and disputed, the architecture field has had many different names and/or sub-parts: post-humanism, agential realism or new or vital materialism (Benson 2019). Together, if one allows for the common circumscription of "new materialism", it represents a shift away from the centrality of human agency to a more inclusive and broadened perspective (ibid). While Graham Harman argues for the OOO being a speculative realism, it can, given the above width of the term new materialism be included in this new shift in spectrum of how reality is understood. New Materialism, especially in the form of OOO is an ontology which also has its own epistemological conceptions. This means that both sensual and real objects are of interest, as imaginary entities can influence real life conditions and vice versa which is unlike hard-line realism (or old materialism) which only acknowledge material empirical facts. At this level, on account of the abovementioned ontological positions, the fundamental way of understanding is already implicit. As Harman was greatly influenced by Bruno Latour, Harman has acknowledged that the epistemological and methodological approach of research for OOO would be very similar to ANT. This basically indicates that such an understanding has world phenomena construed as actants (as Latour would have it) which are engaged in a network (Latour 2005). These phenomena can be of differing "natures" and would then require subsequent and relevant method to be brought forth. As architecture and both its aesthetic and phenomenological conditions could influence how materials are consumed within society and what effect it has on nature, a network of material and immaterial objects as a way of understanding could help to explore and bring forth how the immaterial and material (qualitative and quantitative) interplay. Unlike the old materialism where knowledge is only a product of investigation, the *new* materialism poses the questions of ontology and epistemology are intertwined (Benson 2019) which is again fitting in relation to the need for thinking "multi-cycle" networks and Jevon's Paradox (intention vs. real-life effects). The fundamental assumption is that reality is (not relative) but relational. This also implies that causality is relational and complex and it is thus difficult to claim *one* particular agent/actant was the sole cause of something (Benson 2019).

Phenomenology

Not unlike the above, phenomenology is also a very open epistemological position. In some cases, one could argue that phenomenology already plays a big part in other ontological and epistemological positions. An example of this is OOO (Harman 2014; 2022). Phenomenology has a long history and has roots in Kant and Hegel's philosophies. Nonetheless, phenomenology as we know it today has been shaped by the likes of Edmund Husserl and Martin Heidegger. While phenomenological experience can be confined to simply explaining a momentary experience, phenomenology as an understanding can also shape one's ontological position and Worldview, i.e., where your understanding of reality is shaped from immediate phenomenal engagement within reality (Heidegger 1971). For the relevance of this doctoral study and for analyzing the phenomenological traits of a design while juxtaposing it to the material considerations, this doctorate uses phenomenology to explain the immediate 1stperson perspective and qualities. The challenge is that while it can be difficult to conduct, such phenomenological analysis is the most "openminded" way possible – without the present social and cultural inclinations – in the quest to bring out qualitative data.

Empirical Analysis
Empiricism is a way of knowing and approaching the world in which observable measurable facts can be made of the phenomena/object at hand and is very often data or knowledge of the quantitative kind (Groat & Wang 2013). Empiricism in its early iteration has had significance for modern thinking, with key thinkers such as Francis Bacon, John Locke and David Hume. Empiricism is a philosophy which assumes the existence of reality as measured and sensed experiences. This would allow for gained insight into the conditions and effects of an object/phenomenon in terms of what it is (ontically) and how it performs. This is an important part of this doctoral study, as the quest is to highlight how immaterial aspects push and materialize physical consequences.

Hermeneutics
The fundamental trait of hermeneutics is that of circular interpretation of gathered knowledge (Højberg 2004; Kinsella 2006). Simply having access or having acquired some data does not immediately give its own reading. As Gadamer fundamentally elaborates, the researcher has an active role in the creation and interpretation of knowledge. The acquiring of data can be rather ambiguous in what it "means" and to what the data will be used for (Brinkmann, Tanggaard 2010: pp.243)). In particular relevance for this doctoral study, Højberg elaborates on the "double hermeneutic" which is a kind of circular dynamic of interpretation that takes place with the subject and object (Højberg 2004). As it is clear by now, the challenge is thus to interpret the gathered knowledge in the critical and "materialist" fashion where the observed phenomenon changes character along with how we relate to the subject. This PhD study uses a hermeneutic approach in the iterative process in theory development between testing, applying and building of theory.

3.4.4. Positioning this Doctoral Study (Delineations)

In the following section, some basic outlines and definitions (assumptions, axioms etc.) of this doctoral study will be made explicit regarding what has "governed" the the development of this doctoral study.

The Metabolism
As eco-philosopher Dominique Bourg argues that there is need for a negation of the current modes of operation, and that we need a "new spirituality" – a new kind of meta-physics—which aligns with the challenges of our global predicament of global warming. Fischer-Kowalski postulates that a way to proceed is through a "social-cultural-natural" hybrid approach which he sees as a requirement for a new spirituality stemming from the very edifice of metabolic thinking. Conversely, Moravanszky elaborates the need to realign Tectonic discourse through a kind "return" to a Marxian understanding of metabolism. Furthermore, as we have seen, the origin of contemporary metabolic thinking lies in Marx's development of the metabolism

between nature and society (though he had an emphasis on how labor transforms resources into commodities). With this overlapping of connections historically the challenge is to conceptualize the Negative ontology and “social-cultural-natural” hybrids. Preferably, the challenge is to proceed in developing a Negative perspective which could be done through ontological and epistemological understanding of hybrid-thinking. As is depicted in , the intention is not to to portray human agency is as being privileged by “centrality” but rather that it is contained or even “belittled” ontologically in order to finds itself within a larger scope of finite surrounding which constitute the possibility of its agency.

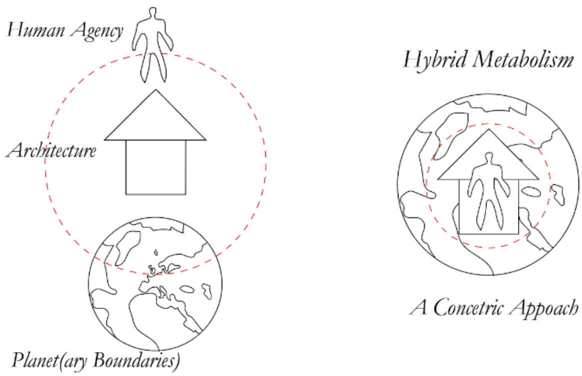


Figure 44. A "hybrid" metabolism: a social-natural hybrid.

If we are to “negate” something, what is *that* which needs to be negated? To a large degree, it can be argued that the current politico-economic fixation of “growth” is paired with world-view that Humans considers themselves as a Master and manipulator of reality and nature. In contrast to this, the era of the Anthropocene is showing us that such an understanding of the world perpetuates conditions of knowledge gathering and use of methods of tools particularly in the industry which negatively effects the natural environment. It can be argued that “man’s” relation to nature was always metabolic and thus merely hitherto metabolic relation has been one of a linear, growth-oriented exploitation in which the current metabolic dynamic risks of overshooting planetary boundaries and impeding on future generations’ ability to sustain themselves. The “new” metabolic shift occurs when we firstly cognitively assuming a new positions of finitude and relationship is conceptualized into a more “concentric” relation between social and natural aspects. The *metabolism* entails many aspects, from social to political to aspects of biodiversity and ecology, but in this doctoral study the metabolism entails the architectural production within the building industry as possibility for critical introspection as well as critical positioning within material conditions and planetary boundaries.

Weltanschauung – Worldview (or Planetary View)

Questions of epistemology and ontology can be deemed quite open and thus any epistemology and ontology can be mobilized with any attitude or world-view. This doctoral study thus conceives two main different world positions to have when deploying any epistemological or ontological position: that of the opportunistic (engaged) and the critical (withdrawn) attitude/sentiment. It is of course possible to mix them in the sense that one can be opportunistic towards an overall critical trajectory and likewise one can be critical towards realizing opportunistic trajectories. There is no such thing as the perfect, balanced synthesis between the two, and this doctoral study wagers and risks the disparate nature between the two and insists on keeping them separate despite overlapping.

Planetary Capacities (boundaries /limits etc.)

So, what are planetary boundaries and what does it really mean to be within planetary boundaries? The most common use of planet boundaries is usually that of Rockström et al. (2009) who posits that the concentric layered diagram of different dimension/parameters which are considered crucial for the well-being of the planet and the humans. Later contributions have also attempted to challenge this definition and “benchmark” of limits (Running 2012; Persson et al., 2013; Mace et al., 2014; Gleeson et al., 2020) as attempt have been made to conceptualize more local and regional levels for a planetary understanding. Kate Raworth’s concept of the donut model introduced the “social” dimension (Raworth 2012). Challenges nevertheless remain regarding how to implement such models (Ferretto et al 2022) as such models would need to provide more than general snapshots and give insight into the temporality of the different limits and their trajectories (ibid). When it comes to planetary boundaries there is also a minimal aspect of relativity where scholars have proposed different boundaries and variables (Persson et al., 2013; Mace et al., 2014; Gleeson et al., 2020). These boundaries and variables indicate that the current way we live and embody “planetary boundaries” on an everyday level (e.g. living in collectives, sharing economies, minimizing consumption, recycling etc.) could be very different in the future as new technology or different material practices could allow for “freer” movement compared to now or near future (Saito 2022, pp. 113). To think and practice in terms of planetary boundaries is pertinent more now than ever. At the same time, it is easier to conceptualize and theorize global models and very difficult find a way to apply them on an everyday level (Ferretto et al 2022). The best-known definition of planetary boundaries (Rockström et al 2009) is simply an anthropocentric definition of the boundaries conditions, as the different parameters and their well-being ultimately favor the benefit of the human population’s ability to reproduce life as we know it. Here, Industrial ecology is concerned with planetary boundaries given the fact that metabolic understanding necessitates the understand of resource availability and capacities/limits of different substances within planetary resource capacities (Wackernagel, Rees 1996; Baccini, Brunner 2012, pp.79; ibid, pp.161). Particularly in the theory of the “metabolism of the anthroposphere” (Baccini, Brunner 2012), planetary boundaries are conceptualized theoretically within the model and thus propose a “more direct” conceptualization of planetary boundaries/capacities through sinks, region, and bio-regions (Baccini, Brunner 2012) implicating a slowing of consumption and "withdrawal" from said planetary boundaries while aspects of politics and economics could pose a challenge for its implementation.

While planetary boundaries are concerned with humanity and the planet at large, i.e., concerns of ecology, biodiversity, food etc., this particular doctoral study is concerned with the built environment and thus the future trajectories of human populations and urbanization are of relevance. Expectations of building stock doubling are correlated with ongoing with urbanization and growth in population which may still require material excavations. Since architecture and the building industry is a "slow" industry compared to others, we may have to already now envision the future conditions of end-stage urbanization and population growth by the end of 21st century, i.e., what would it thus means to think "planetary boundaries" for the built environment? More precisely, what would it mean for the architect who is asked to design a housing complex today? Specifically, what does it mean practically on the everyday level of design and use of a building etc.? We have seen that there may be risks involved with only thinking in terms of circular strategies – and the architecture of the future is being built today and not *in* the future. We should perhaps not strive for the design of a circular building industry in which more and more material and elements can circulate but rather how "still" the building stock can be and at the same time be as multi-functional as possible. Because of planetary boundaries we must acknowledge that growth as we know cannot continue as the material conditions are finite. Buildings of today should be seen as investments for the future generations and as such there are certain requirements that must be fulfilled. While we may still need additional virgin material inputs, we have to think of future trajectories and the end-of-21st century scenario thus envisioning an ambiguous and open-ended architecture which can accommodate fluctuating trends in population and needs with more or less the same building stock. Regardless of the future technological invention, the planetary sentiment would perhaps argue for a kind of material asceticism on the scale of the industry. Such a scenario, I claim, would perhaps cause a kind of architectural end-of-history where the current mode of architectural creativity would need reappropriation.

Material vs. Immaterial – or the (im)materialism

The *old* and *new* materialism conceive of reality differently (Benson 2019). Matter is now "…produced and productive, generated and generative. Matter is agentive, not a fixed essence or property of things" (ibid). On the other hand, being able to answer what exactly matter *is*, is rather difficult as it cannot merely be claimed that is atoms, quarks or strings, as quantum physics indicate a very complex nature of material reality which can be seemingly paradoxical or even "immaterial" or in flux. The fact is that we have yet to explicate the proper ontological consequences (Žižek 2012). The immaterial can also be claimed to have material conditions which structure the human (immaterial) experiences and judgments of phenomena. A feeling of idea can have certain brain impulses caused by external physical stimuli etc., and such conditions would make complex the ideas of a material-immaterial spectrum. This doctoral study pragmatically assumes the existence of the material-immaterial spectrum as it allows for useful application of the spectrum in an architectural and design context. The material domain is concerned with dealing with ontic material aspects relevant to the architectural discipline and built environment, and the immaterial being designated as the subjective, social and cultural aspects which are ground in and affect the material (pre)conditions.

In relation to this doctoral study, it is pertinent to conceive of a material-immaterial way of relating to reality. As Andrew Benjamin has highlighted in his critique of materialism in tectonics, there is a way that being a materialist can have close to nothing to do with actual, empirical material conditions (Benjamin 2007). In extension of the metabolic challenges of societal consumption such an understanding risks of simply perpetuating linear growth paradigm conditions - because it fails to question the legitimacy and necessity of such a mode of architectural production. Žižek elaborates that his theoretical writing on so-called "dialectical" materialism, which is a materialism which has nothing to do with matter (Žižek 2012; 2014). In an almost similar, yet opposite way to Benjamin's, he also conceives of a way of being materialist without the ideology needed to know actual empirical facts. These are not, however, the same as this may indeed be a similar way to conceive of reality the ontological and world-view aspects differ greatly. Žižek's position, unlike the type of materialism that Benjamin criticizes, is one of a withdrawn and contingent nature in which you not only do not fully need to understand something but cannot understanding it. and In this failure to understand, one could/must assume a passive observant attitude instead of an engaging/manipulative one. The fundamental difference here is the first materialism being Positive and the other being Negative.

Object vs. Process – and back to Object?

We are witnessing a still ongoing shift from "object" thinking to processual or relational thinking. The old object-oriented way of thinking in architecture can be characterized by formalism from ancient times through the renaissance of the body and proportions to a more contemporary deconstructivist formalism (Eisenman) (Nygaard 2011). Today there is such extreme shifts away from conventional thinking that people are questioning whether it no longer makes sense to theorize anything due to the existence of vast amounts of data and complex algorithms (Anderson 2008) which one might add that increased complexity may simply require something else of new theories, as epistemological finitude does not allow us to "know all". Tectonic discourse has also made significant contribution in this regard as Gottfried Semper conceptualized a "radical" shift from object to activity (Hartoonian 1994) into a kind of tectonic *materialism* of both matter and ideas/stories (more in chapter 4).

Reality is an obscure entity and according to both Harman and Žižek reality is a Real dimension which is indeterminate and inaccessible fully to human cognition. Thusly, we have to accept that all theories and models of any phenomenon in reality is an approximation of said reality. Whether reality is an object or a process (something in between or something entirely else), both are ultimately epistemological positions which allow for the approach of reality in different ways.[9] As Nygaard indicated, architectural theorizing is also more and more pragmatically oriented towards professionally solving problems (Nyggard 2011), and as such a conceptualizing based on “process” is much more pertinent and relevant as the professionalism and disciplinarity is becoming more stern and well-defined in the market dynamics. While there is certainly profoundly new potentials for insight and knowledge, it can equally be argued that a more inclusive and complex network oriented approach will not necessarily solve all problems if the problem are still designed from within a linear growth paradigm. As such the theoretical shift to process could only risk the opening up the profession for more opportunism with more and more facets of the discipline. Everything today is made into a verb, “architecture as verb”, building as verb etc. and as much potential as this might hold, it equally risks becoming a way to guarantee future ongoing activity within the current market conditions. While it is not pertinent to simply return to an old object-understanding, there is nevertheless a need to appreciate objects in the sense that Graham Harman argues in his object-oriented ontology. There can be ambiguities of relativizing and relational ways of perceiving the world in a non-agential perception of oneself (and the other) which relativize phenomena and thus allow you to act in any way you may want, whether good or bad (Žižek 2012; pp.134). This could risk simply perpetuating a familiar linear growth paradigm but with slightly more complexity and relativism. Surely reality *is* indeed a dynamic, ongoing process, but to slow it down (which is pertinent to material flows in the building industry) a way to do so is to appreciate and conceptualize a “still-ness” or “slowness” of objects. In the context of architecture and the challenges of material consumption, if we develop a particular kind of respect or sentiment for the object, its surrounding flows and effects could be slowed and narrowed. Even from an eco-philosophical perspective, the obliteration of boundaries between entities is not useful in wake of ecological challenges as this “monism” (i.e., all is one, there are no distinct entities etc.) relativized the radical depth of nature, ultimately its non-identity, by obscuring the differences between society and nature (Saito 2022, pp. 113).

Ultimately, the position of this doctoral study with regard the object-process divide is the Harmanian sentiment of complex networks and multitude of relations being designated as objects and likewise objects possessing interchangeable properties over time in relation to other phenomena etc. (Harman 2016; 2018). Given the fact that human cognition is finite and similarity out epistemological capacity is also limited,

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[9] Just consider the problem of indeterminacy in quantum physics, where photons are both waves (network relations/process) or particles (objects) – both are models and the “true” reality eludes. While in contemporary times it common to see critique of the *old* object-thinking which is static and isolates phenomena, urging for a shift towards a more complex way of thinking to tackle the complexity of phenomena and their issues. On the other hand, one seldomly meets critique of process-philosophy. Zidek , while acknowledging potentials of such philosophies, is also very critical about certain aspects; he interprets some potions as being a kind of return to pre-modern mysticism and enchantment of reality (Zidek 2016).

we can *only* constructs models of reality without fully knowing. As such we cannot ultimately claim that reality is either an object or a process as models and theories of both can be mobilized to good use.

Multi-, Inter-, Transdisciplinarity

Architecture has a long tradition of having echoes and reverberations from other disciplines and sciences (Picon, Ponte 2003)As the literature demonstrates, there can be a variety of ways of translating different disciplines into an architectural way of thinking. While some attempts to work with other disciplines in architecture can be considered more radical and radical translations of external sciences into architecture, others run the risk of slight "superficiality" in the sense of "flattening" of the science, construe it and consider its usability insofar as it permits new formal relations and explorations.

In the case of this PhD study, the task is to juggle two disciplines mediated through methodological and theoretical frameworks. The PhD study is not a multidisciplinary project as in such cases disciplines remain separate and not at all informed by other disciplines at a deeper level. For this reason, the categories of inter- and transdisciplinary become relevant. Transdisciplinary can be a rather complex and problematic category. Nonetheless it can be argued that the theory-to-be-built is of a transdisciplinary nature in an open-ended sense, as it would be open to any new discipline which can add relevant knowledge gathering and provide crucial nuance to the material behavior of the architectural field. This PhD can thus be claimed to be more of interdisciplinary endeavor as it combines within the same edifice two main disciplines and their integrative juxtapositions allowing for new insights. It is thus perhaps possible that over time the built theory of this PhD study will provide a founding of the formation of properly transdisciplinary theory.

It is important to mention that even though this PhD study considers two disciplines, as the author is both architect and engineer, the juxtaposition of the two disciplines perhaps hold most significance for architects since industrial ecology study has contributed significant data and also ways of approaching issues of analysis and design which seem to go beyond "mere" LCA thinking. Nevertheless, I am also certain that environmental engineering and chemical engineering both of which are disciplines which concerns themselves with metabolic challenges between nature and society could also nuance their discussions by juxtaposing spatial considerations with their quantitative findings and data gatherings.

3.5. Conclusion: Research Design

With focus on conducting the intended research, chapter 3 has elaborated the key point of the research strategy.

On account of the findings of the literary review in chapter 2 for this research, it is important to take into consideration the developed ontological and eco-physical lines of thought as developed by Harman, Žižek and finally Morton. These are seen as crucial due the fact that the "new spirit" of critical metabolic thinking is best epitomized by this trident of philosophers as they can both provide critical thinking and hybrid-object thinking as they consider how to re-conceptualize the relations between society and nature. Epistemologies of New Materialism, Empiricism, Phenomenology and Hermeneutics are mobilized to acquire the different and relevant types knowledge for this doctoral study.

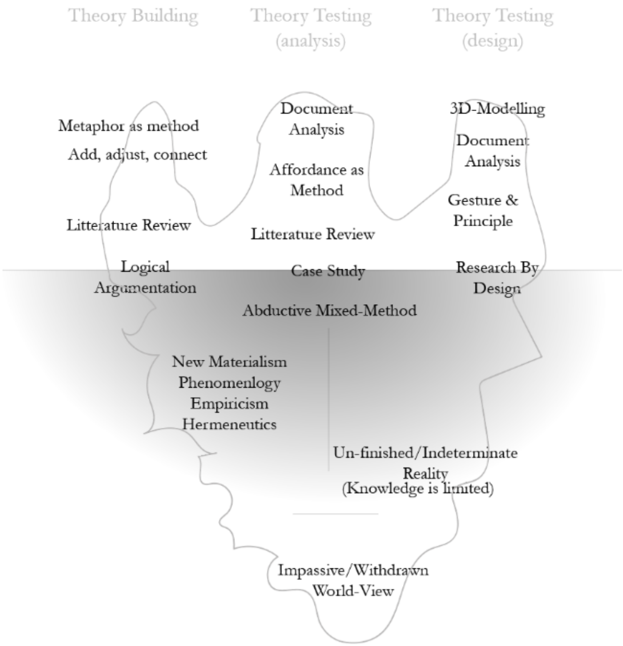

Figure 45. Diagram showing the research strategy in the iceberg model.

Given the fact that this PhD considers it a challenge to introduce industrial metabolic ways of thinking into architecture, the research strategy has had to use "metaphor as method" and the subsequent method of "add, adjust and connect" to methodical control the interdisciplinary "translation".

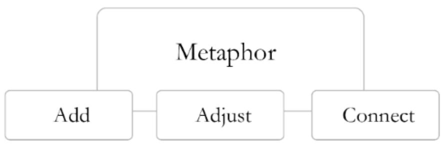

Figure 46. Partial research strategy and method: regarding interdisciplinarity; Metaphor, add, adjust, connect.

Given that tectonic discourse is "missing" the metabolic way of thinking (chapter 2), this PhD considers it pertinent to account for how such an element can be introduced and how to build and test such a theory. It does so in two separate yet connected realms of testing and building which contain the methodologies of logical argumentation, case study and research-by-design.

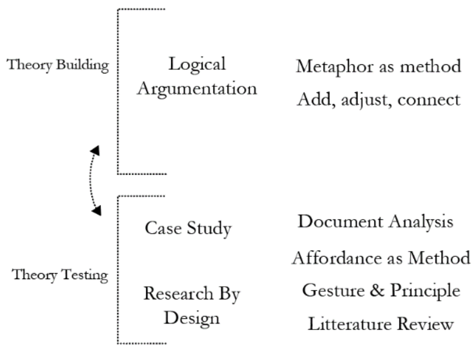

Figure 47. Partial research strategy and methods: regarding testing and building.

Generally, the doctoral study is tasked with testing and building, but these aspects occur in multiple iterations (figure 48). The first instance is the initial building of a tentative theory (hypothesis) which leads to the initial theory. Followingly, the theory is tested through application in an analytical capacity (Paper_1 (Usto et al. 2022)) after which the theory is adjusted (adjust_1). Likewise, the (adjusted) theory gets applied in a design capacity (paper_2 (Usto et al. 2023)) and consequently adjusted (adjust_2). Following the initial applications of theory in both analysis and design, the expanded form of analysis (critique) (expanding_1 in chapter 5) and likewise the design/prescriptive capacities are expanded upon (expanding_2 in chapter 6). Finally, these go through an iterative process of synthesis which amounts to the material presented in this doctoral monography.

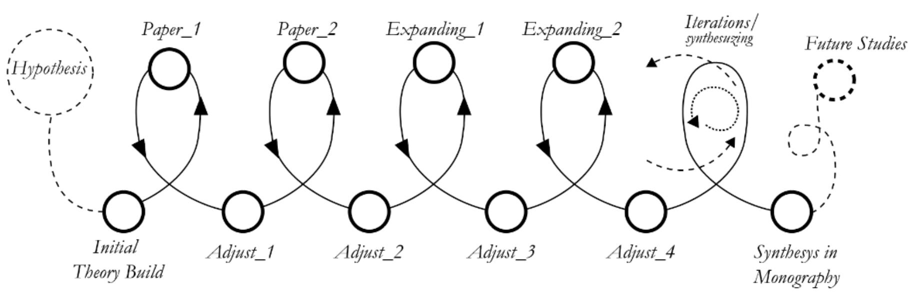

Figure 48. The iterative (hermeneutic) loops of theory development: testing and building.

3.5.1. Research Design

A research design has been formed (Figure 48) and research initiated by a state-of-the-art which proposes the research question. The research strategy singles out the key notion of "safe sink" from industrial metabolism to be added into architectural theory as the first step. While the "safe sink" notion is central, surrounding logics from the two fields are implemented and adjusted through logical argumentation towards the development of 4 main elements of the theory. As architectural theory concerns itself with analysis and practice, two empirical studies are conducted to test the theory using case study and research-by-design mythologies and relevant subsequent methods. As the two empirical study mainly test the construct and propositions of the theory while logic is initially assumed, they too are later given feedback post-findings with the aim of fine-tuning and engaging in iterative theory development. In the building of the four elements of the theory, it can generally be said that the constructs and relations are mainly developed on account of the testing, while the logic and boundaries are developed via ontological considerations (Žižek, Harman, Morton) and logical argumentation. At the same time these do overlap as it is illustrated, among other aspects, in Figure 49.

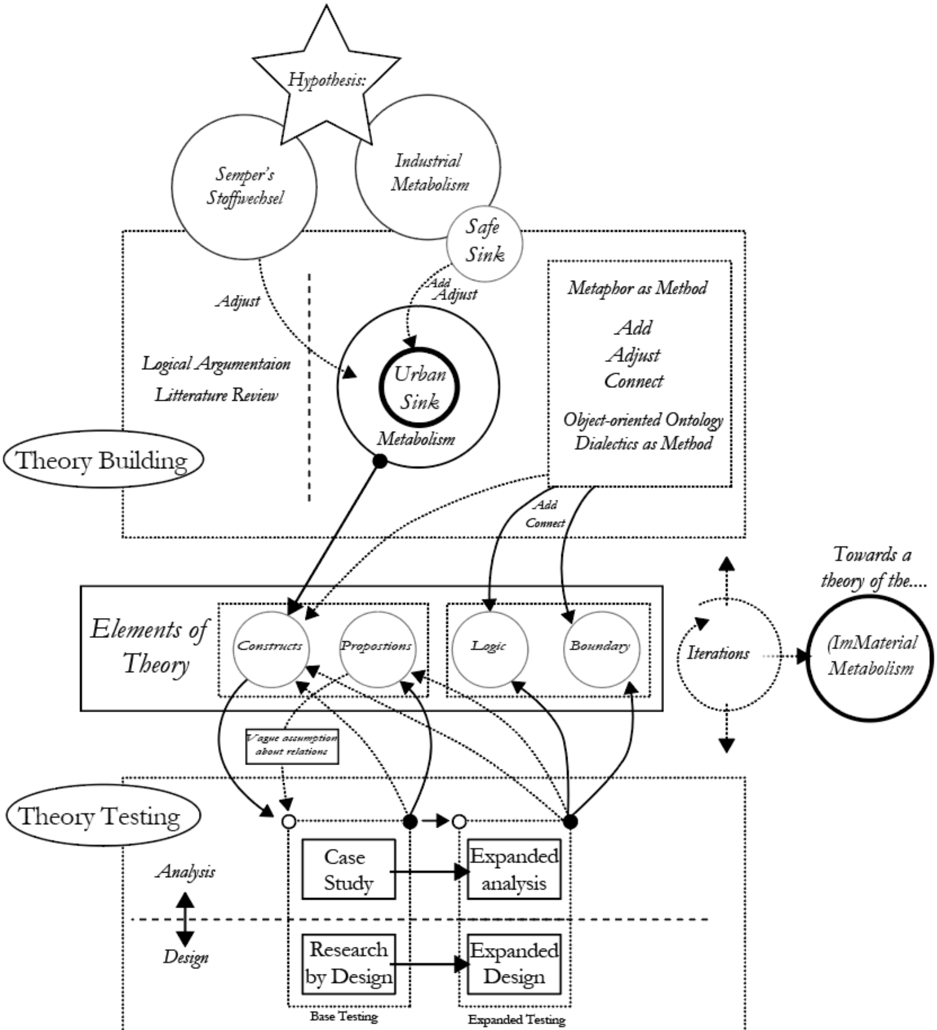

Figure 49. The whole research strategy: a monadic diagram of the research process.

Chapter 4.
Building Theory

This chapter deals with the building of a theory structure through the aforementioned methodological considerations by juxtaposing the theoretical frameworks of tectonic theory and industrial ecology. The chapter is initiated by more thorough mapping and disassembling of the two theoretical frameworks with regard to an interdisciplinary research agenda. With reference to interdisciplinary research literature and the use of the method of “data management table” the purpose is to map the literature of the two disciplines according to the elaborated parameters (Keestra et al. 2016; Repko, 2008) (Specifically, sections 4.2 and 4.3). In extension of the state-of-the-art from chapter 2, this chapter contains (4.2 and 4.3) a more nuanced and detailed dismantling of the two “metabolisms” following the fourfold anatomy of theory: construct, relations, logic, and boundaries. There are within both theoretical frameworks both significant theoretical aspects and seemingly practical/methodic aspects, but as the doctoral study is concerned with theory development (and not new tools, methods, or models) some of the methodical considerations will also be considered (as Nygaard also indicates that theory and method intertwine (Nygaard 2011)) in relation to the theory building purpose. Fundamentally, this PhD thesis is concerned with building a theory which critically reflects both inwards and outwards (meaning that it is aware and critical of the inner ideological mechanisms of architectural productions as well as how such mechanism materialize into material effects and consequences).

Referring to Research Question 1 (Chapter 2.4), in this chapter the building of theory is initiated. The aim is to build a theory which critically situates itself within with regard to both material and immaterial considerations. It does so through the centralization of the key concept “safe sink” and explores ways to translate such a notion into architecture while looking at the consequences and potentials are for architectural thinking and practice.

4.1. Theoretical Disassembling of the two Metabolisms

Building a theory which relies on existing theoretical frameworks will rely on the initial mapping (data management table, see Appendix B) and a subsequent further, more articulated disassembly through the four main theoretical elements: constructs, relations, logic and boundaries (figure 50). This will first be done for industrial ecology (paragraph 4.2) and then for tectonic theory (paragraph 4.3.) The proceeding exploration of building theory is elaborated step by step (paragraph 4.4.) with reference to the existing theoretical frameworks as well as other theory (and subsequently findings from theoretical application).

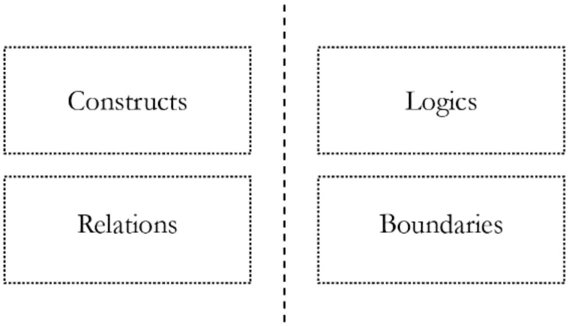

Figure 50. Theory Constituents.

Semper's theoretical writings are quite difficult, with parts missing, and it is a well-known fact that a major (final) work after *Style* (Semper 2004) was supposed to be made but never was. Things can also seem complicated, since some of his earlier writing remerge in a new form later (initial four elements (Semper et al 1989) transform into a new variant (Semper, 2004)). Semper has made a significant and comprehensive contribution which can seem as very complex by way of containing several sets of elements (4 elements of architecture) and "drivers" such a knitting and veiling/dressing (ibid). While Semper does not explicitly outline the "structure" of his theory in a systemic way, it is nevertheless still possible to use Colquitt and Zapata-Phelan's definition of theories on Semper's stoffwechsel. This chapter and its paragraphs will attempt to lay out Semper's writing according to Colquitt and Zapata-Phelan general theory of theories and before doing so, industrial ecology will be subject to the same procedure.

4.2. Industrial Ecology (Metabolism of chemical engineering)

In this section, the four main elements of the industrial ecology theoretical framework are explored—constructs, relations, logics and boundaries. This is followed by a concluding text on the limitations and openings for the interdisciplinary theoretical development found in this doctoral study.

4.2.1. The Outline

The metabolic studies from environmental and chemical engineering hold significant insight for architectural production, and its juxtaposition will require a significant shift regarding the thinking and practicing of architecture. The outline of this mapping is the aim of theory building. Industrial ecology theory along with material flows analysis method hold significant depth, and as the context of theory development, conditions of both theory and theoretical axioms make the methodological framework of individual ecology operable and applicable and must be considered for theory building potentials and considerations. There is rigorous precision particularly in the methodological aspects would later allowed for tool building and methods development (i.e., metabolic design tools within architect’s 3D work environment such as Rhino and grasshopper) This doctoral study will, however, aim to conceptualize a more general level regarding what it means to think “metabolically” in order to transfer the same metabolic thinking into architectural theory.

4.2.2. Constructs

In the common visualization of a material flows systems, we see a societal “metabolism” consisting of stock and process. This almost mirrors the Graham Harman line of thought from object-oriented ontology where Object being and becoming have intricate relations which can change or remain over a given amount of time. In simple chemical engineering terms, a process is a transformation or a storage process. This is significant because an object does not have to move to “move”, i.e., a still object is equally a process albeit one without any change.

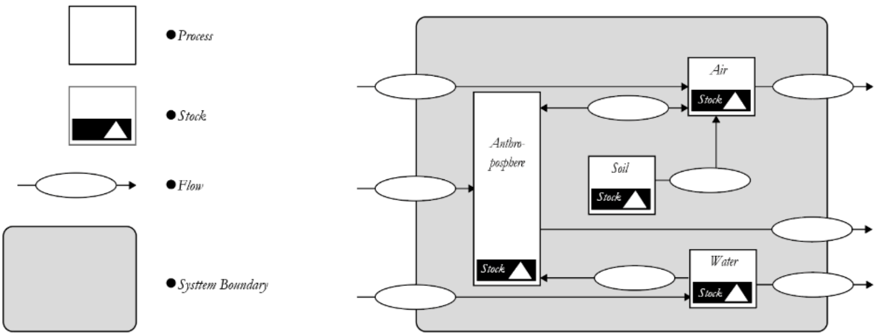

Figure 51. Four main components of industrial metabolism.

In the definition of MFA, process, stock, flow and system boundary are the key components (Baccini, Brunner 2012, pp: 99). Using the dichotomy of “part and whole”, the encompassing aspect being the system boundary can be described as the “whole” which is being analyzed or observed while being at the level of “parts” is where stocks and flows are. A process could be a burning, storage or use of any sort, and a stock could be that of a landfill. Nonetheless, the notion of the safe sink is not “included” here. The notion of sink can be considered a general term but within that taxonomy of constructs (Figure 50) a sink would thus be a process (with corresponding stock) and is attributed to such when it acts an end station for a given material (Baccini, Brunner 2012). Although defined as a process, the process of the sink can also be considered as a "storage" process. Additionally crucial is that even as an entity that stands still (doing nothing), the sink is still performing the act of storage, meaning it does not have to move, be transported or transformed to *be* a process because it is a process as such. The is sink usually found in the context of waste management where the final resting place (final sink) of a material or element is a landfill or incinerator. During the initial and naïve reading of the term sink, one could simply think that it is only a landfill; however, the notion of the sink has a certain "elasticity". The literature indicates that the building stock (built environment embodied as buildings and urban spaces etc.) can also be conceptualized as a sink for building materials such as gravel, metals etc. Herein lies the great challenge in properly understanding the depth of what a sink could be and what significance it could have for the built environment.

This was not instantly clear to me, but later I realized that the challenge was to understand the city as a (potentially) beautiful and meaningfully engaging "landfill" sink which archives/stores materials safely by the very act of being architecture. This would mean that a safe sink performs as such for building stock due to both materials firmness and experiential character.

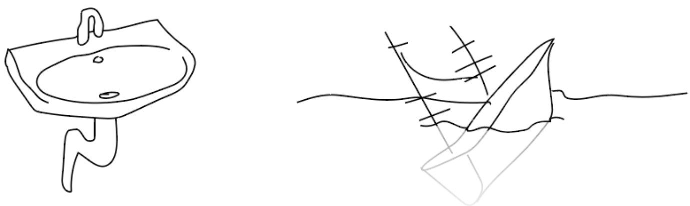

Figure 52. Sink; an object and/or activity.

A "sink", in the chemical engineering sense—or that facility which functions as the sink—is in our human experience something which is often phenomenologically pushed far away (both physically and mentally) from our immediate everyday experience. A "sink" is where our trash and excrements go. A kind of deep netherworld which "magically" absorbs all our undesired entities and substances. This netherworld is the other side of the coin of our everyday reality, i.e., the Real which is necessary for our "nice-surface" everyday life to be what it is. Phenomenologically, a true moment of horror would be for the excrement to return. Thus a lot of effort is done to keep such things away from sight. Herein lies the challenge for future generations when it comes to material consumption—grasping = and accepting the horrible behind-the-scenes Real which is generated by our "nice" everyday life and acceptance of it as part of this life and not keep sweeping it under the rug and out of sight.

4.2.3. Relations

Although thoroughly inherent to each other, it is possible to conceptualize two types of relations . One is general which allows a kind of “part-whole” understanding of a system boundary and its many inner stocks and flows. The second is the general relationship between society (anthroposphere) and its relations to natural environs.

Part-Whole

The set of 4 elements are related in the sense that the first three categories are contained within a chosen system boundary. While not entirely mirrored to the part-whole relation as seen in tectonic theory (Frascari 1981), an industrial metabolic system boundary can contain many parts which can also contain other smaller parts (Brunner, Rechberger 2017). The notion of *metabolism* circumscribes “all physical flows and stocks of energy and matter…” (Baccini, Brunner 2012, pp: 16) which are perceived over long periods of time through usually hourly, daily or yearly intervals (Baccini, Brunner 2012; Brunner, Rechberger 2017).

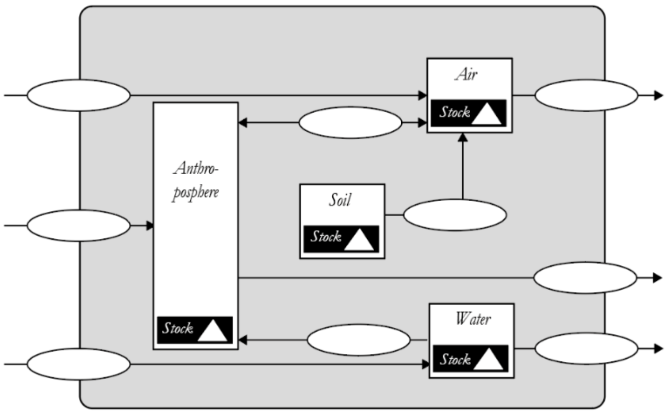

Figure 53. Within Planetary boundaries; Soil, Air, Water and the Anthroposphere.

Chemical Engineering stresses the importance to situate the social infrastructures in relation to the *hinterlands* which the surrounding landscape which provides resources and ecosystem services (Baccini, Brunner 2012). MFA is considered a methodology with 8 main phases where LCA is merely the 7th step, which gives the opportunity to firstly observe/analyses and potentially design material flows in particular system boundaries before assessing their effects on to natural environs and society via LCA (Baccini, Brunner, 2012). Chemical Engineering acknowledges the social importance in relation to the realized material flows but does not include it in qualitative ways (ibid.).

Hinterlands
Another foundational relationship within metabolic thinking is the division of society and *hinterlands* (Baccini, Brunner 2012; Brunner Rechberger 2017): humanity/society and nature. Though it is not divided into opposing entities, but rather as the diagram above indicates (figure 53), it is a sub-division of the larger system boundary within which the anthroposphere is located. In contemporary times, a significant amount of theory has been developed to address the need to halt the old dichotomous division of "human vs. nature" (Benson 2019). In practical terms however, this is difficult and there is still much use in the mobilization of the human-nature dualism in order to properly understand this division and the relationships that come with the division. In the context of chemical engineering ontological and epistemological *constructing* of nature, *hinterland* is understood in the mechanist sense of being a service, resources, or capacity and does not include any consideration of experiential qualities of such landscapes or terrain. By extension, the theory of entanglement has been developed based on the fact that things are connected and entangled (for better or worse). Industrial metabolism is perhaps quite sympathetic towards different understandings of relations between people and nature; even so, in its approach to understand the complex entanglements, it divides the two into separate entities despite the applicability of metabolic studies onto cities, forests, ecosystems etc. It can seem abstract to simply conceive of the relation "human vs. Nature". In the application to theoretical frame of the industrial ecology, it can mean both to position societal stock and activity in a global sense (Baccini Brunner 2012) or locate it within a bio-region in relation to a chosen city or urban area (Ferrao, Fernandez 2013). Industrial metabolism experts often act as consultants and in a specific analysis of a particular city,, they isolate a city, district, or company and observe the input-out, stock, flows etc. of only that particular system boundary. The purposes of such "limited" approach can be both sustainable and circular (to minimize consumption and environmental pollution of a city/company etc.) but it can also be merely to optimize conditions in order to minimize waste in only few flows/paths for the sake of cost optimization.

4.2.4. Logics

There are likewise several aspects to consider when dealing with *logics* of industrial ecology. The most general sense-making logic is that of the metaphor as industrial ecology theory which certainly does not deal with self-governing eco-systems or organisms. The aspect of input-output is circular logic that allows for rigor in both theory and methodological application, while the aspect of *openness* prevents the possibility of a closed circulatory system.

Metaphor
Firstly, it is important to highlight that industrial ecology hinges its practice and theory in the use of the metaphor of metabolism. Unlike the architectural discourse of tectonics, the application of the metaphor of metabolism in initial ecology is very criticized and meticulously deconstructed for evaluation of the usefulness of the continued use of the metaphor and where it fails in its application to mimic an actual metabolism (Graedel 1996). Among the things that complicate the use of the metaphor is that the city is not an organism or organic eco-system but is more of an un-natural eco-system which acts sometimes “unnaturally” or “irrationally” due to social conditions, economy, and politics. For this reason it cannot be easily flattened into a bio-mechanical entity.

Input-output: balance of mass
Partly due to the inability to apply the metaphor of metabolism one-to-one certain logical axioms are needed to structure the logic of industrial metabolism. One of the founding axioms of metabolic approach is that of input-output logic. In extension of this, a metabolism must confine itself to the principle of mass balance in which input equals stock and output. As an extension of this, another key axiom of the industrial metabolism is that it must obey the law of conservation of matter (Baccini Brunner 2012) where input equals stock and output.

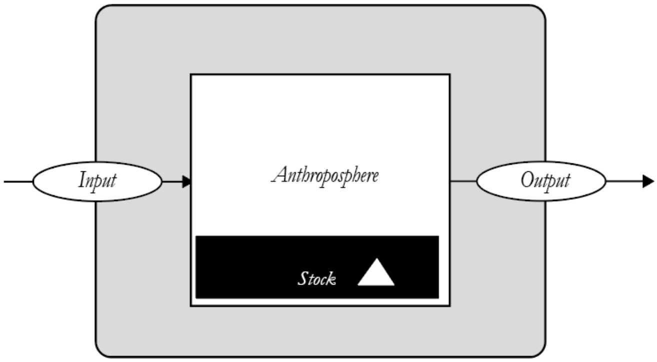

Figure 54. Logic: input-output (mass balance)

Temporality – open systems
Another constitutive logic and founding axiom is that of systems being open and thus in motion over a chosen time frame. Although this can be dealt with in different terms,

entropy can be considered a key logic of the system (Brunner, Rechberger 2012). As most (perhaps all known) physical systems are open, this means that they in some respect keep materials in motion, deteriorate, and increase entropy (increased irreversible order of "chaos" in the material world). This is significant because thinking in metabolic terms without coupling them with sustainable theory means that metabolism is a "free" concept which can be interpreted to increase metabolic rates. This means that its own dynamic and activity would increase material input from nature to society. For the metabolism to be sustainable, it would need to minimize material demand to *significantly* lower it (Ayres 1994).

4.2.5. Boundaries

We have seen that industrial metabolism as metaphor was not directly applicable, and that it required additional logics to maintain a useful application. Nevertheless, the reason why metabolism is useful is that there are some good parallels and assuming boundary conditions which are relevant even if a city or society isn't a living organism itself. Mobilizing the metaphor of metabolism implicates the considerations of suitability (the ability to sustain in future generations), its metabolic rate and overall condition (health if you will) of the organism (is it consuming too much of a particular substance and what are the effects of that in relation to the wellbeing of that organism in its environment). Despite this, industrial ecology and metabolic studies qua material flows analysis is an applied science and can be claimed to be part of materialism (in the old "conventional" science sense)\ but was also influenced by the "other" materialism (i.e. Marx).

Materialism
It is important to point out that the contemporary understanding of material flows as it has come to be known via Material Flow Analysis in industrial ecology and urban metabolisms in chemical engineering field can be traced to Marx (Pincetl et al, 2012). It is also important to mention that Marx died before being able to finish his book *Capital III* which was in fact dealt with the metabolism between society and nature (Saito 2017; 2022). It is interesting to note that in the last years of his life, Marx was fascinated by the notion of the "metabolic rift" between society and nature. He was invested in reading state-of-the-art (at the time) natural and environmental science and already started to develop an understanding of material resources (and scarcity) of such within society which could influence nature negatively in the long run (Saito 2017). While the Marxian dimension is not explicitly present in the contemporary state-of-the-art chemical engineering literature on material flows and societal metabolism, it still harbors a logical "spirit" and critical approach and understanding which (generally) aims at conserving resources, biodiversity, and overall natural environments while stressing the ethical dimension in dealing with material flows and material consumption between society and nature (Baccini, Brunner 2012).

Literature on metabolic studies further emphasizes the need for public education and awareness of material flows (ibid; Brunner, Rechberger 2017); and although MFA is usually practiced as an consular and analytic measure, the methodic and theoretical literature highlights the importance of applying it for designing purposes as well (ibid; Brunner, Rechberger 2017). Materials need sinks and more importantly "safe sinks" which must be facilitated and/or designed (Brunner, Rechberger 2017). This indicates that having "safe sinks" is central and key for sound and sustainable material flows as is argued in chemical engineering literature (Brunner, Kral 2014; Kral et al 2019, Mavropoulos, Nilsen 2020) Furthermore, so-called "closed loops" are physically impossible which can be put as follows:

> "When we examine a biological cell or a city... not only are these systems open, but also they exist only because they are open."
> (Prigogine, Stengers, 2017 , pp: 127)

We should concern ourselves with not only "closing" but, more importantly, "slowing" (higher quality products) and "narrowing" (higher material efficiency i.e., cunning use of less material volume) (Jørgensen et al. 2018; Bocken et al 2016). Although the latter does not have an explicit emphasis on aesthetics and spatial phenomenology along with multifunctionality, the Tectonic implication is nevertheless there since the long-lasting capacities of architecture have the material and immaterial fused.

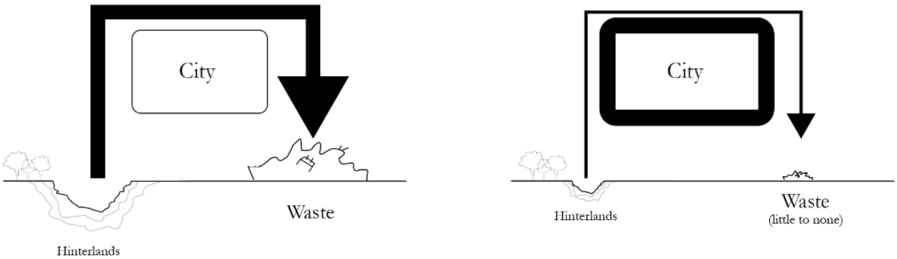

Figure 55. From growth to circulation (or preventions of waste) - still linear, but slow and narrow.

Chemical engineering thus provides methodological rigor to situate design activities, while providing an overview and ability to design material flows on a large scale which includes consequences for many underlying disciplines and fields. Even so, he ontological and epistemological dimension of Chemical Engineering, which constitutes "reality" as a mechanistic systems and components, problematizes how it inscribes itself practically. This means that since social dimensions and aesthetics are not part of the charts and system boundaries but are merely implicit or in the background with little to no understanding of their potential with regard to material flow challenges, because they are difficult to make empirical in the MFA method.

The edifice thus remains too much on a technocratic bias towards solving the challenges of material flows. This mechanist ontology is discernable in the human-nature relation as the two are kept apart ontologically and methodologically. What becomes important here is the possibility that the mechanistic ontological world-view is not the problem as such . One could imagine since we might get a more complex and interconnected understanding of the world that could provide new or at least different horizons for further exploitations within this interconnectedness. It is very much a question of attitude supporting any given world-view and ontological position which goes slightly against the architecture attacks on mechanistic ontologies. I argue that such a ontological world-view is much more neutral than it may seem, since one could just as easily position oneself within such a divided dichotomy and instead of perceive it as "humans against nature". One could furthermore assume a stance of humility and modesty in maintaining this division instead of "withdrawing" from affecting and exploiting it. Metabolic theory and method can both be applied merely for short term and cost-oriented aspects without any genuine concerns for the environment, while also harboring and laying the foundations for new sentiment and world-views which are both radically critical and sympathetic towards ecological concerns both for humans and nature. In this regard, Kohei Saito, a degrowth scholar, elaborates that it is ontologically possible to view the world as interconnected without ontological distinction between society and nature. The argument here is that methodologically it can be critical to keep them separate (Saito 2022) as it is *humanity*'s effects on *nature* which should not be relativized.

Literature on industrial ecology and the built environment, while not explicitly excluding architecture ability to have plants on the roofs or facades or other biodiversity services, emphasizes the ability of building elements to be disassembled/maintained, flexibility/adaptability, and use-intensve in the forms of buildings being able to performs as many functions as possible while each building being empty as little as possible. The implication here that architecture should be designed to not hinder a variety of uses with as minimal as possible transformations (i.e., move a light wall and the like) and that there is some sort of sharing economy of interior space. Some of the key parameters these strategies try to meet a include generation of waste avoidance and reuse of exactly same elements/material. For the theory building purposes of this doctoral study. The implication here is that that *use* or application is one of the key components of buildings from a metabolic perspective. One of the key strategies to slow and narrow material flows is that of prevention of waste generation (Miljøministeriet 2021, pp: 25). There can be several ways to implement this including flexibility in use and function regarding the building stock. If we separate material soundness and buildings being well made from technically and materially (which would allow for long life spans), the key consideration of functionality of building is also what allows for its survival over long spans of time

(Kendall 2011). By extension, the use-intensity is also important to consider so that each building is used at maximum capacity (ideally all 24 hours a day) for multiple purposes and ”intensive” use (and multiple function over the course of days, weeks, months years etc.) (IRP 2020, pp 90-94) thus minimizing the demand for more buildings which will also be empty at give amounts. While other immaterial considerations could also play a part in the functioning of the building stock as “safe sink” for materials, a key factor is the wide and ambiguous usability of building stock.

Metabolic Eco-philosophy

In a meta-physical analysis of the shift from old World-View of domination of nature, the eco-philosopher Dominique Bourg refers to a Hegelian shift (of negation) which he considers inherent to metabolic thinking (Bourg 2003). As we have seen that well-intended technologies can and have produced undesirable effects (Jevons Paradox), Industrial metabolism and ecology brings about a “spiritual” retraction (withdrawal) from nature that acknowledges the unsurpassable “otherness” of nature (ibid). This is a radical shift away from the usual ideology or fantasy of “the all-powerful” human or of conquering and dominating nature (Bourg 2003). This acknowledgement of the “otherness” of nature which is brought about with ecological and metabolic thinking has brought about a “new spirituality” as Bourg sees it. This “spirituality” can not simply solve all our problem as this would be the old idea of control. Rather it requires that this “spirituality” enter the social and economic realms to have a serious imprint (Bourg 2003).

While chemical engineering is usually more practical and pragmatic which allows for engineers to conduct analysis and act as consultants for different agencies, who on account of the findings can reconfigure their systems, there is also a more expanded understanding of what metabolic thinking can and should contribute in the given environmental, social-political, and cultural conditions. More conceptualizations have been developed regarding industrial ecology (metabolic) thinking which already takes a step further in not only being a “neutral” method of mapping material flows but acknowledges the potential and need to construct complex ecological thinking with the aim of minimizing metabolic exchange of materials (and energy) from nature to society (Bourg, Erkman, eds 2003). Similarly, the methodology of material flows has both inspired theoretical development (Fischer-Kowalski 2003) and allowed for speculation on metabolism in relation to both metaphysics and politics (Bourg, 2003). These fundamentally observations show that there is a need to shift away from a fixation on economic growth in the so-called “cowboy economy” to a more holistic understanding as that of the “spaceman economy” (Fischer-Kowalski 2003). Furthermore, the writings observe needs an ideological shift from seeing that society and technology changes nature toa complex understanding of nature shaping society in a way in which industrial metabolism seems to hold the “new spirituality” (Bourg 2003). Chemical engineering literature acknowledges the importance of interdisciplinary collaboration, integration, and projects as through these interdisciplinary interactions we have to nurture the development of “metabolic designers" (Baccini, Brunner 2012).

One can thus consider of how the core methodology of MFA (metabolism) from chemical engineering can bring about a new spirituality. To this end, it could be valuable to compare chemical engineering to structural engineering. When we consider how structural engineering is structured at a meta level, we must acknowledge that one uses and applies different tools and methods to arrive at a structural system which is to be realized in a certain material. While there are different standards and norms for structural solutions -- whether from a legislative perspective or economic – the usual way of doing things is to provide a design which implicitly arrives at the least amount of material which gives an acceptable performance in a cost-effective way. It is important to know that life span is often not an explicit design parameter. This would be an example of what Žižek elaborates as a "contorted field" in which an axiomatic inclination (to lower costs) is present in how the tools and methods operate. As we have seen with Jevons' paradox, a optimized technology can in the long term increase (not decrease) material flows, as structures are designed for short terms parameters. In comparison, a critical metabolic approach is an edifice which implicitly and explicitly poses a challenge to design material flows which manifest an interconnected edifice which goes towards minimizing material flows and as such embody this Negative "spirit."

As chemical engineers develop approaches on industrial ecology in relation to larger spatial schemes, they see system boundaries of bio-regions (Ferrao, Fernandez 2013, pp. 99), meaning that when we design material flows, a bio-region must be able to sustain itself. And while a bio-region is a crucial impetus, the approach further emphasizes the need for interconnectivity of bio-regions in a larger continental and global approaches to material flow design (Ferrao, Fernandez 2013), pp. 100).
This approach emphasizes the need to "close" the loop of material flows between society and nature (Ferrao, Fernandez 2013, pp. 102-103), while nevertheless illustrating that this parameter is not fully possible, as a minimized amounts of waste is inevitable thus requiring new material input.
Such an approach would necessitate a shift in thinking and doing, and in the architectural discipline it would require sub-disciplines across all scales of design and result in having consequences for both theory and practice in building design, planning, urban design, strategic planning etc. (Ferrao, Fernandez 2013), pp. 167). Seen from an chemical engineering discipline's perspective, architecture and engineering is considered a "synthetic" discipline which concentrates more on the activity of manifesting and synthesizing theory and method into physical manifestations, while its analytical capacities are oriented towards the purposes of synthesis (Ferrao, Fernandez 2013), pp. 50).

The immense potential of metabolic thinking (industrial ecology/metabolism) is precisely to think and design in terms of complex interconnectedness and entanglement of societal, meta-physical phenomena in relation to natural conditions with the aim of slowing and narrowing material flows. While much of the industrial metabolic thinking and Mater Flow Analysis have provided mostly tool and methodical approaches, the very methodology and the challenge they put forth has been a foundation of more theoretical elaborations on the significance of metabolic approach for both material and metaphysical considerations society in relation to nature.

A basic concept of industrial metabolism is that the "…industrial system and its societal interactions are embedded…." and has a critical metabolic approach which should accompany the approach in policy making as well as assessment and design of material flows (Bringezu 2003). In a historical analysis of how metabolic thinking came to be, Fischer-Kowalski provides insights into the influences that formed early metabolic thinking (by Marx among others) as well as the later re-introduction (by Ayres, Baccini, Brunner and more) (Fishcer-Kowalski 2003). Fischer-Kowalski shows the expansive interdisciplinary and complexity of an industrial metabolic conception and as Fischer-Kowalski conclusively writes in reference to Bruno Latour, there is a need to stop separating of social "subject" and natural "object" as the contemporary predicament necessitates the development of "social-cultural-natural" hybrids (Fishcer-Kowalski 2003) to properly deal with social-natural entanglements in an age of global warming and climate change.

4.2.6. Interpretation: Limitations and Openings

In this paragraph, the limitations and potentials/openings are put forth with regard to the theory development effort of this doctoral study. It can be argued that industrial ecology theory and methodology is very deep, and its complexity can be used for many different purposes, i.e., potential for making new tools and methods in architecture. However, this delineation outlines the challenges of industrial ecology with regard to the juxtaposition with tectonic theory in architectural discipline and the overall scope of theory building.

Constructs	*Relations*	*Logic*	*Boundary*
Process (Sink)	*"Part-Whole"*	*Metaphor*	*Materialist Science*
Stock	*Society- Hinterland*	*Input-Output*	*Eco-philosophy*
Flow	*(Planetary bound.)*	*Temporality*	
System Boundary			

Figure 56. An overview of the industrial ecology metabolism.

Limitations

One of the crucial limitations of the industrial ecology (metabolic) approach, especially on the methodological side, is that it requires immense knowledge and experience to properly conduct, balance and extract useful knowledge for the findings in relation to one problem. Furthermore, to properly map all material flows can be both difficult and time consuming sometimes requiring several years to provide a result which then gives a snapshot into conditions with 2-5-10 years latency. While chemical engineering wishes for more inter- and multidisciplinary collaborations and research, industrial ecology shows itself to be very difficult to apply on a methodical level for architects, urban designers etc. The fact that industrial ecology is such a rigorous methodical tool allows for future implications regarding architectural design processes potentially being a "translated" method and more easily usable for architects and urban designers.[11]

In an almost mirrored fashion to tectonics, albeit in an entirely different discipline, i.e. industrial ecology, Semper's stoffwechsel (paragraph 4.3) emphasizes objects and transformations processes in a kind of part-whole set of relations. Industrial ecology does not consider this in a spatial/tectonic way, but rather in its own ontological understanding that system boundary contains many processes and flows, and each process can itself be made up from several inner flows and processes. Unlike tectonic discourse, industrial ecology does not contain a significant "narrative" dimension in this regard, as narrative does not influence the mapping of materials and what sets of parts and whole describe them. There is through another dimension of the "subjective" in industrial ecology which is comparable to LCA. While everything may seem "objective" and scientific, the founding gesture, so to speak, is that we have to *choose* a system boundary which may pose problems for either only individuals, larger groups or even larger eco-systems of both people and environments which may perhaps privilege particular (individual or community biased) problems and not address a wider set of problems across communities, nations etc.

Opening/Potentials

One of the founding potentials (for this PhD study) of industrial ecology is that it becomes a tool which can position any practice (whether clothing, transportation or in this case building industry)within planetary boundaries. Conducting a material flow analysis allows for a pragmatist view of material flows irrespective of what is said, claimed, or intended by the people responsible. What of course becomes important now is that almost all industries have a green, sustainable, or circular agenda to juxtapose what is being said/intended to be done (build green, have sustainable industries) with the material reality and consequences of those intentions. It is by use of metabolic studies that "take-back" effects or Jevon's paradoxes became observable, meaning examples where a technology (optimized) should have decreased

[11] This has not been the focus of this PhD study, but in future endeavors this would be pressing matter to consider, potentially with other researchers.

consumption of some particular material/elements ends up increasing it due to lowered cost, increased availability and wide spread use etc., can be observed

Industrial ecology theory and method does not directly extend itself into architecture and design practice and theory, but it does harbor some sentiments which can be translated meaningfully without necessarily demanding that each and every architect and designer becomes a chemical engineer as well. Focusing on the importance of the sink as a concept (which can be transferred into architecture and design) ought to be considered crucial to understanding spatial and architectural terms. While the sink and material have their ontic, scientific material properties and technical considerations, architects could situate their discipline by centralizing the notion of the sink since building stock is the largest sink in terms of weight and volume. When we in general terms consider the building stock in relation to the concept of the "safe sink", what then influences material consumption is the building stock's ability to function as a "safe sink" for the materials it is comprised of. This implication here is that the building either performs as "safe sink" or not based on the meaningful architectural (read tectonic) application of those materials related to not only material concerns (robustness, sturdiness etc.) but immaterial ones as well (usefulness, phenomenological and social/cultural considerations).

Underthe guise of the current environmental challenges, chemical engineers have urged the need for more interdisciplinary collaborations and the need educate what they designate as "metabolic designers" (Baccini, Brunner 2012). This is not a return to the Japanese avantgarde of the post war era; nonetheless by situating and infusing as many disciplines and industries as possible with metabolic understanding, the space would open to align different understandings through a common terminology and agenda across disciplines and within each respective discipline and industry.

4.3. Tectonic Stoffwechsel (Metabolism from Architecture)

Similar to the prior section on industrial ecology, this section regarding the tectonic metabolism will be "disassembled" as a zero-level step prior to the building of a theory. Giving initially brief insight into the context and historical epoch along with the influential forces in "the background", the following section will contain a fourfold structure of the theoretical elements (construct, relations, logic, and boundaries). These elements will be mapped, described, and critically considered for their theory building potentials.

4.3.1. The Outline

Tectonic discourse is found within architectural discipline and is not to be confused with the geological notion of "tectonic plates". Tectonic discourse in architecture is perhaps an unusual phenomenon as it is a theoretical strain which remains relevant and active over a few centuries. I am of the opinion that this is because tectonics somehow managed to "cut" into the core architectural thinking and practice , revealing the "anatomies" of both and remains relevant and potent. Architecture is a vast profession and discipline which often is an umbrella of all sorts of desi, i.e., furniture design, interior design, buildings, urban space, planning etc., and recently design video-game environments (Harris et al ed. 2020). Tectonic theory holds significance for several reason. It has simultaneous emphasis on the design process and critical material understanding with many cross-scalar approaches, e.g., tectonic approach to furnishing, interior space, buildings (Semper 2004; Hvejsel 2018; Moravanszky 2018), and urban design (Sekler 1965; Christiansen 2020). Additionally, tetonic theory emphasizes the integration of tectonics and structural engineering (Schwartz 2018) and material "sciences" (Thomas ed. 2007; Borden, Meredith ed. 2012; Hensel 2013). A crucial dimension of tectonic theory is that of "criticality" (Hartoonian 1994; Frier-Hvejsel 2018). One should also take note of the fact that tectonics as theoretical endeavor has been an ongoing debate and theorization crossing multiple historical epochs, paradigms and styles in architecture to which scholars and practitioners still return to. And it is my speculation that this is so because tectonics deals with something fundamental than mere proposing new stylistic normativity. For these reasons, tectonics can be considered a much more fundamental, ontological even, dimension of architecture as it delves into the very "fabric" of architectural creation and thinking – on both a meta-level and in the most immediate engagements. Inn this strain, Semper's "metabolic" thinking was a crucial attempt to dissect this fabric (Hartoonian 1994).

The Metabolism

Gottfried Semper's theory is both a descriptive and prescriptive, though Semper himself used its descriptive capacities to explore and elaborate in meticulous detail both historical works and creative/transformative processes (Semper 2004). Semper's theory is a general theory which is not limited to the explanation of one particular design but can be applied to explain much of built works and used to design any facility in any size. There is much literature on Tectonics Unlike many other architectural theories, Tectonic, which stems from ancient Greece, was explicitly developed during the enlightenment in the Hellenistic turn in Germany by the likes of Carl Bötticher and Gottfried Semper. Today there is still much ongoing literature developed on Tectonic theory within architecture across different scales and concerns. This doctoral study thus conceives and considers Semper's concept of "stoffwechsel" as a central theoretical notion of importance for this interdisciplinarity of this doctoral study. The central notion is thus the metabolism (stoffwechsel) and not necessarily only Semper's iteration of it thus making this doctoral study is open to other re-iterations, comments, and elaborations of it.

"Stoffwechsel" is usually translated as "Metamorphism" to avoid a misunderstanding of the Japanese Avant Garde Movement (Moravanszky, 2018, pp: 20), but the more literal translation of "stoffwechsel" from German is "metabolism" hence lending to the potential for interdisciplinary integration. Semper was greatly influenced by the natural sciences of the times (biology, chemistry (alchemy) etc.) (Moravanszky 2018, pp:187) in a time when Germany was gaining a national identity and sought to find ways to "build" a society in reference to Greek democratic values in the face of industrialization challenges of modernizing a society. The concept of Semper's stoffwechsel (Metabolism) was later criticized for being too "materialist" by Riegel (Moravanszky, 2018, pp:53). But later, a deeper analysis has shown that Riegel misunderstood Semper and that Tectonic notion of Metabolism was already much more inclined towards Idealism and not purely materialist aspect (technical principles, material scientific facts etc.) (Moravanszky, 2018). Moravanszky even goes as far as to elaborate the relationship between Idealism and Materialism in relation to Tectonics as to highlight that Semper did not intend Tectonics to be a materialist (technical) approach (ibid). Compared to today, but in slightly different variation, we have seen tectonic approaches which are to greater degree concerned with material science (algorithmic optimizing of form design), while others emphasize the "critical" dimension in Tectonics which is culture stemming from the legacy of Hegel, Marx, and the later Frankfurt School philosophers like Adorno who was heavily inspired by Hegel among others.

Historical setting

Although capitalism was already booming at the time, figures like Karl Marx had already postulated and theorized ideas of resource limitations in the face of capitalist dynamics and ecological exploitation prior to Semper's work. (Saito 2017: 2022).Semper's worries lay elsewhere but were nevertheless timely and relevant to the societal challenges at hand (the construction of a new nation/identity). Semper's motivation for the theoretical endeavor was the "decadence" or "decay" in architectural and artistic expression of his time (Hvattum 2001; 2004). This was a time of grand change as industrialization and use of metals (perhaps iron most significantly) were being introduced which along with the "decadence" issues posed a great challenge to "construct" a society. This was also a time in which Germany was working to develop a national identity and the reference to Hellenism and Greek traditions (hence tectonics) was imperative to construct a national building culture which tapped into that sublime Hellenic tradition—though exemplified in a German setting.

While it can be argued that Semper's stoffwechsel is something completely else compared to his theoretical elaborations of the "four elements", scholars have implied that the notion of Stoffwehcel metabolism is the overarching frame of Semper's line of thinking and thus contains other writings such the four elements (Chestnova 2018;

Moravaszky 2018). This doctoral study proceeds as such.

4.3.2. Constructs

Semper’s theory has almost become proverbially known as the “four elements”, but to avoid misunderstanding in the context of the theory building investigation, Semper’s are the equivalent of “constructs” and not the whole four elements: constructs, relations, logic, boundaries.

Semper describes his own key constructs (the 4 main elements (Semper et al 1989)) as “techniques” or “main artistic activates”, but he nevertheless named them as well-known entities (or even objects) within the practice of architectural production: carpentry, textile, ceramics, stereotomy (Figure 57).

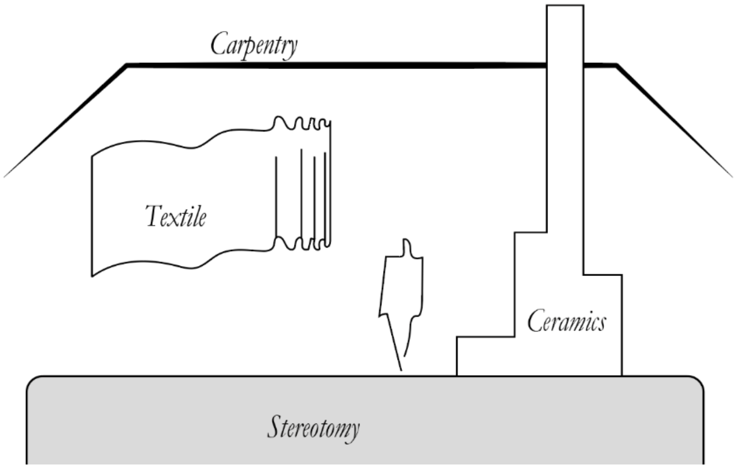

Figure 57. Four main elements of Semper's theory: carpentry, textile, ceramics and stereotomy.

As Moravanszky elaborates, textile is often understood/applied as the wall, while ceramics is often applied as brick or clay as hardened via a “fired” transformation and carpentry is often applied as the roof with stereotomy being often applied as the terrace/base on which buildings are situated (Semper 2004; Moravanszky 2018; pp.99-129). Moravanszky furthermore demonstrates, that Semper’s four categories of activities/objects are loose definitions of ways of appearing. An example of this would be an element which is apparently stone (stereotomy) but is applied in such a delicate way (with intricate detail) that it is more in tune with a textile (albeit made in stone). With this flexibility and inherent ambiguity of each of the elements, each is shown to be both a material and immaterial object as they can be dealing with an actual textile and (the sublime *feeling* of or Thing of) textile-ness.

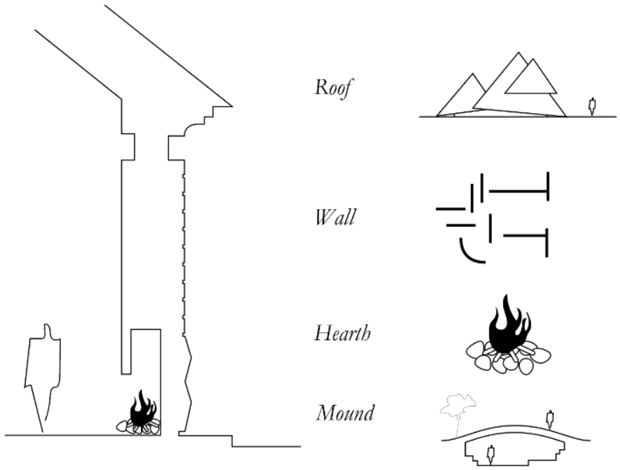

Figure 58. The four elements containing a certain "plasticity" in application.

Although Semper's final iteration (figure 57) of the four elements is as described above, they were derived from an earlier iteration of the 4 elements (figure 58). One could argue that Semper's first set of elements went from being of a more "static" object orientation to more of being "metabolic" categories centered around a material and its processes. Though he "transformed" the early set of elements, the old iterations are still of value. What is of significance in the old quadruple of elements is that, as Moravanszky also elaborates, the category of the hearth is not "necessarily connected with materiality" (Moravanszky 2018, pp. 96). While we can claim that three other categories are more archetypal formal architectural elements linked with familiar material and structural principles, the category of the hearth is perhaps more linked with a function and/or spatial configuration and application rather a particular material or technique, as such is more ambiguous category. In the spirit of Semper himself, the hearth should not necessarily be understood as merely an actual hearth. It can be the hearth (as an essential spatial gesture) of any room/function (table in the dining room, or a desk in an office etc.) or even be further conceptualized as the very "fuel" or burning Will which is already inherent and fundamental to the other three categories, making them take shape one way rather than the other.

4.3.3. Relations

In this section, the ways in which aspects of design relate to each other are brought forth. There are a number of them and each will be elaborated upon though the chronology of them does not indicate a hierarchy as they certainly echo into each other.

Transformation

When observing a piece of architecture, one could observe how the four elements (figure 57) are composed as to ascertain the apparent relations between them (i.e.. color dynamics, proportions, compositions, contrasting textures etc.). However, Semper elaborates on a more central set of relations which are crucial not on the particular level (proportions, relation between roof and wall etc.) but are generally present regardless of the particular compositions. Semper's elaborates on the transformative relations between elements in very broad terms, and he steers away from defining one particular relation as that would merely explain one building or few buildings:

> "When an artistic motive undergoes any kind of material treatment, its original type will be modified; it will receive, so to speak, a specific coloring. The type is no longer in its primary stage of development but has undergone a more or less pronounced metamorphosis. If the motive undergoes a new change of material (Stoffwechsel) as a result of this secondary or even multiple transformation, the result new form will be a composite, one that expresses the primeval type and all the stages preceding the latest form. If development has proceeded correctly, the order of the intermediate links that join the primitively expressed artistic idea with various derivations will be discernable." (Semper 2004; pp:250)

If we try and dissect this formula of transformation, several things are implicated by its formulation. The first sentence indicates a kind of Platonic logic regarding ideas and material manifestations of that idea. In such an application, transformation of its "type" occurs. This type can then transform further, by way of articulation and detailing etc., into composite which expresses the founding idea while containing the former steps of transformation.

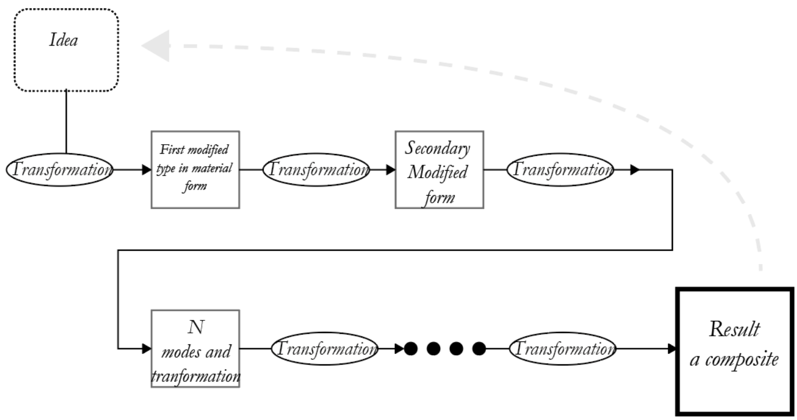

Figure 59. The process of relations as a monadic diagram.

If the entire process is to be a "success", the initial idea along with the n-number of transformations ought to be didactically readable and discernable within the final form. Such a composite is not merely a modest material thing which performs as a practical entity for our everyday lives but exactly a composite of material and immaterial aspects that, by its own presence, emanates and speaks its own story of creation and conception in its final form (a self-relating entity). Another elaboration on this inherent view of material and immaterial considerations already indicates Semper's thinking regarding a complex system

> "Semper proposed a metabolism theory in which materials and instruments, hand movements and body parts blended with religious myths and carried the memories of earlier materials into later ones as ornament and ultimately into monumental art, from textiles through clay, wood, and metals to stone (Payne 2021)"

As such, the transformational process implicitly indicates that there is a "periphery" (what is designated as *hinterlands* in industrial ecology) from where materials arrive. These then undergo multiple transformations, while the *idea* is seemingly universal.

Part-Whole

Yet another relationship-factor which is used by Semper in a rather undefined fashion is that of parts and wholes without having a particular section in his book which elaborates how parts and whole are related. Throughout the book (*Style* (Semper 2004) he inherently or integrally describes particular design by using the part-whole relations in which he describes the relations at hand of a given design object etc. It spans from the descriptions of a motive which is entirely an isolated “part” without a whole (Semper 2004; pp.85) to describing how the ”whole” can be repeated as a decorative detail as the “whole in its parts” (Semper 2004; pp. 640) – along with everything in between the two extreme of part-whole relations.

Self-Relating – or Panpsychism/animism

Seemingly, for the first time since the ancient pre-modern tendencies where the final reference of almost any piece of work was in some way Nature, God or spectral motif (e.g. Primitive Hut), with Semper architectural thinking, the discipline gained an (self-aware) introspective gesture by referring back to itself. In extension of this innate narrative of a thing, the notion of animism becomes of particular architectural relevance. This is seen in later architectural theoreticians’ analyses which describe and depict or analyze an architectural work in its built form as if the architectural elements are alive and self-aware and are doing something = in particular setups while speaking with other elements - as if a fable. In a book chapter, Caroline van Eck elaborates on this animism of building elements (van Eck 2010; 2013, pp.136). This animism (or even panpsychism) occurs not only on the small scale of (architectural elements i.e., wall, mound etc.) but also on larger level where creativity ensures a “cultural continuity” with each new building (Moravanszky 2018) . This, as Mari Hvattum attempted to highlight, is a problem of historicism (Hvattum 2004). What implicitly happens with such an “animi-sation” of the architectural discourse is that architecture becomes too much of an isolated object and seems to come “alive” on its own making us, as architects, merely observers as architecture itself has an inner Will to explore itself as we facilitate/enable these variants and stories. It becomes a set of coordinates which facilitate and (indirectly) maintains building activity while leaving out the possibility of critically situating architecture within planetary boundaries with a non-growth agenda. Heidegger also fundamentally developed this in his text on architecture with the trident of *building, dwelling, thinking,* where to build is to dwell and to dwell is to build – and thinking being an interstitial dimension in both (Heidegger 1971). Van Eck also elaborated on *animism* in Semperian Tectonic discourse as being an “empathic projection” (van Eck 2010) of the architect empathically projecting “life” into inanimate matter, and while there are parallels in the *self-relating* aspect (i.e., a living entity telling the story of its own making), the quest is to link the immediate animation of objects (at hand) with the large-scale cross-historical progression of “cultural continuity”. This is because, following a Žižekian line of thought, the object may gain “life” through personal empathic projection but once it is “already-alive” (as an established discourse among thinkers and practitioners etc.), it simply *causes* itself.

Although tectonics usually positions in more critical corners compared to mainstream building practice, this aspect of animism makes it entirely possible to place tectonic discourse within the usual “swinging of the pendulum” tendency as it aims to “merely” explore more and more new/different variants in the inevitable “continuity” of culture without necessarily having a critical angle on why and how.

Consequently, it can be argued that Semper's theory is a self-relating entity with monadic relations between materials, properties and expressions and is made clear in the process of becoming when the final step tells the whole story of its own creation (figure 59). As Mari Hvattum demonstrated, Semper's analysis of the Assyrian chair mainly focused on the innate properties of the chair while entirely omitting the fact that the chair was positioned in the king's room and performed as the throne (Hvattum 2001). Tectonic discourse in the contemporary setting is explicitly concerned with surroundings and context—whether material or immaterial—in different fashions. Although in Semper's work, perhaps especially in his built work, one can argue that he does nevertheless take into consideration context and surrounding conditions. He should not be refuted for this, because Semper still considers the conception of interiority central to the creative acts in architecture while structural elements are of course needed to facilitate that the feeling of interior and the possibility of considering context on similar footing. As such, Semper is to a lesser degree a formalist concerned with the structural form but emphasizes the atmosphere of the feeling of inferiority, almost "suspending" interiority as essential.

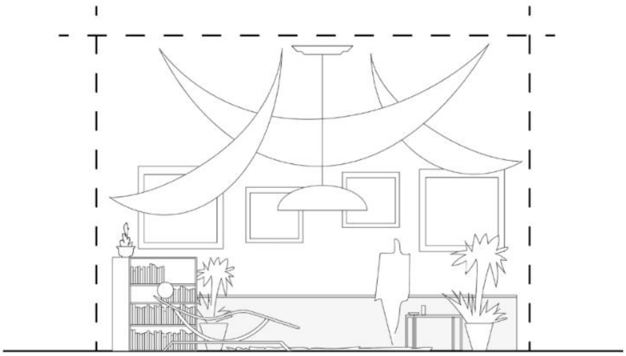

Figure 60. A strong sense of "suspended" interiority constructed entirely from inventory and furniture: hanging drapes in the ceiling, light fixture, furniture, carpets etc. almost irrespective of structural function and its appearance.

Semper writes:

> "Hanging carpets remained the true walls, the visible boundaries of space. The often solid walls *behind* them were necessary for reasons that had nothing to do with the creation of space…" (Semper et al 1989)

As to whether Semper would entirely dismiss structural and formal exploration and if so, to what exact degree, is up to historical scholars of Semper to decide; however, I would argue that the Semperian position is quite open to the structural element providing or being an actor in the manifestation of the dense atmosphere of the

interior. One can here make a comparison to a contemporary case, i.e., of Sou Fujimoto's box-in-box house (Meinhold 2011), where the peculiar, layered structural shells are at the same time what provides the *intensity* of the interior of a kind of sublime confusion of inside and outside relations - thus making the structure not merely withdrawn to facilitate interior effects.
The emphasis on interiority speaks of Semper's willingness to create separated/isolated ideas and subsequent object/forms whether via interiority or details/ornament. One could thus postulate that such a seemingly irrational suspension and isolation of the interior could be a better guarantee for a rich architectural space instead of an bland integration of all factors at once as it is *the* parameter to which all other (composition of HVAC, placing of beams and columns, etc.) are subservient.

In extensions, another potentially important thing to take away from this "isolated" approach to objects, is the meticulousness and care that Semper shows to them outside of its context (Hvattum 2001). While today we certainly need to take contextual considerations into account, perhaps more than ever, there is an immense respect of the object which may be mirrored in its inherent qualities which make it persist over time in becoming a "monumental" form. Compared to today, there is now perhaps too much emphasis on relations and flows and fluxes, and a more care-full respect of objects could both be more embedded into its surroundings and minimize material consumption.

4.3.4. Logic(s)

In this paragraph, the different logics which structure the operability of the theory are laid out.

Metaphor
Perhaps, the fundamental and grounding logic of the Semper's metabolism is that of "metaphor" (i.e., metaphor of metabolism) though he does not explicate this methodically. As elaborated in earlier chapters, mobilizing a metaphor is already a methodology for positioning and endeavoring multi- or interdisciplinary work, and as we have seen, Semper was not only inspired by the sciences but also called his theory "stoffwechsel" and must have used metaphoric reasoning (though there is no explicit methodology chapter on metaphors in his book (Semper 2004)) to extract useful architectural knowledge from other sciences. In the early days, Semper's writing was inspired by sciences of the times (biology, chemistry (alchemy) among others (Moravanszky 2018) and aimed at developing an understanding in architecture which laid out (perhaps similar to the periodic table in chemistry) a founding set of elements which constitute the "nature" of architecture. Using metaphors in architecture is rather common and also used in applied sciences (industrial ecology). There are different ways of mobilizing metaphors. Specifically, how, to what end, and how "literally" can a metaphor be mobilized.

Knitting and Veiling – the Will for making

Since we are dealing with a metaphoric use of the notion metabolism and can see that it is an dynamic entity at is ontological core, the question becomes – which are then the logics which animate this tectonic metabolism? The *logics* are two forces and come in a "lower" and "higher" form: knitting-on (*weiter stricken)* and veiling (i.e. dressing) (Moravanszky 2018). This dualism basically mimics the Žižekian use of the dichotomy of Drive and Desire (Žižek 2012). At the lower end, the drive is this "blind" creative energy ("instinctual" act of knitting, merely the act itself) which animates the building and creative activity - and the higher is that of the social and cultural need to manifest *veiling* interiors, emanating the spirit of "carnival candles."

Semper elaborates the different kinds of yarn, stitching, weaving etc. While these appear in the chapters and paragraphs on textile, one of them, the knot, is of particular importance going beyond a mere category of making among many others. As different scholars have emphasized (Hvattum 2001; Moravanszky 2018), the significance of this in Semper's writing is the fact that he argues that knitting (or the knot) is a fundamental or primordial "motif" and not the proverbial "primitive hut" which was widely popular at the time.

While Semper was against the mental constructs such as the Primitive Hut, Semper nevertheless sketched a primordial motif of his own. Semper's wreath is a kind "first-knot" mythological motor of architectural production. It became, in some way, his own "primordial hut" but a primordial knot of sublime making (Mallgrave 1996, pp.292). The wreath embodied *that* which later was put forth by Riegl; namely, the Will or urge to make the knot and knitting which is an embodiment of creativity-itself.

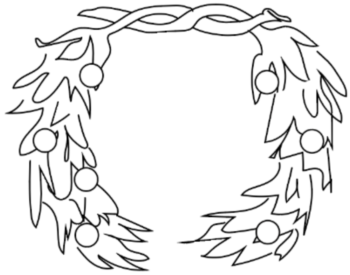

Figure 61. Semper's Wreath (own redrawing) (Mallgrave 1996; pp.292)

Semper's wreath becomes very interesting because it is transformed from merely indicating the "origin" of architectural production to also explaining the logic of making. It is not *this* particular wreath which is of importance but the "circular" dynamic of making-as-such of this and the endless productions of "wreaths".

Again, the significance of this is that Semper positions an activity (of making) as the core of artistic and thus architectural creation and not an object of a spectral imagination of a "primitive hut" motif. Similarly, to the 4 categories of making mentioned earlier, the knot is not necessarily an actual knot (while it too can be that). The knot is also transferred into a metaphysical realm where it is the activity of "knitting" together spatial elements into experiences which have the "carnival haze." This dimension of the essence of architectural creation has also been developed by a Semper contemporary, Alois Riegl. Although his critique of Semper has proven a miss as elaborated by later scholars (Moravanszky 2018), Riegl's own elaboration of Kunstwollen (Will to Art) (Mallgrave 1996, pp.379). can be argued to have some similarities to Semper's centralization of an activity as essential architectural creation. As we are dealing with the notion of metabolism (stoffwechsel) which is a dynamic entity, we cannot claim that it is merely the material realm which animates and manifests material transformations but exactly this activity of the creative Will on behalf of the human creators and users. The will to make corresponds to the "knitting" activity. Semper, as later scholars also argue, is not a materialist who thinks architecture can solely be explained from material conditions as the logic of architects' free will certainly also influences how building take form (Mallgrave 1996).

Semper defines stoffwechsel as a "material transformation" which "explains the ability of materials to undergo change by considering the product of human *techne.* (Moravanszky, 2018, pp: 10). However, regardless of which material is in question there is a kind of "truth to material" paradigm which served a background for Semper before he developed the theory of stoffwechsel (Moravanszky, 2018, pp: 133). Semper was keener on the theory of mimesis (from ancient Greece) which allows "forms to slip from one material to another" – which stands in contrast to the "law of being true to materials" (Moravanszky, 2018, pp:25; pp:133). In today's conditions and challenges in terms of material flows, this allows and asks for defining a different "truth to materials" which both hold metabolic concerns in relation between society and nature, along with new creative possibilities for application as well.
Throughout his book on Semper, Moravanszky reifies different manifestation of "metabolism" which includes phases from drawing to construction and reconstruction (Moravanszky, 2018, pp: 181) and by doing so already indicates a kind of circular material flow along with the "flow" of culture since stoffwechsel is concerned with material transformation but also cultural continuity (Moravanszky, 2018). stoffwechsel thus becomes reified as a kind of "self-causing entity", elaborating the genesis of its own becoming into being thus making it (stoffwechsel) a "hypothesis…which signifies constant renewal" (Moravanszky 2018, pp: 213). This alludes to a kind of "inner" drivenness or creative Will of the very material element which is fused with a kind of animism (albeit an ideological justification for activity) as seen in Kahn's talking bricks. Relevant to this as well is Semper's demands of form making where "free human work that appears as a necessity of nature and becomes the generally understood and perceived formal expression of the idea" (Moravanszky,

2018, pp: 176). This in itself is no longer a guarantee for high quality character in architecture or ecological critical understanding since it simply can invite any type of creativity activity which can be all from pseudo-sustainable, greenwashing opportunism and just as well as a critical ecological understanding. In this relation, Tectonics contains a dimension of creative opportunism in which "cultural continuity" sees a need for new and refreshed aesthetic expenditures within Tectonic discourses which utilize new techniques and manufacturing technologies. Since its inception, Tectonics have always been a hybrid discourse of the physical and metaphysical. Nonetheless, a *metabolic* approach as seen in industrial ecology may require a deconstructing of the Will for creativity if architectural production is to locate itself within planetary capacities.

Figure 62. Semper's Wreath (own redrawing) and Lacan's "objet a" (desiring logic as diagram). (Slavoj Žižek 2001. Enjoy Your Symptom, pp.56)

In structure, Semper's wreath is incidentally almost identical to the elaborations on desire and drive first developed by Lacan then further extended by Žižek (Žižek 2001, pp. 56). The wreath is almost a diagrammatic mirror of the desiring logic developed by Žižek (Žižek 2001). When one has an edifice and fails to properly understand this edifice in its entirety, the emergence of a single object (story, aim etc.) is what provides meaning to it. One could even compare it to the primitive hut discourse, where the hut itself is the "*a*" which is an ideal, yet unattainable, (fictitious) specter that one *must* strive for. While Semper's theoretical contributions provide a significant shift in understanding of architectural production, it does not fall outside of the driving/desiring logic.

Nature likewise had a significant presence is Semper's writing. He conceived that *man* strives "… to make the laws of nature evident in the object he adorns." (Herrmann 1984, pp.219; Hvattum 2004). Nature is something full of "wonder and forces", and for Semper the origins of art are located in the *need to create* order through play and ritual (Hvattum 2004, pp.65). This *need* is to be read as the Will. But if "nature" is to be repeated within the human made objects, and thus propel the "continuity of culture", what sort of an understanding did Semper have of nature? While this in and of itself a difficult question to answer, one could certainly speculate as to whether it could have been an early variant of "materialist" bio-mimicry which later generations would fully expand (Benyus 1997; Weinstock 2008; Pawlyn 2016). Bio-mimicry is not however necessarily metabolic at its core ethos of design. There is thus a founding ideological construction at the core of the creative act in ones' relation to nature(i.e., how one construes nature is mirrored in the built environment), and if one conceives nature as merely a system (or metabolism) of growth, then such property is translated (metaphorically) into the conception of the cities that frame our cultures and society.

While the *free will* of the artist (or architect) is what initiates creative activity, the larger scheme of historical progress becomes the object-cause of desire – the impossible specter guiding all activity beyond and beneath any actual necessity or needs -which is to see "cultural continuity" through more new design variants. In extension, thus remaining within the hegemonic growth paradigm.

Interpretative Plasticity

Much more implicit within the theory is a kind of interpretative plasticity. One could easily miss this aspect because we as architects often work in such a way that allows for some leeway room for interpretation, which is what I am claiming. This plasticity can be asserted as a product of the material-immaterial dualism of Semper's metabolism or even a "structuring" necessity (a *logic*) with which the theory can be manifested since we are not actually dealing with a chemical or biological metabolism. An example, which is quite central, of this plasticity in how any element/construct (roof, wall or material technique like ceramics, stereotomy etc.) can either be aligned with itself (a wall being a textile) on one hand or on the other hand, a stereotomy element in which the stone is intricately made to mimic a textile in which opposites (heavy and light) seem to synthesize into a higher manifestation, a "transformation", of material. This logic can give birth to many different variants in design by juxtaposing different architectural elements with techniques, motifs, effects, experiential qualities etc., but one could likewise mobilize this *logic* when having to construe industrial ecologies thinking into an architectural and tectonic theory.

4.3.5. Boundary

The final aspect of the Semperian metabolism are the philosophical (ontological) assumption and boundary conditions that have formed and structured the metabolism and its operability.

Architectural Setting

Circumscribing Semper's stoffwechsel theory at a more immediate level in terms of its applicability and efficacy is a theory which applies itself in architectural design and practice. There have been later developments on linking tectonic theory and with urban design (Christiansen 2020) or linking stoffwechsel with environmental factors (Foged 2014). Stoffwechsel does not attempt to speak on social hierarchies or politics or even ecological concerns. It rather largely confines itself to architectural production. Even as such, stoffwechsel has different ontological and world-view implications brought forth to "reveal" the hidden dimensions of Semper's theory.

Semper's theory holds a grounding ambiguity regarding whether the theory is *descriptive* or *prescriptive*. It is clear that Semper practiced a significant amount of historical analysis to the point of being considered an architectural and art historian, but he also designed and built a few works as well a basis for his theoretical endeavors. This is something that architectural theory "struggles" with in general because as architects we have to conform to differing conditions and historical settings as well as social and economic fluctuations. To this day, we also see different mobilizations of and practical uses of Semper's theory in experiments and built works.

This ambiguity has later become more distinct as contemporary theoreticians have *metamorphosed* tectonic theory (with impetus in Semper) into a method. An example of this is Marie Frier-Hvejsel's tectonics as method approach of Gesture and Principle (Hvejsel 2018). However generally speaking, it can be argued that tectonic theory, given its practical orientation on making and material, makes it easy to learn from analytic applications and apply similar thinking when designing and thus analysis and design are two sides of the same coin.

Idealist-Materialist Hybrid (quasi-Hegelianism)

The fundamental "twist" in architectural and art theory which was Semper's contribution was the shift from a "fetish" for an imaginary object (the Primitive Hut) to the ceremonial/social act of making as exemplified in the primordial motive of the knot. This shift has an ontological significance. While it was said that the influence of Hegel was minimal (Mallgrave 1996; pp.35) on Semper's writings, I would argue the content of the Semper's theory is fundamentally Hegelian,. Hegel's main contribution was that of "relations" (as seen in Hegelian aesthetics). While Kant insisted on the Thing-In-Itself and the autonomous character of every Thing, Hegel radicalized this Thing into a self-relating entity which often gets boiled down to the expression of "…from the Thing-In-Itself to the Thing-For-Itself". This fundamentally conceives of the idea that a thing exists *because* of its relations and when it has grown sufficiently it starts to cause itself in a kind of circular self-reflectivity (Žižek 2012; 2014). This is a central axiom of Semper's theory as the shift from an object (primitive hut) to an activity of making (knitting) was precisely centralized. This too is present in the discourse of architectural elements and their innate vibrance and incontinence of telling the story of their own conception and making. This line of thought remains within a realm of idealism and thus adds to the argument (against initial critique by Alois Riegl) that Semper was not a materialist. This sidelining of the creative "vibrance" of architectural production onto materials is furthermore comparative to today's notions of "vibrant matter" as developed by Jane Bennett and a kind proto-ANT animism of objects. Bennett's vibrance is to a larger degree founded in material sciences, and she points to the fact that all matter is in fact vibrant and not inanimate as we have long thought--although it conceives of a more flexible temporality which also stretches to longer periods of time in which matters and compounds would react over time (Bennett 2010). Herein lies the biggest difference between “vibrant matter” and the tectonic discourse, as the former (at the time) conceives more or less of matter as inanimate and the “animism” of architectural production was fundamentally an idealist and meta-physical phantasy imbued into matter while Bennett develops the theory that matter is in reality vibrant.

As mentioned, Riegl had initially misunderstood Semper as a materialist and, as Semper himself would refute this, despite some modest materialistic consideration, Mallgrave too would argue and agree that Semper was *not* a materialist. One can only wonder why architects have such a strong reaction against materialism. It almost seems as if they view it as a dirty word. This fact was not merely reiterated for the sake of historical accuracy. Riegl initially misunderstood Semper. Specifically, he thought that Semper conceived architecture as deterministically emerging from material conditions (Mallgrave 1996). Later, Riegl, had to acknowledge that architecture emerges out of material, climate, site, culture, politics and perhaps most importantly the *free will* of the architect. The push against this supposed “material determinism” may be linked to the need for asserting Architecture as its own discipline which perpetuates its existence by problem-solving qua the architects’ creative *will* by showing a respect of it. The juxtaposing of industrial ecology with tectonics (as is the aim of this doctoral study) would need to problematize such an assumption and architecture could in a re-conceptualized manner be understood as emergent from an expanded understanding of the (im)material conditions, be against the primordial *need* to make, and place itself within material conditions (i.e. planetary boundaries/capacities or planetary scarcity).

Though the “knot” and its significance indicate a fundamentally idealist stance of Semper’s thinking, he does not entirely remain there. There is most certainly a pragmatist spirit in Semper’s writings. While he was inspired by the natural sciences, he was also observant and socially aware and was even politically active (Mallgrave 1996). As he perceived the “decadence” in art and architectural practice, his main contribution was a “practical aesthetics” which in very modest terms could be understood as a guiding hand to the lost and perplexed artist and architects of the time. A key axiom (*logic)* of Semper’s theory is that of masking or dressing. While other tectonic theoreticians emphasize the equal importance and integration of material and immaterial concerns (i.e., Karl Bötticher’s *Kunst*- and *Kernform*), Semper emphasizes the “kunst” as the power of veiling and creating interiors. He basically links this to the inherently artistic “drive” in both artistic creation and experience which “…presumes a carnival spirit” or put slightly differently to create a “…haze of carnival candles” (Semper 2004; pp.438,n. 85). Semper continues;

> "The destruction of reality, of the material, is necessary if form is to emerge as a meaningful symbol, as an autonomous human creation" (ibid, 438-9).

The "destruction of reality/material" is not to be understood merely as the material processes of transforming raw matter into building elements. Rather, the statement is more profound as it is my interpretations that ontologically material is of lesser importance than the idea. Here again is a Hegelian dimension apparent in Semper's writing. Another of Hegel's famous phrases is that of "spirit is a bone" (Žižek 2012, pp. 534). Hegel developed this as a relational conception that a "spirit" (some immaterial quality) cannot be a free-floating entity and any particular "spirt" stems directly from its particular "bone" (material existence). This indicates that Semper's simultaneously has a material and scientific understanding of the "fabric" of architectural making, but he conceived of the possibility that how material is transformed into "spirit" from a mere bone. Semper is neither materialist nor entirely idealist (concerned with meta-physics). There are aspects of both in the privileging of "suspended" interiority in which surface (textile/wall) is of utmost/prime importance.

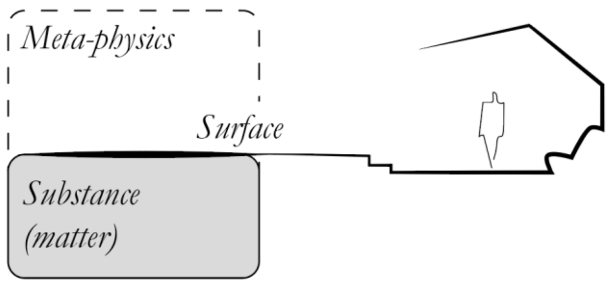

Figure 63. Substance vs. meta-physics;
surface as interstitial mediator.

Although conventionally, Semper's ontological structure is also that of a material and immaterial dualism, similar to that of Bötticher's dualism (and many other tectonic dualisms over the centuries (figure 22, chapter 2.2.4)), t is my interpretation that Semper's emphasis on the interiority and the surface is in fact already a further distillation or nuancing of the dualism into a stratum of three (figure 63) as the experiential dimensions of veiling qua *surface*.

At the opposite end of his idealist stance, Semper thought it pertinent to develop a formula for architectural style (Hvattum 2001) which almost becomes a kind "mathematization" of aesthetics, or a kind mathematical-material pragmatism. While this formula was left behind and fundamentally a "failure" (Hvatuum 2004b), it nevertheless reveals a thinking which is inherently material and immaterial but through the lens of a kind of practical "scientification" of the creativity and making in architecture. Semper acknowledges, in pragmatist ways, that we indeed have to understand the properties of materials (which was perhaps why Riegl misunderstood him as a materialist). He nonetheless entirely mobilized this knowledge for the sake of larger meta-physical considerations. The ontological world-view challenges of architecture are not only confined to tectonic discourse. Christopher Alexander is of the opinion that contemporary architecture has a fundamental worldview which is "…essentially mechanical in nature – what we might call the mechanist-rationalist world-picture…" (Alexander 2002, pp.7). He does not mean that we have become architectural bureaucratic engineers, but rather that even when we are dealing with aesthetic and immaterial conditions, we are treating them in a mechanical way even if consciously we consider ourselves motivated by "spiritual" concerns. Keeping in mind this elaboration by Alexander, one may indeed also observe that Semper himself, albeit motivated by mythical and spiritual considerations, nevertheless develops a practical aesthetic which is dealt with in a kind of "mechanistic" sense. Alexander also claims that this (mechanistic worldview) is what governs our understanding of what *matter* is (Alexander 2002; pp. 8). This particular world-view of matter is one which of exploitation and manipulation, and Semper does not fall outside this position especially qua his formula on styles and monadic process of transformation.

Historicist Progress (of inevitability)

As a way to further unfold the aspect of the animism discourse in Semper's writing, as earlier mentioned, the aspect of historicism is important to consider. Here, it is important to clarify that historicism can be used in different ways. We have seen architects use the notion of "historicist architecture" to describe a style or way of designing buildings which are referenced to some particular historical era etc. (Moravanszky 2018). The other kind of "historicism" is more complex and philosophical in regard to history and historical progress (historicism) (Žižek 2012; Hvattum 2004)). Historicism in this respect is a fundamental position in the understanding of history as epochs and eras which "necessarily" usurp each other in a "necessary" (linear even) historical progress/continuity". Ultimately, the two kinds of historicisms possibly overlap. As both can be said to be present in Semper's thinking, it is the latter which is of interest to highlight with regard to metabolic thinking and material consumption.

A quick exemplification of the historicist self-animism of architecture could be very briefly shown in this limited genealogy of the column (Figure 64). Obviously, the whole genealogy and history of columns is complex, these are but a few chosen cases which highlight this incessant progress of architectural creativity.

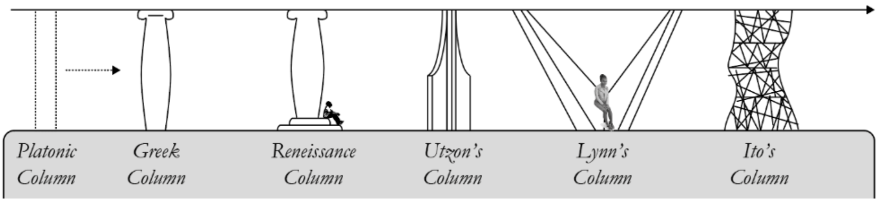

Figure 64. A simplified narrative of progress.

Exemplifying the progress of narrative (figure 64) the first is the Greek Doric column where it is treated aesthetically but serves to hold the roof (Moffert et al 2003). The next entry is an example of one of many later renaissance column bases which afford the possibility to sit on it. Next, Jørn Utzon much later designed a column which is shaped to allow sunlight in the top at the Kuwait parliament (Weston 2008). Next, Greg Lynn designed a branching column in an unbuilt restaurant which affords sitting and leaning (DesignBoom 2012). Lastly, it is Toyo Ito's Sendai Mediatheque building, which was designed with columns that provide structural stability, light and contains all the technical installations)i.e., pipes and cables etc.) (Balmond et al. 2002).
Such a genealogical "analysis" invites one to continue to speculate and keep adding more affordances into a column. Although very limited, such a genealogy implicates a creative progress which further invokes such experimental speculation and manifestations and implicitly hints at that there being an innate necessity (out there in the future iterations) thus drawing you and provoking you to continue this narrative of progress. It would be possible to attempt a more scientific mapping of the genealogy of columns in their messy genesis and complex relations, but that is not the point. The point is rather that architects, in the materialization of the historicist animism, hinge on partial and incomplete narratives, where full knowledge of all empirical columns would kill desire and creativity. Architects would usually, I postulate, conceive of such a progress/genealogy of the column (or any other element) to tinker further with. Such a conception of historicist narrative of architectural elements echoing and commenting on each other through history can be compelling and interesting. It is equally, however, a "danger" which provides ideological footing for more and more material consumption.

The above elaboration on progress is an indication that there is an experienced necessity in that "progress" and things inevitably flow towards their seemingly predetermined conditions. This would be in stark contrast to a contingent or open view of historical conditions (where things and events could have easily turned out differently due to details and conditions) as shared by Hegel and Žižek among others. This kind of "historicism" is of interest in Semper's work (and perhaps even in Tectonic discourse at large today as well as then). Nevertheless, within this necessity of progress Semper did not conceive the progression of architectural works in a linear way but insisted on the creativity of the architect which could cause leaps in the continuity (Mallgrave 1996; pp. 305) As such his idea of the historical progression is manifested by the *free will* (or true creative impulses) of the designer/architect with each new built work. Progress nevertheless remains axiomatic, and its story has to be told in physical manifestations. Within this historicism, there is a kind of blind optimization which has architects think that any new design variant and iteration (even if a grand failure) serves a larger purpose for progress while more skeptical and critically inclined thinkers and practitioner would disagree with this "necessity" of progress. Another example would be Charles Jencks' famous table (theory of evolution) which maps a genealogy and progress of styles and movements in architecture (Jencks 2000). One could also ponder on whether exactly this need for a dynamic edifice is why the metaphor of metabolism was chosen in his writings. Specifically, we could consider if he put it there because as a metaphor, metabolism is in search of "constant renewal" (as Moravanszky puts it).

4.3.6. Interpretation: Limitations and Openings

In conclusion, this section will attempt to highlight the most pertinent limitations and potentials/openings within the tectonic metabolism in relation to the later theory development efforts. Having "disassembled" Semper's theory does not mean that one should simply re-apply the very content of his writing or simply add one extra "construct" among his four (wall, roof, mound, hearth) to make it relevant to today's material flows challenges. What is perhaps more significant and poised with potential is to "repeat Semper" at a formal level – meaning *what* he did instead of what he wrote. What is important to consider is that Semper's theory was very much a response to the tendency of his time. Given the historical fact that Semper perceived the challenges of architectural quality and the challenges that industrialization was bringing about, he saw it pertinent to construct a theory and a way to approach architectural production which would attempt to guarantee a certain level of tectonic character and critical thought and thus steer away from mindless and vulgar aesthetic expenditures. Another aspect on the formal level was the fact that he worked not *ex nihilo* but tried to expand his horizon and developed his theory by attempting to embed himself into other sciences (perhaps most notably chemistry as his four elements (read constructs) can almost be read as a kind of architectural periodic table). This was not to apply them as merely visual metaphors but to use them as new lens to critically deconstruct and understand the creative processes in architectural production.

Constructs	Relations	Logic	Boundary
Textile/wall Carpentry/roof Ceramics/hearth Sterotomy/mound	Transformation Part-Whole Self-Relating	Metaphor Knitting-Veiling Interpretative Plasticity	Architecture Idealist-Materialist Historicit Progress

Figure 65. An overview of the tectonic "metabolism" and its particular points within each of the four theoretical categories.

Limitations

Ultimately, given Semper’s emphasis on the activity of making, his emphasis on interiority with little (or no) regard for the loadbearing capacities and his emphasis on the “destruction” of material for purpose of making– I would go as far as to claim that Semper’s metabolism (stoffwechsel) *is* as such the creative *Will* manifested through *knitting* and subsequently *veiling* in which artistic efforts materialize the cultural continuity. One could even go as far as to say that Semper’s metabolism is materialist ideology as comparable to Andrew Benjamin elaboration (Benjamin 2007) which is, in a way, materialism without matter qua-creativity. As such there is no clear emphasis on the Marxian variant of metabolism of material exchange between society and nature.

When architects are given a theory or model of architecture (like that of Semper’s four elements) it is not in and of itself a guarantee for architectural quality or critical thought. When any set of architectural elements (e.g., Semper’s roof, wall, mound, hearth or Michael Hensel’s grounds and envelopes) is given to architects, their immediate approach is to challenge the coordinates of that theory and play or experiment with new and different relations between the elements, potentially subverting them and transgressing their usual applications. These architects possess, so to speak, the Semperian historicist animism which animates their architectural production regardless of if it is motivated by aesthetics, rationality, or concerns regarding costs or the environment. It can be made furthermore clear that the later form of the four elements (carpentry, textile, ceramics, stereotomy) are transformed to “mirror” the applied materials to a larger degree compared to the former set of elements (roof, wall, mound, hearth) because they are more immediately and practically are applicable in the process of design for practitioners (as Nygaard argued in former chapters). It is again important to highlight that the original set of elements contains a “difficult” element which is not linked to a material directly and is inclined towards a more functional and cultural/ceremonial dimension of architecture. Again, as Nygaard elaborated, *function* is commonly imbued with form and is seldomly a standalone entity. At a conceptual level, this small fire within the edifice opens said edifice. In extension of Nygaard’s observations, Semper’s constructs can also be described as open-ended which allow and perpetuate the linear growth paradigm or at least fail to question creative Will, or what Hvattum calls “historical organicist” (Hvattum 2004). While this is seemingly a limit of the Semperian metabolism, there lies a potential or rather challenge herein for the theory development effort of this dopctoral study at hand. As such, the *will* is a thoroughly metabolic dimension of design and creativity in both tectonic and industrial ecology as it either causes or legitimizes material flows.

Another limitation of Semperian thought is the definition of the process and transformation (Figure 59). Although Semper conceives of the metabolism as a set of processes of transformation - yet from a modern and contemporary perspective the monadic process does not include (but could have included) a few steps before the “idea” in which process of cultivation (construction wood) or excavations process (of stone minerals etc.) could also influence the processes of transformation. Likewise at the opposite end, there could have been a process of use and post-use application and handling of materials after demolition, disassembling or tearing etc.
The relating gesture of elements being animate, “speaking” to each other etc., is not necessarily problematic as a narrative can be quite “neutral” if it is properly situated and not merely mobilized for the sake of constantly manifesting new, never seen before, variants of relations between elements. In extension, the self-reference is merely misunderstood and misapplied, at least from an (industrial) *metabolic* perspective. The aspect that architecture conceptually closes onto itself in meta-physical terms (as a kind of circular self-reflexivity) currently holds a given set of material consequences. Instead of refuting entirely this self-refence, one may get more use of it if the subject was to “shift” in perspective in this regard. Instead of maintaining an understanding and application which perpetuates growth-oriented material consumption, the very same notion can be used to withdrawn architecture, first meta-physically and then hopefully materially. As was Semper’s intent (and according to Hartoonian) the quest of Semper’s metabolic thinking has been to “secularize” (make into a science) the creative production process and not keep hinging on some “ex nihilo” magic of creativity. I, however, claim that they both failed to do so, and this black-box remains. There are two versions of the black-box: “inner” and an “outer”. Firstly, creativity as the *freewill* is still a “dark” force which is not relative to other considerations but *is* its own factor similar to how materials, contexts etc., are factors in production (Mallgrave 1996). On the “opposite” end, the ever-present idea of the necessity of historical progress – which is an extension (I claim) of the creative will – as it provides meaningful coordinates for the dynamic mechanism of the *free will*. Indirectly, such progress consequently perpetuates or aestheticizes/narrativizes the linear growth paradigm at least within the current

coordinates of the social, political and economic frameworks.

Potentials/Openings

On the other hand, there are immense potentials in the tectonic metabolism. A place to start would be to consider the potentials in the part-whole relation. This is important because, as we will see later, this leaves the potential to open up the possibility to link Semper's metabolism with chemical engineering metabolism (industrial ecology). Part-whole logic is very common and broad, and we have seen in both tectonics and industrial ecology (in 4.2 and 4.3). The ontological "construction" of object-oriented ontology is seemingly also compatible with such a logic, while Žižek's materialism is more fixated on the "part", i.e., the partial object (*objet a*). Perhaps *the* theoretician of part-whole relations in architecture is Marco Frascari with his elaboration on *details* or joints and how Parts and Wholes engage in differentiating situations and scales (Frascari 1981). In many ways this pushed for consideration of design and analytic tasks to observe the object or phenomenon of concern as a kind of "anatomy" or bodily entity of disparate entities/organs contained within a "whole." The approach then makes one sensitive of how the process of making and becoming materializes the relations between parts and wholes. While Frascari's theory is not directly "metabolic", the edifice and key constructs of the theory are relevant to consider and hold potential in connecting theories as it indicates a strong link and acts as "extended" writing of Semper's own elaborations on (and not only inclusion of) part-whole relations.

The use of metaphor in architectural production is well-known (Picon, Ponte 2003; Gerber, Patterson 2013; Unwin 2019). Historically, we have almost everything from referring to nature and biology (golden ratio, plant structures etc.), God, music, and one can even postulate that we have returned to mobilizing metaphors from nature with bio-mimicry and the concept of metabolism. Graham Harman elaborates in general terms how architecture has implemented/assumed philosophical concepts in an over-simplified and merely visual fashion (Harman 2022). Without repeating and going too deeply into the history and general challenges of metaphor in relation to architecture, architectural use of metaphor tends to have a certain "usual metabolism" of its own. Through its own transformative sublimating mechanism - meaning how it is translating and assumes a notion within the edifice – architectural discipline tends to transform metaphors for formal expenditures. The weakest types of transformations of metaphors by architects are that of taking a natural notion, concept, or motif (e.g., tree) and applying them as a mere visual trait. This is perhaps not in itself negative, but certain types of metaphors demand more of a sublimation into the architectural edifice. In contemporary times we have seen theories and practice which are basically bio-mimicry where phenomena appear "natural" but do not function as such which could possibly increase undesired waste product generation in type and amount. Such a poor application of good metaphors is precisely why we have phenomena such as green-washing where building are clad with greenery or have seemingly modest/organic appearance while its carbon footprint and experienced quality manifest a different reality from the intentions of sustainability. Semper's own use of the metaphor helped him create a different and critical understanding of architectural production and its process. Nonetheless, the metaphor still remained too poorly sublimated and could have been applied much more thoroughly without an *creative* bias which included aspects at opposing ends of the transformative process, i.e., acquiring of materials and their end of life (as a metabolism both consumes and discards matter).

Moravanszky himself implicitly acknowledges the limits of the current tectonic understanding of "metabolism" and in relation to sustainability and environmental concerns, Moravanszky elaborates:

> "A much more promising approach would be to reflect upon what Karl Marx described as 'metamorphism' between man and nature, and to reconsider the interaction between technology and nature in the light of current social conditions." (Moravanszky, 2018, pp:212)

Moravanszky hits the nail on the head with regard to the potential of the concept in metabolism. Although Moravanszky here translates Marx using the term "metamorphism", the original was again "stoffwechsel" which translates to "metabolism" (Moravanszky, 2018, pp: 163). As mentioned in this chapter (paragraph 4.2), Marx's idea (Saito 2017) of the "metabolism" between man and nature was an early inspiration to the formation of the chemical engineering methodology and theory of Material Flow Analysis—a rigorous scientific method that could make probable that which Moravanszky hints at with reference to Karl Marx. This methodology of Material Flow Analysis and its theoretical frameworks is also referred to as "metabolism" and, regarding the relationship between "man and nature" is further conceptualized as "metabolism of the anthroposphere" (Baccini, Brunner 2012). Moravanszky reifies the "openness" within Tectonic discourse to construct a contemporary understanding of Metabolism which contains critical understanding of both "material flows" (industrial ecology) and ideological critique (Slavoj Žižek) along with new critical eco-aesthetics (Timothy Morton as the leading figure today).

Despite the above quote on ecological awareness of the stoffweschel (though a link to Marx), I understand Moravanszky's to mean the elaboration of metamorphism is positioned in an opportunistic inclination within the tectonic discourse and thus prioritizes "new" variants of creative production. Another aspect to consider is Moravanszky's insistence of moving Semper out of the materialist category. Materialism, while initially merely meaning a simple understanding of the ontic (material) world, was already at the time of Semper politically charged as Karl Marx was perhaps the dominant (historical) materialist thinker. This could be the grounds for Moravanszky calling his stoffwechsel "metamorphism" rather than "metabolism". In spite of this, Moravanszky acknowledges the need to push tectonic discourse in the

Marxian direction given the current climatic and socio-economic conditions. This is not say that Marx directly influenced Semper's ideas. Rather, this emphasizes that Semper not being a materialist seems extreme. I speculate that if the Marxist dimension were to be extrapolated in contours of Marx' metabolism and "metabolic rift," this could radically impede on the creative *Will* which is still present within tectonic discourse. Not unlike Semper himself, who earlier in his career aimed at deciphering the constitutive parts (essential even) of *form* which were not *form* themselves (Hvattum 2004, pp.65). In a similar fashion, the quest is to explore the constitutive parts (constructs) of the *metabolism* which are not *metabolic* themselves (i.e., bio-mimicry, branching systems, tree or other natural motifs etc.).

Given its split ontological foundation of being both "idealist" and "materialist", Tectonics ultimately ends in a very ambiguous condition in which is a combination of both concepts. Interstitially, tectonics thus reifies a kind a circular, self-causing "animism" and inner vitality, i.e., a Will or Drive for creativity which a kind of *a priori* which is by no means profound nor a guarantee for ecological and critical understanding in and of itself. Although there are critical approaches to the challenges of material flows, the ontological nature of Tectonics can both be heavily driven towards building more (albeit in higher quality) along with more variety of material constellations as an end in itself. It additionally can be seen as a "slowing" of building activity and less opportunism towards a more critical slowing of material flows by way of high quality and spatial meaning. Nevertheless, it is possible to claim that a fundamental part of how tectonic discourse "views" or "construes" reality is that of an ontological position of Parts and Wholes; several smaller parts which are circumscribed by an edifice in which the parts and whole are in some sort of material and immaterial balance.

Some disparate, yet relevant considerations

As architects have an "organic" or instinctual (read ideological) inclination to search other disciplines for inspiration for the sake of form giving, Trubiano also reifies how Semper's stoffweschsel might be a kind of facilitator for "thinking *through* making" (own italics) (Trubiano 2022, pp.311). This is in my view not necessarily a redemptive and profound dimension, as it ultimately seems that something metaphysical (a historical progress) is more important than the material manifestations. This cannot and must not be the final horizon of architectural thinking because such an edifice has *thinking* (theory) which is only used insofar as it guides our designing actions. This further gives the implication that the common understanding that the architectural discipline often conflates analysis and design into the same theory should be reconsidered. It may seem merely rhetorical, but dialectically the theory differs, and we may need to conceive of a slow (non-) *making* through (which is guided by) critical-metabolic *thinking.*

Nygaard elaborates that theoretical components (chapter 1.3.) are not building components as such but more abstract or general notions (Nygaard 2011, pp: 28).

However, Semper's contribution is particularly interesting since his four core elements are in a way both very specific (linked to a building element and technique of making) and at the same time being ambiguous and abstract as to allow artistic, "metabolic" transformations of motifs. One could say that Semper "grounds" architectural theory in the material practices of the discipline, while also allowing creative expenditures and the artistic *will.*

Jonas Holst, a contemporary philosopher, in his historical analysis of ancient Greek tectonics elaborates how "original" tectonic approach had indeed a proto-metabolic (though he calls it circular) understanding of how consumption of resources should be considered in a "circular" manner with an understanding of the capacities of forests (for construction wood) etc. (Holst 2019). Although this does not contain in any explicit conceptualizations of metabolic thinking an inherent critical and materially and immaterially appreciative approach which can be expanded into a pertinent metabolic understanding towards potentially situating architecture in a trajectory of slowing and narrowing of material flows within planetary capacities exist. With a kind of proto-metabolic potential and critical approach, Holst indicates the necessity of to nurturing cultural values (immaterial/meta-physical aspects) when we intend to reconsider how we consume material and what kind of exchange these materials have between society and nature. While Semper's stoffwechsel (metabolism) builds on Greek heritage, Holst here demonstrates that a kind "essential" look into the origins of the *tekton* (builder) and the fact that earlier builders have had their own understanding of how the building activity was related to the *hinterlands.*

Tectonic discourse and theorization is usually structured in the dualist way of being material and immaterial, physical or meta-physical, or measurable or immeasurable. It can be argued that how one conceives of the "material" aspects (i.e., stones/wood which is to be transformed) is significantly linked with what "immaterial" notions are brought forth (i.e. space, concept, beauty etc.). In this case, the ontological position of what matter is influences what kind of reality materializes on account of the ideological presuppositions, axiom, values, norms, and prejudicesas well as the need for creative expression (*Kunstwollen)*. What would happen if the material dimension "below our feet" (the base or *mound*) were to be defined in the metabolic (MFA) sense? What kind of immaterial values would follow as consequence of that and would such a reconceptualization introduce a new/different kinds of creativity?

As indicated above, the notions of metabolism—while being a crucial concept which hold significant potential for reaching or perusing a sustainable relationship between society and nature—architecture's conceptualizations of "metabolism" are superficially stylistic (aesthetically emulating the metabolic properties) and therefore limited but not irrelevant, requiring realignment for a more pertinent conceptualization of the term within architectural theory and design given the current challenges found in the hegemonic modus operandi of the building industry. As Moravanszky elaborates, the crucial way to perhaps "realign" Tectonics would be in by looking to the original "materialist" (critical) metabolic understanding developed by Marx (Moravanszky 2018) as its contemporary and more elaborated iteration is industrial ecology. To align tectonic thinking with a critical metabolic understanding, Negative philosophical traditions stemming from Hegel and continuing through Marx and following through contemporary critical theory where acts of designing and building are to be radically Negated or withdrawn in terms of material consequences onto nature as well as society is implicated.

4.4. Towards an (Im)Material Metabolism

This paragraph of chapter 4 builds an expanded metabolic theory and juxtaposes both Semper's stoffwechsel and industrial ecology. After having deconstructed the two former theoretical frames into four main elements (of construct, relations, logic, boundary), this chapter thus proceeds to utilize these building blocks to build a further nuanced variant of tectonic theory which is fused with the cunning understanding of material flows as seen in industrial ecology and with critical meta-physics.
It does so by mobilizing several methods. In reference to the methodology chapter (chapter 3), the *metaphor* of metabolism is a fundamental one. The methods of *addition* and *adjustment* (Kesstra et al 2016) introduce the notion of the "safe sink", and *adjusting* (ibdi) to implicate immaterial aspects which are relevant in an architectural production context. The overall building and description of the theory is likewise structured by the fourfold structure of constructs, relations, logics and boundaries.

4.4.1. Preliminary – lessons from the two disciplines

Keeping in mind the agenda to translate metabolic thinking into architecture through the juxtaposition of tectonics and industrial ecology, the challenge is to highlight the parallels and how to transfer ideas and concepts.

A significant difference between the tectonic metabolism and the industrial ecology metabolism is that of "interpretative plasticity." Whereas tectonic theory from permits itself to "transform" reinterpreting things loosely as "needed" for design thinking purposes and expressive exploration, industrial metabolism limits their use of the metaphor and is highly aware and persistent in mentioning and elaborating on the limitations of the metabolism metaphor. One could here simply say that architects of course permit themselves to interpret concepts and ideas somewhat loosely for the sake of design application, but just as much as this promotes new ideas and creativity it is at the same time a problem. Namely, this axiomatical accepts the design discourse that permits this type of loose interpretations of what partially constitutes the architectural ideological apparatuses. The "interpretative plasticity" is perhaps a key axiom of architectural theory and practice which is not even questioned seemingly due to its form giving potential. To what extent can we critically interpret metaphors? Considering this is an important aspect as we have learned from industrial metabolism. Instead of mobilizing different metaphors for every new design, we should instead use one "good" metaphor and make it ever better: the metaphor of metabolism.

The juxtaposition of tectonics and industrial ecology and the delineations of their four theoretical elements (construct, relation, logic, boundary)) revealed the need for architectural theory to radically rethink its old metaphysical constructions and ideological assumptions which guide and steer both the making of (new) theories and their applied physical manifestations. Perceiving materials in an "ideology-free" way (as is done in industrial metabolism) made it evident that architecture was filled with loose assumption which at times seemed dogmatic thus perpetuating what remains of architectural thinking and production with the linear growth paradigm. So, before we can do anything in the real World, we have to reshuffle our mental constructions.

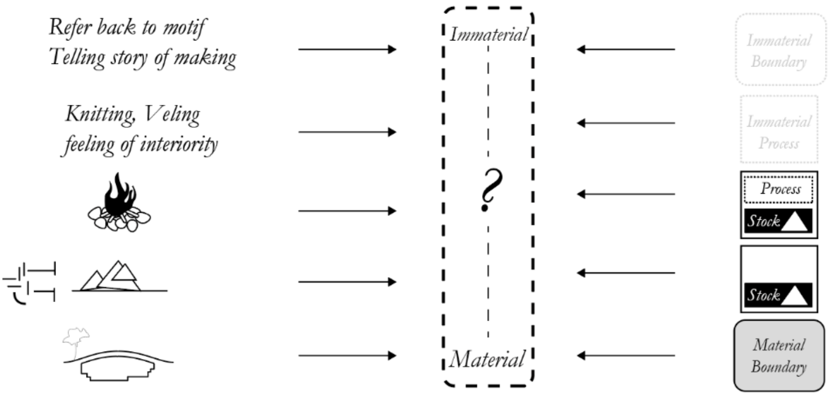

Figure 66. Searching for the material-immaterial spectrum: Interpreting parallels of the two metabolisms.

Furthermore, coupled with the "ideology free" approach to material creativity, it is pertinent to reconsider how architecture could indeed be "...founded in material condition" as industrial ecology allows for such trajectory. In between those two extremes of the material conditions and immaterial "constructions" is the faculty of architecture constituted.

So, what are we looking for in the spectrum of material and immaterial? It has to conceptualize a spectrum of "hybrid" consideration, which constitute a hybrid metabolism or a tectonic metabolism: an (im)material metabolism.

4.4.2. Metabolism Metaphor

The overall scope of this theory development endeavor is that of the overarching method of *metaphor* as this a common way to bring together frames of thought which do not seemingly belong together conventionally. In this case, we are dealing with the metaphor metabolism. The aspect of the metaphor prompts other crucial considerations regarding how to "appreciate" the fact the it is *only* a metaphor (and not an actual metabolism of an organism as in biology) and followingly what the metabolism-metaphor itself means—what its potentials are – in order to potentially establish a way in which metaphors are to be taken seriously without being taken literally in ways relevant for the challenges of material consumption.

How can we rethink how we use metaphors in architecture, and when we consider the aspect of Negativity, what sort of perceptive should we attain with regard to metabolism? In banal terms, a beautiful building which has lasted for centuries or millennia is an example of an indefinite storage process. This hints at the term "metabolism", which is usually understood as something dynamic (and is usually sublimated as such in architecture, i.e. bio-mimicry etc.), can also (and more importantly) be a metabolism of stillness and inactivity, i.e., a *negative* metabolism, so to speak. There is always wear and tear on building material and elements etc., and the current state of the art in relation to practice places an emphasis on design for disassembly which in a way introduces more and more materials and elements which may amplify metabolic processes in the sense of maintaining and perpetuating material flows.
This is not to say that we ought to return to some classical aesthetics and thereby some outdated and pompous notions of permanence. However, the application and interpretation of the metaphor of metabolism should perhaps be more cunning so that we are able to mobilize any measure possible to minimize material flows. This should not comewithout and at the cost of architectural quality but potentially through architectural quality. As seen in biological metabolic studies, the size of an organism indicates its metabolic rate; namely, a small organism (mouse) has a high metabolic rate while a large one (elephant) has a lower metabolic rate. The larger the entity, the lower the metabolic rate. If we conceptualize the city as an organism or eco-system (a metabolism), it then,, as a very large spatial entity, has metabolically illogical behavior where the anthroposphere moves more matter than the natural planetary dynamics (Elhacham et al 2020). Regardless of the logical gymnastics and scientific incomparability (mouse, elephant, city), there is practical potential in mobilizing such a mental construction towards radically slowing material flows.

It becomes important to be wary of the dangers of hitherto known architectural sublimation of the concept of metabolism. As we have already seen in the example, the Japanese Metabolist movement (Koolhaas, Olbrist 2011), the idea of "metabolism" fundamentally serves to animate more a material movement and acts as an enabling concept or narrative to design buildings in the post war era of Japan. Other examples are those bio-mimicry where complex constellations are proposed and designed to look like trees or wings etc., while harboring the risk that such designs could in fact increase carbon footprints with its intention to manifest an appearance of a tree (building looking like a tree) based on a branching logic. Finally, one could also mention the many even more literal applications of natural metaphors into designs such as Simon Unwin's writings on metaphors in which plan drawings and facades appear as metaphors (Unwin 2019). As less recent contributions on metaphors indicate, metaphor and analogy are not the same despite both being covered by "metaphor" research (Gerber 2013, pp.21). The difference is that metaphor is a "replacement" of the signified thing, while analogy uses comparison to highlight similarities and differences. It is my understanding that architecture usually uses mobilized metaphors, while industrial ecology uses a deconstructed analogy for the sake of pragmatic application. Both variants are needed in this doctoral study, as the metaphor "constructs" the object/Thing metaphysically, while the analogy is a practical application.

To merely claim that we ought conceptualize the city as a metabolism can be very broad and abstract, and the challenge is pinpoint concepts which can embody and make particular the metabolic considerations while positioning itself in very practical terms with that of empirical metabolic studies of material flows. As Hegel put it, the *spirit is a bone*; however, in this case we have the "spirt" (of metabolism) and the challenge is to make it concrete and not an abstract metaphor. The metabolism at hand is a kind of "alloyed" metabolism, which further stretches the metaphor of metabolism into also including material and immaterial aspects.
How then can we apply the metaphor practically in meaningful way? In the quest to achieve this in practical terms, a key concept of industrial ecology in general and—likewise of this doctoral study's theory—building endeavor is the notion of the sink.

4.4.3. From Safe Sink to Urban Sink

While we are searching for constructs to represent the material-immaterial spectrum, the conceptual frame has to be provided. What are the constructs constituents of? While metabolism is the wider "abstract" frame, the "safe sink" is a way to materialize metabolic thinking and make it "local" and concrete corporeally and within the everyday function of building stock. While "safe sink" is more materially and ontically constituted concept (as in metabolic studies of industrial ecology (Baccini, Brunner 2012), the notion could be transformed to contain tectonic (partial, experiential) considerations. On the basis of this, the notion of the Urban Sink is formed to include immaterial aspects.

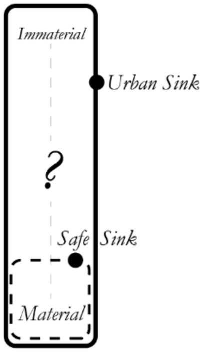

Figure 67. From safe sink to Urban Sink.

Let that Sink in

The central idea of the new metabolism is that of the "safe sink" in an architecturally articulated and transformed nature. A sink in chemical engineering is a concept which can absorb particular materials or elements. If it can do so safely, it is called and conceptualized as a "safe sink." The quest is thus to consider the city as a "safe sink", i.e., a kind of "beautiful landfill", which safely archives/holds building materials, preventing them from becoming waste. In doing so, it therefore potentially limits the danger for the environment and thus ourselves qua its tectonic (material and immaterial) characteristics. If we perceive the city as the accumulated material—what is often in technical terms called the building stock—then we can already observe that some parts of the build stock sink act and perform better as "safe sinks" for material while others merely act as sink or intermediate/temporary sinks which will later have those stored material become waste. In a very broad elaboration, we can currently conceptualize that old classical buildings are mostly well persevered and kept in place, while we have seen many instances of modern buildings (post WWII) and contemporary buildings getting demolished. This indicates that the sound performance of a piece of architecture as a "safe sink" depends on several aspects which can be categorized into a spectrum of material and immaterial considerations. Surely a building gets to stand if it is solid and sturdy, but what also has a building stand the test of time is that its design provides meaningful material and immaterial qualities. When a building or any piece of design by the virtue of its architectural quality and meaningful being within society *slows* and *narrows* material flows from nature to society, we can start calling it an Urban Sink. But what kind of a sink is an Urban Sink to be?

As mentioned above, a sink (chemical engineering) is an entity which can continuously absorb materials and elements. However, as we have seen with actual examples of landfills, spatial perimeters become a boundary and landfills fill out their capacities. The challenge is to conceive of the city (Urban sink) as a sink for materials which, while for now and for some time may still require new material input, would require (even if it is a physical impossibility) to strive for a "detached" Sink which does not require new material input, at least very minimally compared to today. The city goes from a Thing-In-Itself to a Thing-For-Itself, i.e., a self-causing entity. The very first strategy of circular material consumption and metabolic design approach is the prevention of waste generation followed by strategies of reuse and re-circulations etc. (Miljøministeriet 2021, pp: 25). Practically, such a city (For-Itself) would slow down its metabolic rates by either utilizing buildings without demolitions and both maintaining and repairing circulation of elements in strategic ways.

As has already been implied, the building stock is very heterogeneous and certainly performs very differently in many regards. Nonetheless, in relation to performing as a "safe sink", and thus an Urban Sink, certain architectural (material and immaterial) conditions are important to consider as well as what relations they enact. Even when a building is acting as a part of the safe sink—given the heterogenous nature of building designs—there may be different parameters in differing constellations which enact this performance. There is therefore need of a systematic way of observing, explaining, and experimenting with the Urban Sink which requires an ability for "inner" distinguishing of locate sets of relations of architectural constellations.

Given the fact that sinks, or rather safe sinks, are crucial to metabolic thinking, it was not possible to simply say that one of Semper's elements equals the safe sink notion. Rather it was clear that the safe sink notion is a more central, yet encompassing, concept to the theory and thus needed to be "deconstructed" into separate working constructs. The challenge is thus to determine how to construe the safe sink notion as composed of architecture elements which has an architectural work perform as a safe sink (safe storage) for materials.

4.4.4. Constructs

Given that we know that we have to construct a material-immaterial spectrum, there is a need to make specific "points" within the spectrum in order to differentiate it and not leave it entirely vague.
There are a few steps in the initial proposal of the constructs. While this also was an intense iterative process, this section will describe the founding logics of how concepts and aspects were introduced (added) from a discipline, and what methods are used to expand upon these.

As earlier stated, the need is to construct a material-immaterial spectrum whose constructs are not "open-ended" which, so to speak, questions themselves or hold themselves accountable. The need for this has be present at both the material aspect and the immaterial aspects levels. The construct must be general and not "professionally pragmatic" yet at the same time applicable to the point of becoming specific when dealing with chosen analytic or design situations.

The first key step of building the spectrum is the impetus in chemical engineering literature and metabolic studies (industrial ecology) and drawing forth the initial three aspects (). Firstly, the notion of the sink or safe sink (and its translation into an architectural application). This would the encompassing aspect of the two others: those being the stock (the body or material) and the function (process). Function could itself be explained as hybrid-object, fusing material and immaterial conditions along with mere utility (process and stock in industrial ecology terminology). As we are dealing with the built environment, literature broadly conceptualizes functions (Oswald, Baccini 2003; Baccini, Brunner 2012; Brunner, Rechberger 2017) and emphasizes the need of flexibility and use-intensity (IRP 2020, pp. 90-94), which through the very premises of architecture allows for a “metabolic” approach by minimizing need for virgin material input through optimized use. At the lower end of the spectrum, there is need to consider the “sink” in relation to a larger scheme of material boundaries (or capacities and /or consequences), otherwise the sink-concept would have no substance.

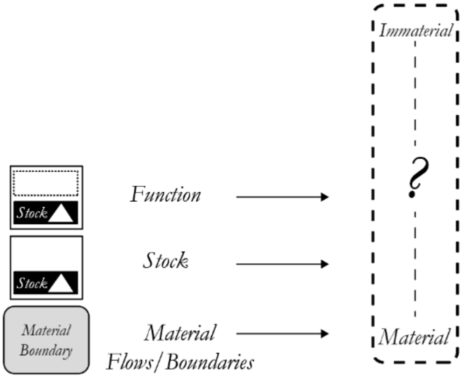

Figure 68. "Inserting" the key initial constructs from industrial metabolism.

Further aspects are added and overlayed (Figure 68) with and onto the hitherto added elements (Figure 69). The lower (material) levels are paired and connected to the constituents of the tectonic metabolism. While its elements are usually (but not always) applied matter-based in conventional architectural elements (mound/stereotomy, wall/textile, hearth/ceramics, roof/carpentry), there is need to “borrow” elements from the “logics” (Figure 69) to introduce the immaterial dimension to the spectrum. At the lower levels, elements such as roof, wall, and mound would be contained within the category of the stock (in the material sense). The function of hearth would occur in the “middle” and act as a kind of joint between the material and immaterial in its fused, alloyed nature as use or function.

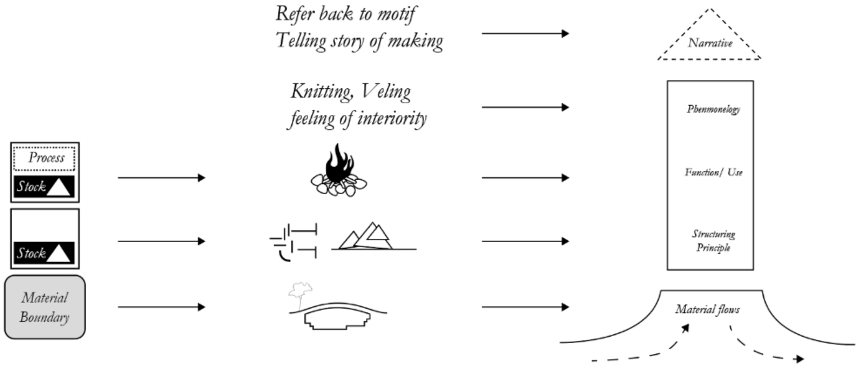

Figure 69. Further adding and connecting the tectonic "metabolic" components.

Going beyond functionality is an experiential dimension of "knitting" and "veiling" concerned with manifestation of interiority which generally deals with phenomenological properties and qualities of a thing at hand. Finally, extracted from the tectonic metabolism, the meta-physical aspect of narrative and storytelling is at play. As discussed in section 4.3.4., while all other aspects are present and are conditions for design, the dimension of "telling the story"oof its own creation is foundational and constitutes the whole edifice.

Starting from the bottom, the mound is a kind of material foundation (material limits or planetary limits ultimately) and when juxtaposed with industrial ecology, this dimension becomes a kind of ontic material precondition on which both design decision hinge. This precondition reveals the material consequences of our material choices and accompanying consumption.

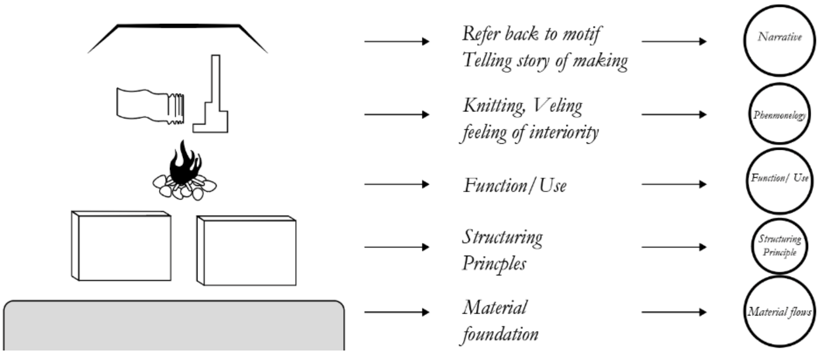

Figure 70. Towards a new set for construct through a transformed hybrid metabolism.

Until now, the five-point metabolism has been constructed through an exercise of adding, adjusting, and connecting elements, but this is not their final form as this is the frame with which the constructs can be further solidified and legitimized with reference.

Objectifying the Constructs

Considered altogether, each of the five constructs are fundamentally a Thing, i.e., all contain both a material and immaterial dimension.

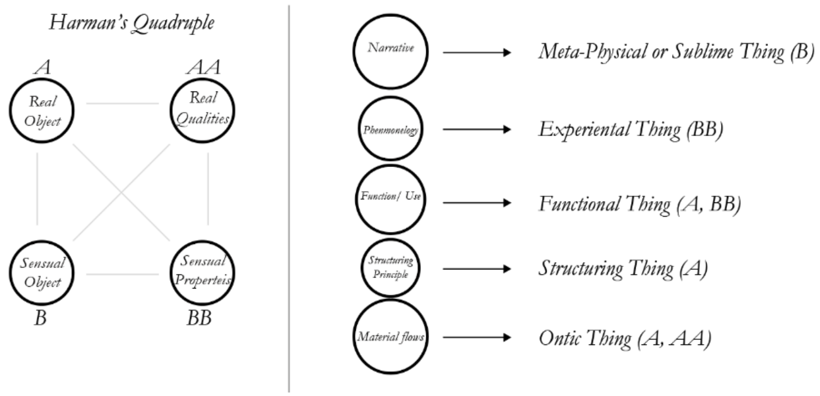

Figure 71. Each Construct is its own Thing according to Harman's quadruple structure (Harman 2011)

The reason for this is, again in a similar strain as Semper, not to make each of the constructs overly dependent on one type of empirical manifestations (e.g., "narrative" equals architect's intention) of each of the five constructs but to demand that the single researcher/architect (in the application of the five construct) critically considers how the five constructs make themselves apparent in any particular situation regardless of if one is dealing with a furniture design or a whole city. Following a Harmanian line of thought, each are a Thing (an Object) because they cannot in their fullest reality be mapped, explained, and made empirical, i.e., there are always hidden facets that elude and effects which actualize later due to changing circumstances etc. As Žižek would claim, such effects are inaccessible not only because of human epistemological finitude (failure to understanding inherent complexity fully) but because they are in and of themselves *open*, or incomplete. Unlike the theoretical division of these constructs, these compounds are never stand-alone in any specific empirical situation. Instead, they always have implications for each other to lesser or greater degree. An example of this would be proposing a structural system cannot help but have consequences for “use” and “experience” etc.

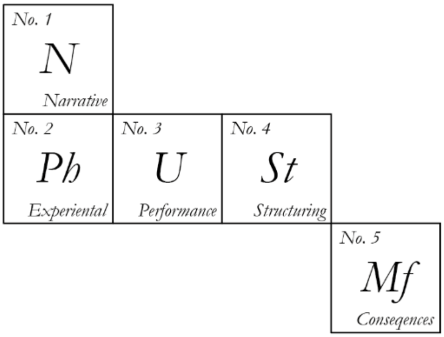

Figure 72. As if a chemistry-like periodic table of founding compounds of architecture.

The next sections will explore, expand and describe five main constructs of the theory: being narrative (surplus-value, *object a*), experiential condition, performance/application (use), material and structural systems, and ontic conditions. Each will be explained in the above-mentioned chronology. These constructs have an impetus in Harman quadruple structure (Harman 2011) and have already been attempted as an architectural application in a tentative and speculative paper (Usto 2020). Through the earlier mappings and critical analysis of the two types of metabolisms, five constructs are proposed as constitutive of architectural thinking.
Being aware of both Harman’s and Žižek’s emphasis on material and immaterial intricacies and how immaterial objects can assert material effects, awareness of how such entities could be constitute of a new edifice was pertinent. In the following expanding of the construct, i.e., the explorative elaborations will done “in reverse” and start from the material conditions and “upwards”.

Construct: *The Ontics – material flows and system boundary*
The “bottom” dimension is the material foundation which is important in the situating of architectural design and built environment within material conditions of material flows (which ultimately amount to planetary boundary and tendencies of material flows on a global scale). With reference to Harman, this is the Real object and qualities in material terms. Industrial ecology has made significant contributions in rendering knowable some of the opaque effects human activity has had on the environment. Although things may differ in the future, a very good snapshot into the current tendencies are provided by Haas et al (2020), where we can learn the current material flows and their increasing tendencies – headed towards a doubling of total building stock material by the year 2050. Thus, whenever we now on propose new design techniques, technologies, and solutions (narratives even), it is of crucial importance

to see whether their application correspond with the actual material consequences.

In accordance with Harman's ontological view, Things contain a temporal and spatial spectrum of possibilities, affordances, and effects. So too does the Ontic dimension of the (im)material metabolism. It contains a span from more close-at-hand material properties to the large scale material flows and behavior. The dimensions of the immediate ontic material can be material properties, material density, as well as physical and chemical properties which can act or react in relation to use and weather. These more immediate material conditions are what directly influence how a design takes form, what materials are chosen and for what functional and experiential (tactile) purposes they serve. In extension, other aspects should be considered as well in the immediate macro and micro scale ontic effects and properties which we can/should observe and include. This could be anything from capacities to insulate, storage heat, amounts of consumed energy etc., all of whichcan be relevant towards gaining insight into how the other four constructs could have had a material (ontic) effect or consequence.

On a large scale scope, the ontic dimension constitutes the material conditions as a wide understanding of planetary boundaries and finitude which necessitate a shift away from the hegemonic linear growth paradigm in the building industry. As such, the ontic dimension at its largest scope should be understood in a chemical engineering sense where planetary boundaries, bio-regional conceptualization are manifested through the ”safe sink” concept in accordance to metabolic frameworks (Oswald, Baccini 2003; Baccini, Brunner 2012; Brunner, Rechberger 2017)

While the notion of "context" has its conventional understanding in architectural discipline, in chemical engineering, the material (pre)conditions are to be understood as kind of extended context with the more immediate contextual conditions such as sun, weather, topography (with its inherent materiality etc.) are certainly also present, the extended context is that the material (pre)conditions of any work. As industrial ecology has it, a system boundary is also its own construct while spatially being very encompassing. In the challenge to include the system boundary, the fifth (bottom) construct is that of the ontic conditions which becomes a category which can be observed and made empirical in any case (whether design or analysis) and since a system boundary as a "whole" circumscribes the observable constructs, it can therefore be very difficult to fully account for. For this reason, the fifth construct (of the ontic conditions) becomes a stand-in which is indicative (stand-in) for the material aspects of the system boundary. In relation to the phenomenon of Jevon's paradox, we are in this construct not interested per se in the narrative or intentions of the architects but the material consequences and effects. Cause and effect may not always correspond from a seemingly rationalist perspective. In some profound sense, all there *is* is context. In other words, everything is "out there" in the context—whether material, climate, nature, or ourselves—and we are building *with* and *in* (with-in) context.

Construct: *Structuring Principles - material and structural systems*

This construct is related to the performative anatomy of a piece of design. This anatomy of any design is the founding frame or formal principles for the function and material, utilitarian and /or immaterial performance permitted and afforded further up the ontological ladder. With refence to Harman, this would also be a real (material) object. While the immediacy of this category would imply the structural systems and the appropriate material considerations, the aspect of "principles" implies several other aspects as well. It can fundamentally also imply principal consideration regarding room and function composition, distances, modules, size, typology in relation to sun and thermodynamic of the indoor climate.

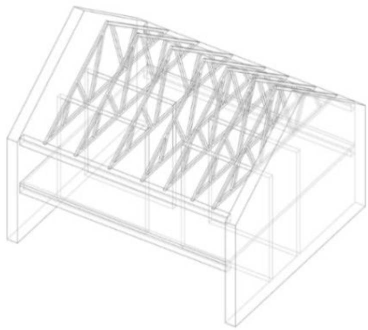

Figure 73. Structural systems as structuring principles.

There are many examples of architecture being conceptually driven by structural principles (i.e., the work of Santiago Calatrava, Cecil Balmond among others): however, it is equally possible to allow other "organs" of anatomical taxonomy to provide both material utility as well as experiential affordances. Conventionally, one could use the design and placing of HVAC systems and its accompanying pipes in ways in which they amplify the interior space (). A more radical version of such thinking would be that of Phillipe Rahm, who envisioned spatial conditions on account of thermal and atmospheric conditions conceptualized as "interior weather" (Clement, Rahm 2007).

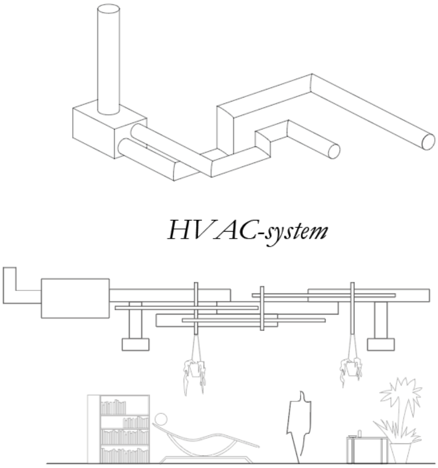

Figure 74. HVAC as a structuring principle; while the HVAC system provides a utilitarian performance of indoor atmosphere in the literal sense (air quality, temperature etc.,) - it likewise provides prime opportunity to manifest the interiority and its immaterial atmosphere.

While there are many examples of one particular principle or system being privileged for exploration and experimentation etc., conventionally there is a multiplicity of principles and systems which play parts within architecture as a whole. Just as the formal composition of the structural (or other) system serves an immediate structuring function, its intricate composition and supplementary conditions (i.e., technical solutions for flexibility etc.) can afford further possibilities for the current and future use. These strategic principles require considerations, regarding the overall structural principles, indoor climatic consideration in relation to HVAC systems or etc., or supplementary flexible modules for space making.
Supplementary to the above considerations, as much as such structuring principles have their material equivalents, they are very often also paired with an “immaterial” aspect of technique, labor[12] as well as legislative dimension of laws, norms, codes which have to be upheld.

Construct: *Use and functionality – Application and performance*
Conceptualizing the city as an organism or metabolism requires its adaptability and malleability by its context and users. As this is the case, the function of such a metabolic entity is crucial to consider. Not *a* function but function as such needs to be essentially generalized. With reference to Harman, function would be both a Real object with Sensual qualities. The fascination with function and performance in architecture has a long tradition. Even so, at the same time, the aspect of performance or function has had difficulty being properly conceptualized. While it can be argued

[12] Labor is usually conceptualized a “immaterial” commodity.

that functionalism certainly applies itself to solve architectural scheme for the purpose of well-functioning unity between users and the everyday use of buildings (Nygaard 2011). The opposite can also be claimed as functionalist having equally been fascinated by a “functional aesthetic” in order to emit the appearance of high performativity. In all actuality the users of such spaces fail to use the building as the architect intended because the form of the building seems to be counterproductive to its supposed performance (Harman 2022, pp.23). As Nygaard highlights, function is usually linked with form (Nygaard 2011). The question is how we can reconceive of (dynamic/ambiguous) form so that it allows for multi-function. This does not mean that the *use*-construct is a theoretically general one which, when applied in design and analysis situations, gains a particular use (a particular usage and thus function). Rather “use” should also be considered as ambiguous as such in its own right.

Usefulness goes both “down” and “up”. This Means that the everyday use of a house which has phenomenological quality and performs as a immaterial function, apart from “mere utility” of sleeping, sitting, reading, cleaning, maintaining etc., is also grounding the material and structuring principles. A “good” house functions well as a house if it also makes you feel at *home* and spiritually grounds you, apart from providing mere utility of sleeping sheltered from the outdoors.

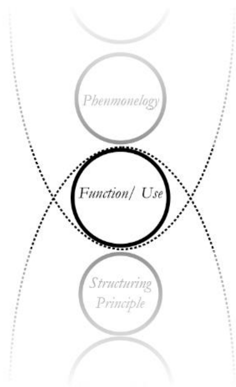

Figure 75. Use in the middle; a hybrid of both material performance, everyday utility, and fleeing of home.

Likewise, usefulness also points downward, as some architectural constellations afford different possibilities and/or flexibilities (dismount elements, easy maintenance, easy repair etc.) which are linked to systematic principles of the design. For these reasons, the different kinds of use can be conceptualized as *affordances* (Gibson 2015) which linger across their own border into the realm of both the phenomenal and the realm of the structural and material. Any material, element, or design thus provides an immediate useful application along with its properties in material, form, and treatment allowing for material and immaterial affordances relevant to architectural production. The phenomenological feeling of home and grounded-ness can be strengthened by material and technical affordance, as they could, for example, allow for easy introduction of an extra room or for new additions to the family etc. If we, on the other hand, are dealing with an urban space or urban area, the *function* would be its capacities to gather people, provide good sense of place and belonging through recreative niceties along with the outdoors space's ability to be flexible while also gathering rain water to prevent flooding etc..

Regardless of what we are designing or analyzing (whether a house or a masterplan), there four important categories of "function" which according to chemical engineering literature are important to consider: dwelling (residing and working), moving (transportation), eating (food management, production etc.), and cleaning (sanitation systems) (Baccini, Brunner 2012; Oswald, Baccini 2003). Sometimes architects simply accept a program (a function) and attempt to provide a building to contain those needs. What is equally important here is to be creative and innovative with these four categories in order to propose new ways of living (or the possibility thereof), share systems and facilities, produce food in inner city areas, and create more better interconnected infrastructure which is inhabitable and recreative etc., while considering what kinds of new design could allow for new relations in the city.

Use and functionality does not only contain the current use and function. Rather, it contains the hidden dimensions of potentiality as developed in object-orient ontology. This can also be understood as *affordance* of elements, materials, forms, solutions which permit change over time, emergence of different or new (intended, or unintended) properties and effects that relate to people's needs, and the needs of living or non-living entities. While this potentiality can seem abstract and general, a way to work with it more particularly in the context of architecture (as plans) would be in line with the open building tool of so-called "capacity analysis" (Kendall 2003) which is a kind of diagrammatic mapping of many different use-potentials of a plan design etc., though this tool could be further systematized and expanded (Franke 2022). Ideally, such capacity or potentiality of a given (open) design could also be considered more than merely on the level of plan design, and could consider affordance relation between both spatial function, technical services, disassembly details in relation to both utility as well as experientiality.

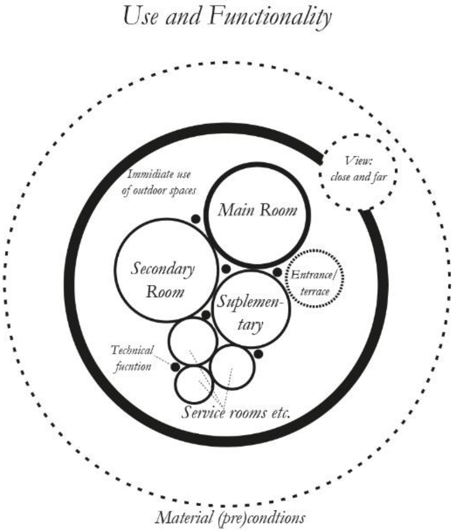

Figure 76. Diagram of generalized aspects of "use".

Another important addition to the category of performance and function is that the architecture performs as a "safe sink." This hints at a technical and material dimension but can only do so by containing both material and immaterial considerations. Having the building perform as a "safe sink" is a kind of zero-level function, a universal function which potentially contain all aspects of a built work (material as well as immaterial) thus acting (functioning) as a Urban Sink. What then does Urban Sink entail? There can be different manifestations of the Urban Sink. Different sorts of designs at any scale can *function* to minimize material consumption. While it is possible for such designs to be both fixed and open/flexible, the open/flexible solutions are preferable to the fixed building body (more on this in chapter 5, especially paragraph 5.3). For these reasons, function has to coincide with its "opposite", a kind of "sublime uselessness". This sublime uselessness is of course not useless but demonstrates a kind of functional ambiguity (where the form is not overly specific to particular commissioned function) which allows an entity to perform in various ways over time without needing material (ex)changes.

Construct: *Experiential Conditions*
When we are veiled in phenomena, such veils prompt both feelings and stories in one's mind. This construct is what Harman would call a Sensual quality.The experiential conditions are founded on the characteristics of the *material, structuring* and *functional* conditions, but also extend to constituting of the *narrative*. While overall narratives of a piece of architecture do not always logically come in extension of the phenomenological traits (of the building, materials, spaces, the harboring experiential qualities (or lack thereof) can have an immense impact on the users and

thus the overall societal narrative. A building or any spatial configuration in any context can provoke phenomenological experiences. Adam Schaar, in relation to the relevance of Martin Heidegger's phenomenology to architecture, elaborates how immediate phenomenological experience helps people make sense of their surroundings through an emotional response to them (Schaar 2007). Heidegger elaborates that one can occupy a building but not necessarily feel at home in them. Thus, regardless of the actual function of a building, (house, office etc.) this homeness and a sense of belonging is an important factor. It is of importance to also mention Husserl's phenomenology, as it has pertinent emphasis on bodily immediacy in how dwellers of a house engage with it (Harman 2022). A fictive example could be when an inhabitant enters the house by gently *caressing* the door handle which is framed by the embrace by curved brick wall. Phenomenological experiences are unique and cannot be retold in ways which fully cover the experience. It is important to note that sometimes a story can itself provide its own surplus. The experiential conditions implicate the senses and immediate haptic ways of relating with the world. Following Harman's logic from his quadruple object elaborations (Harman 2011), a phenomenon like tactility, which is usually pondered upon in tectonic discourse, can thus be explained as the combination of experience which hinges on material conditions. Such phenomenological conditions surely lay the ground for what kind of stories one can tell with the resulting narratives not necessarily being directly linked with that of the phenomenological experience. While phenomenological conditions can influence how one tells stories of the experience, it *is* at the same time influenced by the dwelling conditions and function of a building along with material choice and formal as well as structural applications of those materials.
While one could remain at the level of senses, this category could also contain questions of mental well-being, and the general feeling of being in space or place.

When it comes to the didactic telling of the making of an architecture (as known in tectonic discourse), just as well as the final product can "appear" to merely tell the humble story of itself, it can likewise make itself appear more complex and esoteric with all its visible details to a lay person or even some architects. It is uncommon that phenomenological experience and its narrative are thought apart, but they should be given that crucial gaps arise between them, for better or worse. It is as if the narrative and the experience do not always overlap perfectly, mystery and (perhaps as Semper would have had it) mystique emerges from all the seemingly modest details. At the same time, it is equally possible that a strong story can cheat your senses from "actually" seeing the architecture as it is (e.g., a poorly made design, interior etc.) which is narrated and legitimized through some unhinged esoteric story.
For these reasons, the experiential dimension can be considered thoroughly ambiguous. Specifically, it can both be "in line" with the overall narrative of a design and even be "in line" with the function and everyday use of the emitting of central and intimate feelings of homely interiority. But from the lesson of Heidegger, whose phenomenology is concerned with the stepping outside of mere appearance (Zizek 2012, pp. 892,) into a kind of unattainable (noumena) dimension behind the appearance of things. In the same strain, any spatial arrangement can induce a kind of uncanny fleeing of the un-homely, an uneasy felling which disturbs the feeling of

homely interiority. This unknown dimension can indeed be an accidental property even despite the best efforts of an architect to manifest a positive experience of home.

Construct: *Narrative - or Surplus-value*
Whether we invent stories or retell them, storytelling is a common occurrence in architecture. With reference to Harman, Narrative is a Sensual object, or as Žižek would call it *objet a*. Without focusing on a singular specific story, the general tendency of the mechanism of storytelling as such is of interest. In the architectural profession it is rather commonplace to tell stories as well as to highlight the profundity and potential for form-making and design through storytelling. It is also equally important to expand upon the risks imbued with storytelling. Narrative can be seen as a very immediate approach to architectural design as a narrative mechanism can help to steer or structure or even help evolve ideas and concepts in the mind before the first sketch is even made. The role of the narrative does not stop there as narrative can drive the overall design phases and iterations to the final detail. There are many examples of how narratives are a driving force in architectural production and creativity. Narrative can be tied to a single building or a whole scheme of architectural paradigms and tendencies (Coates 2012). Furthermore, in situations of analysis or mere experiences of a space, it can instill stories in the mind.

Semper's own theory is heavily structured by storytelling. While he does not explicate "narrative" directly as a constitutive element (e.g., roof, wall, mound, hearth, story) of his theory, it is indeed by the force of narrative that the physical manifestation takes specific shape. This is exemplified by his self-referential metabolic mechanism of material elements which undergoes transformations only to end up telling this very same story of its own transformations and process of becoming. The final product is thus a physical manifestation of a process which thoroughly "angled" onto itself by the need to narrativize the final product. Narrative thus becomes constitutive of the final form. It all starts from an idea, as Semper would have put it. The Idea initiates the transformations processes. But as will see, an architecture is initiated on different levels meaning that it starts with an Idea of an idea. As the case study paper will exemplify (chapter 5), different pieces of architecture are conceived from an idea which occurs on different level with some prioritizing experiential aspects while other technical innovations. Thus, in extension of Semper's writings, within the tectonic discourse there is a doubling of narratives, i.e., one at a level of content of the theory and the other on a formal level. The story of the idea that the final design makes occurs at the content level. The other narrative is more fundamental to the whole edifice where "narrative" as such constitutes the ontological being of the design which then necessitates its own narrative that tectonic design is in such a way self-referential and does not tell a separate story. This second type of narrative is what taps into the self-perpetuating loops of (linear) growth paradigm of cultural continuity. Similar to what is discussed in chapter 1.2, conceptually there is fascination with self-perpetuating loops which maintain production within the linear growth paradigm and thus manifest different types of Jevon's paradoxes or other ways of maintaining or amplifying material consumption. While architectural production is surely within finite material conditions, it is as if narrative is a "immortal" dimension which aims at impossibilities with grand story arcs, canons and physically impossible circularities. It *wills* into existence even that which has no legitimacy in all its ambiguity, for better or worse. For these reasons we have to make ourselves aware of the narrative-mechanism and thus critically think of its role. To do so, Slavoj Žižek elaborates in relation to the notion of *objet a* (Žižek 2012; Žižek 2014) (see also chapter 3.4.2.). Narrative helps constitute imaginations and fantasies in everyday life. These narratives help in constituting a sense of reality in one's complex and confusing everyday phenomenological experience. Hinging on a story provides meaningful coordinates in this confusion. For this reason, reality is ontologically impenetrable and is contingent and withdrawn from us. What thus also becomes relevant to consider is the possibility that the narrative and physical manifestation do not go hand in hand. This Mean something is said or intended but the manifested reality is materialized/constituted differently. This can span from anything from an aesthetic intention of an architect being perceived and experienced differently, to intended sustainability actually being green-washing, or to larger societal failures of initially intended modern living conditions becoming ghettos with bad reputations. The narrative mechanism holds the capacity to speak things unto existence, so to speak, while introducing a gap or discrepancy between what is said/intended and what is manifested materially. Narratives can at times become instrumental in legitimizing any material conditions or mode of production, and regardless of the antinomic and contradictory and partial stories, any edifice can be explained or legitimized (despite its actual legitimacy or necessity).

Let's consider a simple thought exercise to exemplify how narrative can distort reality. Imagine a "pristine" natural landscape, and a building that is to be built there which is conceptually narrativized as a house which is embedded in nature. By embedding *architecturally*, and thus spreading the program out on top the landscape, you embrace nature more but get a higher carbon footprint and more literally destroy the landscape and its soil etc. when compared to if you made a compact volume (or didn't build at all). In such a case, the narrative of being "one with nature" or "embracing" nature is almost exactly the opposite, but you "feel" One with nature.

One must initially wonder why constitute narrative at all as key principles or constructs of the metabolism. There are several aspects to unpack (which will be addressed in this section), but the fundamental ones are that of an ontological discrepancy between cause and effect: epistemology and reality. In relation to Jevon's paradox and green washing (chapter 1.2.3.), the capacity of architectural storytelling is thoroughly problematic and ambiguous in the dimension of design, as a compelling story can be atheistically poetic but equally opportunistic (knowingly or unknowingly) ill-intended. Storytelling, whether it be architects' intentions or grand ideas for sustainability and servitude/connection with nature, there is no guarantee that such intentions manifest and may indeed materialize as the opposite (unsustainable and polluting more etc.). Narrative, for the above reasons, is not essentially a good and profound poetic dimension, but thoroughly ambiguous which can always "distort" (our perception) of the actual reality at hand for better or worse and our according engagement with it.

On the other side of the coin of the "narrative" is that which I have to very un-creatively call non-narrative or bliss. It should be conceptualized as a kind of failure of the very mechanism of narrativizing things or phenomena. This can occur both when architects explain their works. Often very artistically driven works are by the architects somehow confusingly explained, and you still do not understand anything. There is something *there*, but it is perhaps impossible to put into words comprehensively. Likewise, this *bliss* can also be experienced when you find yourself in a space. Usually, there is a kind of pressure-for-narrative whenever you look at or experience architecture, but every now and then you find yourself in a space where your narrative mechanism either fails or refuses to narrativize, and you simply are immediately within a breathtakingly beautiful space.

4.4.5. Relations

There are two main relationship types in the (im)material metabolism. One is more immediate regarding the particular constructs' relation to each other – both generally and in specific situations of design and analysis at different spatial scales. The other is the large-scale relationship between human activity (society, or the *anthroposphere)* and natural environs which can be generally described as the relation between the Urban Sink and the *hinterlands.*

Society/Nature, nevertheless…
The *Hinterlands* are in this case a comprised entity which contains the all the bio-regional considerations up to even larger constellations. As we have seen (chapter 3), dealing with planetary boundaries can be very difficult to implement. So too is the approach through regions and bio-regions (Baccini. Brunner 2012) because defining a region can be difficult as a geographical, social and political task. Literature on planetary boundaries and state-of-the-art papers argue that there is vagueness in translating the general theory into concrete action on an everyday level.

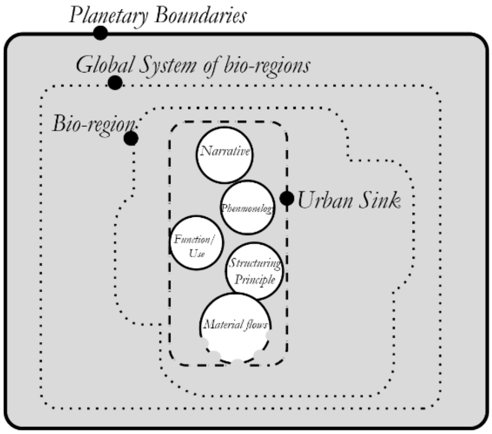

Figure 77. Metabolism; Urban Sink in relation to planetary boundaries.

The general attitude of this theory is that of the need to break with the conventional linear growth-oriented paradigm, through "degrowth", i.e., through slowing and narrowing of material flows. As such, the general relation between the Urban Sink (city, building stock etc.) and the hinterlands (nature) is that of the activity of "construction". This implies that the city ought to withdraw from the current perpetuation and amplification of material consumption qua both material and immaterial strategies. In a similar fashion, and as seen in industrial ecology, this theory also fundamentally conceives of a dualist dichotomy of *society* and *nature*, and thus building stock (the city) and the *hinterlands* (the outside area from where material recourses are excavated and brought into society) as material flows are perceived in this relations. Obviously, the condition of reality is impenetrable and not fully compressible by human cognitions, and reality is thus a complex interconnected entity with humans, cities, and society as mere parts of a large system. Since the observed material flows are flowing mainly in one direction and this tendency is one which perpetuates negative effects on natural environs, it is of great importance and practical utility to maintain this distinction of society-nature. Planetary boundaries/capacity are indeed "out there" by are hard to grasp but to affect or leave them be "out there" something needs to be done "here" (in our everyday life and behavior).

Interconnectivity of Constructs

What particular relation could be present for a sound performance of the Urban Sink? How do they manifest? There are already indications of relationship between the five constructs in the above descriptions of them (4.4.4.). The five constructs constitute a spectrum in which they overlap with each other while having influence and consequences for each other.

The (im)material metabolism is modestly unique in relation to the general tendencies of "constructs" in theories (chapter 1.3.2.) in that the sub-constructs are shared between the main constructs (Figure 78). However, the constructs and sub-constructs can be at odds with each other. An example could be that an architect's intention clashed with social narrative, or the experience of house. Or one could experience an architecture as bland and characterless, but an architect's clever concept-narrative makes you "experience" the building in a positive light. The spectrum that the five constructs form is not necessarily a linear one. The five constructs also relate across the "apparent" linear hierarchy and can demonstrate different hierarchies and design constructs which can act as driving mechanisms in different cases. The elements also seep out into the system boundary. The lowest construct of the ontic material conditions seeps into the system boundary as dynamics within society and has immense material consequence for both itself and the *hinterlands*. Narrative is an "open" category as well but not in the same way. It too can seep into society, or narratives from nature (sometimes as metaphor) can enter into architecture. It is important to note that narrative has a more immediate effect in facilitating transformative dynamics which in the end have material consequences for both itself and nature.

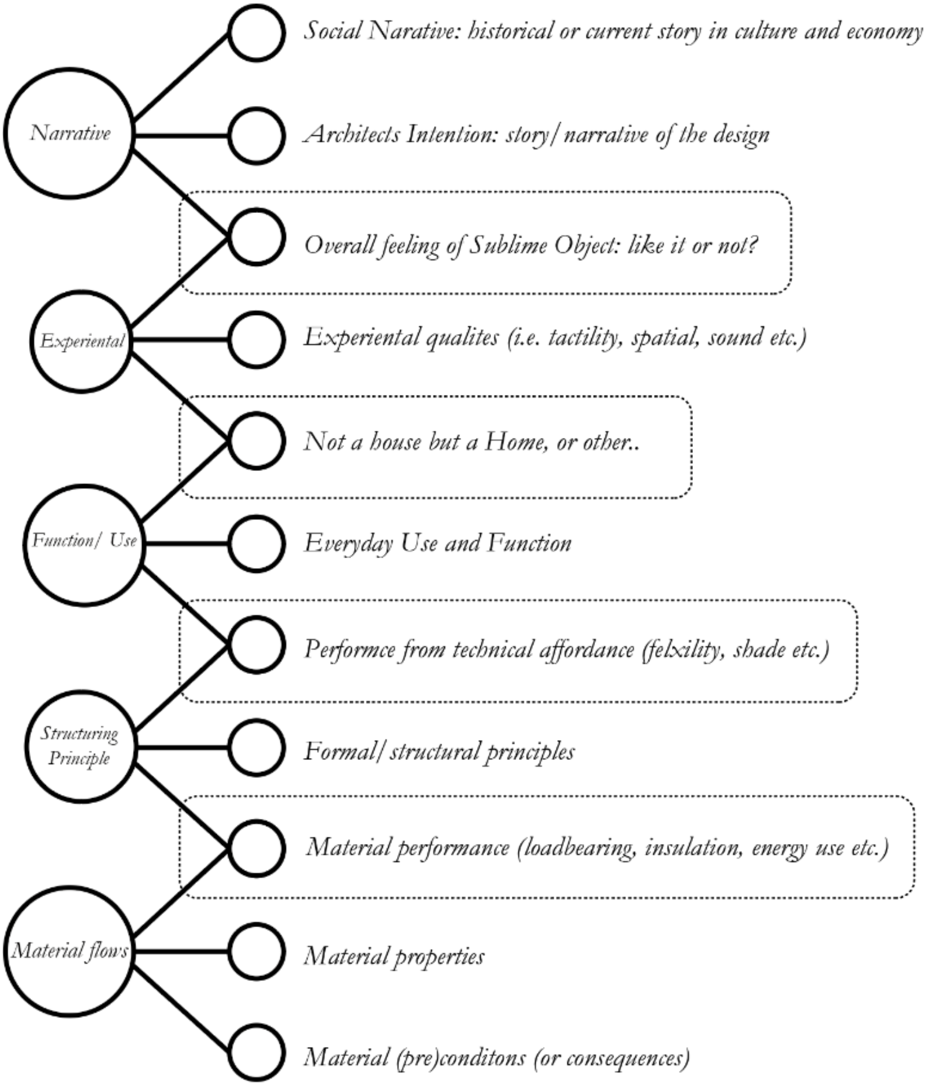

Figure 78. Key constructs and the first set of sub-constructs which constitute relations.

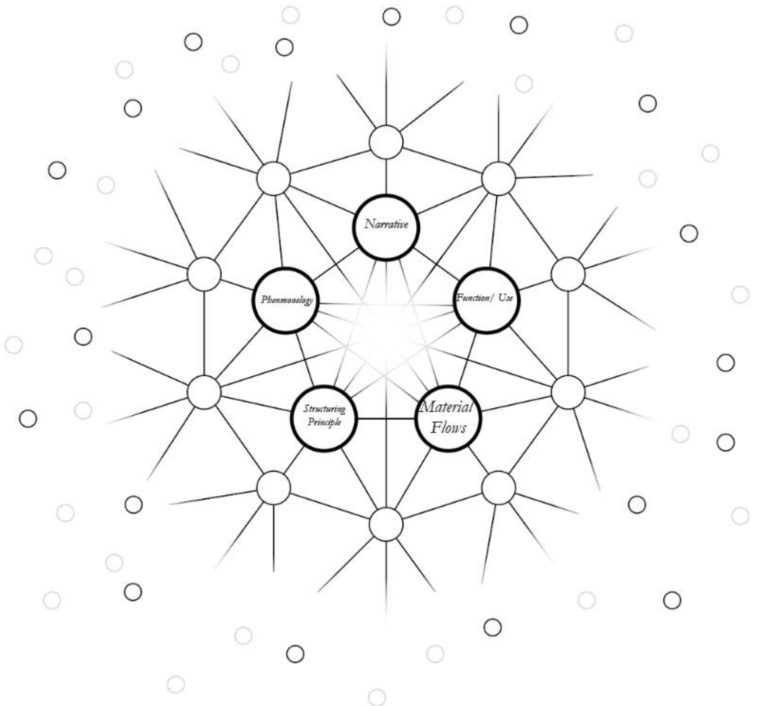

Figure 79. Key constructs and first set of relations
depicted in "circular" interrelations fashion – pointing towards other sub-constituents.

More appropriately, the five constructs are suspended in a very complex set of relations and for pedagogical and communicative reasons, this very complex set of relations need to be theoretically simplified. However, their complexity can remain when having to map empirical data points and properties in order to explain or design certain relations and things. One could here say that at the very core, Ring 0 (Figure 80) of the pentagon has the "quantum" space of uncanny, undiscernible currents, sub-conscious ideas, drives, fantasies, myths, ideologies, and drives (which we are yet to tame or "secularize") while at the outer layer are the many empirical (tangible) objects, effects and relations (observable phenomena and data) and ultimately the planetary periphery of limitations and finitude.

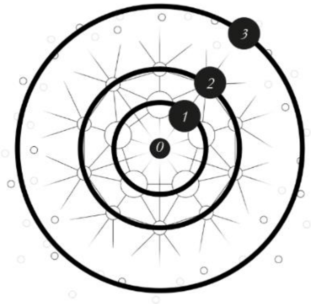

Figure 80. Three (plus zero) rings of the metabolism.

The first set (Ring 1) is the five main constructs of the theory, and the following set (Ring 2) is the set of sub-constructs which constitute relations across the main set of constructs. The outer layer (Ring 3) is the one which itself acts as a spectrum of different yet vastly complex empirical conditions. The last ring is thus the dimension in which a multiplicity of disciplines become relevant to consider as any action in architecture hold consequences not only for itself, material consumption etc., but also regarding whether knowingly or unknowingly has influence for other fields and disciplines.

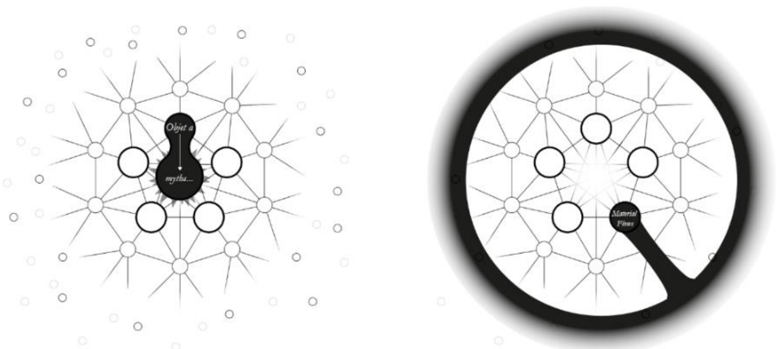

Figure 81. "Narrative" is the representative of the "mythical" core, and "Material flows" is the representative of the materials (pre)conditions and planetary boundaries.

The structure of the constructs is intended to contain a self-reflective introspection in which potentially all constructs are prone to scrutinization. The purpose of the "Material Flows" construct is ultimately to question whether or not the intentions and spoken agenda of sustainability etc., actually corresponds with the actual materialized effects. Similar to how "material flows" construct is a stand-in for the ontic material conditions which allows certain kinds of practices and modes of production, the

“Narrative” is the stand-in for the inner sublime *hysteria* of architectural creativity, i.e., the many myths and ideological constructs of capital-a architecture. This construct in particular should be mobilized to deconstruct all the other constructs as well due to the fact that any story/narrative can be told of any of them. These two constructs become of particular importance as they permeate the whole discourse in wanted and unwanted ways. Regardless of what we say and followingly do, these constructs will have both short- and long-term material consequences. It thus becomes discernable how the axiomatic mental constructions and stories (used for legitimization and argumentation) can manifest physical effects onto reality (as elaborated in chapter 1.2.3.). Knowing the need for a material foundation for architectural production, it is equally crucial to critically questions the (sometimes blind) ideological mechanisms of architectural production (even when they are supposedly capital-a architecture, i.e., the so-called real thing). This would exemplify the need to break out of the ideological texture that has architectural production remaining within conventional growth paradigms under whatever agendas it finds itself (green, sustainable or circular and whatever else will be conceptualized in the future). We can easily imagine a scenario where architects use “blind mechanisms” as an argument to build/design their ideas through the argument of calling it a “true” or “honest” design. Things can naturally get even more complex when grand narratives of subversion and transgression of hegemonic norms can be mobilized with seemingly good purpose. Through a critical reproach, one should always tarry at these blind mechanisms because even the most sympathetic subversive discourse can show itself to be fully fit or aid the established hegemony within the usual linear growth paradigm[13], not in spite but because of the supposed subversive storytelling of the endeavor. Such “flattened” subversions can maintain or simply displace negative impacts elsewhere and generally contribute to the usual material consumption – whether such subversion be small-scale, self-builder off-grid communities, or intricate CE (DfD etc.) design strategies. From a *metabolic* perspective, we have to remain critical even of seemingly “critical” edifices and practices.

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[13] It could relevant here to consider the work of Tina Veteran Olsen who has done substantial research on informal communities.

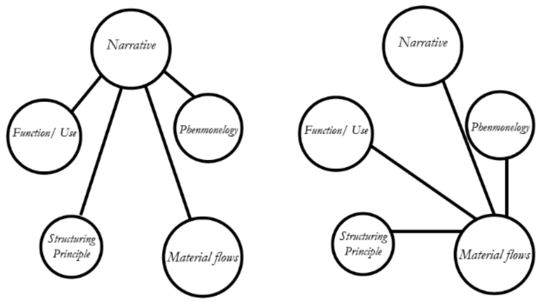

Figure 82. A particular manifestation of a chosen construct can act as design driver.

Projects and design can have different driving parameters, which then can have great consequences for the other constructs. In an analytic application, it important to observe how a built work performs in all the separate constructs, in relation to or apart from its narrative or intention. In general terms, the five constructs thus form more of an interlocking logic of the relations, but different cases or design process will prioritize different elements as driving for the overall design and its narrative. At the same time, in a general sense, the constructs can overlap into each other and can constitute relation both directly (when construct are considered in an integrated way) or indirectly (when other construct merely has indirect consequences for another one).

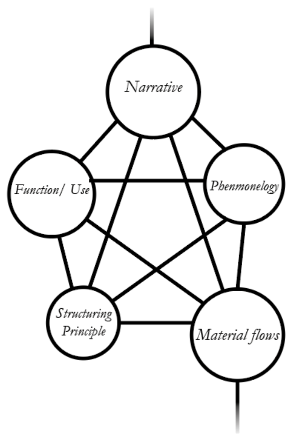

Figure 83. In a simplified way, we may acknowledge that the external relates,
but also emphasize the inherent internal relations.

4.4.6. Logic(s)

In very complex sets of relations between the constructs and their situated conditions, things can become very complicated and even incomprehensible if there is no overarching logic and structure to the different empirical conditions of a design or analytic endeavor. To provide comprehensibility and to be able to discern a pattern in any observed phenomena a set of logics are needed. The development of "logics" used the methods of *metaphor* and the *adding* of elements (from metabolism and tectonics) in addition to the case studies. Furthermore, the methods of *connecting* and *adjusting* has also been used to link ideas across the disciplines. This paragraph will explore and elaborate on how the two disciplines are engaged to build the (im)material metabolism.

Metaphor
As elaborated in methodology chapter 3, metaphor is used in two ways: as metaphor and analogy. Metaphor is used to (mentally) construct the object of metabolism, while the analogy is used to introduce logics of effectivity which structure the metabolism.

There are obviously big differences in Semper's metabolism and the one of industrial ecology and chemical engineering. Semper's fundamental logic of the self-referring material and elements does not necessarily directly explain why material flows continue as seen in industrial ecology studies. This holds conceptual potential because it reveals a fundamental mechanism of architectural creativity and what kinds of line of thought architects mobilize to develop narratives (and concepts) which perpetuate and facilitate material flows in the building industry. This is done without directly causing them as many other societal and economic considerations should be included to fully explain why materials flow as they do. Metabolic understanding of edifice is a grounding one. There is thus a large-scale metabolic exchange which situates minor metabolic exchanges in particular buildings, designs, or areas. At the same time, as architects we have to understand that there are larger forces (societal, economic, political) which manifest those material flows. Even if such conditions are very complex, we still have to be aware of how architectural creativity itself forms a circular metabolism of its own which in many regards provides narrative drive to how the "inevitable" material input gets shaped and designed into place which in the end influences how long it stands, if people like it, and will use it.

More fundamentally within this metabolism, three notions which structure the logic of the metabolism are present. These concepts are taken from the chemical engineering literature: *slowing, narrowing,* and *closing.* While the current building industry is very concerned with circular economy, the concepts are developed in relation to this "circle" which needs to be slowed, narrowed, and closed. In the metabolic theory building of this PhD, the most important concepts are slowing and narrowing where closing is inherent to both. Given the fact that material flows are inevitably linear (forever), we ought to accept this work towards slowing as the

primary concept, narrowing as secondary, and closing as an inherent strategy where the circulation of materials and elements ultimately minimizes the overall need for material input.
Although the sink is also a metaphor, the founding metaphor is still metabolism and not sink (for washing hands, nor a sinking ship) because the concept of the sink is centralized, and it is its elements and relations which are structured by the metaphor of the metabolism. The metabolism metaphors can be seen as metabolizing certain relations of material exchanges between society and nature in general terms while the urban sink is the particularization of the metabolism. The metaphor of metabolism when mobilized requires careful, critical thought regarding how to translate it into architecture. Similar to how industrial ecology literature puts forwards the need to consider the use of metaphors. Metabolic entities (organisms) also have behavior which should not be mirrored (i.e., certain organisms can be aggressive and attack both their own species and others etc.). An architectural metabolism and its success do not hinge on how well it "appears" *metabolic* but on how well it slows materials consumption.

Temporality – Metabolism In Motion or the Slow Ship of Theseus
Another founding axiom of the theory is that reality is in motion. A key constituent of any metabolic dynamic is that it flows, moves, and thus "closes" circles, loops, or systems which are physically impossible as systems deteriorate and increase entropy. This flow can be anything from the natural deterioration of building materials due to usage or weather, or the human induced processes of transformation of virgin materials in the process of making. Circularity is thus an illusion, and we ought to perceive the flows of materials as linear flows which are in dire need of being slowed by more means than only circulating elements and design-for-disassembly. Thus, entropy is a constitutive *logic* of the reality in which built environments take part. Because everything is motion everywhere simultaneously, conceptualizing phenomena in one's immediate context as objects (slowness) could help in the slowing of material consumption rather than conceptualizing an ever-constant flux. Thus, the flows are always linear. The question is, however, how we can slow the flow down through (slow, yet open) metabolic design. There are two types of time in this metabolism: the general and specific. The "general timeframe" is concerned with the fundamental notion that time is not independent of material realit. Rather time is a property of material existence and its movement because matter is *vibrant* (Bennett 2010). In extension of this, the prime property of metabolism is that of constant motion, where material reality is increasing in entropy. The "specific" is related to when dealing with a particular design boundary, one has to choose the observed time span of an entity or envisioned durability.

We cannot remain in Euclidian division of space and time. As Hegel says, the spirit is a bone and time is inherent to the very notion of the metabolism. Otherwise, it is not a metabolism. As material reality is vibrant, as Jane Bennett would claim (Bennett 2010), and a metabolism is inherently dynamic, as we have seen in biology, different organisms or ecosystems have varying metabolic rates. A small entity has a high metabolic rate, while a large one has a slow (i.e., a mouse and elephant). A city is thus a large entity which unfortunately in its current manifestation can be said to have a too high metabolic rate of particular ´materials and elements which endanger future generations' ability to sustain themselves. Time is thus inherent to the material entity in which entropy is a fundamental and inevitable fact. The ontological implication of entropy is that reality is finite and contingent. At the same time, entropy indicates that reality is always going towards increased chaos. As we sometimes see, architects aesthetical and conceptual sublimations of ideas (i.e., wild formal expenditures which require complex composite materials which cannot be dismantled) can entirely maintain or amplify the increasing rate of entropy, and just because reality is headed inevitably towards chaos, it does not necessitate we mimic it in our designs and strategies.

How entropy makes itself evident in the buildings and materials more immediately is related to how we design elements (Roithner et al 2022; Brunner Rechberger 2017). If an architectural element is a composite which does not allow for mechanical (or otherwise) dismantling, then we have an increased entropy as it would be difficult and costly to reverse the design decision. Keeping designs to a minimal number of materials, with little to none composites which are mechanically dismountable would be preferable to the opposite. Even with the 'good' design decisions, entropy is always increasing as energy and some form of excavation is required among other processes which inevitably increase "chaos" (diminished the possibility of *potentiality,* so to speak).

With notion of the *Ship of Theseus,* Graham Harman elaborates on how an idea of a thing can still remain the *same* object even if all its material/physical constituents are replaced by new ones (Harman 2018). Usually, the *Ship of Theseus* is a mental conundrum on whether or not the object is the same after all its transformations. According to Harman one can designate the being of an object despite having changed materially, not unlike how biological bodies change all living cells after a number of years (and still remain the same organism or person etc.). Many buildings are such *ships,* and while some get demolished, others have stood the test of time with lesser or greater degree of interchange and replacement of physical anatomy. The next step would be to conceive of the whole building stock as an Urban Sink which is a *Ship* with a significantly slows metabolic qua regarding its tectonic characteristics.

At a more immediate level, any action has metabolic consequences whenever we act whether we know it or not. Whenever we enact a material change or transformation, it will have prescribed and unprescribed immaterial (experiential) effects. Likewise, when we develop or envision immaterial notions, concepts, or narratives, the way it materializes in reality can vary greatly and either more or less in line with expectations or in totally unknowable and unpredictable ways. With temporality striving for inevitable chaos (entropy), a condition of this process is that causality is not always known to us.

Philotechne – or the smokeless fire

When we observe the human-induced material flows, is it possible to claim that the material flows of the built environment are rational and oriented towards peoples' actual need for shelter in given numbers in time and space? No, because there are also indications that the industry operates "irrationally" meaning a search for profit is its own end-goal apart from actual "needs" of the inhabitants. Building or making as an activity has an actuality of its own, for better or worse, and is not only a means to an end.

Semper was greatly criticized for being a materialist. Being a materialist implicated that his position was that architecture must deterministically emerge from material conditions. Riegl, (who initially called Semper a materialist) later changed his opinion aimed to redeem Semper obviously also acknowledges that architecture emerges from material, technical, social, political, and climatic conditions as well as the artist's *free will* (Kunstwollen) (Mallgrave 1996, pp.379). Riegl's early misinterpretation of Semper thus prompted him to develop his own idea of Kunstwollen (inspired by Semper), the Will or urge for making and creativity. Not unlike Semper's radical shift from "primitive hut" to the "primordial knot", *philotechne* is a shift from the Will for art objects to the will of making, the makers-will. This idea of *free will* as a kind of love for making/art is to be taken as either serious precognition or logic or creative thinking and conception. Riegl, perhaps Semper as well, differentiated two types of *free will:* the true creative impulse and the mechanical drive to imitate (Mallgrave 1996, pp.379-380). While one can be sympathetic to the need of separating the two, they are thoroughly intertwined. Whether we are dealing with the true creative impulse or the mechanical drive, both are "blind" mechanisms which assert themselves while propelling and perpetuating activity in a actualizing and assertive manor onto physical reality; as such, this *will* is a radically ambiguous entity. As Jeremy Till indicated, there is force *ex nihilo* (Till 2009), a kind of strange space of "nothingness", from which creativity springs. There is thus a mechanical aspect even in the supposed "true" creativity, as the basic mechanism of subversion or transgression is central to creativity (i.e., you establish a norm, which your "creativity" subverts). *Philotechne* is thus a "radicalized" *techne,* i.e., the urge/love (philo) of making (techne), which undergoes a Žižekian (Hegelian) sublimation from a Thing-In-Itself to a Thing-For-Itself and in the end is conceptualized as an incessant makers-urge. I claim this is par excellence for the inner motion of architectural creativity which starts to *cause* itself in the that was already exemplified by Semper's self-referential (metabolic) logic. Techne is the Greek word for the integral technical and artistic making (Hartoonian 1994). As Heidegger already established, the essence of "building is letting to live". While Heidegger acknowledges the intertwined nature of the acts of building and dwelling, a more radical position would then be that instead of the essence of building being external ("letting live"), building is causing itself the pleasure to build apart from any essence outside of this self-relating.

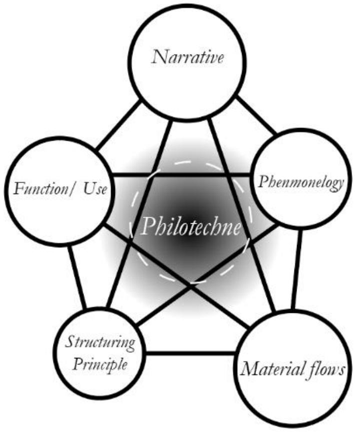

Figure 84. Philotechne: almost as a sixth construct central to the edifice, yet "invisible".

In the Danish language, there are a set of words which describe this dynamic: "skaberglæde" (makers joys, joy of making), "skabertrang" (urge/need to make), "skaberlyst" (desire for making) or "virkelyst" (acting desire, desire or will to act/do). Coupled with this should also be the Danish term of "selvsving" which is translated as a self-animation in which an entity or person is behaving without reference to causes and effects. Drive is such a constellation as described by these Danish terms. Another description of this, apart from Žižek terms of Drive, is the notion of the "compulsion to repeat". supplementarily Žižek also terms this notion as a "partial object" (Žižek 2012). *Philotechne* is a kind of invisible entity, almost a sixth construct of its own which animates the whole edifice (). Using the compulsive self-referential logics of both Semper's stoffwechsel (articulated as the wreath) and dichotomous division of society and nature, a new tautological self-reference can be expressed. We know from chemical engineering that societal metabolism is not a natural ecology (or eco-system) but a human-induced metabolism which is driven by people in their relation to natural surroundings.

Ginger Nolan elaborates that Death Drive (Nolan 2018) in relation to the earliest "modernist" gesture by Marc-Antoine Laugier's Primitive Hut as a purification. This elaboration further conceptualizes this gesture as a compulsion for purification which manifests as a measure of erasing the past while constructing a new measure in order to construct a new present and future. This is par excellence of the modernist compulsion (repetitive loop within the discourse) (ibdi). On the other end of the spectrum, Juhani Palasmaa's book "The Thinking Hand" was written as an ode to the pleasure of making (Palasmaa 2009) in which the profound and poetic dimension of creativity and making are at the forefront. Although both of these describe a tendency in architectural phenomenology, Ginger Nolan exemplifies the Drive (Makers-Urge) within the modernist discourses as the eternal search for purity and truth, while Palasmaa's elaborations exemplify a multitude of pleasures in the making process from a phenomenological and proto-neuro architectural fashion without regard for purity or perfection but merely the poetics of the process of making itself. Regardless of the differing context the creative compulsions, beneath or even within both of these is a blind mechanism which comes prior to the *desiring* coordinates manifested. In the case of Laugier, the Makers-Urge which pushes him to manifest a new set of desiring coordinates (logic and ideas) of a pure, true architecture is seen. The Makers-Urges is in itself an ambiguous entity. Obviously, one has to accept all the potentials of poetics of making, but with this elaboration on Death Drive, it is important to consider the Makers-Urge as an ambiguous and incontinent entity which is not inherently good, true, and poetic. It is perhaps more of a blind mechanism which persists beyond and beneath any actual circumstances and searches for legitimacy to actualize itself. The makers-drive mobilizes creativity and storytelling in clever and slippery ways and at times one cannot tell the difference between pretentious charlatanism and sublime authenticity (irrespective of authors intentions). The drive can equally be destructive and manifest uselessness and ugliness. The need for making comes prior to what is required to be made. Another example of this circular, or perhaps the other side of the creative coin, is the ceaseless “destructive creativity” of the building industry as such in which, as Jeremy Till has argued, demolition has become an integral part of architecture (Till 2009). This can be further hypothesized into current conditions where buildings are being built very fast, on a low budget, with an overly specific form and a corresponding function, and of perhaps questionable or poor aesthetic and phenomenological characteristics. Such buildings are not necessarily intended as future “building heritage” nor are they expected to last 300 years. It can be perceived as a strategy which guarantees future building activity and market dynamics and thus is a self-fulling circular drive.

As Ginger Nolan indicates, architecture is essentially split between engagement and withdrawal. As scholars have observed, the building industry is overly active and self-perpetuating with architects being one of the enabling and driving agents. Juhani Pallasmaa makes a relevant elaboration in this regard when he writes on the relations between creativity and boredom (Pallasmaa 2009, pp. 81). In the endless striving of creativity, one does not achieve perfection or beauty by keeping up the creative activity. The challenge is to know when to stop and basically restrain oneself from making more. Creativity is an incontinent entity, as one can allow oneself to keep working and keep adding more and more layers. A truly creative gesture (fused with that of critical awareness) is to contain/restrain oneself. The proper Žižekian synthesis in this regard would be in our inability to fully contain (restrain) the incontinence of creativity leading us to assert compelling (sublime) narratives to legitimize our creativity.

The makers-urge can empirically be considered in three different variants. First, as the metabolic dynamics of the building industry can be claimed to hinge on multiple actors and agencies, the makers-urges can be seen as multiple. One of the core mechanisms that drive material consumption can be said to be the “developers” or clients (whether private, community, or government). At this level, the agenda of the urge is to make/create profit which can span to anyone from clients, who want something that the architect envisions for them, to manufacturers, who want to claim market shares, and developers or investment foundations, who aim to capitalize on market conditions for profit whether for monetary gain or due to grand vision/delusion of personal or cultural legacy. The second is the architect. The architect's intentions of creative expenditures during creative progress towards the making of new objects etc. The third is the users and inhabitants of the works. These consumers have a kind of nesting-pleasure which has them (due to boredom, desire, need etc.) self-build, partition, rebuild, refurbish, decorate etc. as ways to make the house more "homey" not necessarily as a means to an end but possibly as an end-in-itself.

The creative/design process in architecture is not and cannot entirely be a aseptic, and objective process in which the architects/designers robotically solve the problem of the users' need. There is always a surplus pleasure at hand linked with creative endeavors. One's proposal and synthesis (whether design or text) is a transgression or subversion of a known hegemonic norms for the sake of variation in progress of historical continuity. Regardless of the relevance and significance of any contribution, whether built or written, the creative (circular) mechanism persists first and foremost, and we should consider the possibility that we need to "tame" creativity. There is thus not necessarily anything profound or automatically poetic in this Makers-Urges. While also acknowledging the positive potentials of it, I am not refuting the potential of the immense wealth of creativity energy. Nonetheless, it is important that at the same time there is an understand of the regarding of it as an ambiguous entity that perpetuates the building industry as a dynamic system of material consumption.

Inter-dis-connectedness

Considering material flows (among other thing), interconnected-ness or connectedness (Krogh ed. 2020) has become an important way of perceiving relations under the guise of ecological challenges. It is also a very complex topic which generally speaking implicates material, immaterial, social, political, environmental, technological etc. aspects. The purpose of this would be the development of a more complex understandings as well as an understanding of more connected and intertwined relations between society and nature. State-of-the-art social theory pushes for such an understanding of increased interconnectedness while ultimately dissolving the usual epistemological distinction between society and nature. Yet the world *is* already an very complex and intertwined entity where any (human) activity can have grave consequences for nature and itself even as we still discover more and more facets of this interconnectivity. As the world itself is already interconnected beyond our ability to discern it fully (as per the lessons from chemical engineering and industrial ecology) the challenge is to perhaps *not* dissolve the borders between self-world and society-nature but rather to attain a more respectful attitude within this dualist distinction. Elevated relativizing narratives can be problematic. Žižek exemplifies this in an elaboration on Zen-Buddhism and its application in military combat during World War 2. Žižek elaborates and emphasizes the ambiguous nature of any position using D.T. Suzuki, a former supporter of the Japanese military activity who went to on to become a Buddhism-spokesman in the West as an example. Žižek uses him as an example as he in his early years provided ideological, Buddhist justification of military violence by way of relativized narrative of dissolved phenomenon of self and the other by saying that a sword or knife merely *happens* to wound the other, meaning it was *not you* directly who did so (Žižek 2012; pp.134). Another example which demonstrates the applied ambiguity of process philosophy is the elaborations of Eyal Weizman who analyzes and elaborates how Deleuzian theory, along with other post-modern theory, is used to bring about new approaches to military actions and targets (Weizman 2017, pp.186; ibid. pp.200, ibid. pp.215). This indicates that a “relative” (non-static or process-oriented) epistemology is not necessarily profound in bringing about a radical shift in paradigms, agendas, and intentions in socio-political realms, and so on, but rather indicates that the “old” visions and intentions can easily remain the same while the means/tools are new, more complex, and perhaps more effective in one’s in manifesting one’s usual agenda. A relativizing of the relations between society-nature and the disregard of constitution objects privileging processes, relations, and properties (e.g., there are no individuals as such, only bones, skin, brain activity etc.) could just as well bring about new and more complex forms of domination, exploitation, and violence onto nature whether intended or unintended. There is a risk of, a la the Jevons’ paradox, people’s very “good” intentions may materialize as the opposite which is not due to some people not use it with opportunistic (ill) intention. Ultimately, an emphasis on the networks in both objects and processes in such a relativizing way risks manifestation of a “...premodern enchantment of the world…” (Žižek 2016, pp.55) and thus mystifies ourselves and our relations to our surroundings thus permitting a kind “anything goes” attitude under an umbrella of scientism where any person, entity, set of relations or things can be de-substantialized and ultimately permit the agenda of business-as-usual. An important reminder is therefore that this would not always be the case, but it is a risk which needs to be taken seriously.

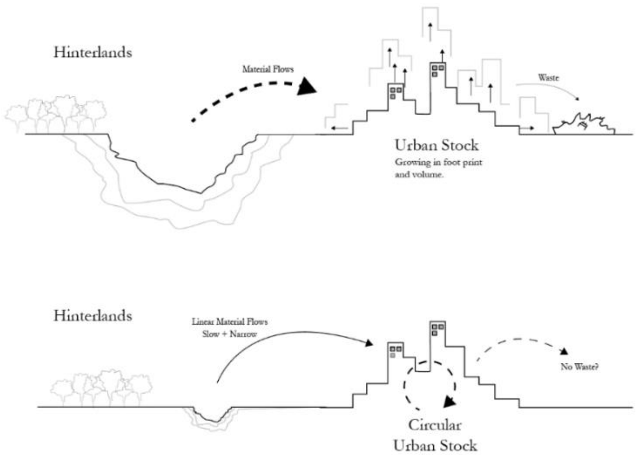

Figure 85. Towards a slowing of material flows.

A crucial aspect is to acknowledge the immense potential of process and network theory modestly and pragmatically while likewise acknowledging that *certain* bundles of properties and effects circumscribe an entity which asserts effects onto *other* bundles of properties. As such, there are crucial patterns of processes and effects which cannot be relativized, like the relations between society and natural environments with regard to material flows. We cannot afford to insist on merely the “here and now” immediacy and forget larger (meta-)schemes and questions of essence. The city (with its current needs) is already materially interconnected with nature by requiring more and more material inputs. The challenge is to “disconnect” from the material world. How? Many architects concerned with haptics and embodiment argue for the need for a “re-connection” with the material world (Pallasma 2009; 2012). To avoid a misunderstanding, I am certainly sensitive towards this necessity in architectural design, and I do not argue antithetically in that regard. My claim is rather that good design (as posited by Pallasma etc.) could also be achieved through reconceptualization of “connecting with materiality” by minimizing material consumption and as such we can have healthy haptic experiences (*immaterial connection with the material world)* while withdrawing the city as a sink from material over-consumption (*materially disconnecting from the material world)*.

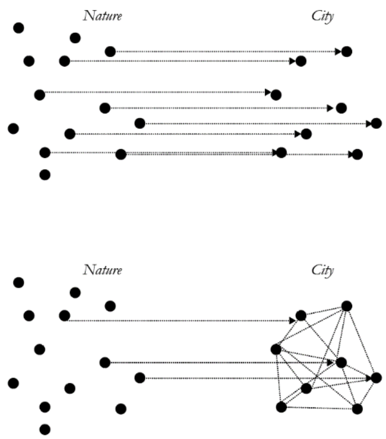

Figure 86. Diagram showing the principle of slowing and narrowing, thus minimizing need for materials by “disconnection” and “interconnection”.

It is thus crucial to instead conceptualize a disconnect from nature (as much as possible) by interconnecting society more and more with itself. This would be a more “precise” metabolic way of conceptualizing the current metaphysical consideration on interconnectivity in an attempt to minimize the ambiguous relativism of abstract dissolutions of entities and borders. Even if nature in this regard is entirely compatible with Timothy Morton’s idea ecology (and not some idealized romantic idea of Nature), by disconnecting cities from nature materially along with more separate interconnectivity conceptualizations which can be created by allowing the existence of the dualist separation of society and nature which is beneficial both mutually and separately. Since nature (or the planet) is not some Gaia-Mother who “knows” how to recreate natural balances (as catastrophe is equally risky), initiatives can be made to (artificially and with human aid) make design, and control natural areas for the purpose to increasing biodiversity which also can be further achieved by a more disconnected society from nature. In such a condition, given the need for metabolisms always being linear, it can be of great utility to still mobilize the “good, old” dualist distinction of society-nature even if practically they are more intertwined than ever. Instead of the usual exploitation and mastering logic in this dualism, it could be a more respectful, withdrawn position in which a minimal material input is ideally required.

It may very well turn out that if we are to achieve this “cutting” of the city from nature in practical terms, we may still require additional amounts of materials by allowing the current material flow tendencies. Even a slight surplus to provide a minimal buffer or a material investment could provide “insurance” for any contingent situation in the future.

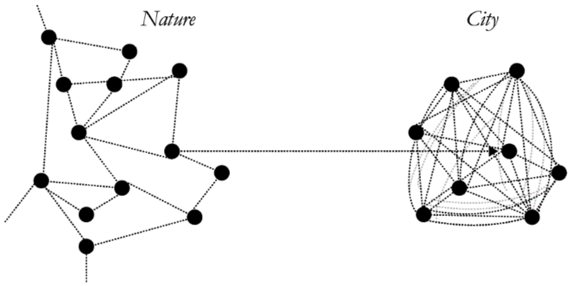

Figure 87. Disconnecting by interconnecting; in material and immaterial terms.

As Žižek has argued, a challenge that we must be aware of in this regard is that of the risk of “re-enchantment” (Žižek 2016, pp.55). Žižek himself is fond of object-oriented-ontology and accepts its potential; however, he is also critical of certain aspects of it with re-enchantment being one of the areas that he sees critically. The problem seems to be that given the many tendencies in modern society, there is a critical distance and perhaps intellectual cynicism regarding many, if not all, all relations with the world where one feels minimally alienated. Along these lines, when reading Žižek, object-oriented-ontology poses a challenge because it would allow for a kind of return to some pre-modern “organicism” and animism/panpsychism meaning that the critical capacities are (willfully) deprioritized and the world is “re-enchanted” (made magical again, if you will). When it comes to architecture and especially to tectonics, it is again important to be aware of how we, for example, use Jonas Holst’s historical analysis (Holst 2019). Holst’s analysis could easily be used to argue for a kind ontological return to pre-modern mythology; however, his analysis holds more important considerations than simply this. By highlighting how with fetishism of the "Architect" (and diminishing of the *tekton*) we went from proto-ecological potential (respectively in those times) ways of thinking cycles to what we have to today in object-fixated architecture (not to be misunderstood as object-oriented), he shows that there were (potentially) moments of "modern" thought already within pre-modern, ancient practices which had disappeared with modern "efficiency". Instead of thinking how to return to some pre-modern ideal, the challenge is to be radically modern with new and accompanying knowledge, tools, sentiments etc.

Tectonics Without Architecture

As we have seen, architects and their theories are more and more disconnected from the actual facts of matter and building with their theories being to lesser or greater degree *suspended* in some meta-physical space (Benjamin 2007; Trubiano 2022) with the antidote seeming to be a return to theorizing on the act of building (Trubiano 2022). I would thus claim, despite the immense value of such writings, that new theory of building could risk of fetishizing the act of building into a sublime act in (in spite of the any given author/architect's intentions) and thus risk the maintenance of architecture within a linear growth paradigm. Perhaps the *suspension* could be of use, but should it be a material instead metaphysical suspension? Since architects don't actually build, but design/advise, could we instead theorize the act of *non-building* as well?

Just as material withdrawal is a material necessity, it is equally an artistic gesture of withdrawal. Based on the idea that the city could be a self-sufficient sink, a beautiful landfill, or a transformed geological crust which *happens* to be inhabitable, we not only need a different way of relating to nature but also society and the built environment. The city itself does not necessarily need to be constantly "renewed" (disassembled etc.) materially to be an adapting, ambiguous entity of multiplies. Rather, the city should first and foremost be conceived as something to maintained and kept "still". This could be done perhaps not only through "design for disassembly" and other material performances, but equally by carefully and meticulously designing usefulness and spaces with a imbued metabolic *sublime ambiguity* (this ambiguity will be explored in chapter 5, especially 5.1)..

Tectonics Without Architecture[14] is fundamentally an architectural heresy at least with regard to the capital-A architecture which I paint as being stuck within the growth paradigm. This notion is an architectural mirror of the Žižekian idea of *organ without body* (Žižek 2004; 2012) as Negation of the linear growth paradigm which essentially describes an entity which is a free floating, in its own right, and detached from its usual ideological presuppositions. This Negation is furthermore founded in a similar

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[14] This term was coined previously (Gusto 2019), but it was very tentative and speculative and needs further grounding and expansion.

sentiment of Timothy Morton's Ecology Without Nature (Morton 2007), who also elaborates an eco-critique of how our current preconceptions and ideological presuppositions of Nature (as an overly romanticized entity) maintain our current controlling and exploitative relations. It is not enough to simply say or write "ecology" to have it mean "ecology without nature" and thus make a deliberate distinction between the two. As with Morton's notion, to give more emphasis to Tectonics, one has to emphasize that tectonics should be "without architecture" without it meaning a return or re-enchantment of the mythic *techne.*

Just as Nature is imbued with ideological constructions, so too is the complex notion of Architecture. Architecture is not simply a modest building activity. Rather, it is almost an alchemical animistic entity which asserts itself for the apparent necessity of historical progression (linear "cultural continuity"). Architecture, especially when it is supposedly capital A architecture, is usually filled with ideological presuppositions and self-animated maxims which structure how we approach and understand design thinking and doing. As such, a once sublime idea of cultural continuity becomes an ideological justification or perpetuation of liner growth paradigm. Architecture with capital A keeps perpetuating new grand narratives, new modern and pre-modern myths, revived canonic narratives of progress. Tectonics does this as well with tectonic visions and poetic "tectonic" designs, but the radically critical instance within tectonic discourse is the "without architecture" tectonics. Tectonics is usually understood as the "poetics of making" (Beim 2004; pp. 47), but tectonics without architecture is the critical self-reflexivity, a concept initially introduced by Semper then radicalized by Hartoonian, and as a self-critical withdrawal from this kind of making. Tectonics is therefore not automatically "tectonics without architecture" as some of the old presuppositions remain in tectonic discourse, albeit in a tectonic *fashion* (honesty, truthiness etc.), as the presuppositions fundamentally remain within a growth-paradigm of the historicist inevitability of progress and the fetish of *the new*. It is a self-reflective instance where architects and designers are able to critically reflect our own roles in perpetuating material consumption. Even if it is not architects who directly move materials from nature to society, much of architectural theory, writings, critique, utopian experimentation opens up space for any agency in society to be caught by (architectural) narratives and desires of building and making. Architectural narratives (in any shape or form) facilitate and act as justification for perpetual material consumption, i.e, where this type of materials consumption basically acts as a guarantee for the need of more material consumption. Narratives of transgressions are very often fundamental to architectural creativity, in the sense of how a new design or theory breaks with the "old" doctrines, norms, and dogmas etc. While this can indeed be sympathetic, there is a danger within such transgressive discourses where grand gestures of subversion are sublimated (swallowed) within the hegemonic practice to the point of acting as yet another way to maintain current conditions or reinvigorate the existing growth dynamics (i.e., new built works using the same terminology and ideological thinking to justify new designs and ideas). Being subversive today is simply mainstream, and my wager is, to change anything in actual reality we will have to a assume an abstract meta-physical equivalent and jump out of this bad "circularity" that has been created to assume a kind of Negative Tectonics: Tectonics without Architecture.

Tectonics Without Architecture is thus a Negative artistic sentiment (in the Žižekian sense) of a way of relating through Negative contemplation and minimal material engagement. Fundamentally, this is all a testament to the fact that both material reality and our engagement with it or within it is one of finitude. This means that both our material precondition (finite reality, finite resources) and that our human Being is a finite being in the world where we cannot approach nor fully understand anything in to its full extent, necessitating a radical shift in attitude. Tectonics Without Architecture is not simply a position where one does not do anything. Rather, if we do not do anything, the predominant conditions will perpetuate or perhaps lead to some form of disaster. We *do* have to do something, but we must do something which, put in abstract terms, amounts to Nothing –not necessarily just in the immediate at hand level but also in the accumulated, meta-material level of material flows. We must invoke a culture of making which has little to no effect on the natural environment. Any attempt to particularize such an abstract universal idea risks failure and necessitates a slowness in our engagements. Spoken as plainly as possible, Tectonic Without Architecture is a design ethos where one critically facilitates everyday life with minimized material flows without any reference to some ideological injunctions of historical progress. Stand-alone Tectonics, in their etymological origins, means building as a verb (i.e. building more and more), whereas Tectonic Without Architecture indicates a Negation of growth activity. In the mental transition from Capital-A architecture to a Tectonics Without Architecture, we proceed from the growth-oriented building industry of "cultural continuity" (of individual creative drives) to a "cultural continuity" of each building persisting over several generations and centuries through care, maintenance, adaptation, flexibility, gentle and modest beautification, as a cross-historical collective effort – a building *culture*.

4.4.7. Boundary

This section will outline the theory: what immediate limitations and boundaries characterize the theory and its application and what ontological assumptions circumscribe it. The theory is limited to the dealings of the built environment with emphasis on material flows, albeit including immaterial considerations which influence these material flows. For this reason, two types of *materialisms* are of interest which circumscribe the (im)material metabolism: the *old* and the *new*. More precisely, it is a combined outline of firstly the chemical engineering and the scientific assumptions on reality and knowing and is akin to the old scientific materialism. Secondly, the materialism and realism of contemporary thinkers Slavoj Žižek and Graham Harman also ground the (im)material metabolism. Žižek is of importance as his theoretical elaborations help to outline the ideological (inner) dealings of the metabolism, while Harman's ontology provides the structuring principle of objects, which as per his *realist* approach allows for an integration with the science of industrial ecology (metabolism) as well as its sensibilities. The development of "boundaries" used the methods of *adding*, *connectin,g* and *adjusting* which are also used to link ideas of ontological significance.

The Built Environment

As a theoretical contribution in architecture, design planning, etc., my metabolism cannot be used as a substitute to all the already known methods, tools, and theory of those fields. It is an addition which can demand a repositioning regarding how we apply our known tools, in what way, and to what end. Furthermore, when as architects and designers, we find ourselves in the current circular agenda which incessantly tries to dissolve borders between society and nature, this theory can also provide some overview into the many confusing renditions of both. As material flow and metabolic concerns are already being evoked through LCA, and it will only increase toward a more rigid conceptualization of the built environment as a metabolism, this theory could act as a bridge for architects, engineers, and designers to better understand environmental sciences, chemical engineers as it provide nuances of terminology and conceptualization of slowing and narrowing instead of open-ended circularity. Another aspect to clarify it that this theory fundamentally does not subscribe to the now common conception that tectonics are only linked with carpentry, but tectonics is more generally concerned with that of the act of building and modesty. It is my opinion that tectonics, at least potentially, is an ontological conception of the act of building. Even though the initial Greek builder mainly dealt with wood, it was merely a question of what materials were being dealt with and what accompanying techniques etc., would be used.

The Scientific Materialism (Analytical Tradition)

Dealing with material flows from a scientific materialist view entails the the understanding of *metabolic* be founded on an empirical understanding of our material preconditions as done in the chemical engineering discipline and the field of industrial ecology. Even if the theoretical frame and its methodical approach uses a metaphorical notion (of the metabolism), there are core scientific notions of understanding which make assumptions about reality, i.e., input/output, mass balance, entropy (see chapter 4.1). Such an understanding assumes the existence of objects and treats them in mechanistic sense.

Another significant outline or limitation provided by industrial ecology is that of planetary carrying capacity (or boundaries, while metabolic studies use more the "capacities" terminology instead). These are not precisely the same as the best-known iteration of planetary boundaries as developed by Rockström et al. (2009). Conversely, metabolic studies approach such questions in the layered elaboration of sinks, regions, and bio-regions up to planetary limits and emphasize the fundamental role of "sinks" (Brunner, Kral, 2014; Kral et al 2019). While Rockström's (et al) key parameters are more of an "abstract" and universal concern (which can be difficult to apply at level of everyday life), industrial ecology provides an immediate practical proposal for how to enact "planetary boundary thinking" in metabolic ways (by

confining living in the cities with regional limits first and foremost). As Semper mentions, architecture is an extension of nature, or a sublime repetition of it. What could that mean without it meaning yet another edifice of "organic" growth?
Given that industrial ecology ultimately deals with metabolic considerations of sinks and flows of a given system boundaries, the outermost boundary is that of the planet. Followingly, it is possible to choose any physical and spatial boundary (a country, region, city, districts or building, technology etc.). Thus, when dealing with (im)material metabolism, whether in instances of designing or analyzing, it is crucial where you put the system boundary because as such, it allows or necessitate that you either only design/analyze a single building or also include to lesser or greater degree the surrounding areas (context) and their material and immaterial conditions (whether they be micro and macroclimatic, material flows, phenomenological characteristics etc.).

Given the fact of reality which is entropy, systems and materials ultimately fail at achieving full circularity, and we have to accept flows are forever linear. The quest is to slow these inevitable linear flows through multitude of sub-strategies by narrowing (limiting amount of material required) and circulating (through various ways of reuse, recycle, waste preventions etc.). Much can achieved by way of the circular economy strategies, LCA calculations or other designations (LEED, BREEAM, DGNB). Nontheless, if the there is no impact on the predicted increase in material consumption (European Commission 2021), and it merely perpetuates the same material flows, then it is not a slow *metabolic* design.

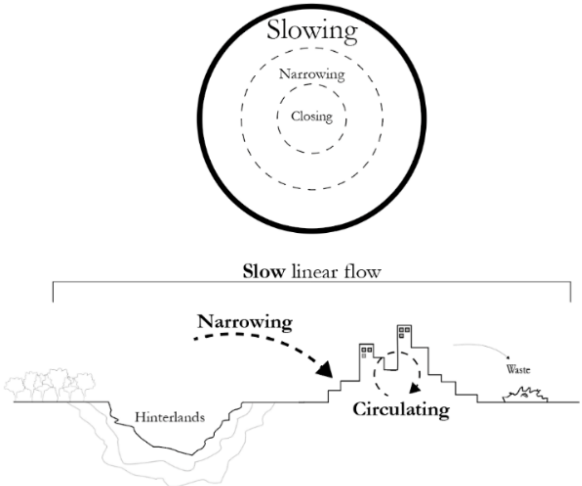


Figure 88. Slowing as the all-encompassing strategy (with narrowing and closing as sub-strategies) since flows are ultimately always linear.

The Meta-Physical Materialism (Continental Tradition)

The (im)material metabolism is not just a *materialist* position. While it is of great necessity to minimize material flows, the meta-physical (immaterial) aspects likewise hold much significance to that end due to the fact that materials do not move themselves (animism is an ideological construction nevertheless) and it is people (i.e. social, cultural, economic and political aspects) which cause the movements.

Is reality a social construction (nature included) (Castree 2013) or should all aspects of realty be included in the social realm and constructed to a scientific (what Harman would designate as *overmining* versus *undermining* (Harman 2018))? If we answer no to both of these questions, a particular kind of ontological positioning should permit us to approach reality in its hybrid constellations. As with Semper, and the notion of the builder or *tekton* (and not the archi-tect), ontologically speaking this theory is ontologically open, and for the very same reason is also open epistemologically, methodologically, and methodically. The fact that the theory is ontologically open means that it does not evoke some teleological narrative of progress and growth which inevitably causes its own necessity. In ontological concerns, this (Im)material theory positions itself along the lines of Graham Harman and Slavoj Žižek. Even though their ontological positions differ, they share some similarities in practical terms. Harman conceives of reality being withdrawn and impenetrable while Žižek claims that it is open and contingent (unfinished). Regarding epistemological concerns, there is need of multi-epistemological approach to approach the challenges of material flows. This means that in acquiring empirical data on the five constructs and their relations would require a spread of epistemological position to reify the five constructs in relevant ways towards either design goals or analytic objectives. We could imagine how instead of personal phenomenological analysis the same case could be used to conduct a neuro-architectural analysis of how brain mechanics perceive the rooms. Methodologically, it can help to position a design or analysis and help structure specific methods of inquiry in the quest to map or design the five constructs and relations.

More precisely regarding the ontological considerations of the (im)material metabolism, and similar to an early speculative text (Usto 2020), Harman's quadruple structure of real and sensual objects provides the core structural build-up, while Žižek's contribution is that of Negativity. Specifically, attaining a kind of impassive ontological position towards reality and its phenomena which does not immediately urge to change, manipulation, or mastering it as it were. There is likewise eco-philosophical justification in the choices of Žižek, and especially Harman, as arguments are made for the usefulness of thinking objects as separate and conceiving nature as an entity of "non-identity" (Görg 2011, pp.49; Saito 2022, pp.109-110). This thus has similarities in the *indeterminate* and *contingent* natures of Harman and Žižek's ontologies, respectively.

The prominent contemporary eco-philosopher, Timothy Morton, develops ideas of how aesthetics, art, and beauty need to play an important role in the current predicament. The key continental philosophical outline of this doctoral study is that the problem of material consumption in many ways lies outside of material concerns as such. This leaves the challenge of aestheticizing the material impassivity as an eco-ontological way of artistic-being within society and nature simultaneously. In the end, this would or could have the desired outcome in societal-nature relations. Thus, we continue to develop the Negative form of thinking in positioning the endeavors of this doctoral study. But what exactly does this mean in relation to ontology and epistemology? Specifically, how do we construct an understanding of what reality is? Further, how dowe understand it, and what are the limits of our knowledge are in relation to it?

Nature and reality at large is ontological in an open entity and is an imbalanced entity which has no original natural balance to which we can return. Just as reality is an open, indeterminate category, so too is the epistemological approach to it. The (im)material metabolism necessitate and relies on the critical (towards slowing and narrowing of material flows) by mobilizing both idealistic materialist eco-philosophical epistemologies as well the hard-science mechanistic construing of realty, as long as it is a non-opportunistic worldview (Weltanschauung) which aims to slow (or in other words de-grow) material consumption.

The 'Hybrid' Object (...still the Meta-Physical Materialism)

As we are dealing a hybrid metabolism of both very different objects, and a hybrid metabolism that includes material and immaterial aspects, it is also important to outline what kind of *hybrid* metabolism the metabolism is. While generally speaking, *New Materialism* sees it pertinent to conceive of relational dynamics and processes and does not ultimately acknowledge the existence of object or even individuals (Benson 2019) who encapsulates Graham Harman's variant of object-oriented ontology into *new materialism* philosophical discourse, but there is a slight nuance to be aware of.

Figure 89. Do Things exist, or are relational processes all there is?

Graham Harman outlines similarities with *new materialism* but at the same time distinguishes and differentiates OOO from the epistemological an ontological construction of new materialism and designates it as Speculative realism (Harman 2018). The key ontological distinction is that Harman conceives of the importance of constituting objects and things and recognizing that not all is simply an intertwined chaotic muck of social constructions where everything is relativizes and de-substantialized. While one must accept that there is vast empirical wealth within materialism and immaterial reality in the form of complexity, antinomic relations and conditions, and contradictions, when it comes to questions of sustainability through the metabolic lens of material flows, certain patterns reveal themselves because some objects cause certain effects when compared to others. Phenomena can be designated as objects regardless of whether they are actual material things or processes and very often they are both at the same time. Incidentally, almost in an extension of the above considerations, eco-critical literature on "social metabolism" insists on the seemingly "conventional" dualism of society-nature divide (Saito 2022, pp. 103), and the same scholar also have argued against a ontological "monism" (relativized epistemology of all is one) where nature does not exist (Castree 2013, pp.177) and thus argues for the insistence of the dualism of society-nature.

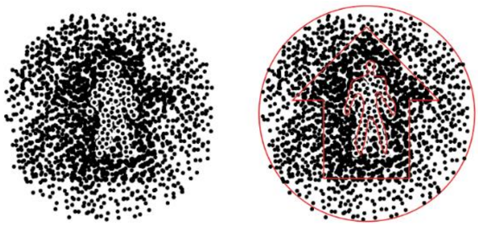


Figure 90. Object-oriented Ontology nevertheless acknowledged the potentials of constituting objects/things.

Thus, the type of *hybrid* relevant to consider, is one where immense wealth of reality (dynamic fluxes and processes) is included and conceived as asymmetrical relations where society is contained within nature. These relations also certainly overlap and between the two extremes many different ontologically unclear hybrids can be constructed. As there are significant patterns of material flows at each end of the said flows, it is of use to conceive of them as objects/things but envision new relations between them. The metabolism is not a metabolism qua its own efficacy – that would the ideology of animism – but it is a metabolism qua human agency and is thus a hybrid object. Whereas the single human has its own agency, the metabolic approach implicates a collective understanding and collective agency. If not for the collective understanding, the *metabolic* approach would only be yet another style or dogma which would merely concern itself with exploring the formal-aesthetic potentials of new styles of the *metabolic* shift.

Drive and Desire of the Metabolism (…still the Meta-Physical Materialism)

Since we are dealing with a (dynamic) metabolism, what is *that* which animates the metabolism? While there are many such "animators", since the built environment necessarily pulls into itself and has consequences for many other disciplines, in the architectural sense the fundamental dimension of architectural creativity is key. Even Semper's theory has a fundamental impetus in the observation (of his time) that architectural creativity has run amok and that in the guise of the initial modernization and industrialization challenges, architecture has become flat, meaningless and vulgar in its creative unfolding. While one can agree or disagree with such statements, is it possible to elaborate something more general about creativity? Žižek elaborates on the more fundamental notions (a priori) which condition us towards creativity: the expansion on the notions of Drive and Desire (Žižek 2012, pp. 205-207) for whom the drive is a philosophical idea. We are familiar with it in architectural and art theory as the variant of Kunstwollen from Alois Rigel (a Will to/for Art or making) (Mallgrave 1996, pp.379). which was also inherent to Semper's own metabolism.

Here we attempt to translate the philosophical notion of Drive and Desire into architecture. Drive is the "lower" vitality, the *material* energy which animates – a kind of "material" a priori (a material vibrancy even) which conditions the architects towards a creative inclination. A vector if you will which satisfies immediate material needs (shelter etc.). Desire – or *objet a* – on the other hand becomes the set of theoretical (desiring) coordinates which can provide direction to that drive-inclination. The Drive, or the urge or will to simply create, is prior to what and how to make something. A desire (or even theory as such) is a way in which the Drive is given a realm for unfolding, that which provides a surplus-value beyond any immediate utilitarian aspect (e.g., "honesty", "truth" in design, historical animism, narratives of legacy or the sublime idea of cultural continuity etc.). As such, a common way the *objet a* manifests in everyday life is through narrative and storytelling (of sublime ideas objects), and thus, what stories we tell, how we word them can have significant consequences.

While such a Drive can be difficult to make empirical and clearly discernable, the drive of creativity is simply the on-going, *un-dead*, formless, creative *hysteria* which keeps iterating and experimenting shapes and designs apart from any immediate necessity or problem-solving. A kind of disconnected blind mechanism which is creative forever. A kind of primordial condition which propels forward motion and cannot sit still. It can also be described as the pleasure of thinking and designing deeply on architectural conundrums where explorations are made before even knowing what problems are being solved and where to apply it. As mentioned earlier (in 4.3.6. Logics), such a force is ambiguous and can be as equally destructive as creative.

Given the fact that the metabolism of interest is one which is human-driven, the building industry contains many disciplines, agents, and actors with differing agendas. Some of these agents are creative, while some are monetary. Regardless, there are different "wills" that animate the creation and production of the built environments and thus the material consumption. At times, these drivers are even beyond any actual reference to cause and effect (demand for housing among people etc.) and simply cause themselves to be perpetually in profit seeking within the growth paradigm. In exemplifying this, we see differing percentages of newly built buildings which are simply empty and, in more extreme cases, so-called ghost towns (Wang et al 2019). These ghost towns can be found in different countries and on continents. They were built, never finished, and never inhabited as intended. Here a self-feeding circular loop can be observed. The question then is does the creative Will manifest the growth paradigm, or does the growth paradigm create and/or amplify the creative Will? Regardless of this tautology, the creative Will, I claim, partakes in situating the current metabolic exchanges in the growth paradigm. As much of today's radical ecological theory proclaims, we will need to shift not to "green growth" but "degrowth." The degrowth agenda is radical antithesis to the current growth-paradigm and situates itself in diametrical opposition to the current tendencies of material input linked to profit growth. When it comes to the economic aspect, the challenge is conceptually to decouple material input from economic growth and understanding of life quality (Ferguson 2018; Jackson 2019; Schmelzer et al 2020). There are of course many challenges in this regard, and if a noticeable shift in material flows will not be immediately observable, society needs create more awareness to arrive at that shift and become more critically introspective of the norms and behaviors that keep us connected to the "growth" (and thus consumption) paradigm of today. As society at large is quested with this, architecture and design professions likewise need to attain such a critical introspective dissection of our ideological presuppositions which has us firmly planted in the current growth/consumption paradigm. Since we know that built environment is a human-induced metabolism, it is crucial to consider and question why architects/engineers or any other professional within the built environment are so "naively" convinced that our problem-solving approaches is inherently "good". This technocratic optimism and opportunism (Saito 2022, pp 34), which conceives that more technology is the solutions, requires reconsideration.

Eco-philosophy (…still the Meta-Physical Materialism)

Since objects (Things) do indeed seem to hold certain gravitas ontologically, what could it mean to "appreciate" things and objects in ecologically relevant and pertinent ways? Literature on ecology and politics highlights that modern “instrumental reasoning” lacks reflection which ignores the non-identity of nature and only reduces it to a tool to be controlled and exploited (Saito 2022, pp. 113). If we can never attain full scientific knowledge of a thing (despite intellectual cognition having its obvious advantages) perhaps an aesthetic way of knowing can also have its efficacy. Eco-philosophy is becoming more and more prominent (also in metabolic studies Bourg, Erkman 2003) and is perhaps best epitomized by the leading thinker Timothy Morton (Morton 2007; Morton 2018), whose ideas have roots in ontological orientations developed by Graham Harman (Harman 2018, pp:59-103). As elaborated in the chapter 3, aesthetics (aesthetic cognition) is a way of knowing differences in intellectual knowledge/cognition (Harman 2018). Aesthetics is not however simply to be dismissed as a kind of reactionary return to tradition, as mostly classical aesthetics are imbued with growth ideology. Morton sees immense potential in aesthetic *knowing* for ecological Being within the world (Morton 2018, pp:178), and the potential lies in the opportunity to construct an artistic edifice of *being-ecological* in which you do not require more new “green” technologies or more and more knowledge and tools because there is a paradoxical causality between our intentions (with new technologies etc.) and their ultimate material consequences which is entirely in our control. Phenomenology in architecture often elaborates the importance of phenomena and their haptic richness (Husserl’s phenomenology). However, as both Harman and Žižek emphasize, the Heideggerian phenomenological has much more important and critical realization in terms of appearance, revealing and the *Unhintergebar*. Such a notion is the insistence on questioning why phenomena appear as they do regardless of their immediate phenomenal richness (in texture and materiality and all forms of heterogeneity and so on) as one may be tricked by this richness and fail to see the “true” being behind it. Why do the phenomena appear as such? What are the behind-mechanisms that make these phenomena appear (a Thing-in-Itself)? Heidegger furthermore simply acknowledges this deadlock of the transcendental horizon and that it is ultimately hard to say anything of substance with regard to the transcendental. Žižek, Harman, and Heidegger thus advocate for critical understanding of not merely embedding oneself into the “richness” of the appearance of material/immaterial phenomena, since they can be quite problematic and deceiving. Rather, these authors suggest a critical approach of this understanding. More importantly, since reality is an impenetrable/indeterminate entity where, as Žižek would put it, you enact a change onto/in reality, and it reacts paradoxically in ways we could not have predicted. The commonsense “cause and effect” cannot be used to explain or predict such consequences (Jevon’s paradox par excellence). This does not mean that we should simply keep doing everything we can to our physical surroundings (natural and built) until we can “fix it”. Ontologically, however, the impenetrability of reality (the inability to fully predict any application of a technology and future consequences) requires a seriousness and slowing down of one’s activities as well as a withdrawn and highly considerate approach to any activity. This ontological position does not implicitly require an overly humanist or mechanistic understanding of reality as both can be mobilized with good intention. It is thus more important to a worldview which is more delicate, meticulous, modest and respectful within both ontological positions and the minimization of opportunism.

Closing Statement on Boundaries

So what does all of this have to do with the Urban Sink? The idea is to be able to differentiate between Things. Not all buildings are the same, especially when it comes to material flows. Some building stock acts as a safe storage for materials to a greater degree qua both material and immaterial properties, while others do not. Moreover, reality is not a relativized process-network even if may appear so. Through relations of the constructs, it is possible to differentiate the building stock where particular relational structures permit or show a pattern of less material flows thus allowing for the designation of those sets of relations as the object, i.e., Urban Sink. While those buildings/works can appear similar (size, typology, style even etc.) a unique constellation between five constructs can turn out to have unique effects in the metabolic sense.

The metabolic position necessitates a stance that we should be able to think a kind of spiritual *end of history* for architecture. The almost “organic” (or inborn) assumption that there will always be need for more new buildings (along with new concepts, new aesthetics qua play and experiments with new technologies etc.) should be seriously reconsidered and/or dismantled with regard to how we mobilize our creative cunningness in the relationship between the built and natural environment. In such a societal constellation, art and aesthetics could have a central performativity in the maintaining of the ecological way of Being in the world.

4.4.8. Descriptive and Prescriptive (analysis and design)

Similar to the dual nature of both industrial ecology and tectonic metabolism of being simultaneously descriptive and prescriptive, so too is the theory of the (im)material metabolism. In general terms, the fact that the theory is prescriptive does not make it a method as such. Rather, it can be mobilized as a methodological framework which is further guided by specific methods. This can be compared to the applications of Bruno Latour’s A.N.T. (Latour 2005) which as a framework requires additional methods and tools in either the design of a piece of architecture or any phenomenon or its analysis.

The overall usability is that of a starting point in the architecture and design field. If architecture students, researchers, or even practitioners were to analyze a piece of design or architecture, 5 fundamental points of attack would be necessitated (although these fundamental points can further be expanded given specific situations). Each of the 5 points may either need separate methods and tools of inquiry, or some can be covered by multiple methods/tools at once. The overall purpose is to situate architectural design within a metabolic agenda with the full knowledge that the architectural ideological implications and discourse at large therefore makes it necessary to compare what is said and what is done and the material consequences of both in whatever capacity it is possible and relevant to the problem and questions at

hand.
The same dimension is of great necessity when having to design. While it can more difficult as architecture to-be-built does not have embodied history, it can generally be difficult to explain the relations between the immaterial and material conditions as per the consequence of material flows. This could be through a more nuanced risk assessment (as to include immaterial properties and potentials), and in general by approaching design with much greater modesty with regarding materials thus acquiring a much greater understanding of what kind of designs are sustainable and which are merely “green washing”.

Finally, analysis and design, i.e., the descriptive and prescriptive capacities of the (im)material metabolism, are to be considered as joint or inherent to a metabolic thinking of the built environment. As (im)material metabolism emphasizes the ability to do nothing as an active measure, analysis can be considered a mode of practice or “negative” design action because analysis can provide insights as to when one should *not build* etc. (an active non-activity).

4.5. Conclusion

The chapter starts with the state-of-the-art respectively on industrial ecology and tectonic metabolism. It does so as a prolegomenon to the theory building effort, which deconstructs the two theories in relation to the 4 main building elements of a theory (construct, relations, logic, boundary). The chapter then proceeds to building theory by using the same 4 main elements. The initial aspect of metaphor usage, which works as a way to mutually include the metabolism of tectonics and the metabolism of industrial ecology, the metaphor obviously being “metabolism”. Followingly, the notion of the sink is centralized as a key concept. The sink is then deconstructed into 5 main constructs which interrelate in differing ways but have cross-related nature. Theory is constructed by mobilizing logical argumentation to form the synthesis of the metaphor of metabolism, t sink and both “external” logics and assumptive boundaries of the theory.

Constructs	*Relations*	*Logic*	*Boundary*
Material *Structural Principle* *Use* *Phenomenology* *Narrative*	*Society-Nature* *Interconnectivity* *(Hierarchies differ)*	*Metaphor* *Temporality* *Philotechne* *Inter-dis-connectedness* *T. Wo. A.*	*Built evnrionment* *Scientific Materialism* *Meta-Physical Materialism*

Figure 91. An overview of the (im)material metabolism.

While many theories highlight their construct and relations, the logic and the boundaries are often left implicit. This theory building effort thus focuses on explicitly highlighting all 4 aspects of a theory, and thus intertwines the “boundary” setting of environmental concerns and preconditions within the constructs with “Material Flows” and “Narrative” as vessels for mapping the material consequences of human activity in the built environment and the ideological presuppositions that maintains the discipline in the still expanding growth paradigm. So, what kind of theory is it?

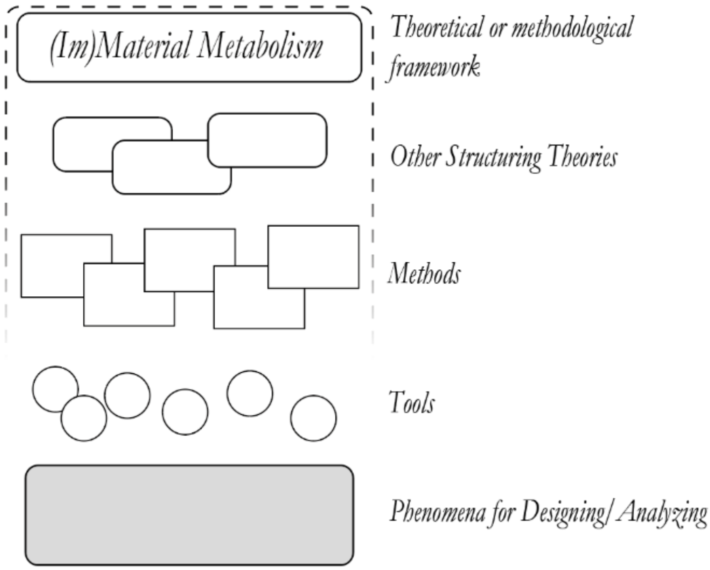
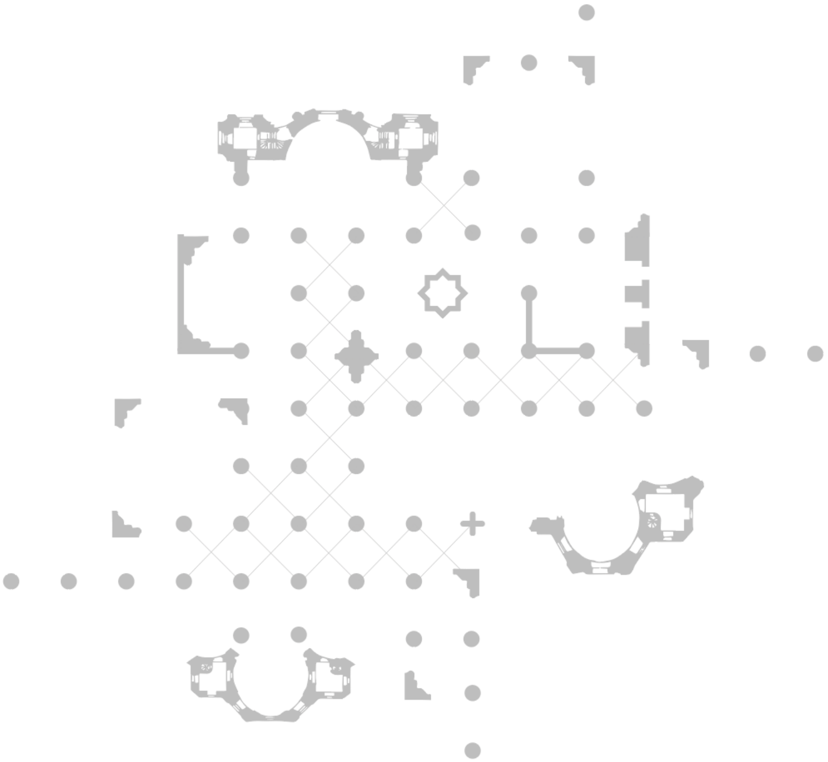


Figure 92. Placing the theory.

The theory is certainly not one which can replace all other theories or methods but acts more as supplementary “layer” () which could potentially permeate other layers and allow one’s own known and oft-used theories, methods, and tools to potentially attain a metabolic dimension. It does so by already containing some complex aspects of ontological and epistemological considerations, as well as questions of *Worldview* which are ecologically pertinent to consider. It likewise insists on juxtaposing the five key constructs of the theory as there can be both significance in their particular constellations regarding the slowing of material flows or an instance of a certain story being told (of sustainability) while the material manifestations shows something entirely different (increased consumption either in immediate context or allocated elsewhere).



Chapter 5.
Testing Theory: Analysis

This section will elaborate on the first round of attempts to test theory by applying the theory for analytical purposes. Referring back to Research Question 2, after an initial building of the theory, it is crucial to attempt an application of said theory to explore what kinds of new insights and potentials a tectonic theory which is fused with metabolic understanding could provide.

The very first instance of theory testing occurred in a published paper, paper 1 (Usto et al, 2022). This chapter will reference this paper, build further upon considerations and findings, and open further pertinent discussion on the case study conducted in the paper. While the case study was an analysis on specific cases, their juxtaposition allows for discussion of generalizable observations which will be further explored in the expanded analysis (5.3). This constitutes an attempt to open the analytic capacities by comparing other relevant tendencies and efforts (*anachronistic analysis*) which are relevant for a metabolic perspective even though these efforts are not explicitly metabolic and furthermore leads to an application of the theory as *metabolic-critique* based on discrepancies observed both in the case study and anachronistic analysis.

5.1. (Im)material Metabolism in Analysis

In the application of the theory, case study methodology is used as it is a well- known foundation for theory building purposes (George, Bennet 2005). Given the many considerations in current theory and practice which seem to heavily favor material concerns, this case study tries to explore how immaterial considerations can influence material consumption and flows. In the application of the theory and its analytical capacities, the endeavor to test the theory mobilized a case study methodology as case study is a very broad approach which can be used in many sciences, fields, and professions. Comparatively, when industrial ecology (metabolism) experts or consultants also conduct an analysis of a city, country, or forest, it is also considered a case study of a particular system boundary – albeit one which requires its own and appropriate supplementary method, tools to acquire data and knowledge of the different set of data needs. Similarly, as social sciences could use Bruno Latour's ANT framework to guide a case study (to acquire data on multiple actants of perhaps both material and immaterial constructs), so too is this case study guided by the theory development developed in chapter 4. In this case, it is an embedded (non-holistic) multiple case study as the focus on the five constructs of interest. In proceeding to apply the theory, there is need of inquiry of five main points across three cases. It is thus of interest to explore those five points (constructs) and followingly map their relations (through a mixed method approach) in order to discuss how and to what extent (constitutive) immaterial considering can affect material flows and consumption. Following the case study, the analytical capacities of the theory are also explored as anachronistic analysis and critique.

5.2. A Study of Multiple Cases

The chosen cases (Usto et al 2022) are three low-dense housing cases located in Denmark in different cities. Case A is a housing settlement which has been located in Hellebæk from 1978 and was designed by Bente Aude and Boje Lundgaard. (Aude, Lundgaard 1975) Case B is located in Amager and was both designed and built by Fællestegnestuen in 1975 (Holmberg 1979). Case C was (in its first iteration) built in 1966 and is located in Aalborg. It was designed by Jacob Blegvad and Arne Kjær (Arkitekten 1965).

Figure 93. Three cases: A. Sjølundsparken (left), B. FlexiBo (middle), C. ConBox (right). Courtesy of "Styrelsen for Dataforsyning og Effektivisering" (SDFE)).

The following analysis will rely upon and reference the findings of the paper (Usto et al 2022). This analysis is not structured like the original paper (by the case A through C) but instead structured by the five constructs (with crucial considerations on the cases within each). Compared to the paper, this chapter will add further layers such as elaborations of each construct, historic backdrop, further critical reflections, and an exploration of a concluding hypothesis with an expanded scope compared to the original paper.

5.2.1. Situating the Cases

The cases are built in separate decades: mid/late 60'ies to mid/late 70'ies. While differences can be observed during this time period, the building culture, and tendencies both globally and in Denmark at that time differ quite a bit from today. Even so, some predominant traits can still be seen. The international influence today was from the time period of these iterations. Specifically, frin 1960-1970 the

predominant influences were still modernist to a large degree and were coupled with the evolving tendencies of brutalism and biological, organic approaches like the Japanese Metabolists and Archi gram (Nygaard 1984, pp:188). The building industry at the time was not as concerned with sustainable and ecological concerns as we are today (even though oil-crisis in the 1970's required some adaption). The building industry was to a large degree marked by lack of housing and during this time period ('60-'70's) a building boom was imminent (Nygaard 1984, pp:13).
Regardless of the circumstances, the chosen cases in the current PhD study, whose architectural styles are seemingly comparable to today's styles and have existed for several decades, permit us to observe how these styles have fared in terms of renovation/demolition etc., in relation to the architectural character.

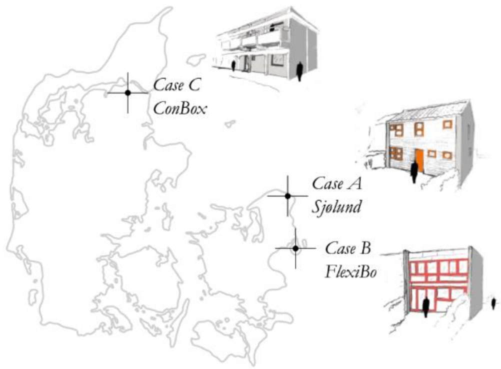


Figure 94.Geographical locations of cases in Denmark.

Considerations regarding the choices
In applying the theory through a case study, some background is needed. As the whole of the building stock is very diverse: different area, materials, typology, program, and function. Generally, there can be challenges in mapping the building stock, but we can at least rely on the general data on materials flows (i.e. the national statistics etc.). Ideally it would be interesting to differentiate all of the building stock (and not rely on average data sets); however, for practical reasons there is need to limit the scope of the case study. It is thus important to start differentiating the building stock both in terms of function (typology and size). It is important to acknowledge the differences within these very categories and to discern material flow differences within them. A significant amount of material flows within the building sector are caused by the housing segment as this is one of the largest segments of all the building stock (IRP 2020; EU Factsheet 2021).
Knowing that housing would be an important segment to focus on, it became from then on difficult in both finding and choosing good cases as there is a great number of housing types/sizes etc.. Given that we in architectural design and theory have put significant emphasis on circularity and that being translated in praxis as "design for disassembly", this case study aimed at comparing a set of cases which have

significantly different architectural character and manufacturing techniques. The aim was to compare cases which would have some similarities to today's "circular" thinking along with more conventional manufacturing techniques. The 3 chosen cases have been chosen to demonstrate this variation: one being very conventional (Sjølund), one being proto-DfD and/or OPEN building concept (FlexiBo), and the last having the most complex manufacturing of whole spatial modules to be clicked-on (ConBox). Another consideration was also to choose a high-density building typology, and even though the chosen instances are categorized in this regard as low-dense, it would also have been interesting to choose larger, multistory housing projects. This turned out to be difficult, as it was a challenge to find multi-story buildings with such variation in manufacturing techniques. For this reason, the chosen cases were in the low-dense category. Another important consideration was the choosing of *modern* buildings. Old, classical building are today usually well-persevered (although that was not always the case (Bendsen, Morgen 2018)). The challenge of today, as demonstrated by Till & Schneider (2005) and Cairns & Jacobs (2014), is to also find discrete ways in which modern buildings could also become cultural heritage or in any case be more persevered and not so easily demolished in order to minimize excessive material consumption.
The respective cases demonstrate three significantly different starting point or "designer-drivers." In extension of the key differences in manufacturing techniques, there is also a vague assumption that the three different cases had three different design-drivers (Figure 95) which also influenced the choice of cases. Specifically, case A was assumed to be mainly driven by phenomenological considerations while case B was assumed to be mainly driven by functional considerations, and case c assumed to be driven by technological innovation.

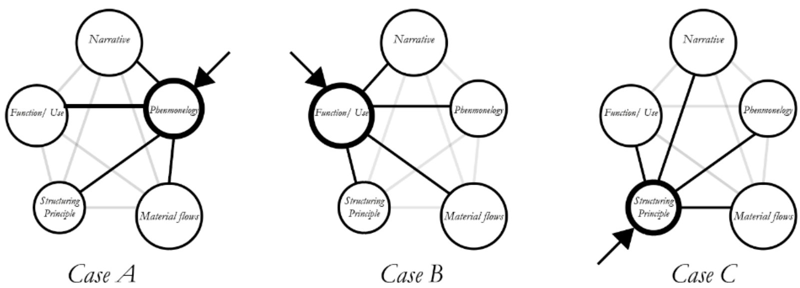


Figure 95. The three cases and their assumed "design-drivers."

When we observed the building stock from an architectural point of view, there was an increased complexity in mapping the *immaterial* aspects in additional to mapping ontic material flowsin in order to ascertain how the *immaterial* considerations could influence the material flows. As the Danish ministry of environment reports, the main strategy for minimizing material flows and waste is the "prevention of waste generation" (Miljøministeriet 2021, pp: 25). In architecture, this does not only apply as material strategies but requires an inclusion of (immaterial) architectural character and the experiential value as well. Architects have perhaps for many decades assumed that "good" architecture is already sustainable because it has a permanence if it is made well (meaning acting as safe sink for materials by the virtue of its architectural characteristics), but can we somehow discern this assumption and further nuance it?

5.2.2. Cases through the Constructs

In this section, the five constructs will be elaborated. We will also consider how they relate as to finally consider how these conditions could have had influence or consequence for material flows. As it written, the following paragraphs are based upon an already published paper (by the author of this PhD study and co-authors). Given the format of the paper, only so much can be included in the findings of said paper. The juxtaposition of the three cases across the five constructs allowed for many considerations between the time of the original writing (Usto et al 2022) and publishing of the above-mentioned paper. These considerations will be further explored here. Another important addition in these paragraphs is that the explorations will be done on a construct-based chronology and not one case at a time (which the published paper did). While the paper was a stand-alone entity, the monography is concerned more with the theoretical constructs (as these were being applied and tested) which was the reason for this adjustment.

Though the paper (paper 1) has a different structure in relation to the chronology of the constructs (spectrum from material to immaterial), this chapter will reverse the original chronology of the paper, and start from "narrative" and go downwards to the material conditions. The reason for this reversal is for communicative as well as explorative reasons of potentially discerning if what is said and/or intended corelates with what is built.

Furthermore, some key considerations from the original paper will be included and expanded upon, while some will be highlighted and reflected upon for their *metabolic* potentials, as not all findings in the original paper prompt crucial critical reflections nor provide important lessons for *metabolic* understanding of the built environment.

Narrative

The "narrative" dimension of the three cases was largely held to the way it appeared outwards based on the availability of literature and writing that had any indication of such (Usto et al 2022). Case A is a liked building (Nygaard 1984) to the point of being labeled an architectural "pearl" (Usto et al 2022). Case B was to lesser degree known and did not have social "footprint" of being known and liked in the same capacity as the case A – though it later has been re-actualized through its modular living concept

(Beim et al. 2012). Case C was initially subject to skepticism even before being fully built (Arkitekten 1965) and was likewise later subject to criticism due to lack of spatial character (Nygaard 1984). These considerations were the basic outline of the "narrative" dimension of the case study in paper 1 (Usto et al 2022). Many other aspects could have certainly been included as well.

An important thing to include would be to consider the narratives that initiated the architectural production. That is not to say that these were the reasons someone wanted to build something there as there are of course a priori conditions of capital intentions, market conditions and demographics which necessitate the building activity at these places. Rather, this aspect concerns itself with the driving narratives (intentions) of the designers. These differ in the three cases. Sjølund (case A) case can be said to be drive by phenomenological consideration of highlighting the characteristics of site conditions and in particular the existing flora along with nearby sea and lake on site (Figure 96) (Aude & Lundgaard 1975, pp. 3). However it also included modest considerations on "flexibility" (ibid, pp.4) which used simple technical solutions and "familiar" materials such wood and clay (ibid., pp. 6) whose "warmth" plays into the feeling of the spaces as well. FlexiBo (case B) was initiated with significant considerations for use and flexibility (Holmberg 1979, pp. 4). The architects also considered user participation in the development of the project but drawing on earlier experiences, this can prove difficult to properly implement (ibid.). The architects thus proposed flexible solutions which had initial enthusiasm (ibid, pp. 5) but was later shown to be mainly used when people move out and others move in (Beim et al. 2012). The ConBox (C) has an impetus on being an innovation modular manufacturing system. Particularly, the hope was to invent a system which could used for very different functions: housing, institutional and hotel facilities "and more" which would have a "high level of rationalization" by having most components manufactured off-site (Arkitekten 1965). This level of ambition is noteworthy.

The third level to consider, is how narrative of the architecture permeates into society. This particular dimension can be difficult to discern and handle, but there are indications of it even if we cannot detect social narratives of three cases in their entirety. When it comes to the case of Sjølund, it is already an area that people tend to associate to in a positive manner in Danish society (Hellebæk being a quite attractive place to live). By extension, the Sjølund case situates itself and further embeds into the preexisting attractiveness of this area in a beautiful fashion. It can be generally hypothesized (and potentially further explored) that the Sjølund case can be considered the high-end upper-class example. FlexiBo can be considered a middle-class example, and ConBox a middle to lower-class example. Perhaps the biggest contrast would be that of Sjølund being a "nice" (possibly an upper middleclass) neighborhood while the ConBox housing settlement is a modernist complex next to a busy road and industry (see Figure 96). Geography, landscape and topography are not created equal, so to speak, and some places are simply more attractive than others - though architecture can have a gravitas on its own in to create a sense of place despite lacking lakes and forest (like the Sjølund case has).

Experiential Conditions - phenomenology

The three mentioned cases also demonstrate differing experiential conditions and characteristics. Although the original paper the explored experiential characteristics, these were limited to including the body of the building only (Usto et al 2022), the case of Sjølund qua its structural system emphasized a spatial "embrace" between two main shear walls (Usto et al 2022). The case of FlexiBo has a similar structural system (shear wall) but the emphasis is on the interior as the external effect of shear wall is diminished compared to the Sjølund gesture (Usto et al. 2022). FlexiBo, given its heavy and characteristic presence of wooden beams (which service the technical-flexible purpose) dominates visually as a "covering" gesture in the interior. Regarding Conbox case, as has already been revealed, the spatial qualities were put into question very early (Arkitekten 1965) which prompted a kind of cell-like dwelling and not in any positive sense (Usto et al 2022).

Figure 96. Case A. Sjølund (top left), Case B. FlexiBo (op rigth), Case C.ConBox (bottom) Courtesy of "Styrelsen for Dataforsyning og Effektivisering" (SDFE)).

While the initial paper focused on the body, in this expanded elaboration, site conditions will also be considered as these also influence the experience of the place. The prior conditions of both the characteristics of the place and some of the narrative structures of the cases' reputations in society also influence the experience of them.

In the case of Sjølund, the overall phenomenological reading is that the housing bodies seemingly arise almost as terrain elements into architectural form for inhabitation, and that the structural shear wall system has an embrace phenomenological gesture (ibid).

The simple shear wall principle is "shifting" over the whole site, and this shifting principle partakes in constituting of an experiential embeddedness into the site conditions. Embedded and surroundings of the forest, lake and sea, the site is already unique and carries a lot of experiential qualities on its own. As the authors of the project folder and the design, the place had a very strong character, and the placing of the houses was done to commemorate and emphasize this (Aude & Lundgaard 1975).

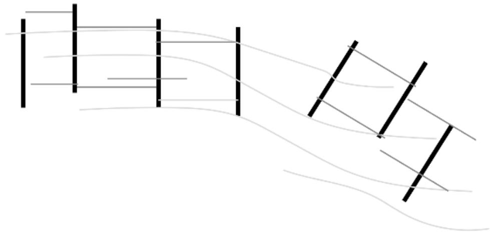


Figure 97. Case A: the shear walls are subject to a shifting principle in relation to site conditions. Though elaborated in the experiential construct, they belong in the construct of the structuring principle.

In the case of FlexiBo, the conditions are more withdrawn and conventional to the time and place of the suburban setting of Amager. The contextual conditions are not as noticeable as in the case of Sjølund. Given the fact that a road nearby is adjacent with the building in a long straight line, so too is the housing body on this flat terrain and low structures in the nearby vicinity. The site is very long, and the composition of the building are made to create a small interior "street" which connects the buildings through a walkable boulevard.
In the case of ConBox, the housing area is placed close to a highly busy road. The site is very long, and the placing of the buildings does little to embrace and create a sense of place via their composition and arrangement on the site.

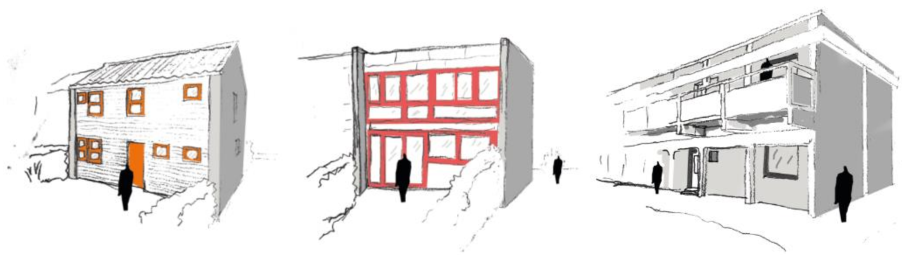


Figure 98. The three cases (respectively A,B, and C) and their characteristic expressions.

In the case of Sjølund as an "positive" outlier, the houses are row houses which have a seemingly clear definition of each unit by the heavy sheer walls (Usto et al 2022).

These indicate individuality and a feeling of home within a dense and vibrant natural area as the units are arranged in a dynamic way given the terrains, water etc. In the case of ConBox as the "negative" outlier, on account of building system limitations, (the original) facades amplified the elongated volumes (especially through placement and articulation of swallow passage), as the manufacturing system privileges the stacking of boxes in rows into long volumes (Usto et al 2022).

Function - Use

The cases certainly also differ with regard to functionality as they have had different ambitions and agendas with regard to the interior. In the case of Sjølund, which seemingly had the more "relaxed" approach regarding plan and functionality, the concern was making a good, functional plan distribution but with minimal opportunity to make an extra room (new office, or children room etc.) (Aude &Lundgaard 1975; Usto et al. 2022). On the other hand, in the case of FlexiBo, the ambition was already a strong concept on flexibility while living in the unit. While this had potential, the current use of the vast flexibility was minimized to people only putting a few walls up when moving in (Beim et al 2012).

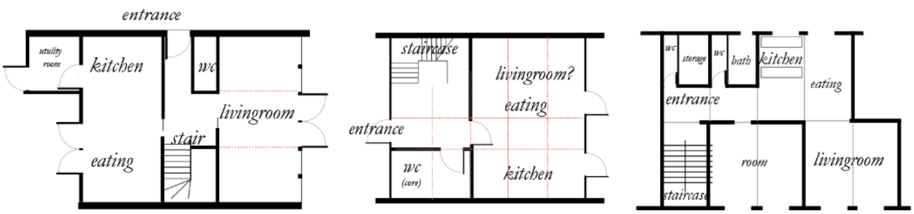


Figure 99. Plans of three cases –
red lines indicate flexibility as possibility of partition walls.

In the case of ConBox, there was already skepticism regarding the spatial and functional quality of the project even before its full realization (Arkitekten 1966; Nygaard 1984). ConBox had a very fixed setup in its plan and each spatial module had its own function (room, bath, kitchen etc.). The same concept was not been used since in a Danish context.

The ConBox case thus holds the least value in terms of function (and flexibility), while the other two are worth taking note of. While the FlexiBo case was in a sense a "failure" in comparison to the intentions of ever-changing interior in vast network of possibilities, the fact that it nevertheless is still used but only when new inhabitants move is a significant find as it indicates a balance in application and that people do not want to experiment endlessly. The Sjølund case on the opposite end, indicates a very limited yet meaningful flexibility at designated spots. Almost in opposition to case B, the Sjølund case shows that less can be enough in the sense that well-made plan organization may require only a small addition to accommodate needs.

Structuring Principles

The published paper elaborates on the structuring principles of the three cases and mainly highlights the structural (loadbearing) system with Case A having a very conventional shear wall system, case B also having a shear wall system through stabilized by cores (wc), and case C having rather a conventional frame system with special box modules (Usto et al 2022). The positive outliers were case B with the beams in the ceiling allowing for easy mounting of new light wall elements (which are stored in a common facility for everyone to borrow if needed). Furthermore, it is also worth noting, that in addition to the modest flexibility of plan design in case A, its façade system was sectioned into modules into which additional changes (new larger windows etc.) could be placed (Aude & Lundgaard 1975, pp. 7) thus allowing changes without impeding on the character of the architecture.

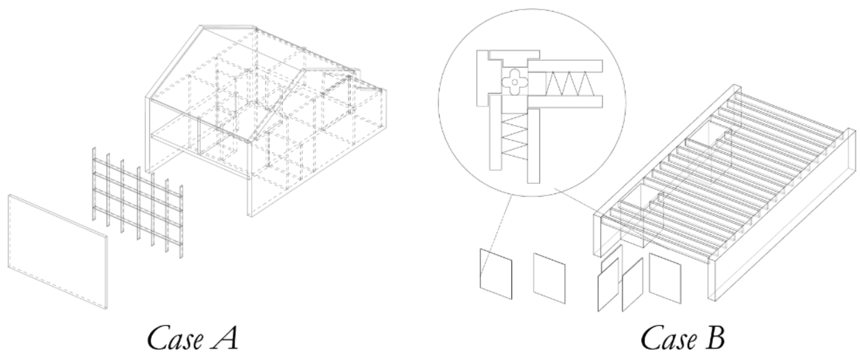


Figure 100. Façade system of Case A and ceiling system (and detail) of Case B.

Case C, ConBox, also holds significance in the negative sense. As earlier elaborated, the technological innovation was very ambitious, where a modular system was to contain variations of applicability to housing, institutions, hotels and more (Arkitekten 1965). One could consider that this ambition of applicability as many functions were what perhaps impeded on its spatial character of the housing variant. On the other hand, what could have complicated this was the fact that the concept was centralized around whole spatial modules and not singular structural elements (a la design-for-disassembly in circular economy thinking in contemporary architecture).

Material Consequences

Given the fact that a significant amount of time has passed since the construction of these buildings, we have the benefit of time to see what has taken place since then. Initially relying on archival data, the quest was to find documents and data on the transformational history for each of these cases, meaning how much has been renovated or if something has been demolished. The most significant finding was that the initial skepticism of Case C was well founded as this case has had the most significant transformations (Usto et al 2022) (see Figure 101). While click-in elements can be good for repair etc., making "circular" elements can also be risky.

Figure 101. Images of two major renovations of case C: the hitherto appearance (middle) and its current ongoing transformation (right). (First image of original facade (left): courtesy by Aalborg Stadsarkiv. Photo 1966 by J. Brems)

The main take-aways lies in the cases of A and B. Case B, although being a mild "failure" with its immense ambitions for instant flexibility, is still a good lesson. people still use the buildings but not necessarily as the architects intended. Case A on the other hand mobilized spatial quality to more significant degree. By providing a minimal possibility of flexibility, the architectural character remains of high phenomenological quality while providing meaningful flexibility. These cases do not demonstrate all-encompassing design-for-disassembly strategies where every single element can be removed but instead allows for minimized click-in strategy with the main building body remaining as is for an indefinite time period. Perhaps case A in particular demonstrates this "gesture" of surplus (im)material effort which hypothetically acts as an investment (higher phenomenological quality) to minimize future material flows.

(Re)considering the Findings

In answering the research question, it is thus not as easy as to saying yes or no regarding if some buildings designs perform as a "safe sink" (Urban sink) for materials. The cases demonstrate that it is a question of degree. As all the cases have shown lesser or greater levels of transformations over time (renovations/demolition), some cases do indeed demonstrate a more careful understanding of how to minimize material consumption over time. It can indeed be observed that immaterial conditions can influence material consumption. Especially in the case of Sjølund whose architectural character is known and appreciated and at the same time legislated and maintained through guiding instructions for renovation and additions over time thus limiting the types and amounts of material changes (Usto et al 2022).

One could furthermore risk a more daring reading. While the original paper is more delicate and careful about the potential correlation between immaterial characteristics and their potential influence on material flows, a few considerations could have been brought forth to potentially emphasize this. Firstly, on account of Harman ontological view, the potential of the (im)material surplus is not an addition of such as a sign or sculpture onto the building body, but an integral part of it. So, when a building acts, it performs as unity despite being comprised of many material and immaterial sub-elements. Another important aspect to highlight from the original paper (which original paper did not emphasize enough) which was also elaborated earlier (Figure 100) was that in the case of Sjølund, the architects' drawings and instructions (prescriptions) acted as local plan law which guided future additions/renovations made by the inhabitants. While the descriptions did hold some qualitative descriptions (i.e., wood being "warm" and "familiar"), the instructions as normative prescriptions were integrated with the aesthetic qualities which indicated where and how changes were possible, at least regarding the façade, which did not impede on the character of the architecture. For these reasons, this aspect could have been included in the "structuring principle" construct, i.e., one which took into account architectural character and changing needs over time.

The paper also hypothesizes a (im)material surplus as potentially metabolic performativity, the original paper did not attempt to further explore this given its limited format. Given the slightly obscure contours of such a concept, it will be explored in the following section.

5.2.3. The Hypothesis of the (im)material Surplus

As Slavoj Žižek has developed, *objet a* or surplus-value is a paradoxical object that can be added to an edifice to makes sense of said edifice. The nature of the object is that it is fundamentally immaterial but can be (often is) embodied in some physical form which acts as the material manifestation of the surplus (like the crown of the king etc.,). When it comes to the immaterial conditions of architecture, as we have seen in the case study, we can argue for the existence of a surplus, most prominent perhaps in the case A of Sjølund; and while the initial variant of the hypothesis of the (im)material surplus was related to the overlapping of structural principle and spatial gesture (Usto et al 2022), this exploration will attempt to further nuance it as it can be observed that the shear walls "shift" (structuring principle) creates a dynamic and embedded phenomenological relation (experiential construct) to site conditions.

Figure 102. Images of chosen cluster.
Courtesy of "Styrelsen for Dataforsyning og Effektivisering" (SDFE)).

For this reason, given that we can phenomenologically discern the immaterial surplus, an important question is thus *what material consequences does this architectural surplus have and can we discern the surplus in material terms*? To answer this, a limited exploration was conducted with impetus on a cluster in Sjølund project. The task is to take the housing cluster (see Figure 102) of 3 dwelling units (unit names *Is, Ns, Ls)* (Aude, Lundgaard 1975) of the Sjølund project in its original manifestation and compare it to a fictional "rationalized" cost-effective version. Although the architecture would radically change, the experiment will maintain amounts of square meter and function as the most import parameters. The roof girders and roof in its entirety were not included in accumulated volume as drawing material was not available (for more specific delineation of background conditions of this comparison, see appendix C).

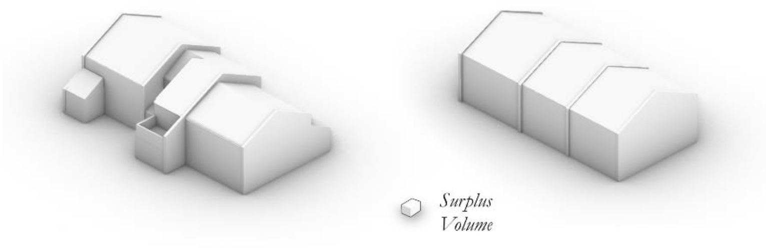


Figure 103. The surplus volume is a metric which is to be viewed as volume pr. floor area. But in this case, floor area is constant in the two versions.

This exploration attempted to model the building body (external walls, interior walls etc.) of the original and fictive variant as to discern the differences in the material volume of the two. We can thus see a surplus volume of materials in the original design compared to the modified and rationalized version (which incidentally had similarities with case C in external expression). One would have initially thought that the surplus would have been much more but due to having to change lengths in the modified version, volume was added as well in order to attain functionality and the same amount of floor area on both ground level and first floor. The surplus volume of 1.3 cubic meters (see Figure 103) is perhaps not much which adds an immaterial quality compared to the potential of acting as a metabolic/material investment. It can be argued that the extra envelope area of the façade in the original (by way of complex geometry compared to the rationalized version) increased the energy. This is due to the fact that the floor-area to building-envelope-area ratio is worse in the original design. By merely considering use of material in volume, the surplus of 1.3 cubic meters is in a simplified and abstracted sense what provides the immaterial quality in the Sjølund case. Obviously, due to good work by the architect, this hypothetical surplus is masterfully composed and not a mere addition (sign or sculpture). This surplus is furthermore not some exquisite material (marble etc.) and is merely the average of the main body of the building which is composed mainly of brick, concrete and wood along with other materials. This surplus of 1.3 cubic meters is also an abstract measure as it does not say anything about what the composition of materials: its merely, at this point, an abstract volume. What is clear about this hypothetical comparison is that the architecture greatly suffers in the modified version compared to the original in relation to the intended dynamic relation with the terrain, almost given the impression that it is an extension of said terrain. That is not to say that the modified version would not have its own qualities and tectonic niceties. Rather, they would perhaps be less sensitive to the contextual conditions. By adding a surplus of material volume, and by masterfully composing it, (surplus of 1.3 cubic meters) the building contains a (im)material "investment" which add character to the built environment. I would argue that this surplus has the potential to act as an insurance for the minimizing future material flows through both interior spatial character and variation as well as a phenomenological grounding in the "spirit" of the site.

The 'surplus' is already a familiar notion in design and particularly in engineering via the concept of "abundance". In the engineering context, abundance is usually used as a surplus of materials or design which is a safety measure or fail-safe. As exemplified in the above exploration, the aspect of abundance could also include an "abundant" wall element (like case B) which can actualize itself in the future. At the same time, there is an immaterial dimension to the surplus, which is not hands-on like the stored wall elements but an integral part of the architectural character. At the same time the challenge would be to avoid a kind of fetishization of this surplus, which could introduce complex aesthetic expressions beyond any efficacy and relevance (for users, site, culture etc.) for the sake of esoteric appearances. Here the edifice becomes problematic as aesthetics presents itself as constitutive for what kind of surplus is relevant in what social and cultural contexts. The intention is not to claim that the (im)material surplus can always be brought forth in such an exercise as the "feeling" of the surplus may vary in its materializations.

The conclusion is thus paradoxical: to be properly "efficient" with regard to slowing material flows, a seemingly "irrational surplus" is required. Mere utility and efficient performative alignment within the capitalist realism could turn out to have a negative effect (like case C) while a sensitivity to interior experience and site specificity could strengthen the overall narrative in everyday use, in society and potentially minimize the need for future material input. The significance of this type of *surplus* is that it is not an ornamental excess (which is very costly and time-consuming today) but something very conventional which is feasible within a contemporary building practice.

5.2.4. Relation between intention and material consequences

Juxtaposing the five constructs across the three cases has encouraged the examination of many considerations. While the paper was aimed at exploring if and how the immaterial aspects could or did influence the material flows, this section of the monograph more precisely explored a different chronology of the constructs for the purpose of exploring constructs. It has been observed that each construct can hold a multiplicity of empirical points. The five constructs can thus have many sub-constructs simultaneously which relate to both the case as well as external site conditions and social context. While relations and sub-construct as presented in theory building (chapter 4.4.5., Figure 78) are a "balanced" example which contains general points, a specific case could have multiple empirical points in each construct to the point of containing multiple narratives or multiple intention which could be contradictory.

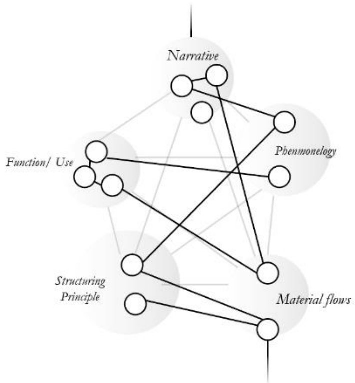


Figure 104. Abstract example: each construct can have multiple empirical counterparts.

When applying the (im)material metabolism theory as analysis there is significance is conducting the analysis (i.e., case study) by initiating the inquiry with the construct of the "narrative" dimension then going through "experimental conditions", "use", and"structuring principle" to finally arrive at the "material flows." This is due to the fact that the object of analysis already exists (and does not need to be designed) and because such a chronology allows for critical reflection in order to observe what is said/intended/narrated and how such intentions are materialized. Ultimately, such a dialectical process allows for observation if the final matericorresponducts corresponds with the intentions or if there is Jevons Paradox phenomena (where good intentions materialized negatively).

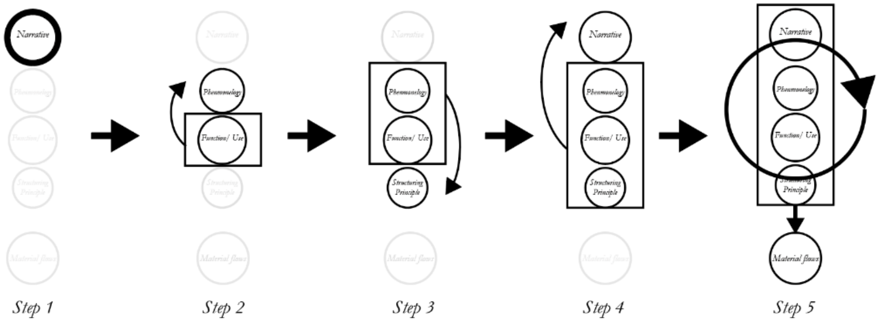


Figure 105. Starting from Narrative, through the middle, and relating all to material consequences.

In actuality, the process was not linear. While it was pertinent to start from the "narrative" dimension, it was always necessary to iterate and reflect in relation to other constructs throughout the analytical endeavor. After an initial look into the "narrative" (step 1), it was useful to read the design drawings and gain an overview of the functional and organizational aspects. Followingly, the construct of "use" (step 2) was immediately set in relation to the experimental (phenomenological) conditions. Next, the couple "use" and "experience" are related to the "structuring principles" (step 3) in order to gain insight into how the above-mentioned functionality and its experimental properties were manifested through construction and material considerations. Next, the three constructions in the middle were again related to the respective "narrative" (step 4) in order to ascertain if the projects' own intentions were met. Finally, the whole edifice composed by the architects is related to the actualized material consequences (though in a limited scope).

Concludingly, it was not possible to find any written intentions or design considerations explicitly dealing with sustainability, but the intentions that *were* found have their own material flow consequences regardless of the missing explicit considerations regarding sustainability. Hypothetically, even in another future application of the (im)material metabolism, a chosen case which may have explicit sustainable goals could turn out to have a very different material consequences. Furthermore, in relation to the Urban Sink concept, it is not unequivocal that site-oriented phenomenological intentions (like case A) are always positive regarding material flows, nor should it be taken that technologically driven concepts (like case C) are always doomed for failure. This juxtaposition of phenomena nevertheless prompted considerations, gave new insight and critical reflection, and will be further explored to consider other possibilities which could be relevant for expanding of the notion of the Urban Sink in a critical metabolic approach.

5.3. Expanding the horizon – anachronistic analysis and critique

While the first part of this chapter, i.e., the empirical application (analytical tradition) of the (im)material metabolism, was mainly concerned with exploring the constructs and their relations, the second part, i.e., the expansion of the horizon, is concerned with exploring insights which could provide contours for the last to elements of theory building: the "logics" and the "boundaries". To do this, the exploration follows a continent tradition in which a more general approach to analysis is needed. Likewise, a larger set of cases are needed without delving into the complex empirical facts of each and only hinge on aspects relevant to expansive exploration of what the Urban Sink concept could entail. How can we use metabolic thinking in an application of a more general analysis and critique? The purpose here is to both explore the width of (im)material metabolic analysis and apply it as critique. The intention with this exploration is at the same time to expand the meaning of metabolism and thus nuance the debate on material consumption in the built environment. If any design or system ought to perform as Urban Sink, what should we also keep in mind, apart from the initial findings and considerations from paper 1 (and paragraph 5.2)?

5.3.1. Anachronistic analysis – towards a spectrum of the Urban Sink

On basis of the case study only having 3 variants (acting as Urban Sink to lesser or greater degree), it became pertinent to further explore what the Urban Sink notion could entail. The urban sink is potentially its own spectrum, there are many examples of practices which are worth noting in the development of the spectrum in the quest to explore and nuance the Urban Sink concept.

On grounds of the above case study, findings have allowed for insight into the empirical data on conditions in the three cases as they allowed for speculation and qualified discussions on the relations and correlation between the five constructs of inquire, albeit in differing hierarchies and constellations. The case study has also prompted more general insights regarding challenges of metabolism by opening "visibility" to other relevant fields which are very relevant but not directly "metabolic." Circular economy strategies, such as design-for-disassembly fundamentally also holds Urban Sink capacity, but it is not necessary that all elements need to be disassembled if building design is to slow and narrow material flows. As already mentioned, the concept of the Open building (Habraken 1962; Kendall, Teicher 2000) design is not merely a concept. Rather it has its own history and is also a field, edifice, or discourse within architectural design. It differs from circular economy as the support is usually permanent and the infill only is designed for disassembly and not the whole building though there can also be variants of open buildings which also include the whole body intended for disassembly.

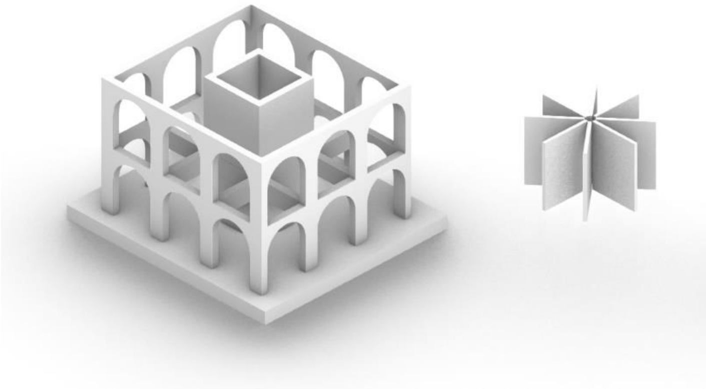


Figure 106. Principle of Open Building Concept; support (structure) and infill (light walls etc.).

Prior to the study, the author(s) were vaguely aware of the notion of the OPEN building concept (support/infill). They were not, however, aware of its full potential until they conducted the study and discussed the findings. When it comes to metabolic considerations in relation to building design and analysis, the concept of the OPEN building design is highly relevant; nonetheless, there are also other pertinent considerations to include and consider.

The FIXED building concept (own naming)

It is possible that particular constellations of the five constructs within a architectural work where the particular compositions and internal relations of spaces, functions, technical service etc., allow for flexibility without needing any movable (infill) elements other than furniture. The idea is to differentiate this particular type from other classical architecture because it also has a contemporary relevance to material flows as this allows for certain ambiguity without any or very little material unput.

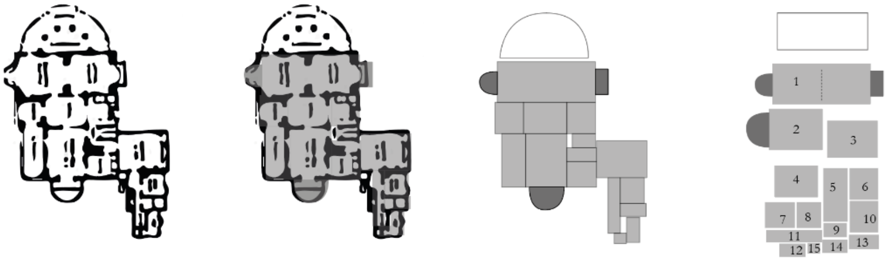


Figure 107. Internal variety and composition permitting flexibility and adaptability (own redrawing based on (Alexander et al 1977)).

The reference here is Christopher Alexanders who very briefly, yet interestingly, elaborated on flexibility (Alexander et al 1977). Alexander elaborated that old classical houses (), due to their organization, proportions, and compositions allow for an easy shift from acting as a home to performing as an office. Alexander emphasized the different rooms sizes, and their different ceiling heights which *afforded* (Gibson 2015) themselves for a differing functional application. The particular case that Alexander shows (as redrawn in aforementioned figure) is not *the only* way such a setup could be organized but should prompt further investigation. Many buildings can be said to contain such composition setup, or something similar to it. The quest is nonetheless to discern particular relations in its given contexts. One is almost tempted to accept that there is fundamental formalism (one of ambiguity) at play in such a performativity of a fixed variant of the Urban Sink.

Mixing Sacred and profane - Islamic Architecture

In a comprehensive contribution of the vast movements in Islamic architecture, Robert Hillenbrand notes a few founding characteristics of how Islamic architects would conceive of spatial and architecture challenges. He elaborates Islamic architects were "…not relentlessly experimenting with new forms..." but preferred to "…refine existing ones…or to load them with extra decoration." (Hillenbrand 1994, pp.24). As we have later learned from scholars such as Michael Hensel, some of these "simple" forms with "extra decoration" have been observed to have intrinsic tectonic character with structural capabilities and abilities to act climatically within the surrounding physical and atmospheric conditions (Hensel 2013). This hints at the attitude of refinement of known principles instead of mere formal exploration, and in more ways than merely visual decoration. This particular way of thinking of adaptability, flexibility etc. with "permanent" heavy elements allows for a cultural continuity and recognizability in terms of local and national heritage etc.

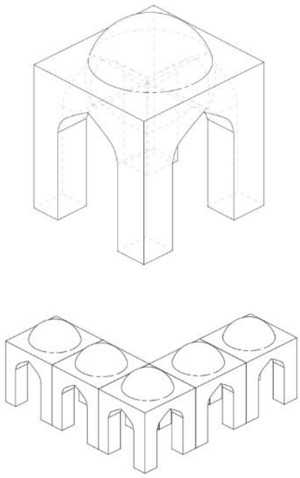


Figure 108. An additive logic of simple ("refined") elements.

In extension of this, Hensel also elaborates how the sacred and profane function (i.e, ceremonial use and everyday use) are to be contained within one and the same module/form and containing a flexibility and functional ambiguity within a simple and beautiful form. Hillenbrand brings forth an example where a *madrasa* (an religious educational institution) was also used as a hostel (Hillenbrand 1994, pp. 202) along with other examples of much wider flexibility affordance of a single piece of an architecture having more than two different functions (ibid, pp.246). Finally, there is an interesting passage from Hillenbrand regarding a "palace" (ibid., pp.426-7). This particular "palace" contain an uncertainty of the functional performance even though the remaining structure is that of a beautiful form which has a functional ambiguity. Yet paradoxically, as it may seem that Islamic architecture is very "formalist" (object-fixated), the fact is exactly the opposite. Interior are given much more weight than exteriors where the façade was basically "…moved inside..." (ibid. pp.126).

Incidentally, though not crucial for my main arguments, a later scholar also postulated that Gottfried Semper, although using Greek architecture as main reference, may have been inspired by Islamic architecture for the concepts of *bekleidung*, as Islamic architecture is more concerned with the "surface" than the structural "body" (Klein 2014). With this shift away from "idolatry" of the body/material onto space, the shift was intended for "...inwardness and contemplation..." (Klein 2014). The historical Islamic building culture can thus be said to be mirroring of Semper's emphasis on interiors, veiling, and the haze of carnival candles. Comparing to more recent architectural practice, we can perhaps clearly see, as is already known, how the work of Danish architects Jørn Utzon was influence by Islamic architecture, not visually but perhaps especially in the development of his additive systems and the *Espansiva* system (Weston 2008).

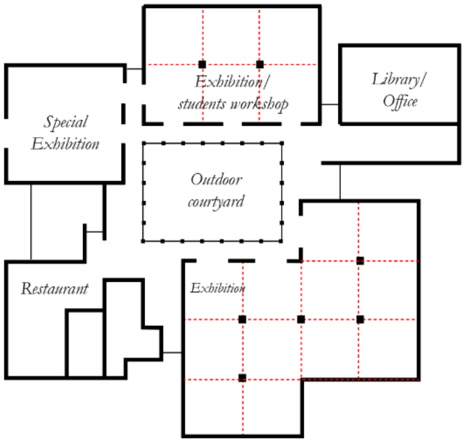


Figure 109. Own diagrammatic redrawing the Utzon Center (by Kim and Jørn Utzon) - showing the "openness" of the plan (red lines indicates possible walls).

There are some important lessons to translate from Islamic architecture. Not to repeat the visual characteristics (content), but there is deep lesson in the meta-formal attitude and way of thinking which can be translated into a modern setting in relation to climate change and challenges of material consumption. While the historical tendencies in Islamic architecture can be said to have similarities to the “fixed” building concepts, there is likewise a mental flexibility in Islamic architecture which allows for a mixing of sacred and profane program due to a kind of functional ambiguity in the formal designs. As the architectural challenge is to think in both large constellations and eco-systems, it is likewise a challenge to consider the immaterial dimensions in how the building body is shaped as to make it functionally ambiguous and beautiful at the same time.

Architectural Association School of Architecture, London

An example of an early OPEN building design (sometimes referring to as loose-fit) is none other than the Architectural Association, London. This design is exemplified in Georgian townhouses which, given the adaptable affordances, have evolved over time but kept their character (Wright 2017). Seeing the building from the outside, one could think that is an entire housing complex. At one point, these townhouses were indeed seven former family homes which have continuously evolved to provide facilities for teaching and designing/making for circa 1000 people (Wright 2017).

Figure 110. Georgian housing turned architectural studios
(Photo: Public Domain by Jeremysm.
https://en.wikipedia.org/wiki/Architectural_Association_School_of_Architecture#/media/File:Aabedfordsq2.jpg)

As Wright reifies, there has been significant growth over time which testifies to the fact that the design of the Georgian houses has allowed for the spaces to remain attractive and functional despite changing needs over time and while retaining a social and contextual character.

Modernism and Modernity

We can also see how different debates, which have spanned decade in architectural discourse, get a new light from the perspective of metabolism and open building designs. For a long time, we have debated the extent to which the architect is expected or allowed to “control” how you live your life (Sarnitz 2020, pp.94-103). From another famous example of the modernism positions, we have seen the “battle” of Farnsworth House by Ludwig van der Rohe whose client was very dissatisfied with his design (Craven 2019). While modernism is usually seen as being more radical regarding its control of how the inhabitants dwell, there are also examples of early modernism which testifies to the opposite. Dutch architect Gerrit Rietveld‘s design of the Schröder House is an example of building that is open, with no fixed furniture and thus allowed for differentiated setup according the needs within those perimeters (Habraken 1998,pp. 75). Rietveld’s design also featured a set of sliding walls that allow for flexibility in plan design and variation in use (Bosma et al 2000, pp. 28).

Figure 111. The Schröder House by Gerrit Rietveld (Photo: creative common. Photo: Sailko. https://en.wikipedia.org/wiki/Rietveld_Schr%C3%B6der_House#/media/File:Casa_Rietveld_Schr%C3%B6der_11.jpg)

Although later in the century higher sensitivity towards flexibility arose, perhaps especially the early and high Modernism with its "modernist realism" had the character of striving for total control. While modernism also contributed significant increase in life quality of more space, functional uses and in general a kind of democratization of space, it still retained a kind of *un-modern* gesture within its edifice which can be said to be present today. Jeremy Till, as well as David Leatherbarrow, from respectively different perspectives, elaborate how, well beyond our perceived visions of control, architecture certainly contains uncontrollable characteristics and properties which are to lesser or greater degree out of reach for designers while at the same time having aspects which we indeed can influence.

Late Modernism and Post-Modernism

Modernism was slowly developing into post-modernism through movements such as brutalist and the Avant grade movements of Archi zoom and Japanese Metabolist, we started to see example of modular systems and dynamic architectural solutions. Some considered themselves more radical as with the example of the Japanese Metabolist, while later movements and dogma simplified the notion into more of an tech-like look or appearance (high-tech style of Norman Foster and Richard Rogers among others) but lacking the actual possibility for adapting (Lifschutz 2017).

Figure 112. Nakagin Capsule Tower by Kisho Kurokawa (Japanese Metabolist) (Creative commons. Photo: Jordy Meow, https://en.wikipedia.org/wiki/Nakagin_Capsule_Tower#/media/File:Nakagin.jpg)

Perhaps comparable to both OPEN building concept and the circular agenda of today, the example of Nakagin Capsule Tower (Gardini, A., 2022), was an example a click-on system of whole spatial modules with slight similarities in principle to case C in the case study above. The current situation of this building is one of deterioration and lack of maintenance (and failure of the concrete) has led to the decision to demolish and partially remove (Block 2021). This can serve as an example that the proto-circular affordances will not necessarily be used as intended, as both materials can fail, they could have produced new better modules compatible with the given system. This was not the case as there was no incentive to continue an outdated technology. This prompts the consideration, with the open building in mind as well, that a kind of "total" circularity of the architectural anatomy is perhaps not desirable as much uncertainty arises over long spans of time – whereas having a more ambiguous "permanent" form supplemented by light weight "infill" would be a safer approach in terms of material consumption. On the other side of this coin, as in the case of Architectural Association building, the character of the architecture in relation to the surrounding park and urban area is maintained.

It would also be relevant to mention Le Corbusier's Domino system, as its intention was to allow for flexibility in both plan and façade, but the practical and physical built works were not entirely in spirit with open building concept (Bosma et al 2000, pp. 105-6). John Habraken - one of the founding figures and popularizer of OPEN building concept - elaborated in a book that the technical and structural component of the Domino system is not entirely the same as the OPEN building concept. Habraken develops the notions of "support" and "infill" across scales (city, tissue, support, allocation, infill) (Habraken 1962) and distinguishes from what he designates as "support" from the domino system, as the support is already a category which is not merely the structural system but a body of the architecture which supports flexibility (which includes more considerations than mere resisting gravity). The Open Building concept is flexible as to contain considerations for not only buildings but also urban design, building, products, but also management and finance among others (Kendall, Teicher 2000, pp.40-49).

Another important contribution to the open building concept was that of Stewart Brand in his book on “How Buildings Learn” (Brand 1994, pp.13). Here he made the now famous image of concentric layers of the building’s anatomy and its approximated life spans (*stuff, space, service, skin, structure, site*). Stewart Brand notes:

> “Almost no buildings adapt well. They’re *designed* not to adapt; also budgeted and financed not to, constructed not to, administered not to, maintained not to, regulated and taxed not to, and even remodeled not to. But alle buildings (except monuments) adapt anyway, however poorly, because the usages in and around them are changing constantly.” (Brand 1994)

Another good example of later post-modernism, John Habraken, designed a home for his parents in Apeldoorn in 1998. The home was composed of two separate volumes which are not functionally distinct (in the sense of one of them being private rooms for sleeping and the other the active rooms like living room, dining etc.). In the larger volume there is a interior colonnade which can add options to segment the larger space if needed to create intimate nooks etc. But more than anything, the concept is open building which would allow the layout to be different or even an entirely different function all together. One could easily imagine how such a design could act as small restaurant or café, with sitting area in the large volume and kitchen in the smaller. A point of critique of this design would be the detailing and lack of tectonic finesse. This could be made into a general critique of open building concepts, as they often fall down into a kind lower form of sublime “flat” appearance which lack expression.

Figure 113. The original plan from 1961, and the house with the later extension in 1998. (Own redrawing)

While we can observe the potentials and lack Japanese metabolic thinking, which was in tune with the contemporary tendencies of Archigram, who also had similar considerations on moving parts and cities – the spirit of the post-war metabolism can be argued to have remained with its core principles in the OPEN building concept. But for the open building concept to gain a proper metabolic angle, would mean that it is a measure towards slowing and narrowing of material flows from nature to society. Open building concept could equally be used in a overly opportunistic manor as it can become yet another way to explore aesthetic appearances which would have the pertinent principles squandered of their inherent potential and thus flattened to merely a new appearance, like it happened with the early works of Foster and Rogers, as Lifschutz argued.

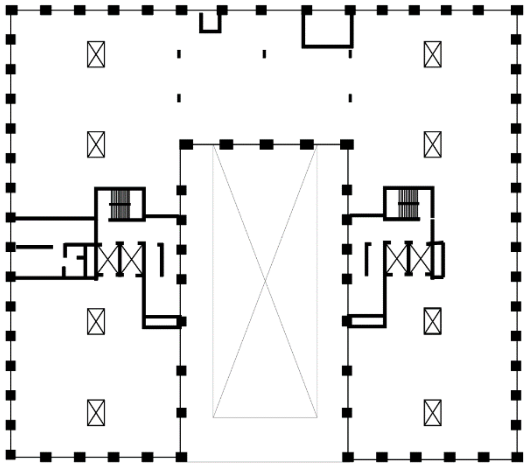


Figure 114. A contemporary example of the open building concept - large portions of the plan are simply open to large variety of uses and infills (own redrawing). Solid11 by Tony Fretton Architects (Kruit 2022).

While the open building concept may seem simple, its challenge is that it is not widely applied despite the fact that it is not significantly more expensive to realize such buildings for developers (Franke 2022).

We can thus observe that it is not necessarily a question of style in the sense that Modernism is “bad”, or some other style is supposedly better for open building concepts. The principles of open building can potentially permeate any style, and styles can add a surplus value to an ambiguous structure.

A Contemporary Return to “Permanence”

A recent significant contribution designated as architecture of persistence (Fannon et al 2022) is of urgent relevance when we attempt to outline the Urban Sink in different scales of building design. Although the following descriptions does not do the literature justice, the “architecture of persistence” is a significant expansion of the OPEN building concept, provides much significant nuance and background while relying on differentiated existing literature to develop the different facets of what it means for architecture to be “persistent”. The authors Fannon et al. designate a variety of ways in which a building can be persistent (an expanded form of architectural permanence) which is constituted of three main elements (constructs), i.e., Material Ecology, Changing Use, Alternative Futures, all of which have accompanying sub-elements (ibid). Respectively, they include all from the material performativity of the “essential” (structural) elements and facilitating changes in services and technologies, to highlighting the need for the capacity for changing uses over time, and the cultural memory of building in social setting (ibid). Speculatively, they indicate (qua one of their interviewees) that buildings (in concrete) could potentially last centuries—up to a thousand years (ibid. pp.24). Concludingly, the authors synthesize a diagram of considerations to have in mind when designing a persistent architecture: strategic structure (not impeding on future use), tactical tampering (enclosure and active systems), and flux form (meeting longevity and change) (ibid, pp. 285-88).

Furniture and Inventory

In both material (utilitarian terms) and immaterial (experiential) terms, furniture and inventory also holds significance for a building's capacity to perform as Urban Sinks. Specifically, furnishing and inventory can also come in both fixed and floating variants though the most common tendency is obviously that of movable furniture along with other more or less fixed or movable inventory. This category can span anything from tectonic wallpaper (Hvejsel, Kirkegaard 2013), to visible or non-visible technical services (as considered in 4.4.4), to moveable and fixed furniture, among many other aspects of interiority (Sarnitz 2020, pp.191-202).

Detail

As we have seen both in this chapter (especially case B) and with several references (Kjær Frederiksen, Munch-Petersen 2019), the detail is also a crucial aspect of manifesting the Urban Sink. Given the "circular" turn in the building industry, the detail has gotten a fresh breath of life, as disassembly is a pertinent design parameter for buildings. The detail additionally does not have to be only "open" to be able to dismantle the entire building. It does need to be more in tune with the open building concept in order to possibly partially dismantle where the "support" is fixed while the infill is open/loose. It is not impossible that a building whose every detail is "fixed" can perform as a Urban Sink given its masterful application of principles, materials, experiences, use etc.

The (Im)Material Surplus

This category is more ambiguous. It does have, first and foremost, a material dimension and material performativity, not unlike abundance in engineering as guarantee for robustness, regardless of if it is structural, indoor climatic, or something else. Similarly, some minimal surplus could also be ascribed to flexibility and adaptability. The final aspect of this category could thus be that a more "irrational" excess, whether or not in extension of material performativity, is a gesturing surplus (as in the case of Sjølund). While seemingly useless from an utilitarian and cost effective point of view, the category may hold "performative" significance in relation to the contextual, social, and cultural dimensions of experience and heritage.

…some reflections regarding the Urban Sink variants

In the ideal future, where we no longer demolish buildings, and many buildings will be made to be open and adaptable. Along those lines, there would still be need for a metabolic design approach because the infill dimension would show tendencies of potentially becoming a whole new market and industry of its own (Kendall 2011). This would mean that the very aspect of the infill, regardless of whether the instance is of new or old buildings, would require that the interior would always need to change. The prospect of the infill aspect becoming an industry could potentially turn from a mere need to have to all kinds of luxury variants, to changing trends in dwelling etc. This would be a Hegelian/Žižekian reversal from In-itself to for It-self, and in this instance, there would be a need for aligning and relating material flows with the overall scheme. The implication is thus that the support and infill are two separate markets, where the support is made by the architects and the infill is given to someone else. This is perhaps be challenged by the practice of the case B (local storage of light walls).

When we consider the Urban Sink spectrum in relation to contemporary challenges of material flows, tit can be argued that there is more need for open building concepts or "architecture of persistence" which is an open and adaptable category of buildings, rather than the fixed variants of the Urban Sink. Furthermore, it is also important to point out that, while Urban Sink does have variation, it is not entirely clear which variant would be more or less fitting in any given context (whether that context be the fixed types or the open types of buildings). Open building concepts strategies can easily be perceived as a very technical architectural solution to environmental challenges. The challenge at the same time is thus how to introduce a significant shift in tectonic character in what is usually mostly associated with a technical solution of environmental problem. How beautiful can such seemingly technical solutions be?

While the listed variants of the Urban Sink in the building scale need to be considered for each building, more *metabolic* relations can be manifested and explored if we also start relating buildings to each and to other infrastructure in the city. This is significant as a particular building design may seem arbitrary with respect to the examples of the "persistence" perspective exactly because such considerations partake in a wider metabolic scheme (this "wider scheme" will be explore further in chapter 6.).

5.3.2. (Im)material Metabolism as Critique

Based on the observed discrepancies in both the case study and in the anachronistic analysis, the dealing with the limitations of "sustainable" concepts (circularity, reuse etc.) containing the risk of such concepts being misused or not used in the future as intended or as its potential allowed. These observations prompted a need to consider these and similar phenomena from a *metabolic-critique* perspective.

In what comes below, the hitherto built theory of the (im)material metabolism is also tested as an applied method of critique. The theory provides a particular kind of "materialist" ontological grounding from which other phenomena can be critiqued. While a case study is more systematic (analytical philosophy), critique moves more at the surface level of phenomena (in the spirit of continental philosophy) by focusing on only chosen objects/construct and a limited (yet critical) set of relations between constructs which assert effects and consequences of interest for criticism.

Dialectical Materialism is often linked with the *critical* tradition in philosophy, and thus one would assume that this doctoral study would have strong foundations in critical thinking – and it does through use of Žižek's writing, accompanied by Harman (who is not a part of the *critical* traditions). One would perhaps also assume that because of this, this doctoral study positions itself in the architectural discipline as such while being *critical architecture.* Nonetheless, things are a complex here and need outlining. *Critical Architecture* spans and can be different things; it entails both an emphasis on the autonomy of architectural discipline and a dissolution (post-critical) of the discipline into a multiplicity of performances or practices (Rendell 2007, pp.3). Michael Hays, a paragon of the *critical* trajectory in architecture, elaborates that the *critical* entails "…the constant imagination, search for, and construction of alternatives..." (ibid). In relation to the Semperian "cultural continuity" in each new building, the critical trajectory is not necessarily a kind of proto-degrowth antithesis to it, whereas the critical advocates for a kind of "disruptive continuity" which continually transgresses the old horizons of knowing and practice with some sort of sublime disruption. This is not in itself a profound view in relation to metabolic concerns and as such a position may easily perpetuate material consumptions or amplify them in its search for alternatives. Ultimately, the *critical* trajectory or *critique*, is to be considered a practice in-itself on which companies design practice (Rendell 2007). The trajectory has a wide variety of applications, ontological implications, and general attitudes towards design (Worldviews). The *critical* trajectory thus contains many directions and as such there is an "openness" where *critical* practice is not necessarily *metabolic* (minimizing and slowing material flows and tectonic application within planetary boundaries). Likewise, critical practice could also absorb the metabolic dimension, and it is thus my aim to construe a *metabolic* thinking which is a way critical with regard to material flows and planetary capacities. A kind of *metabolic-critical* architecture if you will.

Intentions and Manifestations

As with the three cases in the case study in the beginning of this chapter, there are likewise other examples of buildings which have had intentions which were not realized as intended. As Edwin Heathcote indicates, when it comes to OPEN building concepts, architecture can start to fetishize flexibility (Heathcote 2017). This could translate into, as we have in case B of FlexiBo, that the flexibility-way of living was intended as its own kind of sublime dwelling while the truth is that people sparsely applied it in limited yet practical ways only when moving in (Beim et al 2012). Moreover, it is also important to not allow this fetishism to introduce unnecessary overdesigned measures as these measures would pose no positive benefit or affordances. More to the point, as a "fetish" the measures can introduce some market optimism and risk of increasing material consumption with more and more new

building built with such design strategies.
As mentioned earlier (5.3.1), the high-tech style was initially "spiritually" linked with OPEN building concepts, and was concerned with democratization of spaces and allowing the inhabitants to freely dwell as they please – but got interpreted into a mere style deprived of its critical substance or depth (Lifshcutz 2017). This can be called a Hegelian sublimation (of the bad sort), where a thing "transforms" (like coffee without caffeine) and loses its crucial "essence". When this happens, any current and future sustainable design agenda risks undergoing such a transformation for the sake of "lightening the mood" in an opportunistic trajectory. One could also consider a positive example of such a transformation. As mentioned earlier, before the current emphasis on sustainability, the open building concept field and both its methodological and theoretical literature emphasized contingent design in order to often allow freedom from an architectural ethos of being anti-modernist so that architects could provide people with the opportunity to dwell as they please. In today's setting, and with climate change, there is more material necessity for the open building designs (and similar variants of it) and for architects to explore better variants of this design while refining it to be of high architectural quality (high art) by providing modest and simple "profane" flexibility.

The abovementioned phenomenon and tendencies can be used to extract a new hypothesis in relation to today's shift towards circular economy. If we put this into perspective, this to the large-scale linear material flow conditions (Figure 4 in chapter 1) in which the building stock is expected to double by the year 2050, it becomes pertinent to speculate on new hypotheses. The new hypothesis to be aware of, and which will require further exploration in future studies, is that there is risk that current measures (theoretical, practical, legislative) of LCA and CE could act as the enabling measure which, in the end would either meet the expected doubling of material input into society or even amplify it. As CE strategies provide a set of tools which allows for a continued optimism in the building industry and as architects and engineers are become better versed in LCA and CE, the optimism could allow for continued material input. As the techniques and tools are becoming easier to use, more and more of it will be used and more and more buildings will be built with "good intentions", as the Jevon Paradox would have it. Whether it be circular economy, an *architecture of persistence* or any variant of *critical* architecture, all stand to risk a perpetuation of material consumption if they fail to introduce the *metabolic* aspect.

Tools…
Another aspect also to highlight, is—especially in engineering—whether structural or indoor climate (HVAC) (when elements are calculated and simulated) is inherent "capitalist realism" already present within how such tools are used. The quest is usually to design something whose dimensions are minimal yet acceptable according to some decency or written norm of the elements performance. This is considered while minimizing the amount of material needed and cost. When elements are calculated, what are they being dimensioned for - certainly not extended life span. In

a Danish context regulation and law are made regarding structural and energy aspects, and LCA is also becoming integrated into building law (Dansk Industri 2023). Although this is not yet in its final form and is expected to become more ambitious, I would argue that there is cause for caution and careful considerations on architectural and tectonic character in relation to this legislation. If LCA and CE, as they sometimes do, are ultimately only used to optimize cost by focusing on efficiency (and if this tendency gets amplified) LCA and CE could be used to make bland and characterless architectural works which are not appreciated, easily removed, and do not perform in any socially and culturally significant capacity in its given social context (i.e., becoming cultural heritage or some equivalent to it). Even if they are made following circular principles (i.e., DfD), there is still risk that any particular technique (DfD etc.) would be outdated and not reused – possibly as in the instances of case C and Nakagin capsule tower described earlier in this chapter. The risk is thus that this could become the future scenario (doubling of building stock by 2050), not in spite of LCA, CE and other sustainable agendas but because of them. Such measures have inherent lacks partly due to being linked with mostly building scale design. On the other hand, urban design could also be mobilized to introduce new and pertinent facets in the strategic approaches to slow and narrow material flows. Design Tools (or methods) are thus never neutral and can be imbued with certain agenda for growth efficacy; however, at the level of *content*, its *form* allows for an application in any given agenda.

The radical critical synthesis of this critique-exploration is thus that whenever there is a noticeable discrepancy between what is said/intended and what manifests materially (no matter what theoretical framework or school of thought is used_ fundamentally goes from being that to being an ideology which fails to critically address the wider scope. The *metabolic* approach of this doctoral study is thus not the final way to address this as it too still holds significant gaps but could modestly provide a platform for such critical reflection.

5.3.3. Synthesis on Analysis

The Urban Sink can safely be considered a spectrum across several levels of consideration: furniture/inventory, elements (wall etc.) and support with the first two acting as infill. While the spectrum indicates that both fixed and open variants of each aspect could hypothetically permit the functioning of the Urban Sink, it is still important to note that the open variants are currently of critical importance given the uncertainties and expansion of urbanization and climate change. Anything from an entirely fixed furniture scheme to conventional use of furniture, can both strengthen the performance of the Urban Sink (thus minimizing need for additional flows) with the same being relevant to consider with both elements and the supports. What could differ is the particular nuances of context, social, and cultural currents as well as (dis)likability of heritage value in general at any level (or lack thereof) of the built work which can solidify it as Urban Sink or not.

Paper 1 (Usto et al 2022) concluded that the buildings only acted partially as Urban Sink. Nonetheless, later analysis and reflection (in this dissertation) has shown it important to distinguish (a la OPEN building concept) between the support and the infill. This means that the support did perform as safe sink while for the interior and parts of façade didn't (case A). This implies that there are separate sinks for support and infill.

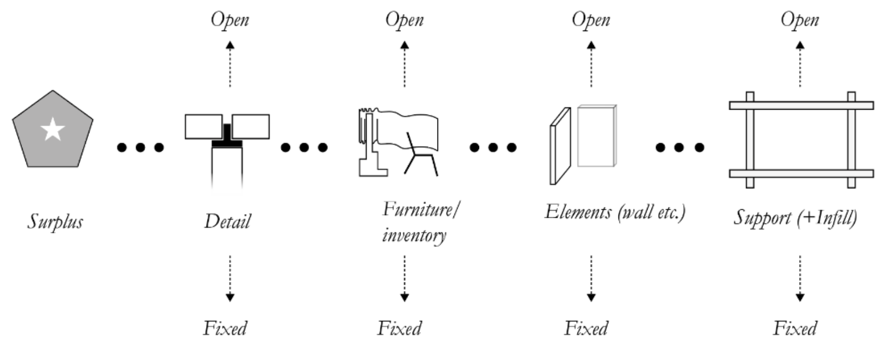


Figure 115. The Urban Sink spectrum of furniture/element/building scales in open/fixed variants.

Generally speaking, it could be considered a safer approach to employ the "open" category of each aspect, but there will be need for a more systematic exploration of such nuancing though further case study analyses (or any other type of analysis) to also be able to indicate more precise prescriptive trajectories and not only propose a generic open approach. This second aspect (of more specific nuance for which type of Urban Sink strategy should be employed) is precisely what links to the critique paragraph (5.3.2). There is a need to gain a more nuanced understanding of when a building body performs as a safe storage for material qua tectonic characteristics (Urban Sink). This is because there is a risk that even a supposed *metabolic* approach will get flattened when we design with open strategies. Furthermore, in relation to the notion of "sublime uselessness", there is much to explore. Finding more nuance in the possible spans of functional ambiguity (the building body having affordances permitting different uses) in order to systematize according to the context, topography etc. exactly how much or how little span is enough, because not every building needs to be able to be any function. Such a building would be an impossible myth which could risk increasing material consumption or using materials in questionable terms. There are modest considerations in this regard in the case study (paper 1) which discusses the extremities of case A (Sjølund) and case B (FlexiBo), where case A offer one modest possibility for light wall partition, whereas case B is perhaps too open, and people use it sparsely. In extension, there may be potential to develop a different architectural language or even style with the Urban Sink, but the risk is equally, as elaborated earlier in this chapter, like that of the early variant of Open building concepts which was simplified into High-tech style.

There is no way around it, the everyday use (utilitarian) aspect of a building is central in its ability to prevent waste generation, while the immaterial considerations can help to strengthen such a building body to perform as an Urban Sink.
In a careful linking back to Semper, it could be argued that the support is what steps back and is usually associated with the material/principle considerations, while the infill is what potentially constitutes the experimental "haze" of interiority (immaterial). Whether in some fixed or open arrangement, the support and infill can be said to respectively be dealing with the material and immaterial consideration. Not unlike how Semper conceptualized, the structure is there to facilitate the "haze of carnival candles."

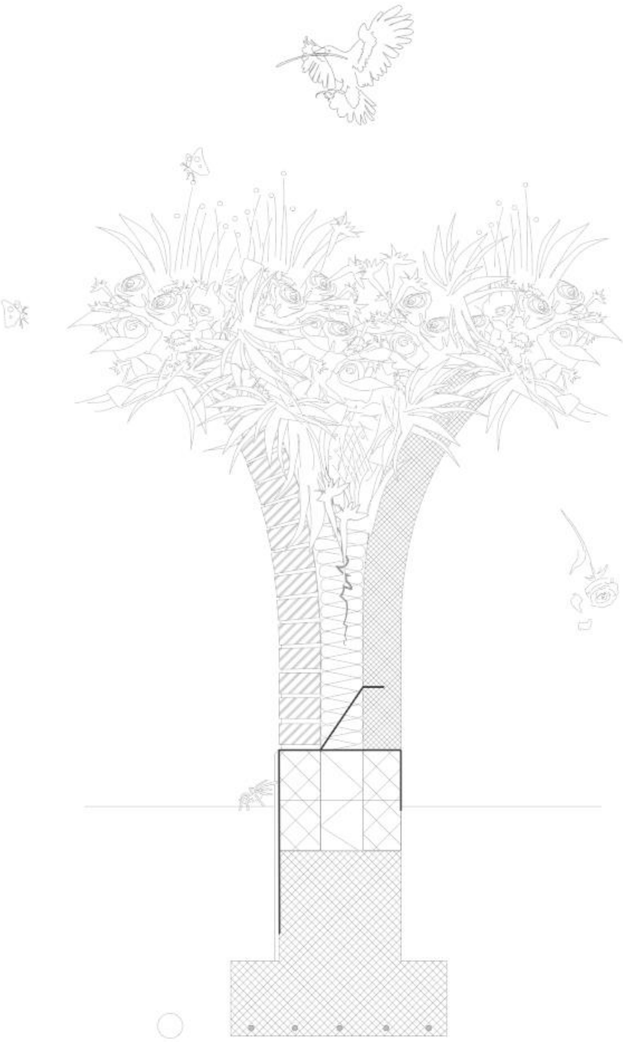
5.4. Conclusion

This chapter explored the analytical application of the built theory having a dual purpose to first apply the theory and attain findings in its immediate application and then to explore what significant insight can be gained from its application.
The built theory (chapter 4), and particularly its constructs were applied as a case study as to discern relations. The case study provided the basis for both interesting empirical comparisons between cases and their constructs (and relations) as well as interesting conditions along with the hypothesis of the "surplus volume." The findings of the case study showed indications of immaterial considerations possibly helping a building body perform as a "safe sink" at least with regard to the main "supporting" structural elements as there has been changes in floors, windows etc. over time. While the cases were within the same typology and function, they were made from differing "philosophies" of being more or less conventional (Case A), open-building-like (Case B), and a high-tech solution of click-on modules (Case C). This differentiation allowed for crucial discussion which fed into the anachronistic analysis of the Urban Sink spectrum and paragraph on critique thus allowing the constructs and its relations to be expanded, generalized, and discussed in order to explore the contours of the "logics" and boundaries of the theory building effort. The further expansion of analytic capacity indicates that the Urban Sink is a spectrum which varies across the scales of furniture/inventory, element (wall) and support. The findings additionally promoted a linking or inclusion of another design field within architecture which is not usually categorized as metabolic or tectonic bus is rather the category or field of OPEN building design and so-called "pattern-book" housing concepts. This realization greatly opened the scope in relevant ways for metabolic thinking and was significant for both analysis and future designs. Since the Urban Sink is varied, much more research could be done to contextualize which variant is more appropriate where. Nonetheless, for the time being, the open variants is considerable importance

given the urbanization tendencies and climate change challenges.
The "use/function" construct has been considered in the case study only as flexibility within the same functional category (housing), allowing for extra room for an office or newly born child etc. This type of analysis (*capacity analysis* (Kendall 2003)) could also have been applied to test the same building body for other functions (office, hair salon, boutique etc.) to property test Urban Sink performance and perhaps explore the threshold of the functional variability possible in the same building.

5.4.1. Contributions to Theory Building from Analysis

The initial application as the juxtaposition of cases and their constructs in the paper, along with subsequent unfolding in this monograph allowed the findings to prompt many considerations which were scaled up, so to speak, to both more general considerations in the anachronistic analysis and the critique. The testing of the theory in its analytical capacities provided feedback for the initial theory building. Looking further back than this monography, the very first instance of testing (the written paper) required further expansion of the analytic approach as it was clear that both precise empirical gathering was possible as well as anachronistic analysis and metabolic-critique. At the same time, the metabolic approach allowed for equally pertinent comparative analysis and critique which was less rigorous and systematic (akin to continental philosophy) but equally useful as it provided possibility for speculative thinking which could further allow for pertinent hypotheses for future research. Likewise, after the writing of the first paper (Usto et al 2022) there was a seemingly inborn "perplexity" of notion of Urban Sink, and it did not contain clear indications of how to outline such a notion – necessitating further reflection and elaboration in this dissertation. While the original paper (Usto et al 2022) was concerned with testing and applying the constructs (and relations) (see chapter 4.4.4 and 4.4.3.), the written paper permitted reflection which allowed for the development of the "logics" (4.4.6.) and "boundaries" (4.4.7.) of the (im)material metabolism.
While the analytical capacities of the (im)material metabolism started to get its contours (figure 115) the question of design was becoming pressing.



Chapter 6.
Testing Theory: Design

This chapter will elaborate the second round of attempts to test theory by applying the theory (im)material metabolism in its prescriptive capacities (design). Referring back to research question in chapter 2 (sub-question 2), the aim is to further explore how the theory can be applied in a prescriptive/design capacity and what new significant findings and considerations a *metabolic* tectonic theory could prompt.

This chapter is first and foremost based on the exploration and finding from paper 2 (Usto et al, 2023), but the chapter will attempt to further explore design capacities based on the lessons and reflections from the original paper 2. In comparison to chapter 5 (analysis) this chapter will explore the design capacities in an urban design and planning scale. In the expanding of the scope (6.3), the chapter explores more varieties, so the Urban Sink is further linked to relevant design theory and practice is made. Finally, I propose a set of normative design rules/indicators on account of the lessons and reflections in both analysis and design chapter explorations.

6.1. (Im)Material Metabolism in Design

As the purpose of this chapter is to explore the design capacities of the theory, experimental design research (research-by-design) (Hauberg 2011) is used as a method to test and build theory (Cash 2018; Horváth 2016). As the quest is to test the prescriptive (design) capacities of the theory, an experimental research-by-design approach is used to explore and develop so-called 'design 'rules' which act as prescriptive principles for designing.

Similar to the original paper, the challenge is again to attempt to explore conditions which could bring forth further nuance to the Urban Sink concept and as such explore possibilities that can potentially facilitate reuse of larger amounts of construction waste. This will, however, attempt to increase complexity and scale. The first paper (paper 1) and paper 2 are connected thematically in the sense that the three cases generate waste to a lesser or greater degree, and the task is to explore what could have been done with such waste. As we are still seeing limited practice of reuse of construction waste materials, how could an urban scheme propose potential trajectories instead?

Not unlike the case study, the testing of the theory is done by again mobilizing the five main constructs of the (im)material metabolism: however, in the case of the design scenario, the quest is to iteratively develop and explore the relations between the five constructs and not to map and analyze as was the case in the case study. As

Research-by-design requires a method or logic which indicates the design steps (process) (Hauberg 2011), the constructs were attempted and explored in such a capacity that aimed at discovering relations and ultimately proposing “design rules”.

Lessons and reflections from Case study

Based on lessons and reflections from the case study paper (paper 1) and the analysis chapter of the PhD study (chapter 5), a few considerations were crucial for initiating the design testing of the (im)material metabolism. On account of the original paper 1, and the subsequent further reflections in the analysis chapter (chapter 4), it was considered pertinent to expand the scope in scale to urbanism as a metabolic design approach is not only confined to the building scale and further insights could be gained by relating material concerns with both other building stock and outdoor areas.

Another consideration was the interesting phenomena of case A and the fact that its design drawings and instructions performed as local plan law. This indicated that design or “prescription” as expanded to “legislation” (prescription for how people build, renovate etc.), could hold immense potential.

6.2. Design Scenario – Research by Design

The quest is to explore a future scenario of a possible urban strategy which could minimize the need for new material input and increase reuse rates in the current conditions of waste generation. Exploring the potentials, challenges, and limitations of the design scenario has the aim of legitimizing and rendering plausible the urban sink and metabolic approach through design application of the waste material. This intention is mirrored by the original design paper, paper 2 (Usto et al 2023). Similar to the in the original design paper (paper 2), the storage function qua architectural application is key but further exploration could be done regarding the reappropriation of the stored materials and networks they could engage in. The materials could otherwise remain at the storage site indefinitely. The difference in this section will be that instead of exploring the single design site and its possible functions as recreative urban space, the aim of the investigation is that of the “whole” network as was hypothesized in the conclusion of the original paper (Usto et al 2023).

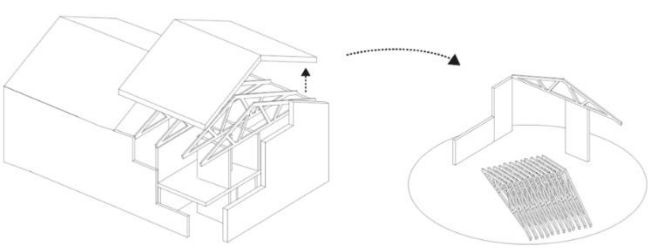


Figure 116. Waste materials - from a building volume to an urban space (storage site)?

If we are to make the potential of the hypothesis of larger urban system plausible, and by relying on the potentials and reflections from the original paper (paper 2), how would the five constructs be applied on a much larger scale, and what considerations do they entail across the (im)material spectrum?

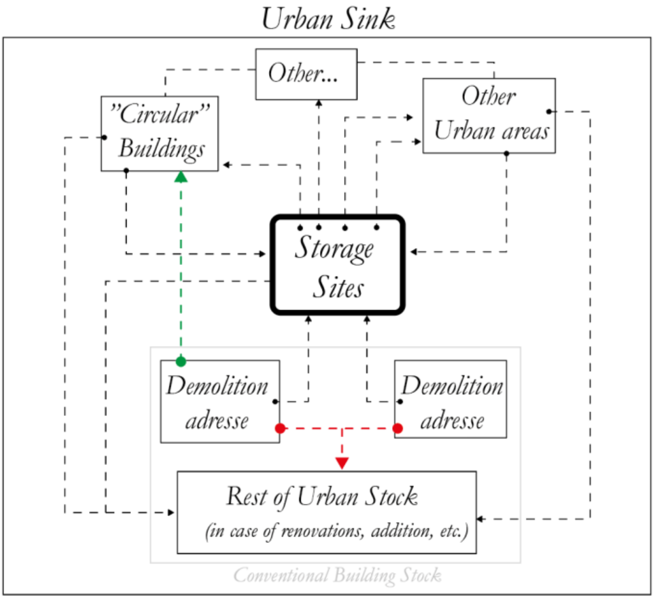


Figure 117. Urban Sink: the storage site as an important Detail.

The green line (Figure 112) is the representation of the currently known examples of "proof of concept" where we have seen that it is possible to use waste materials in new buildings. The challenge is, nonetheless, the amount of waste materials and thus the subsequent facilitation and design application of large amounts of material waste. The red line indicates the ideal solution but is currently halted due to warranty issues, lack of awareness in public, legislation and more. As time is a pressing issue (due short timeframe from request to approval of demolition) and since the green line did not permit the expansion of red line, there is need of a different system or network which can redirect material flows qua the storage sites as they were elaborated in paper 2 (Usto et al. 2023).

6.2.1. Situating the design scenario (vol 2)

In situating the design scenario, it is important to consider some empirical material flows conditions. From a global perspective, the building industry is one of the major polluting industries (IPCC 2021). As anthropogenic flows are overtaking natural flows (Elhacham et al 2020) , and we can see how these materials move (Haas 2020), can we somehow minimize the ever-increasing consumption of materials in urban area? In a Danish context, as it is with many countries, there are similar tendencies which are coupled with the fact that significant amounts of waste materials is transported internationally to other countries or poorly reused (crushed) (Miljøministeriet 2021; Building-Supply 2021). If we consider these tendencies more precisely, in Denmark there is approximately 5 million ton of building waste: 7% incinerated, 36% reused and 52% reused "otherwise" (meaning crushed for roads etc.) (ibid.). As there are ideas regarding so-called material banks or archives, could we perhaps store large amounts of construction waste materials outside as creative structures in the city?

Figure 118. Aalborg and Nørresundby provide the spatial footprint for the design scenario (vol.2).

The premise for this design scenario (i.e. the expanded version of this chapter in comparison to paper 2) is to propose an outer periphery of the design scenario to that of the urban (and sub-urban) areas of Aalborg and Nørresundby, respectively. The reason for this expansion is to increase the possibility of shareability and potential variety of materials, since Aalborg Municipality holds data on all addresses approved for demolition. The reason for limiting it on (dual) city level is because both Aalborg and Nørresundby are within the same municipality, and they are additionally their near in proximity. It would have been too complex to include the whole of Jutland or Denmark, and the intention was *not* to propose long transportations of elements. The intention was to instead keep them within the Urban Sink capacities of the proposed urban footprint.

The design scenario of this chapter does not deal with the actual waste materials from the case study (paper 1) but instead works withmore conventional and generic waste materials from housing building stock which is fundamentally comparable and similar to the case study materials. Fundamentally, the waste materials could be any other segments of the building stock and not only housing as industrial buildings would perhaps have larger structures which could make it more interesting to apply them spatially in order to allow for more grand gestures, unique shapes and designs etc. The challenge is nevertheless the large amounts of conventional materials as they are usually applied in housing functions and thus find interesting and meaningful ways to appropriate the waste materials.

Initiating Intentions
Given the abovementioned conditions, could there be different ways to conceptualize material flows and thus propose new designs and strategies to better deal with material consumption and waste generations in the quest to minimize material flows? Not unlike the original paper (Usto et al 2023), this design scenario initiates with intentions of material flows (Figure 119), i.e., the large amounts of construction waste.

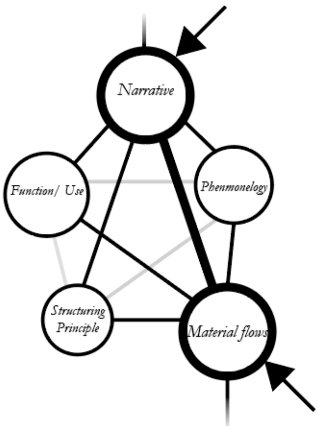


Figure 119. The design initiator: the design agenda starts from the material conditions and the narrative of material flows.

6.2.2. Design through the Constructs

The noticeable difference from the analytical application of the (im)material metabolism is that the constructs are opposite in chronology in order to initiate from the “material flows” aspect. The reason for this is that due to the intended task finding ways of re-introducing waste materials into the building stock (without it being crushed) necessitated an approach which starts from the available materials instead of a conventional design process where concept and ideas come before choosing materials. In the following paragraphs, the design process will be described where the first step is the gathering of materials through the structuring principles, etc., and finally ending with the “narrative”. Though the “narrative” was also an initiator, “narrative” will also finalize the chapter in a more finished form.
The design exploration is a conceptual and diagrammatic abstraction of principles and ideas elaborated in the paper 2 (Usto et al, 2023).

Design ‘step’ 1 – material conditions:
The main aspects of the first step in the design process was to find materials. This had its own delineation, both in finding a site for the design scenario and the finding and choosing of building materials (Usto et al. 2023). This was proceeded by relying on a municipal list of addresses approved for demolition and on account of which two were chosen. Followingly, in the paper, the building stock from said addresses were remodeled in 3D software in order to facilitate the design process.
Even so, something more is needed in an extended version. Paper (2) provided the core of the process (demolition addresses, building stock, modeling), but in this chapter these elements will instead be conceptualized a network of addresses instead of choosing two new ones.

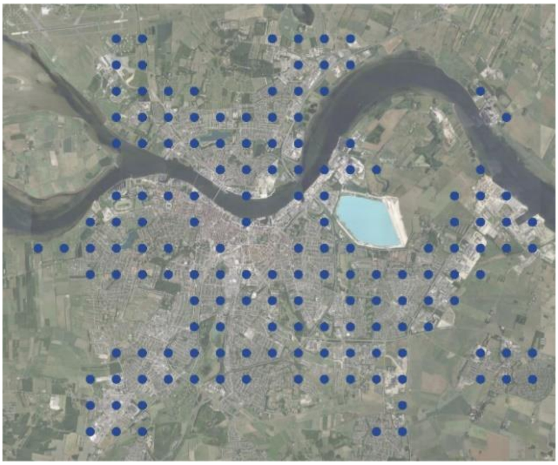


Figure 120. All addresses approved for demolition (blue dots) by Aalborg Municipality (an abstracted conceptual version).

The challenges with this are many. Firstly, the political aspect of collaborating systematically with the municipality. Secondly, the reading of the archival material of the demolition addresses and modeling/mapping of the available material. The reading and mapping of waste materials on account of archival municipal data can be very time consuming and difficult as sometimes the drawings can be difficult to properly comprehend. It was thus necessary to corelate with areal footage (skårfoto.dk) and google satellite imagery to discern the current conditions. Together these two tools gave initial insight. Even so, due to contamination risks, personnel would be needed to categorize the usability of said materials. The mapping of available waste material would require much effort and potentially many manual work hours. Given that A.I. tools are becoming more and more prominent, there could potential for systematizing the mapping of all addresses approved for demolition.

Design 'Step' 2 – structuring principles:
When having to deal with such an amount of construction waste, there is need to facilitate it. In the original paper (Usto et al 2023) the brick and concrete elements are cut in 1-meter-long segments while the full height (2,35 m) is maintained. This allows for later uses to maintain the room height if the elements would later move from the urban setting into a new building. While the elements would have these dimensions they could still be freely used as either full height wall, half height wall or flooring elements.

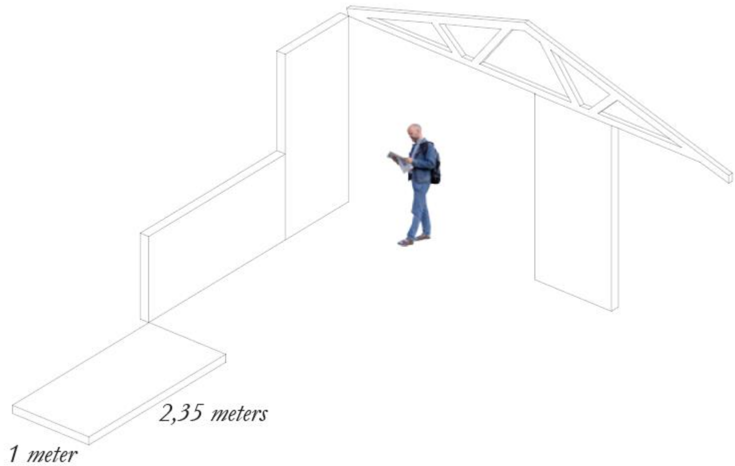


Figure 121.Cutting and applying principles.

To facilitate the large amount of construction waste, a city-wide strategy is needed, i.e., a "web" of storage sites (white dots). Each of these sites would then be made in accordance with the exploration recreative affordance and potentials as presented in the original paper (Usto et al 2023).

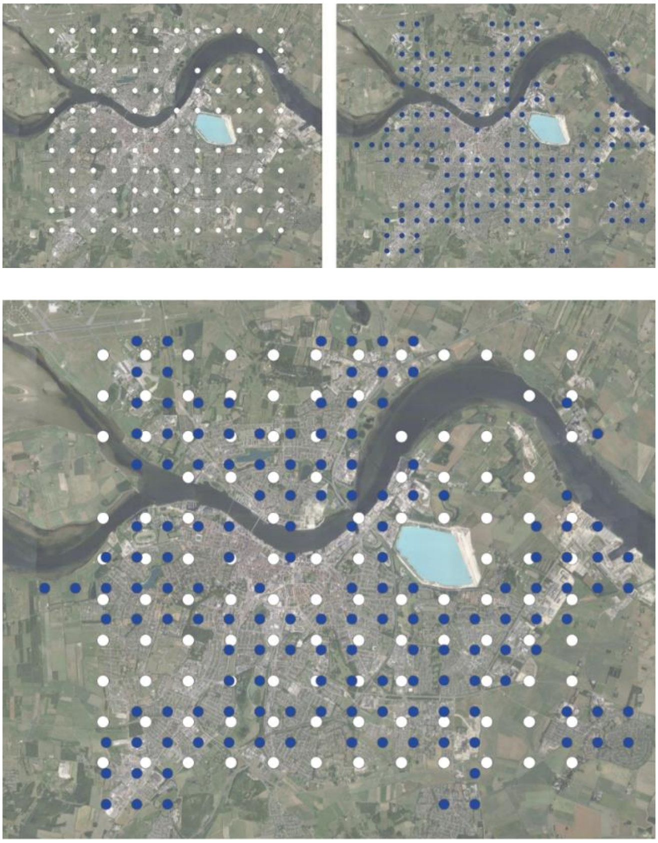


Figure 122. The city of Aalborg (and Nørresundby) with a conceptual overlay of storage sites (white dots) - and addresses approved for demolition/renovation (blue dots.)

A significant principle would furthermore be that of the address of approved for demolition should have its construction waste material contained at the nearest storage site (Figure 123) a “proximity principle” so to speak. From an initial perspective, the purpose of this is to minimize the traveling distance of materials from address to storage site. Later the experiential aspects of this principle will also be elaborated.

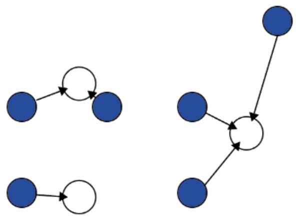


Figure 123. Diagrammatic principle (algorithm) for allocation of materials (blue dots) to available sites (white dots).

Once there is an overview of storage sites (and their principles for receiving materials), the next crucial step is to include the addresses where new building will be made. This implies available materials at the storage sites, as well as a digital corresponding catalog that allows architects to use said materials.

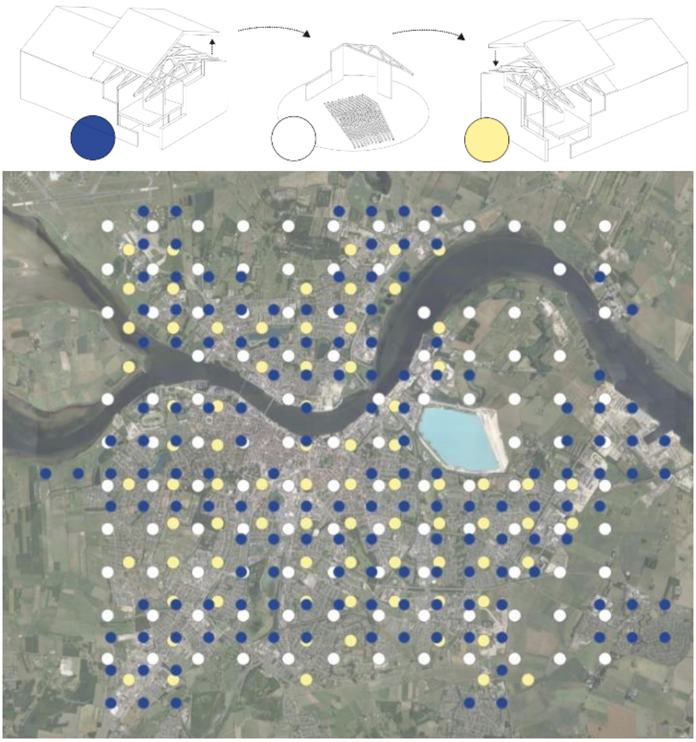


Figure 124. From demolition to construction, through the storage sites. In extension of Figure 36, the yellow dots are the mappings of addresses approved for building new structures.

Design 'Step' 3 – functional application:

Applying an increased amount of waste materials would require the mapping of designated storage sites and categorization which could indicate what function would be pertinent to gain. In the original paper 2 (Usto et al. 2023), the main types of function were that of recreative urban affordances (i.e. seating area, biodiversity tower, pavilion etc.,) (Usto et al 2023), and there is likewise a need of a wider range of functional application of construction waste materials as many more affordances can be imbued into storage sites. This is not to say that the repertoire of design proposals could not be applied in very different settings than merely urban/recreative areas.

Figure 125. A bus stop made from the same waste materials. The wooden elements are used for canopy, while the folded brick walls are stabilized via the seating elements.

The expanding of the catalogue of possible applications necessitates variety in storage sites. This could be, for example, systematic use of construction waste materials for a new bus stop (figure 125) or it could be used as additional material to an existing one (repair etc.). It could also be the application of construction waste as a sound barrier along the highways in the near vicinity of housing areas.

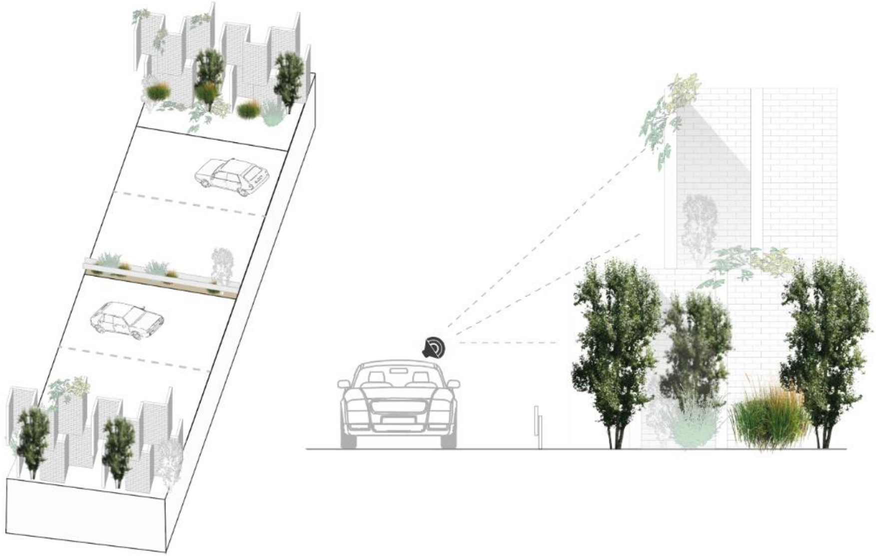


Figure 126. Waste materials used as noise barrier on highways.

Generally speaking, when it comes to the application of construct and different uses, there can be an unknown number of types and functions. It should thus be considered that there can be two main types of storage sites. One could solve a problem or in some sense provide a certain level of meaningful recreative potentials which permits and invite interaction. The other would be art installations which can be viewed from a distance and are not necessarily intended for close encounters.

Design 'step' 4 – experiential properties:
As there is a variety of utility of the different design, there is equally a variety of experiential potentials and qualities. The challenge is to create meaningful urban structures which can provide phenomenological experiences and have people engage with waste materials while not having a feeling of being near something disgusting like a trash heap or dump site. As it was developed already in the paper (Usto et al. 2023), there can be immediate haptic and corporeal niceties of each designed structure at the storage sites, i.e., like that of closeness and embrace especially on windy day.

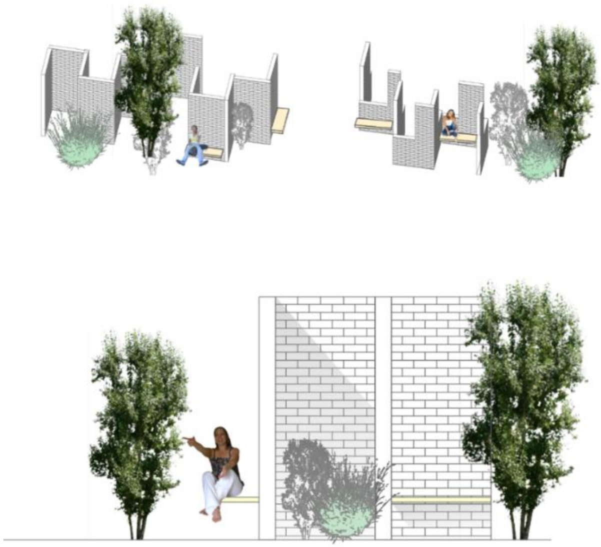


Figure 127. Small, human scale spatial enclosure with seating and wind protection.

As the separate installations at the storage sites may have their particular spatial and reactive properties and purposes, there can likewise be a more general experience of the network, or at least parts of it in one's daily dealings and mingling within the city. Let us then try and imagine an everyday life scenario.

Figure 128. Partial image of the city. An everyday cycle of living in area A, shopping in area B and working in areas C.

Imagine (Figure 128), you live in area A, you shop in area B, and you work in area C. The principle of moving waste materials from their address of demolition to the nearest storage site (white dots) will play a significant part in the potenial experience of the storage sites. On a daily basis you pass these sites and may think of them as peculiar or strange art installation. You may notice them every now and then and observe people having a closer look or children playing in and on them. Sometimes, when taking a walk with family or friends in the area or taking your bike for shopping, you notice that there are a number of them that are difficult to categorize. These could be the are sometimes playgrounds, art installations, or something else entirely. You notice that they are both very different and at the same time very similar. You noticed these art forms elsewhere in the city and recognize that they must have a larger purpose or are perhaps somehow connected. Let's furthermore imagine that you have lived here for some time and have noticed that one of the peculiar "art" installations seems very familiar. And entirely by chance something struck your eye. You remembered that a house from your street recently had a significant renovation inside and out and you happen to recognized your neighbor's old facade at one of the storage sites.

Design 'Step' 5 - Narrative:
The dimension of "narrative" is present both at the level of intended narrative and experienced narrative. This means the narrative of the material is embedded in the immediate context (the proximity principle). At the same time, it is a narrative of a slow "cultural continuity" (with reference to theory building, chapter 4) of material life within site specific conditions.
The story above is one of *unfinishedness* which is in constant motion. This may manifest both in the literal sense of materials and elements being transported to a storage sites and later moving to become parts of fabçade or interior in new building. On the other hand, the *unfinished-ness* is also an aesthetic and conceptual category of the lived spaces that we would find ourselves in in the near future; namely due to the potential increase in use of construction waste, our structure may seem "confused" or "irrational" which sets a different design burden or challenge on the designer. A new or different sentiment would be needed among the public, in addition to significant effort on the part of the architects, engconsultantsd other consultant etc., to provide meaning in what could appear chaotic. This hints at the mortality and finitude of materials and their dynamic which ought to prompt consideration on how we as individuals consume and how our behavior affects material flows. Apart from the intended and overall narrative of the design, the very conceptual unfinishedness of the design opens up a dialogue with users and visitors. This could by allowing people to form their own narratives and engage in dialogue of their own prompts' reflection and introspective consideration regarding consumption of materials. As it is important to design strategies to reuse larger amounts of materials, it is just as important to not only educate citizens on material consumption but at least make people reflect and

contemplate their own roles and potentials with regards to material consumption and its effects on the built environment and global warming in general.

Synthesizing Findings – design rules:

Concludingly, the purpose of the design scenario has been to extract design rules – given that the overall research agenda of this PhD is to test the *prescriptive* capacities of the theory and as such include them in the iterative process of building theory. The four design rules that the paper proposes are “keep the materials, transform as little as possible, bottom-up approach, metabolism should be slow” (Usto et al 2023). In addition to the design rules from the original paper, there are aspects to consider in utilizing as much construction waste as possible.

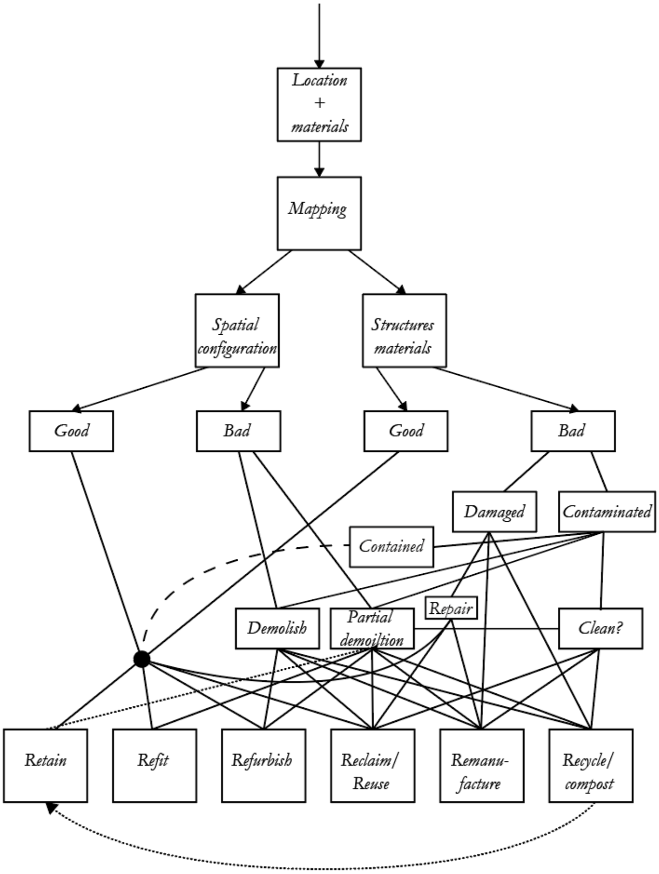


Figure 129. A prescriptive monadic diagram which ends in well-known and familiar circular strategies (Cheshire 2021).

In approaching any challenge or "design" problem when it comes to waste materials and reuse old structure in any capacity, it is important to try and save as much as possible on account of different considerations— both in regard to the inherent possibilities of the structures and materials in comparison to the intentions and agenda of clients, municipality etc. at any site.
When it then comes to any specific site and its materials, an analysis is first needed of spatial configuration (size, ceiling height, composition, experiential quality, and potentials) as well as the structures and materials which facilitate these spaces (if they are support or infill, movable, texture and experiential quality). On account of these mappings, it is possible to categorize into "good" and "bad" conditions. Sometimes a building can have poor ceiling height and poor composition which can make it difficult to simply retain it as is and can thus be limited in use as other functions. Structure and materials can likewise be either "good", and thus useful and workable, or "bad", i.e., damaged or contaminated by chemicals etc., which poses a hazard in some way for either human or non-human actors or conditions. This necessitates at this level of categorizing spaces, structures, and materials be observant in relation to the specific conditions. Just because materials are contaminated, it doesn't necessarily mean that they ought to be demolished. There can be instances where the hazardous elements is safely contained and not a problem if other structural and spatial affordances allow for retainment, refitting etc..
If this is the case, the elements could be cleane although there are no such cleaning machinery within Danish borders (e.g. in case of asbestos) which is why contaminated materials and elements are sold internationally (Building Supply 2021). While we are waiting for this ideal situation of approaching systematically construction waste and building stock reuse, a large amount of construction waste is being generated irrespective of the different categories of the above diagram as the owners simply apply for a demolition permit. As the design scenario explores, it could be possible to find a way in which demolished materials can be recycled as a way to 'retain' materials instead of shipping it off or crushing it. Here, the aspect of 'retaining' materials is usually understood as allowing materials in the building body to remain in their current form and location, whereas the design scenario explored the potential of expanding this category of 'retaining' in a more dynamic form through storage sites.

Reflection
The further elaborated design scenario (of this chapter) revealed a problem that will require addressing, ideally in potential future 1:1 experiment - a problem which the original paper 2 (Usto et al. 2023) did not prompt due to paper focusing on an isolated, single site and not a network. This reflection occurred in design step 2 (structuring principles, paragraph 6.2.2.). That is the problem of how materials stored at the sites are to be taken from the storage sites. The implication is that either entire structures are taken and reused - or the structures are made in a way which permits partial demounting for only certain materials at the storage site without needing to take the

whole pavilion/structure.
While this design scenario used archival document as basis for design exploration, the future challenges would to approach a similar issue but on larger scale and with more rigor for large amounts of material. Here different method could be used to mapping and estimate larger quantities of materials in the urban stock (Honic et al 2023).

6.2.3. Constructs as Design Steps

The design process is thus initiated as a dual or joint approach of "narrative" and "material flows", meaning there is an inherent vague narrative in mind from the start. The initial intent of this PhD study was to attempt to apply the constructs as design steps in chronological order starting from material aspect. However, in the application of the construct, the process could not help but become intertwined across the constructs as a proposal of principle for cutting the material would automatically have implications on sizes, scales and possible applications for recreative function and thus experiential conditions. The actual design process of the design scenario will be elaborated in later (see figure 130).

The design scenario was initiated from material concerns (and material availability of demolished addresses) (step 1), but the following considerations on "principle" (step 2) promoted simultaneous reflections for what kind of experiences and spatial conditions. As a consequence of this, the "structing principle" was itself partially "structured" by use and experiential considerations. Following, the utility aspects were further explored (step 3) to analyze the consequences and possibilities as well as limitations of the proposed principles in relation to the former two constructs. The experiential possibilities were them more closely considered (step 4) and ended with the narrative dimension of synthesizing all other considerations through the prospect of the telling a *metabolic* story. This indicates that a linear process is impossible as one is constantly forced to iterate across all the constructs.

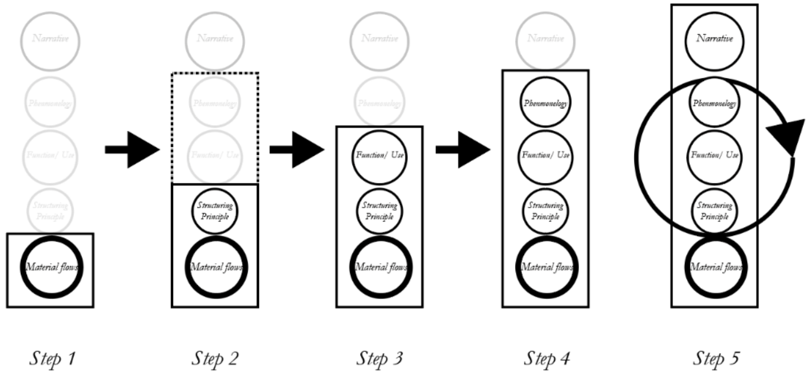


Figure 130. The process was initiated by with a joint priority of "narrative" and "material flows".

The process was thus not linear as any proposal on one construct has consequences for any of the other ones. It turned out to be almost impossible not to develop reflections and considerations on other construct (looking forward) in order to constitute the current one (i.e. look at "use" and "experience" when having to deal with "structuring principles"). Looking backwards from "use", "experience" and "narrative" it is likewise needed to see if the structuring principles are either adequate or lacking in some regard. With both of these in mind, in the final synthesis (in developing the umbrella of the narrative) there is much non-linear iterative adjustment and reflection needed (step 5). Despite this t, there is still significance in initiating the design process in a material condition (of the construction waste).

6.3. Expanding the Horizon – other prescriptive capacities

Doing design (prescription) can contain many considerations but is usually manifested as iterative design drawings/sketches in different media (whether technical or diagrammatic). The quest is now to explore an expasionof the design prescription capacities. The original papers on analyses (Usto et al. 2022) and design (Usto et al. 2023), along with the subsequent further exploration and expansion promoted the consideration of how to include design prescription in building legislation.
This section furthermore develops a future scenario which argues for a temporal as well as an spatial understanding of metabolic thinking in the built environment, whose purpose is to "telegraph from the future" how we are to proceed in metabolic terms here and now. Concludingly, the section will end the chapter with bringing together

reflections from both the analysis exploration (paper 1 and chapter 5) along the reflections and findings of this chapter.

6.3.1. Other Relevant Design Prescription

With an (im)material metabolic understanding, we need to expand what "objects" we have to design and likewise what "design" further entails. There is little chance of merely changing material flow patterns by designing good houses or urban spaces, and as such, we have to include more "objects" of design, or at least an "object", that have immense potential for what and how things are designed. In expanding the prescriptive capacities, there is need to further categorize the types of "design" possible through metabolic thinking.

In extension of the chapter on analysis of the case study of three housing projects (paper 1 and chapter 5.2.) and the notion of the "surplus", ideas and prescriptive principles or rules arise regarding how to design new building stock in the future. The following section will be structured based on four main activities (or functions): dwelling/working, eating, transporting, cleaning (Oswald, Baccini 2003; Baccini Brunner 2012).

Dwelling/working
The category of dwelling/working is most commonly associated with architects who design buildings, urban design, and master planning with the aim of arranging dwelling and working conditions. That includes many already mentioned tendencies and trajectories founded in open building and circular design trajectories. The plethora of the "dwelling/working" potentially spans from the smallest detail to large infrastructural consideration of the city.

How we live can immensely influence our carbon footprint, and researchers are looking deeply into how we can facilitate changing needs over time with the building stock. Among others, David Cheshire, practitioner on circular building, has shown, integrating flexibility and affordances can occur at many levels (Cheshire 2020). Providing flexibility and adaptability both in plan and section (possibility of adding an extra floor in double high rooms) can prove crucial for transitioning to a "circular" thinking and perhaps more critically a metabolic understanding of the built environment. There can likewise be more social considerations on livability in a more collectively oriented approach (Chan, Zhang 2020). Such approach on dwelling necessitates a decrease in square meter pr. capita, through collectives and sharing of facilities, equipment etc., towards achieving a decrease in total footprint and foot prints pr. capita thus minimizing material input from nature to society.

Eating
This particular category does not necessitate a deep insight into gastronomy but, like the former category, implies an understanding of planning for an alternative way of

providing nourishment, not necessarily only for humans, in increasingly sustainable ways. There is both practice and theory regarding such tendencies (Tornaghi, Certoma 2019), and the examples are becoming more and more ambitious (Croxford et al 2020). Fundamentally, the core dynamic deals with bringing production back to the city. However, as this has a sustainable consideration (minimizing transportation etc.), there are likewise new possibilities and trajectories for developing new cultures of consumption.

Transporting

The category implicates many different things simultaneously: the transportation of goods as well as people or other aspects also in need of being moved in one way or another. Perhaps the most commonly known and immediately relevant field to consider when it comes to architecture, urban design, and planning would the field of mobilities. While mobility is its own field, mobilities have been part of metabolic studies including flows of people, goods, information etc. (Oswald, Baccini 2003, pp. 54). There are likewise variants of mobiles known in the discipline (Jensen, Laang 2016) which also deals with sustainability considerations as well as connection along with the phenomenological consequences of designed mobilities. Furthermore, scholars and practitioners are developing life cycle assessment tools in particular for mobility and transportation (MobiTool 2023)

Cleaning

Waste management is field of its own and contains many aspects: anything from landfills, sewage systems to reuse schemes and much more. Very often such mechanisms are crucial for the wellbeing of the city but are not always visible and architecturally significant in people's everyday use of the built environment. In a more immediate and familiar type of "cleaning" relevant to architecture and urbanism is the consideration of how we clean and maintain building and urban areas, how we design spaces and areas which are easily cleaned and maintain, and how we choose and apply materials which are likewise easily cared for.

Design Criteria and Scales

The design method and model for NetStadt (Oswald. Baccini 2003) likewise proposes a set of design criteria to consider when designing metabolic schemes in urban settings. Those are that of Identification, diversity, flexibility, degree of self-sufficiency, and resource efficiency (Oswald, Baccini 2003, pp. 49-52). These respectively deal with making a meaningful and recognizable urban area; differentiation and variation of functions and possibilities for any needs; ability to adapt to changing needs; ability to provide for a city within regional boundaries; and ability to efficiently utilize resources (ibid). already indicated in chapter 4.1, several levels of spatial scales should be considered as well: those of the individual (house, the local (neighborhood), the community, region, nation (Oswald, Baccini 2003, pp. 54).

Reflective considerations
While the four main activity types of stem from industrial ecology and chemical engineering studies, it is important to note that there are differences from those of their counterparts in architecture and urban design disciplines. The variants of the activities outside of industrial ecology, with their very different theoretical frameworks and methodical tools, are not necessarily *metabolic* approaches. As was brought forth in the introductory chapter (chapter 1.), there is always a risk of manifesting Jevons Paradox when optimizing urban systems thus requiring a critical metabolic understanding.

Compiling activities and things - Symbiosis
We are seeing more initiatives and designs regarding sharing economies where the planning practice allows and facilitates sharing communities of anything from tools, books etc. even up to walls (as seen in case B in chapter 4). Industrial ecology also allows for the design of energetic symbioses where (Gulipac 2016) where given energy systems produce an energy or heat surplus which get appropriated elsewhere. Such practices are commonly used in industrial areas and industrial parks. There are likewise modest attempts of this in the central urban area of Skive (Blå Diamant). Such practices are called urban or industrial symbiosis (ibid). To increase the likelihood of such "symbiosis", new and appropriate master planning practices could be developed which allow for larger heterogeneity of building programs (such aa more production in cities next to housing, working etc.) to allow for different and more positive affordances between them both materially (less energy use, less material needed etc.) and immaterially (new or different spatial character, social practice and cultural values).

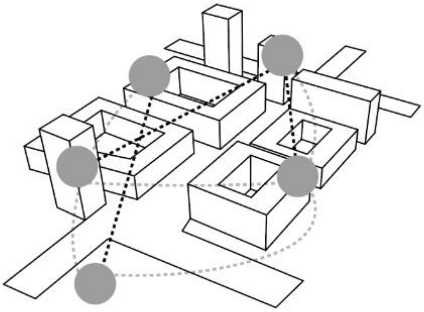


Figure 131. Urban Symbiosis; city as an interrelated network of sharing economies of facilities, tools, books, products, walls, energy, heat etc.

It is thus possible to expand on the scales of design of the Urban Sink and thus explore new ones. Urban Symbioses and industrial ecology are closely related terms, and they are complex notions with many definitions and variants. It may seem that such notions are mostly related to the design and planning of industries and industrial facilities, yet their principles can also be considered in relevant ways in urban areas for everyday use. Making buildings dependent on each other based on specific technologies (whether related to energy or heat) can seem to pose a challenge due to technologies being prone to change over time. However, as literature on *persistent* architecture has pointed out, it is also possible to facilitate adaptations and change in technical services and technologies within a building anatomy (Fannon et al 2022) thus allowing for potential "symbiotic" design considerations.

Each of the four activity categories are design platforms which contain design criteria and scales with which new constellations and relations can be designed both within each of the categories and in the relations to each other. Each of the categories are complex, but central "objects" as way to design conditions of the built environment which meets human needs in the most "material" (utilitarian) sense.

Linking Metabolic Thinking – Urban Sink across variants

When we are engaged with designing and prescribing material conditions the general quest is to prescribe from a position of awareness of material conditions as well as regional, national, and ultimately planetary boundaries. As the concept of metabolism can seem immediately complex, there are several ways to make it approachable as elaborated in prior chapters and paragraphs. The purpose of this paragraph is to create an overview of the different approach and scales of metabolic design thinking. It can be difficult to comprehend all aspects at once, but it would be preferable to have basic insight into all metabolic scales and aspect while dealing with one's own particular interest.

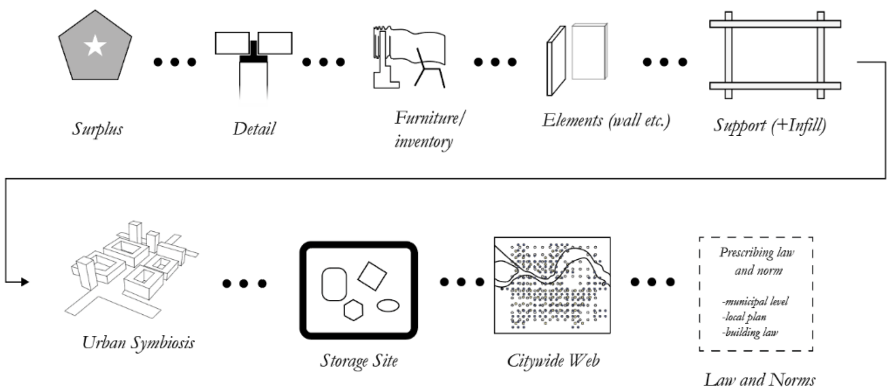


Figure 132. There can be different variants of the Urban Sink;
Surplus, detail, furniture, elements, support, urban symbiosis, storage sites, city web, law and norms.

In our endeavors to design and prescribe conditions, several aspects can be considered. As shown in figure 132, there is a spectrum of scales and considerations which exemplify the possible attacking points in the quest for designing a sound Urban Sink through a (im)material metabolic approach. Each of the scales (furniture, wall elements, support, urban area/district, city "web" strategic network, writing new law and guidelines) are to be considered exemplifications and possible starting points. There can be many more interstitial scales to explore, and many variants in type and typology of each scale as they can be adjusted according to new data and analysis contributed potentially from any discipline, science or profession. The manifestation of the Urban Sink thus has very tangible and physical strategies to consider the meta-physical and immaterial (experimental, social, political and economic) considerations while considering the slowing and narrowing of material flows. All of these have to be grounded in material preconditions in order to promote a critical metabolic approach. The last level of the prescribing of laws and norms ought to have influence on all the former scales and approaches.

The range of the Urban Sink in the above figure (132) is illustrated in a way to communicate relevance for this doctoral study and its exploration. More precisely, the category of the "symbiosis" could practically contain all the other considerations (except the "law" dimensions). Despite this, the most common application of the concept is materialized in industrial parks and similar industrial settings. The reason for this application was to lay out the different "attack points" and not conflate all of them to the urban symbiosis concept. The applications placing in the middle is thus fitting of the possible range of the concept of urban symbiosis. That is not to say that the concept of symbiosis is entirely interchangeable with the Urban Sink because the Urban Sink incorporates immaterial considerations for the purpose of slowing and narrowing material flows alongside the material considerations (material, function, energy performance etc.).

When we are designing, we are not only designing objects (elements, buildings, urban areas/districts, networks or normative guidelines or law etc.) but also the conditions from where we design. Specifically, we are also "designing" a new generation of metabolic designers, designing new educational and teaching practices, and a mental space from where metabolic design manifestations can be conceptualized before they take physical form. With all the different attack points of designing metabolically, regardless of scale or activity, when we design, we are not just making a new design for a space or disassemble construction detail, we are also ultimately proposing designs for new or different (material) cultural practices along with new or different building cultures which could be liked with new modes of well-beings (Delhey 2010; Pandelaere 2016).

6.3.2. Metabolic Design Prescription as Law?

It is not uncommon that a municipality makes new land plot available for buildingwhen the municipality has not provided a corresponding local plan law for that land. Once the land is sold for real estate (i.e., to a private actor), the municipality also requires both designs and proposals for a local plan and design. The challenge here is not to rely on the “good willed” clients and the consulting architects to include circular and metabolic design conditions within such a design and plan law proposal. Firstly, there would be many differences if such efforts were relied on. Secondly, such a hypothetic “ideal” sustainable approach would only be present within a few new sites whereas the challenge is to expand metabolic design thinking to as much of the city as possible to possibly guarantee a systemic sustainable approach. If we are to propose metabolic design considerations becoming part of building legislations, how could such a trajectory be approached in Danish legislative setting of the built environment?

There can be several ways to approach the question of legislation in relation to design that occur on several levels. As there is already dialogue to phase in LCA into building law in the Danish context, the challenge is how to prescribe such considerations to attain desired outcomes. The potential is to “design” metabolic legislation or, more precisely, to prescribe the form/outline of material consumption in order to minimize it overall. There are different possibilities of implementing such considerations. The different levels of legislative possibilities are hierarchical and have different efficacy compared to each other. The different facets of planning law are local plan, municipal plan, regional plan, land planning law, and land zones (RealDania 2004). Of these, four will be highlighted;

- Local plan law
- Municipal plan
- Plan law
- Building law

The place to start would be to initiate a dialogue with the municipality, politicians, and general public as this aspect of dialogue and sharing of knowledge/ideas is crucial for any of the levels. Only through the creation awareness in both the social and political realm can any consideration be implemented into legislation.

Local Plan

Another opportunity could also be to rewrite or approve new local plans which could have integrally written aspects of reuse rates, but this could perhaps be a lengthy process as a city has many different local plan laws for each area, requiring significant effort to change all of them. At the same time, the local plan has openings and already allows architects (as was done in principle done case A, see paper 1 and chapter 5) to include (more ambitious metabolic) design instructions for how to reuse, maintain etc. which are designated as a “project local plan” (where a new project is coupled with an accompanying local plan (RealDania 2004, pp.7). The challenge would be to not avoid the risk of keeping buyers away. Rather, there should be an offer that allows for a range of possibilities which can be of higher or lower metabolic ambitions in order to slowly phase in such design principles. Local plans are mainly concerned with external placement of the building volumes and external appearance (among many other aspects). It is thus crucial that plan law does not necessitate characteristics of the interior and that there is likewise no need for building permits and approval when wanting to change the interior. Due to the urgency of climate change, it could be pertinent to mimic already existing legislation related to cultural heritage buildings which *do* have instructions for the interior and require subsequent building permit applications in case of intended renovations and changes. While it cannot directly be translated as cultural heritage buildings having other complex concerns, this nevertheless opens up the possibility of developing legislated design strategies for the interior as well which could follow metabolic design principles from open building concept and "persistence" architecture principles for the infill and not only the support. While there is potential in local plans and project local plans, there are likewise risks of leaving out citizens participation among other down sides.

Municipal Plan
A place to initiate dialogue with the municipality is what in a Danish context is called a "municipal plan". This is a legally binding document with a set of intentions and agendas which are important and pressing for the municipality. Such plans are made every 12 years. Many municipalities generally have many intentions towards being sustainable and green and promote themselves accordingly. The challenge to introduce more precise strategies to be included at this level. While Plan Law and Building Law are indefinite, and though 12 years is can seem a long time, it is nevertheless a component in legislation which is to be considered.

Plan Law
Perhaps preferable to this would be to write in legal sections (e.g., for reuse and limiting of demolition etc.) which cover all local plan laws at the city, municipal or national level. This could occur on the plan law ("planloven" not to be confused with local plan law) as this is higher in hierarchy and thus above the local plan law as it would allow a potential inclusion of *metabolic* measure to circumvent the need to change every single local plan law and the writing of supplementary appendices and declarations for each. The plan law is at state level, and covers all municipalities simultaneously. To change anything at this level would require politicians from the environmental ministry to initiate change which would then be put in effect through plan law, and followingly practiced within each municipality.

Building Law
Over time, the ideal situation would that of having included metabolic design considerations within building law. Metabolic design ambitions could be included not unlike how the newly added legislation on carbon footprints in the building legislation. As already mentioned in chapter 4, the current LCA legislation is not ambitious enough but has initiated modest steps in the right direction. Based on the finding and reflections (in the papers and this PhD in general), it would likewise be important to find ways to include "architectural character" into the building law as well as OPEN building principles among other aspects to potentially avoid a new manifestation of the Jevons Paradox where an emphasis on optimizing single buildings would allow a perpetuation of materials flows.
At the state level, the challenge would be to somehow incentivize implementation of metabolic design principles.

Something in between?
As legislation related to “planning” (plan law, local plan) is concerned with urban and master planning of cities, the building law is concerned with the single buildings more directly. For this reason, there is potential for legislation in the gap between building law and plan law two, as a metabolic understanding makes it evident that inter-building relations (within a given proximity) can have many positive affordances by relating buildings in a metabolic (symbiotic) sense. Such an “Inter-building law” does not necessarily need to be a law on its own on par with the plan law and building law. Instead, it could potentially be a continuation/expansion of the plan law and contain instruction and normative guidelines for intra-district, intra-municipal or intra-regional metabolic design principles.

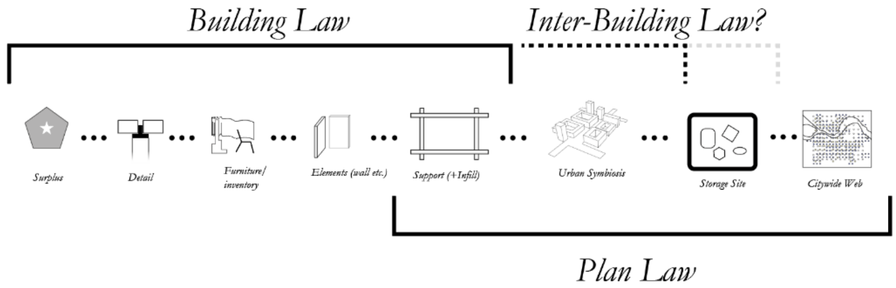


Figure 133. A proposal of including Urban Sink into legislation; the Urban Sink scale are covered differently by existing legislation, and possibly missing something in between (Inter-Building Law).

Conclusive considerations and reflections
Another central dynamic which is also at the heart of metabolic concerns is the mechanisms behind how land use is practiced. Whenever a municipality frees new terrain from other purposes and makes it available for private uses, such terrain is usually allocated for either agriculture or real estate (Lyle 1985; IPCC 2019, p.6). From a metabolic perspective, there may be indeed need for some additional material input with subsequent new plots to build on (all the while we also increase the waste prevention and reuse etc.). There is likewise need for strategic understanding of how and towards what end such plots are made available so that we do not merely perpetuate current linear growth dynamic under the umbrella of “metabolic design” or any other sustainable agenda.

Requesting implementation of more sustainable principles within legislations of the entire built environment is very complex will thus require time and many minor implementations before something of significance can be achieved. At the same time, a sense of urgency is needed based on the alarming indications of the latest IPCC reports (IPCC 2022). There is need that we always press for more awareness, debate and knowledge on challenges of material flows and the consequences of consumption.

6.3.3. What are we designing towards?

In this section, I want to initiate a hypothetical object, i.e., a sensual object, as Harman would put it. Similar to how in mathematics there are imaginary numbers, through which comes their very irrationality which allows for the making of sense of very complex systems, there is a similarity that is to be imagined here. This aspect of design is seemingly "useless" speculative imagination, but as an immaterial (*sensual)* object (in the Harman sense), there could be possibilities of utilizing such imaginary objects for our current predicament of climate change and material flows in the building industry.

This is a vision of the future which has to be considered critically at any step of the way. It may be fully and entirely flawed, but the purpose is nevertheless to force us to think critically about our current predicament. The speculative future scenario is based on current scientific predictions, but only through insinuation. The goal would be to afterwards find ways to make the vision more workable and useful for current conditions.

The" Future-Object"
When architect, designers or engineers design or prescribe at any level, to what end are we doing it? The final aspect of the prescriptive capacities of the (im)material metabolism is to discuss and speculate the future. Knowing well that it is impossible to predict the future, it could nevertheless be useful to attempt to do so in very broad terms. The development of the future scenario should be based on current tendencies and predictions made in scientific circles. The tendencies highlighted are as follows:

- expected increase/doubling of building stock by 2050 (European Commission 2021, UNEP 2022)
- population growth possibly to 11 billion by 2100, (UNDESAPD 2022)
- increase in urbanization (Baeumler et al 2021)
- increase in floor area pr. capita (Bierwirth, Thomas 2019, pp. 15; EU Buildings Database 2023)
- global migration patterns (Davis et al 2013)

These considerations manifest a very ambiguous "future-object" (figure 134) (in the Harmanian sense). Depending on many complex current and future circumstances, different variants of the "future-object" could materialize. Whether the overshooting of building stock volume beyond actual societal needs (only for economic speculation and profit) and with an increased floor pr. capita, with little to no flexibility and adaptability integrated. Or the opposite could also materialize. While latter "opposite" scenario would be more desirable, the danger of the first one should always keep us on our toes.

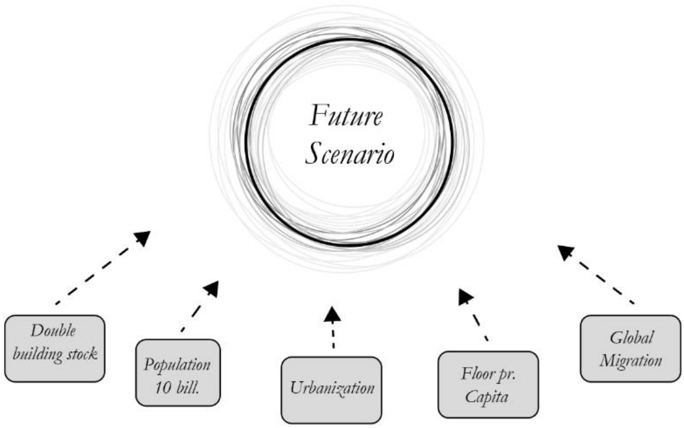


Figure 134. The future-object: future scenario S(f).

The future scenarios' two main takeaways should be that of the needs of the people in the future. In the context of this PhD study, this is to be facilitated by building stock volume. While the passing of time is certainly not predictable, and many unexpected things could happen, it nevertheless be possible for each city (based on the future scenario) to propose an approximation (as a starting point) regarding how much city do we need for a given (S(f) figure 134) amount of people. If, and they will, these numbers fluctuate, could we also propose a contingency plan regionally? What we have to avoid is, in the case of a halted global population, building stock and city footprint growing endlessly. Even with a halted global population, there is still the risk of the buildings stock's continued growth. If different migration tendencies actualize due to climate change, social and political development, or popularity etc., and this could create demand for cities to continue growing. Something like would necessitate global scale cooperation and close dialogue at any level, especially socially and geopolitically.

Further speculative imagination

When we consider the prospect that building stock volumes will double by 2050 and the risks with the current optimism with circular strategies and LCA tools, there is a risks that we might overshoot building stock volume unnecessarily. There are other important aspects to consider as well. If we attempt to model a future on the projections of current material flows and in relation to projects of both urbanization and population growth (and its expected stagnation by circa 2100), then the 2050 projections of building stock volume issue get a few more nuances. From a contemporary perspective, more and more materials will be needed to accommodate future generations and the influx from rural areas for some time to come. Even if the 2050 projections is overshot by a significant amount, this overshot-surplus can have positive effects. However, it will need to be made with the future in mind so that it is indeed flexible in 2100. There will need to be a kind of building stock volume “cap” or valve where it can be possible to significantly slow and narrow flows at a time where population size, urbanization etc. can be argued to correspond to the existing volume of the building stock (having included a surplus for unplanned activities etc.). This could possibly be developed as a working model based on mathematical estimation of population number as well as models on demography in relation to rural and urban compositions. Along with other factors, and on account of those estimates, a certain volume of building stock material will be needed for such a future scenario. Several scenarios can thus be developed in this regard: conservative proposals versus more liberal proposals. One aspect to consider is the possibility that the tendency of increase in floor area pr. capita can possibly be legislated or prescribed against (a legislative upper limit of area) where it is considered socio-economically and ecologically feasible and strategic to do so.

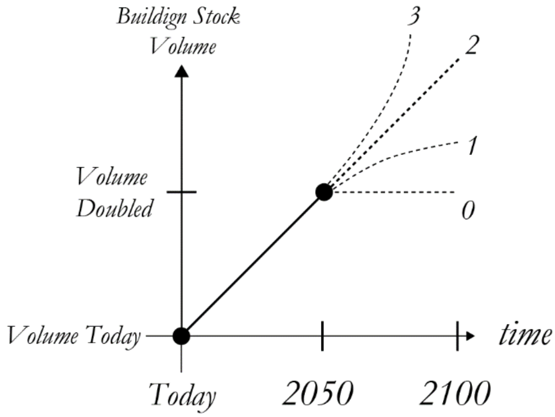


Figure 135. future scenarios; 0,1,2,3.

This does not mean that we today should build insane volumes of building stock to accommodate such a future scenario. Doing so would merely mean that we know what we are designing towards and where the threshold could be in terms of building. The future scenario is thus open and if we continue the current practice in the built environment, we may materialize a thoroughly undesirable future scenario and consequential impact on the natural environments. Likewise, if there should be a *metabolic* shift in practices, it could be possible to facilitate meaningful living conditions through as little as possible material consumption. To enact metabolic design –-we have to design and prescribe at almost any level, necessitating the taking activity at a social, economic and environmental level with both designers and activists.

$$BV(t) = BV_{current} + \Delta BV$$

$$\Delta BV = \underset{anno\ 2100}{Future\ Needs} \bullet BP_{Metabolism}$$

Figure 136. Building volume at a given time is influenced by the needs of people and the accompanying building practice.

The building volume of the future (BV) will obviously be accompanied by an additional building volume (ΔBV (delta building volume)). The challenge is to make this delta (ΔBV) in a *metabolic* way so that it is both *open* and at the same time appropriate the current building stock in accordance to *metabolic* principles.

With our current building practices, we may indeed materialize undesirable scenarios (current rate) and 3 (amplification of material use) in Figure 135. Scenario 0 is entirely impossible as such a solution would indicate that a perfect circularity is achieved. It is not an unlikely scenario that building volume could double or perhaps even triple by 2100. This is because if there is modest increase in population by 2050, the building stock volume would double making it unlikely that some ideal variant of scenario 1 would actualize. This could be due to the still increasing global population during the 21st century which will lead to rise in wealth on average and boost the subsequent need for increased floor area pr. capita. If current tendencies in building practice and material consumption perpetuate, it is highly unlikely that any of the positive variants of scenario 1 will materialize.
There are risks attached to any sustainable agenda, whether Open building concept or circular strategy, because there are always risks that such strategies (if they remain single-building-oriented) could perpetuate material consumption on an accumulated level. Even if single buildings have to minimize impacts, more and more new buildings can be built and risk accumulatively increased regarding impact and material consumption through legitimization of a single building polluting less when compared to a given benchmark. Since such sustainable concepts are also at risk of not being used as intended in the future, there is need for guaranteed or increased likelihood (e.g., through legislation) that such principles will be used purposefully and strategically in order to avoid the scenario that current circular design merely acted as an opportunistic measure to maintain growth-oriented material consumption.

Today we see the prediction of the doubling of building stock materials by 2050 could be legitimate consideration (European Commission 2021). Given the fact that 2050 is 27 years away (from the time of writing this), how we the design this additional building volume (ΔBV) is of immense importance. Would it be possible to design such additional building stock (ΔBV (delta building volume)) which complement the current building stock so that the 2100-scenarion could be to a great degree facilitated

by the 2050 scenario building stock? As we are building today, we of course have to minimize climate impacts on each new building. However, at the same time, can we make our buildings ready for the future scenario (through functional ambiguity, flexibility and adaptability). There is a need not only gives us spatial planetary boundaries but also
temporal boundaries (e.g., the year 2100 scenario) where we envision how society with a stagnated global population will be facilitated and what accompanying (Urban Sink) building stock could facilitate this.

6.3.4. We ought to…

If we are seriously attempting to minimize material consumption, we have to use critical knowledge and find ways to implement it. This section will attempt to outline a number of normative design prescriptions which contain both findings from chapter 5 (analysis) as well as chapter 6 (on design). As both the analysis chapter 5 and design chapter 6 have explored different trajectories and brought together different fields and approaches into a metabolic framework, there is a sense of urgency to find ways to implement metabolic design considerations and different variants of the Urban Sink. That is not to say that all aspects of metabolic design thinking ought to be legislated as that would also be impossible and could risk becoming counterproductive for unpredictable reasons. The following design prescriptions are mixed in both advocating for design and more public awareness as well as more political actions as to potentially introduce more and more ambitious metabolic considerations in plan law and building law including both material and immaterial considerate.

Including more immediate and small-scale considerations into higher scales and general conditions of the metabolic design trajectory, we ought to:

- find ways to innovate and design new relations within and between the four main activities: eating, dwelling, moving, cleaning.
- not demolish, and promote more renovation. Instead we should reuse, refurb etc.
- keep all materials with as little as possible entropy increase due to future scarcity.
- consider a complex and multi-material and multi-principle strategy instead of opportunistic “green highways” of mere focus on *more* wood and *more* design for disassembly etc. Not all building should be able to fully disassemble, and there is need for strategic overview, what amount of elements circulates for different temporary purposes, while others are more permanent (or as long the material allows it).
- include and mobilize immaterial aspects.

- consider a large-scale strategic approach which kinds of Urban Sink variants are relevant in a given time and place.
- design beautiful OPEN, persistent, “permanent” structures which allows flexibility and adaptability.
- develop (FEM-type) tools that simulate life span and do not merely show minimally acceptable performance with a minimal material application at best cost effectivity.
- legislate for storage sites but also introduce both OPEN dimension of building legislation, as well as “beatification” (for lack of better word).
- find ways to challenge the trend of increasing floor area pr. capita.
- envision (to the best of our ability) the future scenario in this crucial time when global population may stagnate, where urbanization possibly halts etc. and define a building stock which can house such a scenario even with changes. Such a scenario would allow for the potential development of a metabolic strategic model for now and the future. One that we know what we are building towards from now.
- provide reasonable flexibility and adaptability within a purposeful range.
- consider and advocate not only legislation on single buildings/complexes but also more metabolic consideration of a larger, inter-building, city, region schemes etc.
- approach any level or problem of design from a *metabolic* understanding because any concept or agenda can diverge from its intentions, and the overall purpose is to relate design intentions and actualized material flows.
- define the city perimeter/periphery as a legislative (not actual physical wall) line which limits the city’s spatial footprint. This would promote dense living and not grab more and more land for real estate but consider biodiversity.
- be aware of and reconsider the notions of “cultural continuity”. Here, we are not referring to the one which acts as ideological justification of a continued linear growth paradigm where the cultural continuity is materialized *as* each new building in the progress of history. Rather, we are referring to a variant of cultural continuity where buildings qua their tectonic characteristics remain and where new additions, adaptations, decorations or even ornaments are gently added overtime, beautifying the building and solidifying it within the culture.
- always be aware that any new design imperative (build more like *this* or *that*), any new tools, ideas, or new future iterations of the sustainability agenda always have the possibility of being misconstrued and mobilized as yet another legitimization of the perpetuation of material flows (and their subsequential socio-political conditions). Does the (im)material metabolism also risk being flattened is such a way? Perhaps, if one willfully ignores its scope. It would again be possible that some might equate a particular style or design ethos (as the “phony ethics” of tectonics as elaborated by Jeremy Till) with metabolism, but that would not be *metabolic* but more of an ideology imposed onto it. Through the emphasis on minimizing material

flows, we have to cunningly and critically consider which relational nuances are pertinent in what contexts as to minimize material consumption.

- always be aware that many new design prescriptions (agendas) and imperatives will be developed, making it necessary to always couple prescriptive approaches with an inherent metabolic, critical-analytic, and reflective angle.

These are but a few of the design prescriptions to consider when approaching the built environment from a metabolic understanding. There can of course be many more; however, the (im)material metabolic understanding (through the Urban Sink concept) allows for further reflection, critical thinking and the proposal of new and more pertinent design prescriptions when designing, proposing awareness and education, creating dialogue and advocating for legislative and political action. When we are designing, we have to be painstakingly aware of if we want to design a "building industry" (which maintains the need for its services) or the "built environment" and its subsequent building culture. These two are not the same. The question is thus are to remain at the level of defining the problem of material flows as to "design" a circular economy which will enable us consume material as we have known it (profit-oriented growth paradigm) – or are we to design a built environment which will minimize its material consumption through lasting structures. The creative agencies within the built environment have to face this inherent struggle of building practice before anything can meaningfully change.

6.4. Conclusion

This chapter was concerned with exploring the prescriptive capacities of the (im)material metabolism. Relying on the lessons and reflections on analytic efforts (paper 1 and chapter 5), this chapter further attempted to discern the variants of the Urban Sink and explore different or unique design capacities which were brought about with (im)material metabolic design thinking.

When designing with the (im)material metabolism, the design process necessitates an approach which is initiated from material concerns and considerations. In the instance of the paper 2 (Usto et al 2023) and its subsequent further exploration in this chapter (6.2), there is an indication that a seemingly "reversed" design process (compared to the analytic approach) is mobilized and that the process starts from material conditions (the flows of construction waste thus necessitating a design endeavor towards facilitating large amounts of such waste through outdoor storage sites).
This chapter also expands on the Urban Sink notions, relying on lessons and reflections from chapter 5 (on analysis) regarding the exploration what other, perhaps more unusual, design/prescriptive capacities could be considered with an (im)material metabolic approach. Chapter 5 thus, in expanding the notion of Urban Sink, brings

together other relevant methods, theoretical positions, practices, schemes, and methodical considerations for further contouring of what it means to think metabolic design through Urban Sink notion. The testing of the theory happened through research-by-design methodology used the theory of (im)material metabolism's own constructs as design steps initially. Later, a more iterative process occurred regarding the exploration of further potential between the constructs and their relations. With the example of the design scenario, the design process had to occur "in reverse", relatively speaking, when compared to more conventional design processes where architects first find a concept then choose material and volumes of materials on account of that. The five constructs served as design steps which both needed to be developed in their own right and needed to be developed in order to engage in a relation with the other four constructs of the (im)material metabolism.

The notion of "design" or prescriptive capacities can thus be claimed to have common "design" applicability when designing an object or a urban system. But it can furthermore be considered as having a more expanded design and prescriptive ability regarding speculative thinking which indicates what ought to be considered, i.e., what new agendas, new and different material consumption patterns and subsequent social practices we could manifest, in order to potentially influence public awareness and legislation. Through the use of the five constructs to guide the design process – the methodology of research-by-design had the purpose of both extracting "steps" and concludingly "design principles." The paper was for this reason equally a test of the theory's capacity to acts as a guide for the process and extract design 'rules' (prescriptive trajectories). Ultumately, it showed that there is potential in thining of the construct in a processual manor along, and also allow to develop rules or principles for each construct and rules in general.

Figure 137. Different variants of the Urban Sink at different scales.

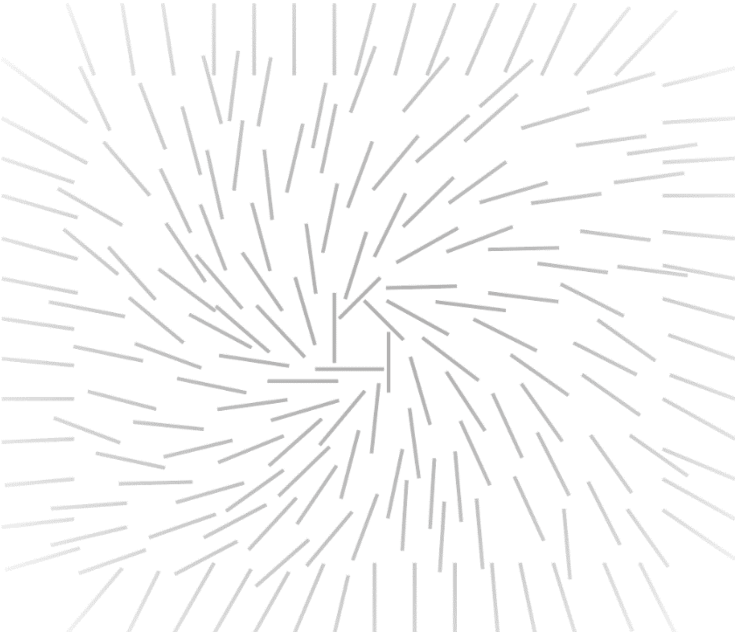
The explored variants of the Urban Sink (figure 137) are still tentative, as new aspects and considerations could very well become relevant both in the near and distant future – while some could need further refinement or be left behind as other conditions and challenges need addressing.

In potentially making this Urban Sink considerations more probable, dialog with many parties would be necessary: municipalities, private owners of real estate. There are many ways to strategically approach the built environment, and several more variants of scale, typology and strategic design of the Urban Sink can be explored and developed in future studies. While we ought to develop theory, methods, and design tools, there is need of the accompanying of larger scale political involvement and strategic thinking regarding how to design and prescribe conditions and tendencies in the built environment.

6.4.1. Contributions to Theory Building from Design

The combining of tectonics and industrial ecology, i.e., the (im)material metabolic approach, seem to open up a new "design space" or field which nuances design considerations more extensively not merely as a way to optimize life path or cycles but metabolic systems and sub-systems. This new "open space" will need much further exploration especially on the side of methodology and methods and tool development.

The testing of the theory in its design/prescriptive capacities provided feedback for theory building and subsequent adjusting. As the prescriptive capacities of the theory necessitated an increase in scale and thus complexity which not only had indicated a need for including other relevant design consideration (which are not developing from a industrial ecology approach) but were still relevant for a (im)material metabolic approach. The increase in scale and complexity, as well as the impetus in material conditions, reified how the five constructs relate and, in particular, how the “reversal” of starting from material wastes affects “narrative”, implying that narratives are not self-evident and given but socially constructed through alternative practices. The increase in scale and complexity also made it evident that both social and political aspects must be included into metabolic thinking. This would implicate questions of general social attitudes and world-view of individuals and communities and with questions of what it means to consume and what social practices could be constructed towards a slow of materials consumption.



Chapter 7.
Conclusion: Synthesis on Theory Development

This concluding chapter will provide an overview of the findings and will concludingly reiterate how the theory development process proceeded, how the “safe sink” notion got transformed in relevant ways for the disciplines architecture, engineering and design, and what sort of notion (object) the Urban Sink is and what it could further entail. The chapter will also reiterate the theory elements: constructs, relations, logics and boundaries. With these, the chapter will outline the found insights and potential for new insights qua the (im)material metabolism. Followingly the chapter will outline limitations and challenges of the (im)material metabolism potential future research.

7.1. Conclusion: The (Im)Material Metabolism

The development of the theory is informed by two pertinent theoretical frameworks. The juxtaposing of tectonic theory with industrial ecology (societal metabolism) in relation to challenges of material flows within the built environment was done through the centralization of the notion of “safe sink” from industrial ecology. The industrial ecology notion of “safe sink” is mainly concerned with the material aspect of safely storing materials. As this notion of safe sink (or more generally sink) is central to a sustainable approach in any industry, its transition into architectural discourse necessitated a nuancing of the “safe sink” notion towards being more sensitive immaterial as well as material consideration.

This was done through a meticulous process of adding, the adjusting and connecting (Keestra et al 2016) of notions and concepts from the two theoretical frameworks. The process was furthermore supplemented by an overall scope of the metaphor of metabolism, logical argumentation, using existing tectonic and industrial ecology theory (and methodology) along with existing philosophical texts (as was described in chapter 3 and done in chapter 4).

The (im)material metabolism was thus manifested as a spectrum of material and immaterial constructs and relations (unlike the usual tectonic material-immaterial dualisms) which were also coupled with a set of logics and boundaries which grounds the constructs in critical (and self-critical) discourse regarding design and its subsequent material consequences.

The (Im)Material Metabolism

The (im)material metabolism is theory built by juxtaposing industrial ecology and the tectonic stoffwechsel theory. This was further supplemented by the use of the metaphor method, along with the adding, adjusting, and connecting of ideas concepts. So, what kind of metabolism are we dealing with? The metaphor of metabolism can seem very complex. The *metabolism* is certainly not something which can directly be touched, perhaps you can. Rather it is something that one partakes in, i.e., space of movement whose contours and metabolic rates are socially constructed. It can be said that the planet has its own metabolism as well, but the (im)material metabolism does not include the whole of the planetary dynamics. Such an aspect would be too complex to include in (im)material metabolism. There are thus two *metabolisms* to be aware of, i.e., the planets own and the societal metabolism though only the latter is considered, which can be seen as a concentric relationship (as shown in chapter 4). The overlapping dimensions between the two metabolisms is the *matter*. The continued dynamics of the metabolism are caused by what we do and how we apply said matter. The (metaphor of the) metabolism is thus the meta-physical idea which certainly could have been translated into architecture in very different ways, but *the* pertinent way to make it architectural is through the concept of the Urban Sink. This is not unlike how in industrial ecology theory and methodology the "metabolism" is the whole scope. The emphasis on "safe sinks" is a way to manifest a slow and narrow metabolism. One cannot simply change the whole metabolism in its full (planetary) scope, you do so through the Urban Sink as the vessel.

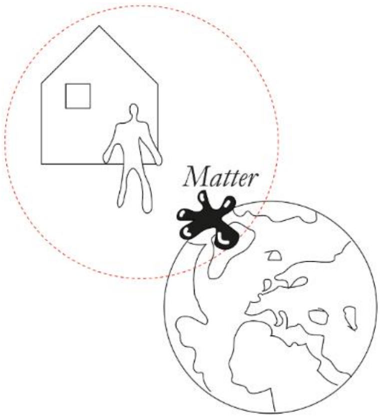


Figure 138. The Metabolism, not total and universal, but societal and planetary via matter.

Urban Sink

While the planet-in-itself (all complex interrelation dynamics) cannot be known or comprehended, the way to relate to planetary capacities (or scarcity, limits, boundaries) is thought to be the conceptual centralization of the “safe sink” notion and its architectural reiteration, i.e., Urban Sink, through a slowing and narrowing of materiel flows. The Urban Sink is the key contribution of this doctoral study, as it is the particularization of the (complex) overarching idea of the *metabolism.* So, what is the Urban Sink? While the metabolism is the general idea, the Urban Sink is a way to comprehend and enact a metabolic understanding because it is difficult if not impossible to “directly” affect the metabolism (and ultimately the planet). The complex notion of the *metabolism* can be approached indirectly through the Urban Sink. The initial assumption of the doctoral study was if the “safe sink” concept is to be transferred into architectural thinking, something new will be invented. This, however, was not the case. There were already existing edifices within the architectural discipline which could be included in a *metabolic* approach such as the Open building concept (see chapter 5 and 6) along with the general attitude of the tectonic ways of thinking. I do think, with all due respect, that some of these fields (e.g. mentioned in 6.3.1) could attain a further *metabolic* inclination. The Urban Sink is constituted by many variants at different scales of design. These span from the *surplus,* the detail, inventory, elements, and support to urban symbiosis, storage site, city web and legislative action. Most of these can be both fixed and open /movable as any particular building stock’s ability to perform as safe sink for materials. The Urban Sink will need a multi-material (not only wood and straw but also concrete etc.,) and a multi-strategy approach (not only DfD but also Open building, storage sites etc.). The Urban Sink is thus both the materials objects and the surrounding immaterial cultures which constitute the underlying processes of the performance of the Urban Sink.

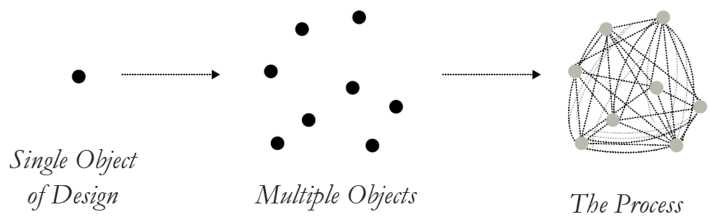


Figure 139. The Urban Sink is a spectrum from Object to Process: a single object (house, storage site), to the network of objects and finally the very relational process which allows the circulation and storage of materials. All are the Urban Sink simultaneously if they have the capacity to store materials through material and immaterial aspects.

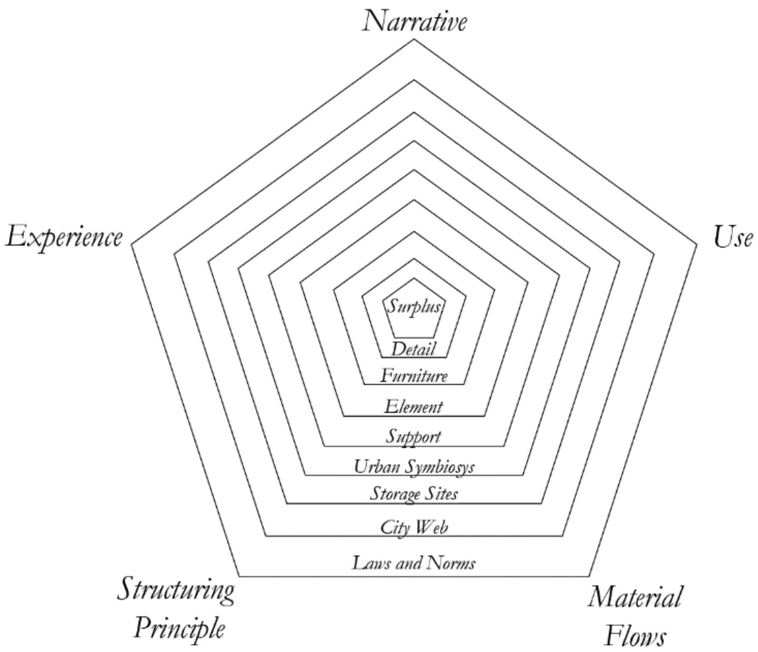


Figure 140. Urban Sink specified across variants/scales and constructs.

Across its different variants and scales, the Urban Sink is still constituted by the five construct of material-immaterial spectrum (figure 140). These 5 constructs are not perfectly segmented as it is diagrammatically depicted in the above-mentioned figure as categories can overlap to lesser or greater degree (e.g., integrated furniture within a wall etc.).

Constructs, Relations, Logics, Boundaries

The material and immaterial spectrum of the metabolism spans from material flows, structuring principles, use/function, experiential conditions and narrative. Each of the constructs can have many different specific counterparts in the cases of analysis or design. There is likewise a set of sub-constructs which overlap and as such constitute the possibility for complex sets of relations in any empirical situation.

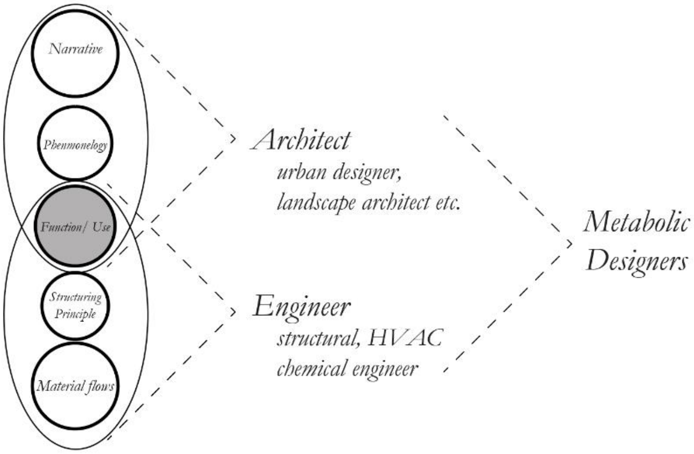


Figure 141. Five constructs - two overlapping sets of threes which provide crucial juxtapositions – towards a horizon of the metabolic designer.

The five constructs of the theory are "material flows", "structuring principles", "use/functionality", "experiential conditions", and "narrative". These can, for communication and pedagogical reasons, be explained as two sets of threes with the upper and the lower being slightly oversimplified in a "conventional" way. The upper would be the scope of the architect, and the lower deals with the engineering aspects. Together, both of these ideally make up the whole spectrum which permits us to think in *metabolic* terms about the design of the built environment.

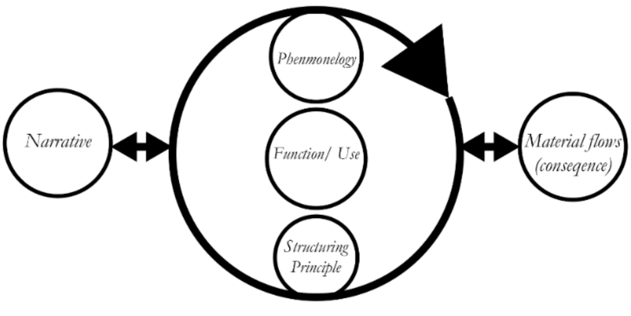


Figure 142. The metabolic dialectic.

The constructs constitute a central dialectic or metabolic mechanism which necessitates a critical relating of constructs. When using the (im)material metabolism in either design or analysis any process can be initiated with a "narrative" (or intention) - through the mapping of architectural characteristics - and finally arrive at the materialized consequence (of a building). Or in the other direction, a process can be initiated from the material concerns which ends in “narrative” (advocacy, social awareness of material use etc.). This inter-relation of constructs is also presented in the descriptions of the (im)material metabolism’s logics and boundaries as the Narrative-dimension is the critical and self-reflective object while the material flows construct deals with actualized material consequences of a given edifice or approach. As such, the epistemological and ontological reflection of the logics and boundaries of the (im)material metabolism theory are both reflected and dialectically practiced through the application of the constructs. Regarding the dialectic (figure 142), there could be a possibility of employing it in a different way. Imagine that we arrive at some ideal sustainable situation, which would surmise that the “material flows” are “optimal”, the consequence of interest would thus not be the material consequences but the social and experiential (immaterial) ones. Depending on a given case study or experiment, different research aims can be developed in order to discern particular relations of interest.

Analysis and Design (Descriptive and Prescriptive capacities)

In the cases of applying the (im)material metabolism as analysis and design, there are differing approaches to consider. Fundamentally, in the case of applying the (im)material metabolism in a analytic capacity, it should be considered to initiate the analysis from the “narrative” dimension in order to conclusively map/analyse the material consequences and thus discern to what extent there might be a correspondence between intentions and final product. In the case of design, it could be considerable to initiate from the material conditions (flows) as to arrive at new and different (constructed) narratives which could permeate into society towards more awareness and shift in consumption and making cultures.

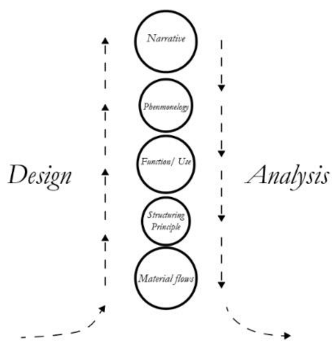


Figure 143. The approaches (arrows)of analysis (from top) and design (from bottom).

Though the processes are more complex (as was elaborated in chapters 5 and 6), they are not entirely linear although it still can be largely claimed that the general processes of analysis and design can be initiated either from the "top" (analysis) and from the "bottom" (design) (see figure 143). As was already elaborated at the end of chapter 4, the (im)material metabolism cannot be used as a substitute for a different method. In the ambiguity of the analysis and design, the (im)material metabolism is a theory whose edifice can be mobilized as methodological frameworks in both analysis as design and thus necessitates the use of additional supplementary methods and tools which are guided/framed by the theory.

Significance of the (im)material metabolism

The (im)material metabolism theory's significance lies in its nuancing of the material-immaterial spectrum and the possibilities that the juxtaposition of the five key constructs (and the many particular counterparts in an empirical applications) allows for the discernment of pertinent relations that can have consequence for material flows. That is to say that a wide range of known facts can be put into a "metabolic" framework in order to discern key relations which should be emphasized over others thus making a difference for the synthesis of lessons or design principles etc. This is the concept of the *parallax view* (Žižek 2006), where the same known facts are given a different meaning due to a shift in perspective (this being a *metabolic* one) due to an expanded scope. An example could be that a building is deemed "sustainable", but an actual tracking of the material flows shows it is in fact "green washing" whether it knowingly or unknowingly done. The study thus shows that if we ought to propose sustainable, viable solutions to the challenges of the built environment, a *metabolic* approach is pertinent.

The spectrum likewise necessitated the inclusion of other research fields' knowledge and principles to make the metabolism, an otherwise complex and abstract notion, into approachable particularizations within different scales (see figure 137 or figure 140) . With the (im)material metabolism empirical conditions of, for example, the "narrative" or "experiential conditions" can only be considered as non-causal correlation to "material flows". Nonetheless, through the relational spectrum of the *metabolism* (i.e. figure 78), it can potentially be discerned or nuanced into an (in)direct causal relation.

The (im)material metabolism is obviously a theory, but it is not linked to a more "conventional" architectural theory as much as it is an architectural, or rather tectonic, ontology, of the architectural discipline. Given the purposefully "general" nature of the constructs, it is possible that they could also be used to include and consider other fields, lines of thought, and disciplines. Furthermore, despite needing much more research towards the placement of the architectural discipline within planetary capacities/boundaries (potentially via the bio-regional approach as developed in industrial ecology - yet through the centralization of the "safe sink" notion), future knowledge and contribution developed in other sciences or within the architectural research could easily be implemented into a more specific "planetary" approach within the (im)material metabolism.

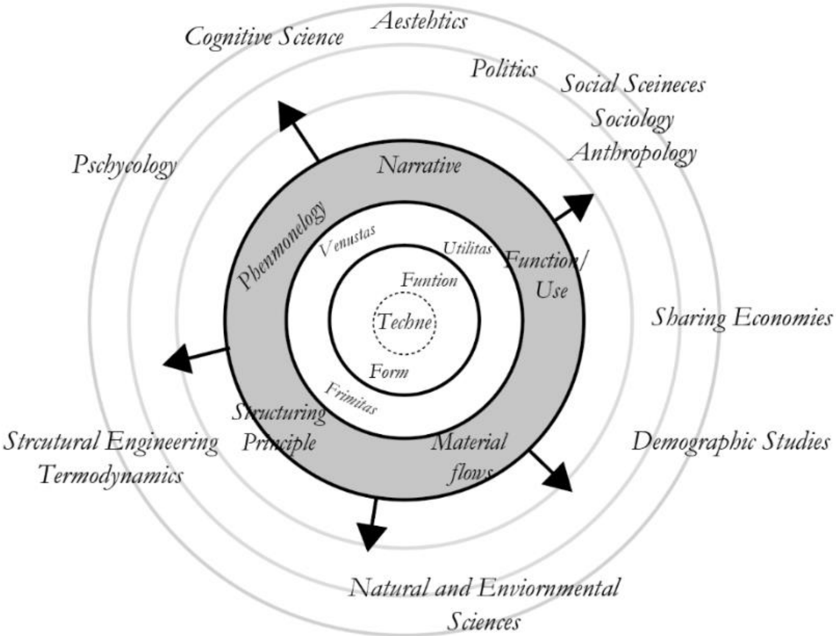


Figure 144. The (im)material metabolism (grey ring) as platform for future metabolic interdisciplinarity both for collaboration and integration.

New Insights

The application of the (im)material metabolism prompted new insights in the case of analysis and design, respectively. In the initial analytic application, it was concludingly hypothesized in paper 1 (Usto et al 2022) that a kind of (im)material "surplus" which potentially could perform as an material investment for the future and thus potentially strengthen its cultural relevance as well as its performance as a Urban Sink (safe storage of materials qua architectonic characteristics).

In the case of design application of the theory, the *metabolic* approach allowed for very different approaches to that of so-called material banks or archives (which are often envisioned as physical facilities for storage of construction waste materials) and allowed for reconceptualization of the storage function through architectural and recreative qualities in the city.

7.2. Reflections

Initially within this PhD, there were also ambitions of pedagogic and educational research in order to provide the theory to students at different levels of education, monitor and evaluate student projects, and observe what direct (if any) influence it has had on their design when thinking *metabolically*.

In retrospect, the theory building effort proved more complex than anticipated. Considerable amounts of time was necessary to attempt to understand material flow analysis, the chemical engineering field and its sub-field of industrial ecology. Likewise, it was complex to couple all of this in a simplified way with the tectonic framework. Because the proceeding theory building effort was not based on grounded theory (on basis of empirical observation) but via existing theory supplemented with empirical findings, the gap between them was significant and thus necessitated an elaborate methodology to work with the two chosen disciplinary frameworks as to meaningfully transfer metabolic thinking or make architectural discipline *metabolically* inherently. It is not enough to only focus on the method of metaphor; additional methods were needed for the theory development.

The metaphor as method could potentially be much more explored, especially in the “analogy” variant. It would be interesting to explore a trajectory already put forth by Benedikte Zitouni with her exploration on a more particular mechanisms within actual living organisms (Zitouni 2013), and its potentially architectural relevance if translated in relevant ways. Such an aspect is modestly already contained within this PhD study in the idea of “slowing” which can be said to “mimic” a metabolic characteristic in the sense that small entities have a “fast” metabolism while large ones have slow metabolisms. To explore new/different trajectories similar to those of Zitouni could potentially provide new inspiration for “inner” relations of the metabolism and its different variants of the Urban Sink which could potentially provide new insights for how to “slow” material flows further. Such a trajectory would require a “deep dive” into biology, though without a considerable and new theory building effort in mind and only with focus on the metabolic mechanisms which could hold meaningful conceptual translation for design principles or design criteria.

Obviously, it would also be of interest to analyze more cases and explore other design variants but given the immense emphasis on constructs and their relationality, the implementation of different levels of complexity could have also promoted a research approach of correlation research (Groat, Wang 2013). While this was not fully relevant for the scales of analysis and design in this PhD study, such an research methodology could be necessary. This may be so because, as with industrial ecology, a metabolic approach necessitates a largescale understanding regarding where questions of public opinions, general public attitudes, data on use etc., (which could not possibly be directly linked as causality to certain material flows, but patterns and lessons) could still be discerned through hints of causality (correlation) which could be pertinent to consider. In this regard, there is an early variant of New Materialism called “correlationism" developed by Quentin Meillassoux (2010).

Thinking in terms of planetary limitations or capacities is difficult and more research will be needed in this regard as well – hence the subtitle of this doctoral study being "towards" a planetary understanding of the built environment. While there are separate attempts to think "planetary limitations" (Rockström et al 2009; Petersen et al 2022), the particular approach from industrial ecology (of bio-regional thinking) would require further research. Perhaps the biggest challenge is the international and geopolitical dialog and awareness of the need to define and agree on the spatial perimeters of such regions and followingly provide political incentive to enact them.

7.3. Future studies

There will be need for further research with regard to the (im)material metabolism, both in refining the hitherto built aspects and further development of normative design principles. Additionally, there is potentially a need to look at methods and tools. The PhD study at hand was the initial step (A1 in figure 145) and was concerned with the development of the general theoretical and methodological framework.

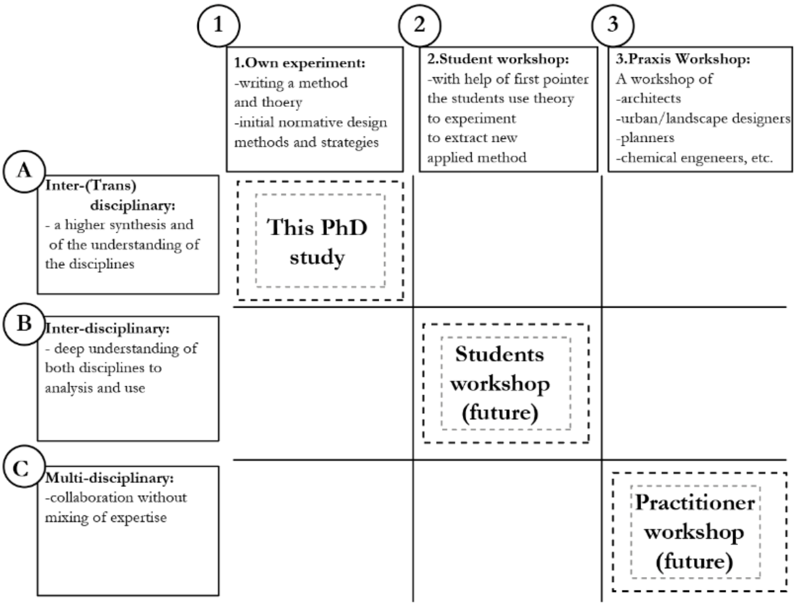


Figure 145. Possible future research trajectories.

The further exploration (B2 in figure 145) on a student level would rely on the hitherto theoretical findings along with the analytical and design considerations and reflections of students at different levels. The students' experimental application of the theory (im)material metabolism would have the purpose of monitoring to what extent a *metabolic* approach could influence their work as well as to what extent the written text (perhaps a shortened version of this dissertation) is comprehensible and applicable to both the undergraduate and graduate levels. This would further give feedback to the future development and adjustment of the (im)material metabolism theory to either lessen certain aspects or add or emphasize other ones. Lastly, (C3 in figure 145) based on the findings, potentials and challenges of the application on a students' level, more considered and reflected design principles and consideration (in a future simplified and shortened version of this PhD study) can be provided at a professional level. Here, it would be interesting to conduct and workshop experiments with a number of different disciplines in order to discern the feasibility of the theory in multi-disciplinary effort. Generally, the idea is to test if the (im)material metabolism, given its dialectic relation between constructs, could indeed embody the many "difficult" philosophical considerations (logics and boundaries) through the application of the constructs only. Will it always be necessary for both students and practitioners to familiarize themselves with the whole of the (im)material metabolism, and not just its construct (and relations)? It would be pertinent to explore all different scales as well as principles. My ultimate ambition in this regard would be that students and practitioners only be familiar with the "constructs and relations" without the "heavy" epistemological and ontological considerations of the "logics and boundaries" of the theory and still enact/practice *metabolically*.

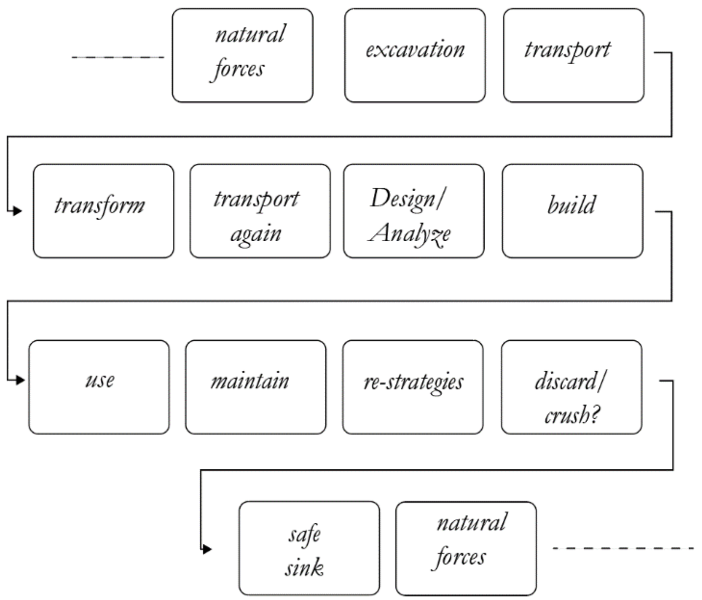


Figure 146. A proposal of the different possible types of "labor" - whether machine, human or natural.

Since industrial ecology already permits the inclusion of energy, future research endeavors would also focus on implementing flows of energy along with the material. Just as the creative design process requires energy, many different types of labor (whether human, machine or other), will need implementation. The aspects of labor and energy are interstitial and inherent to all the constructs and the (im)material spectrum. While it is already a fact that scholars are thinking material flows and energy consumption are as a whole an accumulated footprint, it could likewise be pertinent to align and relate the two in relation to the reflections of case A in chapter 5 where a *surplus* of building envelope may cause increased heat loss. This hints that material investment and energy performance may point in separate directions at times and indicate a "sustainable" conundrum or a paradoxical relation between the two. In conceptualizing the aspects of "labor" (an *immaterial* commodity), it would be important to include all the different types of labor (figure 146). Each has their appropriation, spatial and time scales of operations. They can be anything from natural forces, physical human labor and intellectual labor to machines transforming or transporting materials etc..

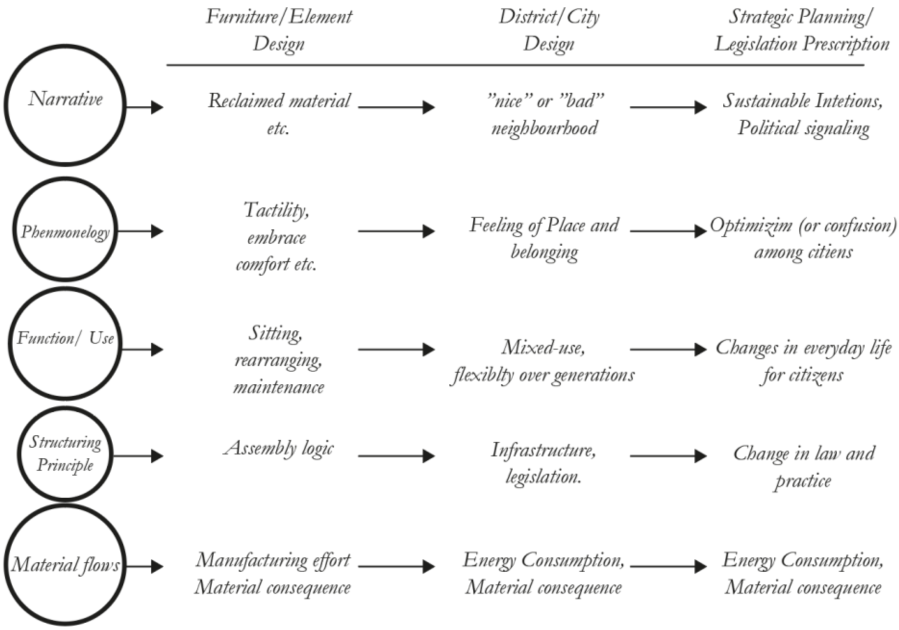


Figure 147. A hypothetical (fictive) overview of different scales and their construct-values - (speculation for future research possibilities).

Lastly, I will keep an open eye for any cases from which we could learn from (Figure 147). I imagine there must be not only single buildings and complexes, but also neighborhoods or districts that possibly demonstrate a significantly lower material and energy consumption and whose particular sizes, dimensions, principles, proportions, practices, flexibilities, adaptabilities, experiential conditions and narratives could be discerned and understood to allow reflection and consideration when designing new inter-building relations and larger infrastructural constellations or reconsidering existing ones. One would need high resolution material and energy flow data (not general for whole city) and juxtapose it with the spatial conditions. Generally, I also intend to work more with LCA tools in order to further qualify different considerations and possibly attempt to translate (ideally) collaborations with chemical engineering the MFA into a workable design method/tool which can be used in a commonly applied 3d environment among students and practitioners (ideally Rhino).

Epilogue

Steve Jobs once said that musicians played their instruments but that he himself plays the orchestra. We cannot remain fixated on merely one instruments (read building) at the time, and the challenge is exactly to design the whole orchestra (read metabolism) at once and have it play a beautifully slow and tender yet vigorous, lively and powerful tune. But at the same time, we have to know the instruments as well; we have to know the tension of the strings, their elasticity, the density of air molecule which the strings set in motion to create vibrations that stimulate our senses.

There is an immense challenge in conceptualizing the whole of architecture-as-such (building industry/culture), because thinking about architecture and building in expanded scope we can start to observe complicated and paradoxical mechanisms and patterns which are both transposed onto it (from outside) or which are inherent to it already. And while the whole of the building industry and culture practices still seem outside of a comprehensive onto-epistemological grasp, the (im)material metabolism was my modest attempt to think of the architecture-Thing as a metabolic entity.

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Appendix A. Mind Map

This is a supplementary text which give some insight in the background dynamics of the literary research and review of literature (as done in the chapter 1) which would lay the grounds for later State-of-the-art chapter. This appendix elaborates the use of the Mind-map method which allows to structure ones thinking while delving into a complex problem.

In the very early phase of the doctoral study, the challenge was to work with materials, and gain different insight into material concerns with regard to the built environment. There were many challenges, many partial considerations and many problems to consider. And as such it can quickly become difficult and even confusing on how to focus on the essential or core concerns of material consumption challenges. As an very easy attempt to map a very general problem field (or fields) and a potential means to find a different discipline which may hold significant insight relevant for architecture, design and engineering the method of mind map (Keestra et al 2016) was used. This allowed to formulate a problem field or topic from a kind of overview irrespective of disciplines, which is the poor quality of the building stock which is ever more increasing materials flows into societal infrastructure.

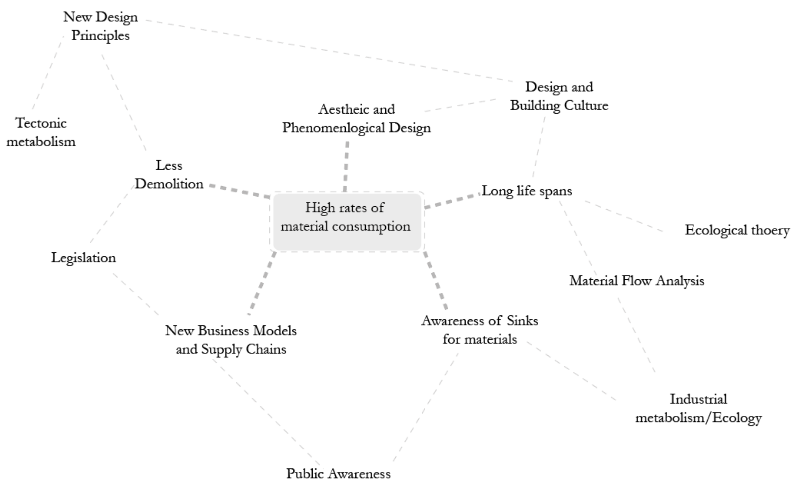

Figure 148. Mind Map for the purpose of locating a central problem field or topic.

This very step did not automatically provide the need to delve into chemical engineering (industrial ecology in particular) but such a mapping permitted the possibility to systemize ones thinking while reading different literature, exploring different practices, mapping out different challenges and problems etc..

Such a map implicates anthropology, sociology, geography due to population growth and urbanization, along with architecture and planning due to lack of designed quality and cultural significance and finally the disciplines of chemistry, biology and ecology due to the immense impacts on natural environment in terms of increase CO2, disappearance of biodiversity and the degradation of soils and carbon sinks like forest etc., and as such necessitates a constant reflection to be able to limit the scope and focusing on a few core disciplines which are connected to the topic/problem. Overall, the topic of interest was limited to that of material flows (material consumption) within the built environment. And while the mind map was being used a "thinking" tool for mapping of topics and problems, literature was being read on said topics and problems. The reading of said literature started to indicate that a large portion of much of the most pertinent findings (which actualized in the content of chapter 1) were contribution from either environmental engineering or chemical engineering metabolic studies. Likewise, the architectural materialist approach where material and immaterial aspects were considered together also indicates potential for the problem/topic at hand.

This doctoral study considers it crucial to proceed in an interdisciplinary manor with the two key disciplines which are the overarching disciplines as categorized in interdisciplinary literature (Keestra et al 2016, pp:29) ; Chemistry (Chemical Engineering), Geography and Urban planning (Architecture). While this is an overall categorization and definition of the disciplines involved, more specifically this doctoral study aims at exploring the potential interdisciplinary insights from tectonic theory (architecture), and industrial ecology (chemical engineering).

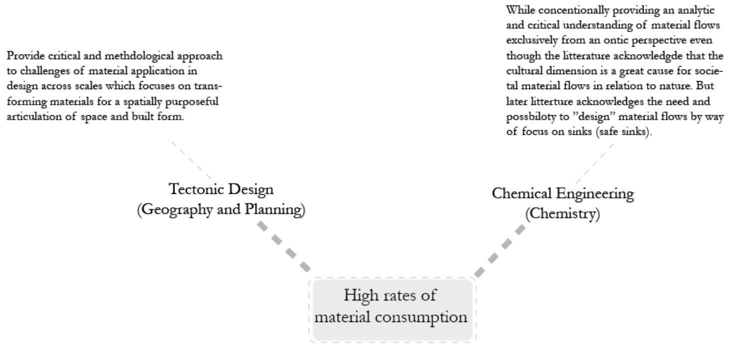

Figure 149. A Concept Map of gaining a preliminary overview of the perspectives of the chosen disciplines.

The reason to proceed with these two key disciplines is due to them having an impetus in “matter” although from very different epistemological and ontological positions – some of which are explicit and some of which are more implicit. Another crucial aspect, is that, given the complexity of issues of material flows in society in relation to nature, an approach in required which does not discriminate scales, from small scale to larger societal scale which position themselves critical in relation to materials and how they flow in relation to their ideological justification. The predominant perspectives onto the problem field (topic) of the two disciplines is thus; Tectonic acknowledges the need for more inclusion of a critical awareness of material application towards a more quality-oriented and appreciative built environment; industrial ecology (metabolism) while providing a crucial overview of material flows also acknowledges the need for an understanding of societal and cultural aspects.

While this appendix only shows one image of the mind-map, it has in reality undergone may iterations during the actual process of reading literature as to adjust for new findings of practices and theories.

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Keestra, M., Rutting, L., Post, G., de Roo, M., Blad, S., & de Greef, L. 2016. An Introduction to Interdisciplinary Research: Theory and Practice (S. Menken & M. Keestra, Eds.). Amsterdam University Press. http://www.jstor.org/stable/j.ctt1bc540s

Appendix B. Data Management Table for the two disciplines

This is a supplementary text which give some insight in the background dynamics of the data management table method (Keestra et al 2016) which was used a way to gain an overview of the inherent conditions and potentials of the two pertinent disciplines and their frameworks. This was utilized both in chapter 2 (state-of-the-art) and in chapter 4 (theory building, though further elaborated as well in chapter 4).

After having a general overview of the topic (problems and challenges of material flows in the built environment and their relations to experiential architectural conditions) which was elaborated in chapter 1, a hypothesis is developed. The hypothesis considers the potential of developing an interdisciplinary theory by juxtaposing tectonic theory and industrial ecology theory could be hold pertinent value for the application of materials within the built environment. But if such a theory were to be built, an appropriate state-of-the-art of the two pertinent disciplines has to be elaborated as to get a better understanding of the potentials of the disciplines for the topic.

Following method of “data managemental table” (Keestra et al 2016), the state-of-the-art refines how the two disciplines hold potential to each other but also contain challenges and antagonism both in relationship to each other, but also inherently within themselves as perceived from critical analytic perspective. Thus, following the logic of categories for “data management table” (Theory, Concept, Methodology (ontology and epistemology), and insight into problem) this doctoral study hypothesizes that a pertinent insight could potentially be gained regarding the challenges of material flows via an interdisciplinary approach by realigning tectonic theory in the spirit of critical metabolic (industrial ecology) thinking towards a tectonic theory.

	Theory/ Hypothesis	Key Concept	Method	Insight into problem
Architecture; Tectonics:	Tectonics (stoffwechsel)	Detail and Whole (various)	Tectonic as method (various)	Integrating and corela-ting material and imma-terial conditions of design.
Chemical Engineering; Industrial Ecology/ Metablolism	Metabolism of the Anthroposphere	Sink (safe sink)	Material Flow Analysis	Heavily technical and rigorous understanding of how materials flow though society in relati-on to natural limits.

Figure 150. Data Management Table: Overview of Theory, Concepts and Methods and insight into problem of the two disciplines.

It is also the case that these two disciplines are in fact not totally foreign to each other (elaborated in chapter 3 and 4) and that the challenge is to integrate them at both a theoretical level. Furthermore, the challenge is to reify and build upon the reciprocal traditions of these disciplines towards a more critical understanding of material flows.

References.

Keestra, M., Rutting, L., Post, G., de Roo, M., Blad, S., & de Greef, L. 2016. An Introduction to Interdisciplinary Research: Theory and Practice (S. Menken & M. Keestra, Eds.). Amsterdam University Press. http://www.jstor.org/stable/j.ctt1bc540s

Appendix C. The (im)material surplus

This appendix document provides the background and delineations of the (im)material surplus as was elaborated in chapter 5 (paragraph 5.2.3.).
The reification of the (im)material surplus is based on a exercise which is grounded on a set of assumption and margin of errors. This was due to several aspect, one of the main margins of error was the non-availability of comprehensive technical drawing material especially on the slightly complex geometry of the roof and its inner anatomy. Likewise, the foundation is not included.

The impetus of this exercise was to take the original cluster and model a hypothetical "rationalization" as to reify the surplus (extra) material used which were the foundation for the phenomenological embeddedness into site conditions as well as provide meaningful spaces for the single unit as well.

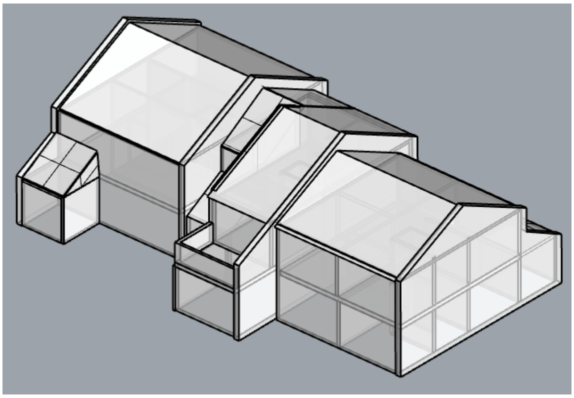

Figure 151. The impetus building cluster volume.

The initial building volume o the cluster unit names *Is, Ns, Ls* of consideration was modelled in 3d environment based on the existing drawing accessible in the municipal archives and the architects own project booklet (Aude, Lundgaard 1975).
And while the purpose was to model a fictive hypothetical version of the original design, there are several aspects to consider to minimally make it realistic and comparable. The overall goal is to maintain total area of the cluster while "rationalizing" the building volume. In doing so a set of procedures need to be considered.

The total area is 400 m2, the ground floor having 215 and the first floor having 185. In the rationalized version both would be 200. Firstly, the original footprint was modelled as to find an average width of the footprint which would equal the 200 square meter footprint of the floor area.

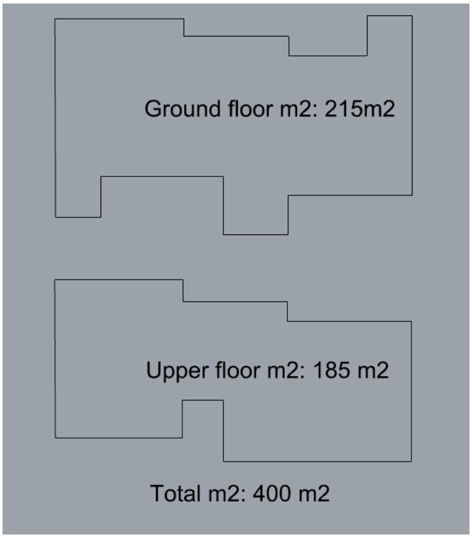

Figure 152. Total area of ground floor and first floor of the cluster of three units.

And while the total floor area is accounted for, it is likewise relevant to consider the sizes of the original units, as to later be able to compare the change is sizes, though the average area of each unit is maintained.

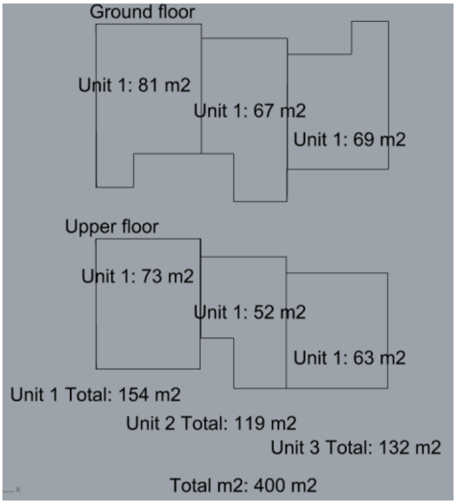

Figure 153. Areas of the existing units, ground and first floor.

Next, as to find the average width of the whole cluster, six different widths were measured, and followingly divided arriving at the value of 10,19 meters.

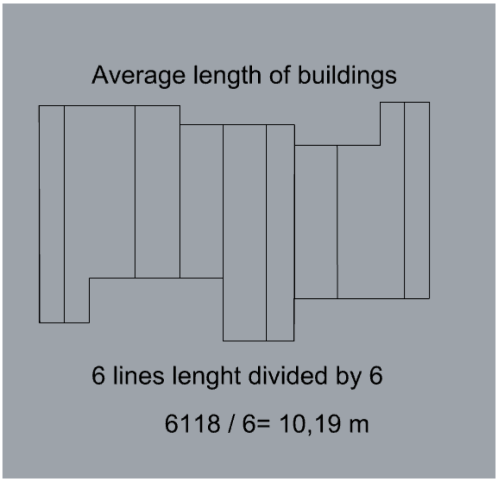

Figure 154. Six measured width across the footprint.

The next step entails the finding of the total (new) length of the cluster based on the average width. If the area is to be 200, then we divide the total area with new width to get the new length, which equals 20,2 meters. While the initial averages had decimals, for the purpose of this exercise the width and length were simplified to 10m and 20m (figure 155).

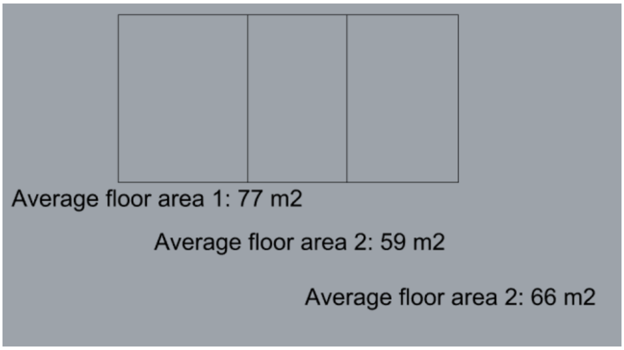

*Figure 155. The new footprint of 10m * 20m (first floor having the same) equals the total of 400 square meters.*

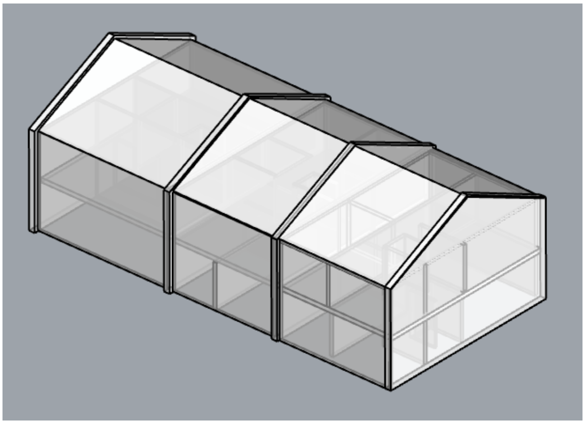

Figure 156. The resulting volume; a "rationalized" cluster.

The resulting cluster volume obviously appears differently and functions differently, as certain rooms have become slightly bigger, and some have become slight smaller. while still remaining similarly functional. The focus is the material surplus which exactly facilitates this difference.

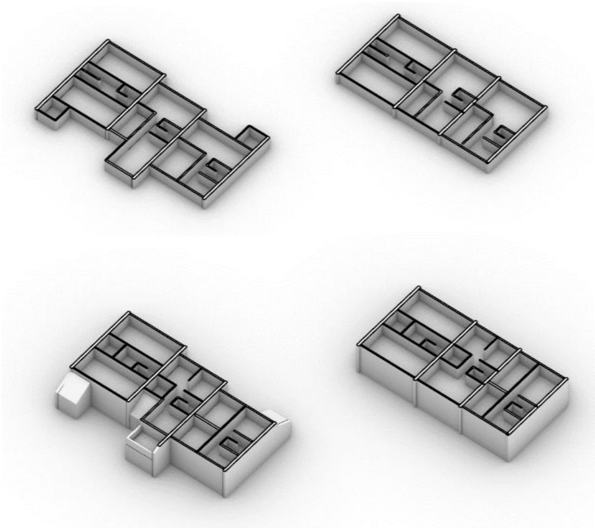

Figure 157. Figure showing the difference in plans between first and second version. There is difference is composition and proportions of spaces, while functionality remain comparable.

The last step is thus calculating the total volume. This is as well done in the 3d environment. The assumption was that the first volume was greater than the second (hence its designation of being "rational" in quotation marks). Therefore, the first cluster total volume was subtracted from the second cluster's total volume.

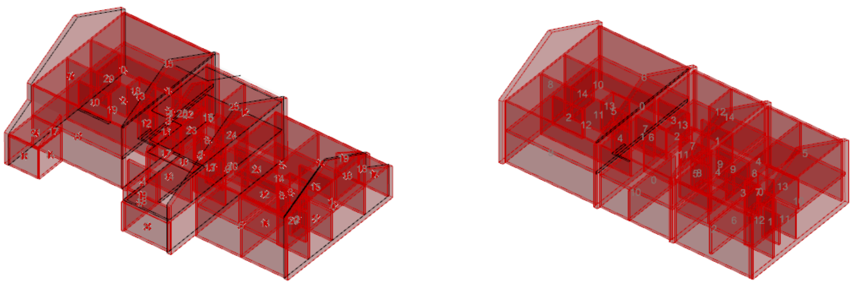

Figure 158. finding the difference volume between the two versions.

By using the native plugin of Grasshopper in the 3d modelling environment Rhino7, through a simple mechanism of marking of the first buildings total volume and subtracting the second total volume, the result arrives at 1,3 cubic meters.

This volume is an average volume which does not differentiate between wall, floor, brick, concrete, wood etc., but it is an average volume which contains all of these. As mentioned earlier, given the lack drawing materials, the roof geometries was not included (only surfaces and not volume, and thus not included in calculation). Likewise, the walls are not differentiated to the point of including where the solid wall is and where the window is, and the general width of the wall is used of the envelope. If a more precise calculation of this kind were to be made with a higher resolution, the surplus volume of 1,3 cubic meter would most probably be higher. Though it is a simple volume of matter, at the same time it is the surplus which permits experiential gestures in relation to the interior and exterior.

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