



Aalborg Universitet

AALBORG UNIVERSITY
DENMARK

Towards automatisisation of the Swedish property formation process

A structural and logical analysis of property subdivision

Hjelmbom, Magnus; Paasch, Jesper Mayntz; Paulsson, Jenny; Eklund, Marina; Bökman, Fredrik

Published in:
Nordic Journal of Surveying and Real Estate Research

DOI (link to publication from Publisher):
[10.30672/njsr.78170](https://doi.org/10.30672/njsr.78170)

Creative Commons License
CC BY 4.0

Publication date:
2019

Document Version
Publisher's PDF, also known as Version of record

[Link to publication from Aalborg University](#)

Citation for published version (APA):
Hjelmbom, M., Paasch, J. M., Paulsson, J., Eklund, M., & Bökman, F. (2019). Towards automatisisation of the Swedish property formation process: A structural and logical analysis of property subdivision. *Nordic Journal of Surveying and Real Estate Research*, 14(1), 29-63. <https://doi.org/10.30672/njsr.78170>

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal -

Take down policy

If you believe that this document breaches copyright please contact us at vbn@aub.aau.dk providing details, and we will remove access to the work immediately and investigate your claim.

Nordic Journal of Surveying and Real Estate Research 14:1 (2019) 29–63

submitted on 8 February, 2019

revised on 10 May, 2019

accepted on 4 June, 2019

Towards Automation of the Swedish Property Formation Process: A Structural and Logical Analysis of Property Subdivision

**Magnus Hjelmblom^a, Jesper M. Paasch^{ab}, Jenny Paulsson^c,
Marina Edlund^d, and Fredrik Bökman^a**

^a Faculty of Engineering and Sustainable Development, University of Gävle

^b Aalborg University

^c Real Estate Planning and Land Law, KTH Royal Institute of Technology,
Stockholm

^d The Swedish Mapping, Cadastral and Land Registration Authority

Contact: magnus.hjelmblom@hig.se

***Abstract.** The ongoing digitalization of public administration and increased automation of legal decision-making bears promise to benefit citizens, businesses and other stakeholders through simpler and more efficient civil processes, and thus has great impact on the urban planning and building process. However, automation of decision-making that is directed or constrained by normative systems such as laws, regulations and policies, requires a detailed and accurate representation of these concepts and their constituent parts, and the domain to which they are applied. This paper combines two perspectives on formalisation and classification of legal relations within the urban planning and building domain. In a cross-disciplinary fashion, the paper analyses and describes a small part of this domain at a higher level of abstraction and formalization using two different analysis instruments. Using these tools, we perform structural and conceptual as well as logical analyses of two specific snapshots of a fictitious property subdivision case in Sweden, focusing on the legal relations between different entities and parties involved in the specific situations. The structural analysis uses the Land Administration Domain Model ISO 19152:2012 standard formalism, and the logical analysis is based on the notion of atomic types of legal relations. The paper discusses some of the strengths and weaknesses of the two tools regarding the formal representation of rights, restrictions and responsibilities of different parties in the land administration domain, as well as how the tools relate to each other and how they can be aligned. This paper takes one step towards a deeper understanding of the domain, and identify areas for future research that may provide better conditions for efficient and transparent use of geospatial information, and automation of the property subdivision process and other related civil processes.*

***Keywords:** cadastre, land management, digitalisation, automation, subdivision, real property, LADM, normative positions*

1 Introduction

The growing interest in e-government, i.e. the digitalization of public administration, has great impact on the urban planning and building process, and goes hand in hand with increased automation of decision-making in legal domains. The automation and semi-automation of legal decision-making has potential not only to reduce costs of public administration, but also to facilitate accuracy and transparency of public decision-making and benefit citizens, businesses and other stakeholders through simpler and more efficient civil processes. In the Swedish property registration domain, featuring a high number (around 800,000) of annual transactions such as registrations of title and mortgages, systems for automated decision-making in simple cases, where the requirements are easily checked by a computer, are already in place. In the real property formation domain, characterized by significantly fewer (around 16,000 annually) but generally more complex transactions that require more difficult legal decisions, automated decision-making systems have not yet been developed to any greater extent. However, since property formation is one of the bottlenecks in the Swedish urban planning and building process, digitalization of real property processes for automated decision-making is an area of interest to Lantmäteriet (The Swedish Mapping, Cadastral and Land Registration Authority). Many recent Swedish research and development projects (see for example Smart Built Environment (2019), Boverket (2019), Ekbäck (2019) and Olsson et al. (2018)) have aimed to contribute to making the urban planning and building process more streamlined, transparent and collaborative. This is in line with the UN Sustainable Development Goal 11 (Make cities and human settlements inclusive, safe, resilient and sustainable), which includes enhancing “*inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries*”, and supporting “*positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning*” (UN, 2015).

Automation of decision-making that is constrained by normative systems¹ requires a formal representation of both the normative systems and the domain to which they are applied. A natural tool for structural analyses of the domain of real property processes is the Land Administration Domain Model (LADM) ISO 19152:2012 standard, whose purpose is to serve as a conceptual basis for development and/or maintenance of effective and efficient land administration systems. A structural analysis of the domain is, however, not enough. Automated application of normative systems requires not only a representation of the domain to which they are applied, including the rights, restrictions and responsibilities (in the following, as in the standard, collectively referred to as RRRs) of different parties in different situations, but also a formal representation of the normative

¹ In the following, the term *normative system* will be used for a collection of normative sentences, such as a body of legislation or a specific law, a local regulation or a policy. An individual item (e.g. a legal paragraph or a policy rule) in a normative system will be referred to as a *norm* for short. Thus, the term norm is used in a more general sense than in the everyday use as an unwritten ‘social law’.

systems themselves and their constituent parts. For this, tools based on deontic logic (the branch of logic that deals with concepts such as permission and obligation) can be used.

1.1 Property formation

Property formation aims to make possible efficient land use and thereby to promote dynamic urban development. Property formation is a complex domain, and includes for example real property subdivision, amalgamation, reallocation, partition, and other processes. A property subdivision process is the most common process that assigns land for future use. For example, the number of newly formed real property units created through subdivision during 2018 in Sweden was 15,022, while 645 property units were created by partition and 203 by amalgamation (Lantmäteriet, 2019).

Property subdivision creates new real property units by dividing a real property unit into a (limited) number of smaller ones. The result of this process, which will be described in more detail in Section 3, is newly formed property units with unique property identifiers. In the case discussed in Section 3, a subdivision of a property unit is made, where the original owner (seller) keeps ownership of the residual property (i.e., the original but now smaller property after subdivision) while another person (buyer) becomes owner of the subdivided lot. Moreover, each property unit might also be associated with a variety of property rights attached to an owner, a right holder or some other real property unit. A natural first step to speed up the property subdivision process is automation of such decision situations. In the case example, the decision situation for the cadastral surveyor is uncomplicated, and the decision is straightforward, but this is not always the case. The assessment of certain law criteria, such as the requirement in the Swedish Property Formation Act that property formation shall be performed so that each property unit becomes *enduringly suited to its purpose* (FBL, 1970, 3 chap. 1 §), is in many cases non-trivial and often requires demanding judgments that are not easy and straightforward to formalize. To handle this kind of complexity requires combining different analysis tools, aimed for structural and logical analysis, and the development of more sophisticated theoretical frameworks.

1.2 Aim, scope and method

As already noted, a prerequisite for automation of decision-making that is directed or constrained by normative systems is a detailed and accurate representation of the normative systems as well as of the domain to which the normative systems are applied, including the relationships between different (types of) concepts in the domain. Unfortunately, the importance of especially the former is often overlooked in practice, and the authors are not aware of any previous work that attempts to integrate both in the land administration domain. To address this issue, the theoretical and conceptual framework for digitalization and automation of the urban planning and building process needs to be further developed. This includes bringing the tools for structural and conceptual analyses of the land administration domain and the tools for logical analyses of normative systems (and the legal positions

of different parties in different situations that follow from them) closer to each other. A suitable method for this is to perform a number of interrelated case studies of selected subprocesses, including the property formation process. Within such a 'process case study' it is possible to single out a number of process 'snapshots' (i.e. specific situations in the studied process) to be structurally and logically analysed. For such a process snapshot, a 'situation case study' may be performed, in which the types of entities and parties involved in the specific situation, as well as their relationships and their legal positions, are analysed and formally described. The aim of this paper is to take a first step towards developing this theoretical and conceptual framework, by performing a situation case study within the property subdivision process. The point of departure is a specific property subdivision case, in which the types of entities and parties involved in the specific situation, as well as their relationships and their legal positions, are analysed and formally described. The formalism offered by the Land Administration Domain Model (LADM) ISO 19152:2012 standard (see Section 2.3 in this paper), as well as the logic-based theory of normative positions (see Section 2.4 and 2.5) are utilized for this. In a cross-disciplinary fashion, the paper thereby combines two different perspectives on the formalisation and classification of such legal positions.

Joining and aligning analysis tools and formalisms from two different research areas, the paper aims to gain insight on the strengths and weaknesses of the two tools regarding the formal representation of rights, restrictions and responsibilities of different parties in the case at hand. The attempt is to outline the further work needed to gain a better understanding of the land administration domain (including how to analyse and describe it at a higher level of abstraction and formalization using partly new analysis tools). The long-term goal is to contribute to efficient and transparent use of geospatial information in, and increased automation of, currently manual civil processes that will benefit many actors within the urban planning and building process.

Cadastral (and other) authorities can make decisions manually by one or more decision-making officers or by automated procedures (FL, 2017, 28 §). It is outside the scope of this paper to describe how the motives for the decisions made in the investigated cadastral processes are documented or archived by the authorities. Furthermore, research concerning the emergence and importance of real property rights due to social, political and economic factors has been conducted through several decades (see e.g. Ekbäck, 2009; Libecap, 1989 and Umbeck, 1981) and will not be investigated in this paper.

This paper is structured as follows. Section 2.1 discusses the notions of (land use) rights and real property ownership, and Section 2.2 discusses property ownership as an intermediate concept. Sections 2.3–2.5 present the theoretical frameworks and formalisms that will be applied for describing and analysing rights, restrictions and responsibilities in a property subdivision case. A specific property subdivision case is presented and structurally and logically analysed in Section 3. Section 4 discusses the analysis and its implications for automation of the property subdivision process and identify topics for future work, and Section 5 concludes the results.

2 Theoretical framework

Land is a limited resource and has to be administered in order to regulate the various private and public interests of individuals, companies or the State. The way land is administered includes decisions on access to land, land rights, land use and land development. Human activities (housing, farming, husbandry, forestry, recreation etc.) presuppose certain rights. These rights are defined according to law or custom. This section discusses the notion of (land use) rights and presents some theoretical frameworks and formalisms for describing and analysing rights.

2.1 Land use rights and real property ownership

Real property legislation, and in a broader context land use legislation, is concerned with regulating what may be done with land. “Real” in real property usually is associated with something solid, fixed and permanent, which has to do with land. Land use rights are links between the legal owner(s), the right, restriction or responsibility and the area(s) of land in question, and thus have at least three dimensions: what is included in a right, who is the holder of this right and the physical extension this right has (Larsson, 2010). A recent discussion of the real property concept and the relation owner, right and property, as well as its relation to digital processes, can be found in Ekbäck (2019).

There is no universally accepted definition of the term *right*, but a right has been given a number of rather similar definitions, such as an “action, activity or class of actions that a system participant may perform on or using an associated resource” (ISO, 2007, Section 4.38), “a claim or title to or an interest in anything that is enforceable by law” (Gifis, 1984, p. 416), and “[a]right to a specific property, whether tangible or intangible” (Garner, 1891, p. 1096). A *restriction* has been defined as a formal or informal obligation to refrain from doing something (ISO, 2012, Section 4.1.19), “[...] a limitation [...] placed on the use or enjoyment of property” (Garner, 1891, p. 1089).² A *responsibility* has e.g. been defined as a “formal or informal obligation to do something” (ISO, 2012, Section 4.1.18), “a liability” (Garner, 1891, p. 1087), and “an obligation” (Gifis, 1984, p. 408).³

As previously mentioned, land use rights often follow from (or is interconnected to) real property ownership. Thus, real property ownership is a central notion concerning the relation between person and land. The authors are not aware of a commonly accepted definition of ‘ownership’, but it has been argued that ownership can be described as the greatest possible interest in a thing which a mature system of law recognizes (Honoré, 1987). A common approach is to regard real property ownership as a right of its own, ‘ownership right’, which in turn is a combination of several rights. Together in a ‘bundle’ these rights form the concept of real property ownership: The right of unlimited possession of the property;

² An example is a building restriction prohibiting building within 200 metres of a fuel station (ISO, 2012, Section 4.1.19).

³ An example is the “responsibility to clean a ditch, to keep a snow-free pavement or to remove icicles from the roof during winter, or to maintain a monument” (ISO, 2012, Section 4.1.18).

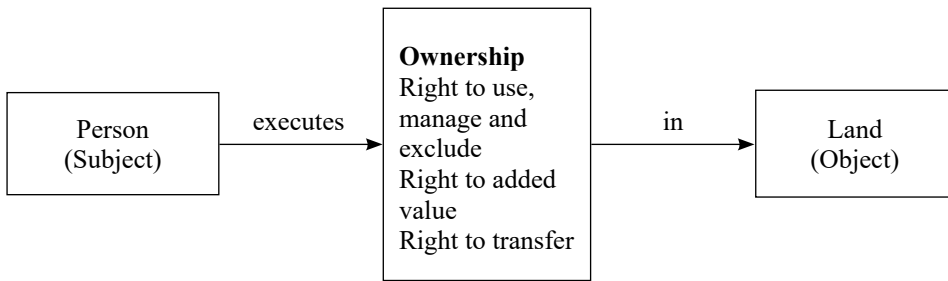


Figure 1. The concept of ownership in land (Paasch, 2012, p. 24).

the right to use the property; the right to manage the property and exclude others from the property; the right to added value of the property; the right to transfer the property to somebody else according to the owner's choice (see e.g. Honoré (1987), Snare (1972), Bergström (1956), and Hohfeld (1917; 1913)). The concept is illustrated in Figure 1.

2.2 Real property ownership as an intermediate concept

Another way to treat the notion of real property ownership is to regard it as a so-called *intermediate (legal) concept*, also known in the literature under names such as 'intermediaries', 'ground-consequence-terms', 'middle terms' or 'coupling terms'.⁴ According to Lindahl (1985), it is an old observation that a number of legal concepts, e.g. contract, ownership and tenure, are linked both to certain legal facts and to certain legal consequences, and thus can be regarded as syntactic tools for formulating legal rules and 'vehicles of inference' for legal reasoning. In fact, ownership is a classic example of an intermediate concept, whose function (and, thus, meaning) is tied to its role as a vehicle of inference linking factual grounds for ownership with legal consequences of ownership. In this view, the term *being the owner of* functions as a bridge or transition between different conceptual systems, one containing facts⁵ (e.g. events, actions, or circumstances) and one containing normative positions⁶ like obligations, claims, legal powers, etc. According to this view, ownership is attached to certain facts, and different normative positions are attached to ownership. In other words, the term ownership (like other intermediate concepts) connects legal information of two different sorts, factual (descriptive) and normative, and is in itself neither a purely descriptive nor a purely normative concept. This idea is illustrated by the scheme shown in Figure 2 where O denotes ownership, G_1, \dots, G_p denote factual (legal) grounds for ownership and C_1, \dots, C_n denote legal consequences of ownership. Each G_{iS} may represent circumstances

⁴ The term *intermediate concept*, for concepts that lie conceptually in between purely descriptive and purely normative concepts, derives from the discussion between Scandinavian legal philosophers Ekelöf, Ross, Wedberg and others. An overview of this discourse is given in, for example, Lindahl and Odelstad (2013, Section 1.7).

⁵ 'Is-objects' in the terminology of Lindahl and Odelstad (2013, p. 552).

⁶ 'Ought-objects'.

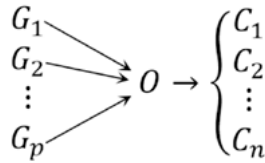


Figure 2. A schematic view of ownership (O) as an intermediate concept, linking its grounds G_1, G_2, \dots, G_p to its consequences C_1, C_2, \dots, C_n (Lindahl & Odelstad, 2013, p. 553).

that hold, or events or actions that take place, in a particular situation. G_i often takes the form of a condition on a number of agents⁷, such as a binary condition $g_i(x,y)$ involving two agents x and y . For example, if g_i represents the condition *having inherited from*, then $g_i^u(x,y)$ may be read as *x has inherited property unit u from y*.

In Figure 2, G_1, G_2, \dots, G_p express different legal grounds for x being the owner of (e.g.) a property unit u , and C_1, C_2, \dots, C_n express different consequences of x being owner of u (cf. Odelstad, 2017, p. 34). Examples of legal grounds for ownership of u may be having lawfully purchased u or having inherited u . Some possible legal consequences of ownership of u are mentioned above; e.g. having the right of unlimited possession of u and having the right to transfer (ownership of) u to somebody else. It thus seems that the view of ownership as a ‘bundle of rights’ mainly focuses on the normative side of the concept.

According to the scheme, it holds for all $i, 1 \leq i \leq p$, and all $j, 1 \leq j \leq n$, that

G_i implies O

O implies C_j

Thus the communicative function of O is to link the grounds G_1, \dots, G_p to the consequences C_1, \dots, C_n . This syntactical tool offers economy of expression since it only requires $p+n$ implications instead of $p*n$ compared to formulating the rules by attaching each G_i to each C_j (Lindahl & Odelstad, 2013, p. 231). It is not uncommon that intermediate concepts form chains, so that what constitutes a consequence of a certain concept in turn constitutes a ground for another concept. For example, as illustrated in Figure 3, the condition *having inherited u* has certain legal grounds, such as *being the sole heir to u* and *being the heir to u according to will*, and certain consequences, such as *being the owner of u*. Thus, *having inherited u* is a ground for *being the owner of u*, which in turn has various legal consequences. *Inheritance of property u* and *ownership of property u* thus form part of a chain or network of intermediate concepts.

⁷ Here, *agent* is used as a generic term for various legal parties such as persons, groups, organisations, or other entities capable of action. The term *actor* will mainly be used to indicate an agent that is in some sense ‘active’ in a particular scenario.

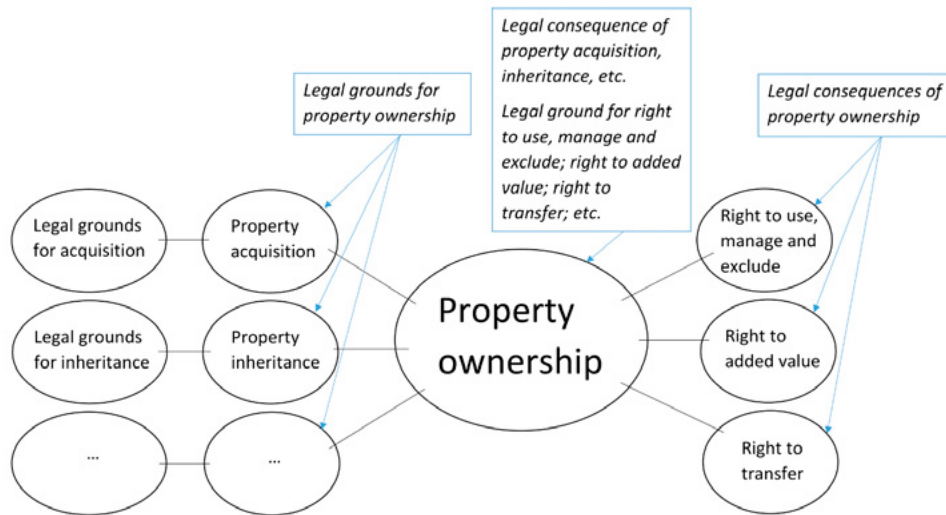


Figure 3. A network of intermediate concepts. (Cf. Figure 23 in Lindahl & Odelstad, 2013). As in Figure 2, the intermediate concept is placed to the right of its grounds and to the left of its consequences.

A particularly interesting class of intermediate concepts are the so-called *open* intermediate concepts, i.e. concepts whose grounds are not wholly specified ('ground-open intermediate concepts') or whose consequences are not ('consequence-open intermediate concepts'); see for example Lindahl and Odelstad (2013, Section 1.7.5). Regarding real property ownership, it seems reasonable to believe that in most legal systems and traditions, both its grounds and its consequences are fairly well specified, but the exact extent to which real property ownership is a ground-open and/or consequence-open intermediate concept might vary from one legal system to another. A more interesting example is the condition *being enduringly suited to its purpose* (see Section 1.1) which Section 4 will discuss further. In a decision process, a ground-open intermediate concept is of special significance, since it functions as a 'point of decision' where it must be decided if the grounds of the concept are fulfilled, and thus its normative consequence applies.

2.3 The Land Administration Domain Model

The Land Administration Domain Model, LADM, ISO 19152:2012 (ISO, 2012), is an international standard and a tool for structuring land administration. It is not limited to any legal system or tradition, thus possible to use as a reference model regardless of a nation's legal system. The LADM is developed by the International Organization for Standardization, ISO, and even accepted as a national standard by a number of countries and as a European standard. The purposes of the model are several; to be used as a conceptual basis for development and/or maintenance of effective and efficient land administration systems and to enable communication and transfer of real property and land administration terms based on a shared

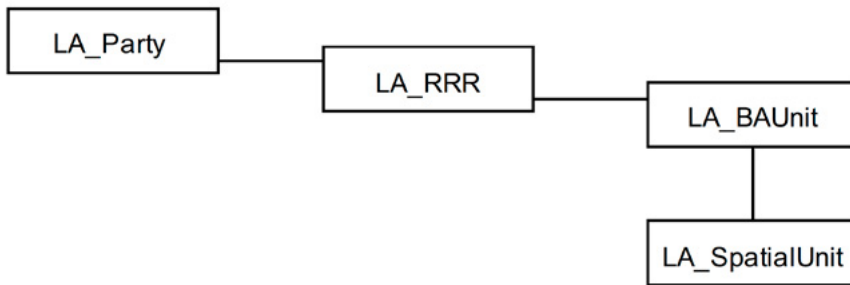


Figure 4. LADM's *LA_Party*, *LA_RRR*, *LA_BAUnit* and *LA_SpatialUnit* (ISO, 2012, p. 9).

vocabulary. In LADM, RRRs are seen as general relations between a (legal) person and land. The LADM does not focus on technical implementation of IT systems for land management, but describes the legal and spatial relations between e.g. a right-holder (e.g. an owner of a real property) and the RRRs that affect a specific piece of land. The basic LADM classes are

- Party (a person or organization playing a role in a rights transaction (ISO, 2012, p. 4)),
- RRR (a right, restriction or responsibility (ISO, 2012, p. 5)),
- BAUnit (a basic administrative unit subject to registration or recordation or customary or social entity with RRRs associated to it (ISO, 2012, pp. 2–3)), and
- SpatialUnit (one or multiple areas of land and/or water, or one or multiple volumes of space (ISO, 2012, p. 6)).

In Figure 4, the classes have the prefix “LA_” attached to them to make them unique in the ISO series of geographic information standards.

LADM is an important part of the foundation for automation within the cadastral field, since it offers a standardized terminology for describing entities in the domain and their relationships, including different types of rights (or absence of rights) of different parties in particular situations. To build further on this foundation, a logical analysis of the notions of RRRs is close at hand.

2.4 Fundamental jural relations

A natural point of departure (see for example Paasch, 2012) for a logical analysis of RRRs is the work by Hohfeld (1913; 1917) on the “fundamental jural relations” (often also referred to as “fundamental legal conceptions”) *right*⁸ (claim), *privilege*

⁸ A note on terminology: The term ‘right’ is somewhat ambiguous, since it is sometimes used in the generic sense of what in Section 2.3 was referred to as ‘right, restriction or responsibility’ (RRR). In the following, the more specific term ‘claim’ (‘claim-right’) is used instead of ‘right’ when referring to the fundamental jural relation, while ‘legal position’ will be used for the generic term that also includes restrictions and responsibilities, i.e. the absence of claim-rights. In other words, a (claim-) right is a kind of legal position, but not

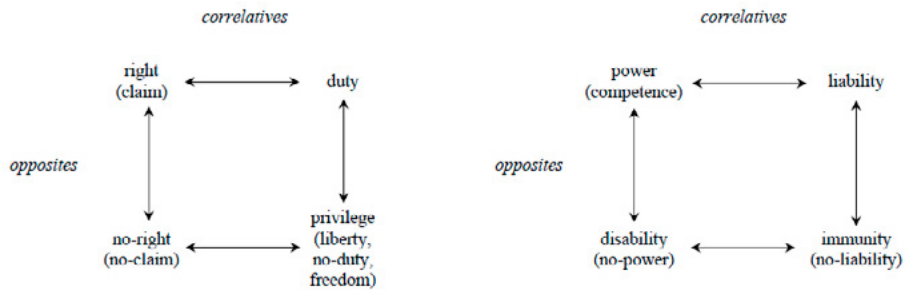


Figure 5. Hohfeld's fundamental legal conceptions (adapted from Sergot, 2001, Figure 1).

(liberty, freedom), *power*, and *immunity*, and their 'correlatives' *duty*, *no-right* (no-claim), *liability*, and *disability*. See Figure 5.

A common view is that the so-called first-order 'Hohfeldian incidents' Privilege and Claim (shown in the left part of Figure 5) directly regulate what actions people may perform, while the second-order incidents Power and Immunity (right part) regulate the introduction and changing of other incidents. That some agent *x* has a power versus some other agent *y* means that *x* has the 'legal capacity' (according to some legal system) to alter *y*'s Hohfeldian incidents, and that *x* has an immunity versus *y* means that *y* lacks the legal capacity to alter *x*'s Hohfeldian incident. Privilege and Power are sometimes referred to as "active" rights, i.e. rights that concern the actions of the bearer of the right, while Claim and Immunity are referred to as "passive" rights that regulate the actions of others.

The fundamental legal conceptions are correlated to each other⁹ in the following way (cf. Figure 5):

- If *x* has a Claim versus *y* regarding some state of affairs *F*, then *y* has a Duty versus *x* regarding *F*.
- If *x* has a Privilege versus *y* regarding *F*, then *y* has a No-claim versus *x* regarding *not:F*, i.e. the negation of *F*.
- If *x* has a Power versus *y* regarding *F*, then *y* has a Liability versus *x* regarding *F*.
- If *x* has an Immunity versus *y* regarding *F*, then *y* has a Disability versus *x* regarding *not:F*.

Also note that some fundamental legal conceptions are the 'opposites' of others:

- If *x* has a Claim versus *y* regarding *F*, then *x* does not have a No-claim versus *y* regarding *F*.
- If *x* has a Privilege versus *y* regarding *F*, then *x* does not have a Duty versus *y* regarding *not:F*.

all legal positions are (claim-) rights. The acronym RRR will be used when referring to the notion of legal position in the LADM context.

⁹ A comprehensive review of the relationships between Hohfeld's fundamental legal conceptions is given by Lindahl (2006, pp. 327–331).

- If x has a Power versus y regarding F , then x does not have a Disability versus y regarding F .
- If x has an Immunity versus y regarding F , then x does not have a Liability versus y regarding *not*: F .

As an example, let us assume that subdividing the property unit u_o into two property units, the residual property (here denoted u_r) and the new subdivided property (u_d), is in line with the current municipal development plan. Let us further assume that both u_r and u_d are deemed enduringly suited to their purposes. Then if a person x owns u_o , x has (versus any person y that does not own u_o) a legal position of type Immunity with respect to subdividing u_o into u_r and u_d . In other words, y does not have a Power versus x regarding x 's subdividing u_o , i.e. y does not have the legal capacity to make x subdivide u_o . Furthermore, x also has a legal position of type Immunity with respect to *not* subdividing u_o into u_r and u_d . That is, y does not have a Power versus x regarding not subdividing u_o ; y does not have the legal capacity to prevent x from subdividing u_o . Hohfeld regarded the fundamental legal conceptions as “the lowest common denominators of the law” that could be used to express jural relations exhaustively and with high precision. It appears that what in LADM is referred to as restrictions and responsibilities may be expressed as no-claims, duties, disabilities or liabilities in Hohfeld's terminology. The fundamental legal conceptions and their correlatives thus seem to have the potential to capture the notions of RRRs (see Section 2.3) with higher precision. The observation, that what is expressed as a right for one party may also be expressed as a restriction or responsibility for some other party, is also in accordance with the LADM (ISO, 2012).

2.5 The theory of normative positions

A logical reconstruction of Hohfeld's theory was suggested by Kanger (1957) who combined the standard operator ‘Shall’ from deontic logic, i.e. the logic that deals with concepts such as obligation and permission, and the action operator ‘Do’. This combination together with the negation operation ‘not’ gives us a powerful language for expressing normative sentences. For example, Shall Do(x , *not*: F) can be interpreted as ‘it shall be (the case that) x sees to it that not F ’ or ‘it shall be that x brings it about that not F ’. Similarly, *not*:Shall Do(x , F) can be read as ‘it is not the case that it shall be that x sees to it that F ’ or ‘it is not the case that it shall be that x brings it about that F ’. Hohfeld's fundamental jural relations may be formally stated in this language, and when combined with standard logical connectives, they can be used to express complex conditional normative sentences. Despite its compactness, the logical formalism has great expressive power that makes it possible to formulate and analyse normative systems with high precision. This, in turn is a prerequisite for automated application of norms, i.e. what Olsson et al. (2018, Sect. 2.3) refer to as “rule checking”.

Table 1. Hohfeld and Kanger (based on Lindahl 1977, p. 49).

Kanger	Hohfeld		Kanger
Claim	Right	Duty	Not Counter-freedom
Counter-claim			Not Freedom
Counter-inunity			NotPower
Immunity			NotCounter-power
Not Claim	No-right	Privilege	Counter-freedom
Not Counter-claim			Freedom
Not Counter-immunity			Power
Not Immunity			Counter-power

Kanger distinguished between four simple types of legal positions (claim, freedom¹⁰, power, immunity) and four simple ‘counter-types’ (counter-claim, counter-freedom¹¹, counter-power, counter-immunity), where “counter” refers to the negation of some event or state of affairs. Thus, the expression ‘*x* has versus *y* a privilege regarding not *F*’ is synonymous to ‘*x* has versus *y* a counter-privilege regarding *F*’ (Lindahl, 1977, p. 43), where *F* may denote (cf. the example in Section 2.4) that the property *u* is subdivided into *u*₁ and *u*₂. The relationship between Hohfeld’s and Kanger’s primitive concepts is shown in Table 1.

In the logical language described above, Kanger’s explication of Claim(*x*, *y*, *F*) is Shall Do(*y*, *F*)¹² and the explication of Privilege(*x*, *y*, *F*) is not:Shall Do(*x*, not:*F*)¹³. The explication of each of the eight simple types is shown in Table 2, where May *P* is used as an abbreviation of ‘not:Shall not:*P*’, and the generic symbol *F* is replaced by a condition *f*(*x*,*y*) representing some binary relation *f* that may hold between *x* and *y*.

Note that for Privilege, Counter-privilege, Power and Counter-power it is the rights-bearer *x* that is ‘active’ in the sense of ‘seeing to it that’. These types express *x*’s freedom and capacity. Claim, Counter-claim, Immunity and Counter-immunity express obligations of the counterparty *y*, who is the active agent. Also, note that, for example, the explication Shall Do(*y*, *F*) of Claim(*x*, *y*, *F*) only explicitly references one of the agents involved, in this case the counterpart *y*. However, it is common that *F* represents some condition *f* on a number of agents, such as the binary condition *having received the down payment for property u*. In this case, Shall Do(*y*, *f*(*x*,*y*)) can be interpreted as follows: ‘*y* shall see to it that *x* receives the down payment for *u* from *y*’. This implicitly represents that *x* has a claim on *y* regarding receiving the down payment for *u*.

A list of legal positions regarding *f*(*x*,*y*) may be constructed by forming the conjunction of each simple type, either negated or unnegated, and removing those conjunctions that are logically inconsistent given the underlying logic of Shall, May and Do. This list contains 26 ‘atomic’ legal positions (see Section 3.4. for

¹⁰ Here, ‘privilege’ will be used instead of ‘freedom’.

¹¹ ‘counter-privilege’.

¹² ‘*y* shall see to it that *F*’.

¹³ ‘it is not the case that *x* shall see to it that not *F*’.

Table 2. Kanger's explication of the simple types of rights. (See for example Lindahl, 1977, p. 43.)

Simple type	Explication	Active agent
Claim($x, y, f(x,y)$)	Shall Do($y, f(x,y)$)	y (counterparty)
Privilege($x, y, f(x,y)$)	not:Shall Do($x, not:f(x,y)$), i.e. May not:Do($x, not:f(x,y)$)	x (rights-bearer)
Power($x, y, f(x,y)$)	May Do($x, f(x,y)$)	x
Immunity($x, y, f(x,y)$)	Shall not:Do($y, not:f(x,y)$), i.e. not:May Do($y, not:f(x,y)$)	y
Counter-type	Explication	
Counter-claim($x, y, f(x,y)$)	Shall Do($y, not:f(x,y)$)	y
Counter-privilege($x, y, f(x,y)$)	not:Shall Do($x, f(x,y)$), i.e. May not:Do($x, f(x,y)$)	x
Counter-power($x, y, f(x,y)$)	May Do($x, not:f(x,y)$)	x
Counter-immunity($x, y, f(x,y)$)	Shall not:Do($y, f(x,y)$), i.e. not:May Do($y, f(x,y)$)	y

examples). Kanger's typology of atomic types of normative relations between two agents and a state of affairs was developed by Lindahl (1977) into three systems of types of *normative positions*. That x versus some counterpart y has a certain type of normative position with respect to, e.g., the state of affairs $f(x,y)$ means that x has, or does not have, certain (types of) rights versus y as regards $f(x,y)$. The simplest of these systems of types of normative positions, the so-called *one-agent types of normative positions*, is shown in Table A1 in the appendix.

Although not without its problems as a theory of rights (see, e.g., Makinson, 1986), the so-called Kanger-Lindahl theory of normative positions is generally regarded (Sergot, 2013, p. 355) as the most comprehensive and best developed attempt to formalize Hohfeld's fundamental jural relations, which may be expressed as logical combinations of normative positions.

3 Subdivision of a real property unit: A 'Situation Case Study'

Since property formation is central to the urban planning and building process, property subdivision (which, by far, is the most common case of property formation in Sweden) is selected as the object of study. A Swedish property formation process is generally divided into the four phases *initiation, preparation, decision* and *registration* (see for example Figure 31 in Vaskovich, 2012, for an overview). The analysis focuses on the decision phase of the property subdivision process, described in Section 3.1. Two 'Situation Case Studies' analyse snapshots of the property subdivision process, along with the types of entities and parties involved in the specific situations. Furthermore, the case studies formally describe the relationships and legal positions of said entities and parties. The paper studies (i) the situation where the cadastral surveyor is about to take the cadastral decision, and (ii) the situation just after the decision has entered into force. The goal of the analysis is to be more acquainted with the selected decision situation, in order to get a better understanding (and formal

description) of the domain of the property subdivision process. A challenge here is to delimit the scope of the analysis. Explicitly mapping out all the legal positions that hold between all different parties and objects, is way beyond the scope of this paper. The aim is not to perform an exhaustive analysis of the decision situation, but to compare and discuss different tools for analysis and formal representation of legal positions between different parties. Therefore, Sections 3.3–3.5 focus on a subset of the legal positions that is manageable, yet rich enough to illustrate the ‘analytic capacity’ and expressiveness of the different analysis tools. Section 3.6. further discusses this approach.

3.1 The property subdivision process

A subdivision process is exclusively performed through decision of a cadastral surveyor. A completed subdivision may only be changed by another decision of a surveyor or through a court decision. The surveyor is in general rather free to arrange the subdivision process in the way seen as most suitable, not being bound by statutory regulations in this aspect.

During the subdivision process, the cadastral surveyor makes several legal decisions, *viz.* the cadastral decision, the cost-distribution decision and the completion decision. The central decision is the actual cadastral decision to form a new property unit for e.g. housing purposes, which legalises (the existence of) the newly formed property (FBL, 1970, 4 chap. 25 a §). The decision must be made by the surveyor after all details of subdivision are investigated, i.e. after, among others, preparation, rearrangement of related property rights and the necessary surveying have been done. The decision includes the assessment of the requirement in the Swedish Property Formation Act that a newly formed real property unit must be *enduringly suited to its purpose* (FBL, 1970, 3 chap. 1 §), which includes being suitably designed and having (potential) access to both a road and acceptable sewerage arrangements and water supplies. Therefore, the surveyor takes the size of the new land plot and the future access to road, water and sewerage systems under particular consideration. Moreover, the surveyor assesses whether a requested subdivision is consistent with the existing municipal detailed development plan as well as with public land policy. If needed, the surveyor may (choose to, or be required to) consult with the municipality (typically regarding sewerage, water supply and/or development plan issues), the Road Authority (typically regarding road access), and the County Board (regarding environmental protection).

As soon as the cadastral decision is taken, a bundle of respective property rights is legally attached to the new property unit. When the appeal period expires, the cadastral surveyor finalises the registration of the new property unit. Subdivision completes by the respective entry regarding newly formed property units into the real property register.

The following Section 3.2 describes a fairly normal and uncomplicated property subdivision case, based on certain simplifying assumptions. The aim is to highlight important parts of the process and show how it may be carried out in this specific case. In general, the process can be much more complex.

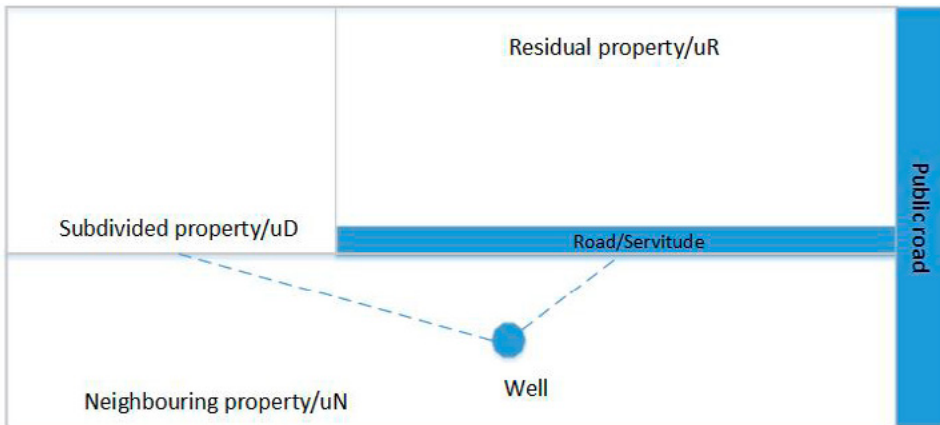


Figure 6. A schematic overview of the intended situation on the ground after subdivision. (The dashed lines indicate u_R 's and u_D 's right-of-use servitudes.)

3.2 Case description

The owner of a property (the 'original' property, in the following referred to as u_O) would like to subdivide the land parcel into two smaller property units, with the aim of keeping ownership of one part (the 'residual' property, u_R) and selling the other (the 'subdivided' property, u_D) to the buyer. The buyer plans to build a house on u_D , and a preliminary building permit has already been applied for and granted by the municipality. There is no mortgage attached to u_O , and there will be no mortgage attached to u_D . A servitude with u_O as the dominant property and the neighbouring property u_N as the servient property grants the owner of u_O the right of access to and use of the well situated on u_N . (See Figure 6 for an overview of the intended situation after subdivision.)

In the case presented here, the seller and the buyer make purchase arrangements and sign a purchase contract before subdivision, and then submit an application for subdivision. As soon as the application is registered at Lantmäteriet, a new cadastral dossier is created and the case is assigned to a cadastral surveyor. The cadastral surveyor examines the general conditions of subdivision, including a bundle of attached property rights, and the requirement that the new property unit is *enduringly suited to its purpose*. As already mentioned, this means that a newly formed property unit needs (potential) access to water supply and sewerage arrangements as well as free passage from the property (i.e. right of way). The requested subdivision must also be consistent with the existing municipal detailed development plan as well as with public land policy.

To ensure right of way for the owner of the subdivided property u_D over the residual property u_R to the public road, a new servitude has to be created.¹⁴

¹⁴ Instead of creating servitudes, it would be possible to create a so-called joint facility, i.e. a construction (facility) beneficial for two or more real property units (AL 1973). Since it is more common to use servitudes to secure rights of access when very few properties are involved, and to avoid unnecessary complexity in the example, the study abstains from creating a joint facility here.

Likewise, to ensure the owner of u_D the right of use to the well on the neighbouring property u_N , a servitude (with u_N as the servient property and u_D as the dominant property) can be created if an agreement is reached with the owner of u_N . The existing servitude ensuring right of use of the well on u_N to the owner of u_O is not affected by the property subdivision process and will thus remain unchanged, since it still belongs to u_O (now called u_R). The new servitudes are given unique designations and database id's in the real property register.

Subdividing the original property u_O into u_D and u_R results in a new cadastral boundary being created to separate the properties. The area of u_O is thus changed (i.e. reduced) in the property formation process, but the residual property u_R keeps u_O 's property unit designation and database identification number in the real property register. Some of u_R 's former cadastral boundaries now mark the subdivided property together with the new created boundary dividing the properties¹⁵, thus creating a closed geographic area. u_D receives a new database identification number and a new real property designation within the series used for the cadastral district in which the property is located.

As part of the property formation process, the cadastral surveyor has to ensure that the subdivided property u_D will be connected to a sewage network or otherwise be able to discharge of its waste. In this example, the buyer has chosen to construct a small plant for sewage discharge treatment on the property. A permission for the construction of such a facility has been obtained from the municipality's environmental department prior to the subdivision.

To summarise, the buyer (in the following referred to as a_B) is assumed to sign an agreement with a_N , the owner of u_N , regarding right of access to the well also for the owner of u_D , i.e. that a_N agrees to the creation of a new servitude for this purpose. The creation of a servitude that grants the owner of u_D access to the road on u_R is likewise assumed, as well as that preliminary building permits for a new building and a sewage discharge facility have been obtained. Furthermore, this property formation is assumed uncomplicated in the sense that it is entirely in line with the current municipal detailed development plan and public land policy, and no consultation with other authorities is necessary.

3.3 Preamble to analysis: Actors and entities

The 'Situation Case Study' is prepared for by first identifying in the case description the parties (actors and stakeholders) that are directly involved in or affected by the decision:

- a_S : Actor S (Seller, Owner of original property u_O , Owner of residual property u_R)
- a_B : Actor B (Buyer, Owner of future subdivided property u_D)
- a_N : Actor N (Owner of neighbouring property u_N)
- a_C : Cadastral surveyor

¹⁵ In some cases, a technical surveyor visits the property to demarcate the boundaries physically on the ground.

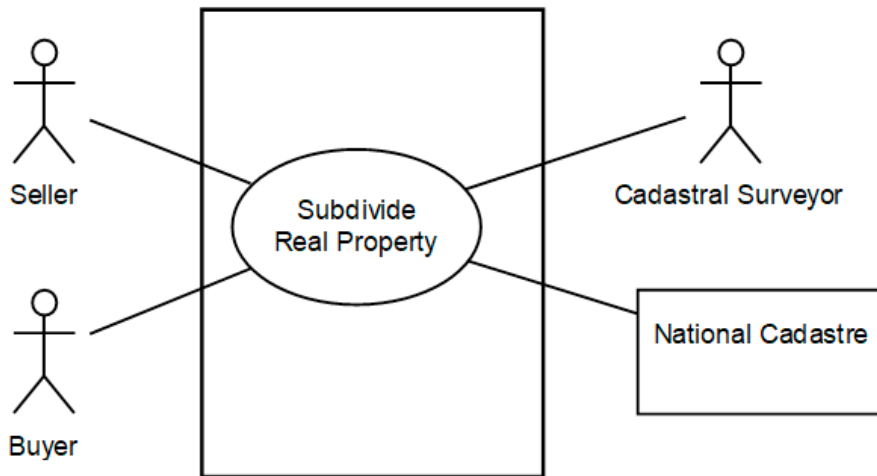


Figure 7. Use case diagram showing the main actors of Subdivide Real Property.

Other parties that can be extracted from the case description, but do not occur explicitly in the analysis, include other neighbours, a technical surveyor, the Municipality, the County Board, the Road Authority, and the State.

The Use Case diagram in Figure 7 shows the main actors of the real property subdivision process. Zooming in on the particular decision situation, the cadastral decision, it can be seen that some actors are more directly involved than others are. The cadastral surveyor a_c is the main actor in the sense of being the decision maker, while the seller a_s and the buyer a_b are also central actors that are directly affected by the decision. To some extent, other stakeholders such as an owner of a neighbouring property or some other private citizen (who, for example, for some reason opposes the formation of the new property) are also affected, whereas the previously mentioned public authority parties are not directly involved in or affected by this step of the process.

Next, central concepts are identified that occur in the case description. The following entities occur explicitly in the analysis:

- d : Cadastral dossier
- u_o : Original property (before subdivision)
- u_r : Residual property (original property after subdivision)
- u_d : Subdivided property
- w_N : Water source (well) on neighbouring property
- $s_{w,o}$: Water source easement/servitude (u_o vs. u_N)
- $s_{w,r}$: Water source easement/servitude (u_r vs. u_N)
- $s_{w,d}$: Water source easement/servitude (u_d vs. u_N).

Examples of other entities that can be extracted from the case description, but do not occur explicitly in the analysis, are the subdivision application, the road on the residual property, the preliminary building permits for a building and a sewerage arrangement on u_d , and ‘technical’ entities such as cadastral boundaries and database id’s.

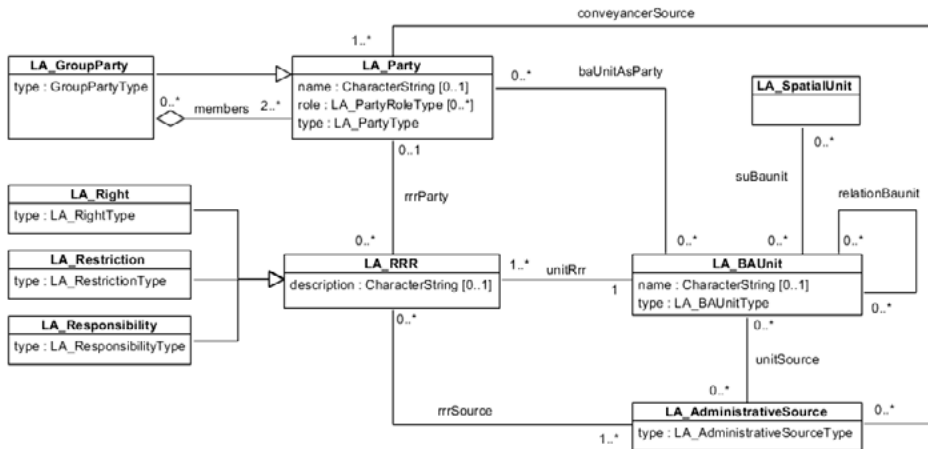


Figure 8. A class diagram of relevant parts from the LADM (adapted from ISO, 2012, Figures 9, 10 and 11).

3.4 Structural analysis using LADM terminology

This section structures the case of property subdivision from Section 3.2 with the help of LADM object diagrams, i.e. UML diagrams following the LADM standard (ISO, 2012). The notations from Section 3.3 are utilized, slightly adapted. The original owner, and seller of the subdivided part, will be denoted as_S in the diagrams (not a_s as in the text). This and similar adaptations are made to make the diagrams more readable. Further, the class names of the LADM (e.g. LA_BAUnit) are utilised, but package names (e.g. Administrative) are not written out. Thus, LA_BAUnit stands for the class whose full name according to the LADM standard is Administrative::LA_BAUnit.

A starting point for modelling the case according with LADM is the class diagram in Figure 8, which is adapted from Figures 9, 10, and 11 in the LADM standard (ISO, 2012). The classes are drawn from three of LADM’s main packages (Party, Administrative, and Spatial Unit). As the case study focuses on RRRs, spatial relationships are not included in the models. E.g., the fact that a passageway over some property must spatially be ‘within’ this property, will not be represented in the models. (See, e.g., ISO (2012, Figure C.21) for an example.)

Although UML class diagrams are static structure diagrams, it is worth noting that the LADM can be used for state-based modelling as well as event-based modelling, see Appendix N of the LADM standard (ISO, 2012). Section 3.4.1 represents the situation before subdivision, and Section 3.4.2. the situation after subdivision.

3.4.1 Situation before subdivision

Before subdivision, the seller a_s owns the original property u_o . A servitude attached to the original property u_o and the neighbouring property u_n grants a_s the right to use the well situated on u_n . LADM can model the servitude as a restriction on the

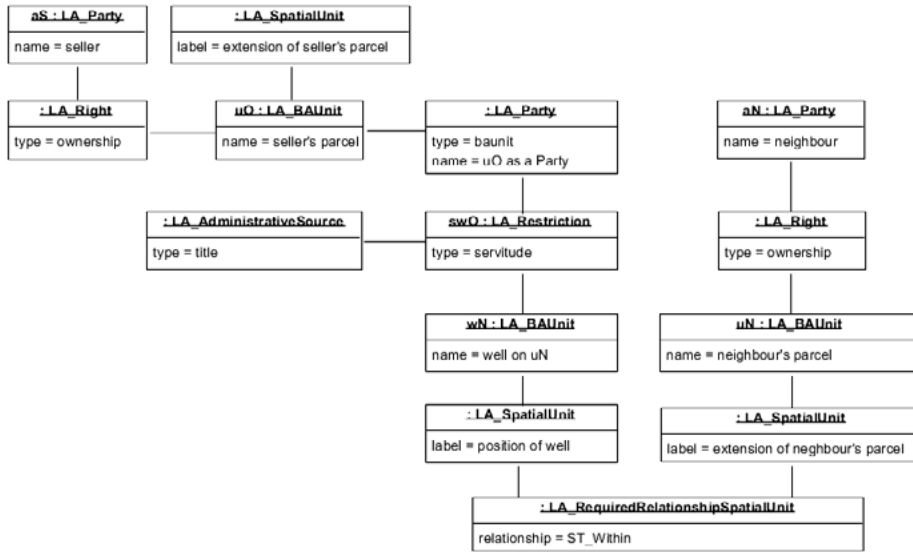


Figure 9. An object diagram showing the situation before subdivision.

neighbouring property, in the sense that the ownership rights of the neighbour a_N are restricted. Further, in the (non-normative) code list `LA_RestrictionType` there is a type *servitude*. The choice to represent a servitude as an instance of `LA_Restriction` is discussed in Section 3.6.

Figure 9 follows the approach of Figure C.21 of the LADM standard (ISO, 2012), although in a different context. The well on the neighbour’s property is represented by the `LA_BAUnit` instance w_N , which is spatially located within the neighbour’s property. According to the class diagram and other specifications in the LADM, each instance of `LA_Restriction` is associated to (linked to) exactly one `LA_BAUnit`, and to one (or none) `LA_Party`.¹⁶

The `LA_Restriction` object is associated to an instance of `LA_AdministrativeSource`, where the latter represent documents (in this case files in the cadastral dossier d) internal or external to the land administration organization. Not shown in the figure is the association between the administrative source for the original servitude and the cadastral surveyor (`LA_Party`) who once established it.

3.4.2 Situation after subdivision

When the original property u_O has been subdivided into a remaining part u_R and a subdivided part u_D , both properties will have the right to access the neighbour’s

¹⁶ A difference from Figure C.21 of the LADM standard is that we do not link the owner a_S of the original property u_O directly to the Restriction object $s_{w,O}$. Instead, we follow Swedish law, which says that it is u_O that has the servitude, not the owner of u_O . (In order to follow the LADM specifications, we had to insert an `LA_Party` object representing u_O acting as a party, *viz.* the nameless object between u_O and $s_{w,O}$.)

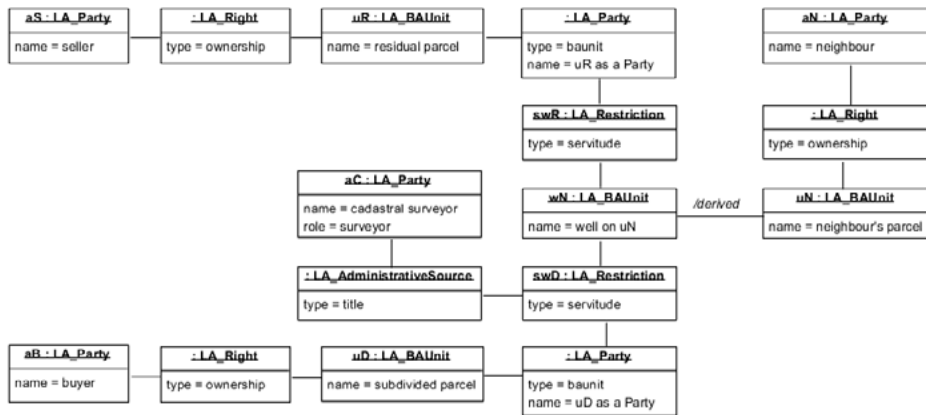


Figure 10. An object diagram showing the situation after subdivision.

well. In Figure 10, this has been represented as the two properties each having a unique servitude on u_N .¹⁷

For simplicity, Figure 10 excludes the instances of classes SpatialUnit and RequiredRelationshipSpatialUnit from the object diagram. Instead, a link is drawn directly from w_N (the LA_BAUnit representing the well) to u_N (the LA_BAUnit representing the neighbour's parcel). This might be seen as a link derived from a spatial relationship that is not shown. Section 3.6. discusses the spatial relationship between the two BA_Unit objects u_R and u_N further.

3.5 Logical analysis of atomic types of rights

To perform a logical analysis of the legal relations that hold between different parties (see section 3.3) regarding different conditions is not a simple task. The list of possible conditions to examine is practically endless, and each condition may be instantiated with different combinations of parties, and in different situations (e.g. before or after subdivision of u_O). However, some conditions that might be relevant to consider can be inferred from the process and case descriptions in Sections 3.1 and 3.2:

1. using the well on u_N
2. using the road on u_R
3. subdividing u_O into u_R and u_D
4. receiving agreed payment for u_D
5. retracting an application to subdivide u_O into u_R and u_D
6. appealing a decision to subdivide u_O into u_R and u_D
7. appealing a decision to deny subdivision of u_O into u_R and u_D .

The following analysis, based on the fundamental jural relations and their logical explications (or, as will be discussed in Section 3.6, a generalisation of these notions) that were presented in Section 2.4, focuses on items 1 and 3. As in

¹⁷ An object diagram showing the situation where the two properties u_R and u_D have a common servitude on u_N would be slightly different, e.g. using the LADM LA_GroupParty class to group the two real properties as a single party (not shown).

Section 3.4, this section starts with the situation before subdivision of u_O into u_R and u_D , and then look at the situation after.

3.5.1 Situation before subdivision

First, this section looks at the condition *using the well on u_N* and the two parties a_S and a_N . If x is an agent, let $w_N(x)$ represent the event x uses the well on u_N .¹⁸ Which simple types of legal relations hold in this situation between the seller a_S and the neighbour a_N regarding $w_N(a_S)$, i.e. a_S 's using the well on u_N ? Given the assumptions in 3.3, which includes the existence of a servitude for the owner of u_O (i.e. a_S) to use the well on u_N , it seems reasonable to say that a_S does not have a duty (versus a_N) to not use the well. It is natural to express this as the fundamental jural relation

$$\text{not:Duty}(a_S, a_N, \text{not}:w_N(a_S)), \tag{1a}$$

which (since Privilege and Duty are ‘opposites’; cf. Figure 5) is the same as

$$\text{Privilege}(a_S, a_N, w_N(a_S)). \tag{1b}$$

By substituting the binary condition f in Table 2 for the unary condition w_N , a possible logical explication is obtained of (1ab):

$$\text{May not:Do}(a_S, \text{not}:w_N(a_S)) \tag{2}$$

This can be read as ‘it may be that a_S does not see to it that a_S does not use the well on u_N ’. It also seems reasonable to claim that a_N lacks capacity to prevent a_S from using the well. Below it is suggested how to express this as a fundamental jural relation, together with a possible logical explication:

$$\text{not:Power}(a_N, a_S, \text{not}:w_N(a_S)) \tag{3a}$$

$$\text{Alternatively put: Immunity}(a_S, a_N, w_N(a_S)) \tag{3b}$$

$$\text{not:May Do}(a_N, \text{not}:w_N(a_S)) \tag{4}$$

A possible interpretation of (4) is ‘it is not the case that a_N may see to it that a_S does not use the well on u_N ’. By similar reasoning applied to the remaining simple types of legal relations, leaving out the details for brevity, Table 3 shows the suggested analysis.

Table 3. Simple legal relations between a_S and a_N (before subdivision) regarding $w_N(a_S)$.

Simple type	Possible logical explication
Privilege($a_S, a_N, w_N(a_S)$)	not:Shall Do($a_S, \text{not}:w_N(a_S)$)
Counter-privilege($a_S, a_N, w_N(a_S)$)	not:Shall Do($a_S, w_N(a_S)$)
not:Claim($a_S, a_N, w_N(a_S)$)	not:Shall Do($a_N, w_N(a_S)$)
not:Counter-claim($a_S, a_N, w_N(a_S)$)	not:Shall Do($a_N, \text{not}:w_N(a_S)$)
Power($a_S, a_N, w_N(a_S)$)	May Do($a_S, w_N(a_S)$)
Counter-power($a_S, a_N, w_N(a_S)$)	May Do($a_S, \text{not}:w_N(a_S)$)
Immunity($a_S, a_N, w_N(a_S)$)	not:May Do($a_N, \text{not}:w_N(a_S)$)
Counter-immunity($a_S, a_N, w_N(a_S)$)	not:May Do($a_N, w_N(a_S)$)

¹⁸ Despite some risk of confusion; in previous sections w_N is also used to denote a domain entity, viz. the well on u_N .

From this follows that the atomic type of legal relation between a_s and a_N (before subdivision) with regard to a_s 's using the well on u_N is the following:

$$\begin{aligned} & \text{Privilege \& Counter-privilege \& not:Claim \& not:Counter-claim \&} \\ & \text{Power \& Counter-power \& Immunity \& Counter-immunity.} \end{aligned} \tag{5}$$

Looking instead at the parties a_B and a_N and the event $w_N(a_B)$, by similar reasoning is suggested that the atomic type of legal relation between a_B and a_N (before subdivision) with regard to a_B 's using the well on u_N is the following:

$$\begin{aligned} & \text{not:Privilege \& Counter-privilege \& not:Claim \& not:Counter-claim \&} \\ & \text{not:Power \& Counter-power \& not:Immunity \& Counter-immunity.} \end{aligned} \tag{6}$$

A similar analysis regarding the same event but instead considering the parties a_s and a_B , suggests the following atomic type of legal relation between a_s and a_B (before subdivision) with regard to $w_N(a_B)$:

$$\begin{aligned} & \text{Privilege \& Counter-privilege \& not:Claim \& not:Counter-claim \&} \\ & \text{not:Power \& not:Counter-power \& not:Immunity \& Counter-immunity.} \end{aligned} \tag{7}$$

The difference between (5), (6) and (7) is further discussed in Section 3.6.

Similar analyses (not shown here due to lack of space) may be performed for other combinations of parties, as well as for the listed conditions 2, 4, 5, 6, and 7. An important observation is the following: the atomic legal relations regarding conditions 1–2 and 4–7 are significant for decisions on whether some party at some point does or does not act in compliance with applicable regulations and agreements¹⁹, but they do not affect (i.e. put restrictions on) the actual cadastral decision that our example focuses on. In contrast, condition 3, *subdividing u_O into u_R and u_D* , is directly related to the cadastral decision. The paper will therefore examine this condition instantiated with the cadastral surveyor a_C , and consider the two parties a_s and a_C . Let $s_{O,R,D}(x)$ represent the event x subdivides u_O into u_R and u_D .

Table 4. Simple legal relations between a_s and a_C regarding that a_C subdivides u_O into u_R and u_D .

Simple type of legal relation	Possible logical explication
Privilege($a_s, a_C, s_{O,R,D}(a_C)$)	not:Shall Do($a_s, \text{not}:s_{O,R,D}(a_C)$)
Counter-privilege($a_s, a_C, s_{O,R,D}(a_C)$)	not:Shall Do($a_s, s_{O,R,D}(a_C)$)
Claim($a_s, a_C, s_{O,R,D}(a_C)$)	Shall Do($a_C, s_{O,R,D}(a_C)$)
not:Counter-claim($a_s, a_C, s_{O,R,D}(a_C)$)	not:Shall Do($a_C, \text{not}:s_{O,R,D}(a_C)$)
Power($a_s, a_C, s_{O,R,D}(a_C)$)	May Do($a_s, s_{O,R,D}(a_C)$)
Counter-power($a_s, a_C, s_{O,R,D}(a_C)$)	May Do($a_s, \text{not}:s_{O,R,D}(a_C)$)
Immunity($a_s, a_C, s_{O,R,D}(a_C)$)	not:May Do($a_C, \text{not}:s_{O,R,D}(a_C)$)
not:Counter-immunity($a_s, a_C, s_{O,R,D}(a_C)$)	May Do($a_C, s_{O,R,D}(a_C)$)

¹⁹ For example, a court decision on whether a_N at some point was entitled to prevent a_B from using the well. (Before subdivision, a_N has this right, but no longer after.)

Given the assumptions in 3.2 (that u_R and u_D are considered enduringly suited to their purposes, etc.), which simple types of legal positions regarding $s_{O,R,D}(a_C)$ hold between the seller a_S and the cadastral surveyor a_C ? Leaving out the details, Table 4 shows the suggested analysis.

As Section 3.6 will discuss, the analysis in Table 4 can be questioned, but if it is accepted the atomic type of legal relation between a_S and a_C regarding the event $s_{O,R,D}(a_C)$ is the following:

$$\begin{aligned} & \text{Privilege \& Counter-privilege \& Claim \& not:Counter-claim \&} \\ & \text{Power \& Counter-power \& Immunity \& not:Counter-immunity.} \end{aligned} \quad (8)$$

Given that this atomic legal relation holds in the cadastral decision situation, the cadastral surveyor has a duty to perform the requested subdivision, i.e. a_C 's room for manoeuvre is restricted in this situation.

3.5.2 Situation after subdivision

First, looking at the condition w_N , how do the atomic types of legal relations discussed in the previous section change as a result of performing the subdivision? After subdivision, the servitude for the owner of u_O (now called u_R) to use the well on u_N remains attached to u_R . Therefore, the atomic type of legal relation between a_S and a_N regarding $w_N(a_S)$ that holds after subdivision is the same as before, viz. (5). The same type of legal relation now also holds between a_B and a_N regarding $w_N(a_B)$, due to the creation of a similar servitude for (the owner of) u_D , i.e. the type of atomic relation changes from (6) to (5). The legal relation between the parties a_S and a_B regarding $w_N(a_B)$ is not changed during the subdivision process, i.e. the type of atomic legal relation (7) still holds.

As for the condition $s_{O,R,D}$, subdividing u_O into u_R and u_D , it no longer represents a meaningful condition: the event $s_{O,R,D}(x)$ is not possible for any agent x , since the property u_O no longer exists in its original form. Therefore, after subdivision it is not meaningful to talk about the atomic legal relation between any two agents as regards $s_{O,R,D}(x)$.

3.6 Experiences and reflections

Sections 3.4 and 3.5 apply two different analysis tools to analyse and describe two 'snapshots' of the subdivision process. Although being simplistic in many ways, the case is still both realistic and rich enough to put the formalisms to the test, and no claims are made that the analyses are exhaustive. Here, the paper will reflect upon perceived strengths and weaknesses of the two formalisms, as well as their potential relation.

The analysis in Section 3.4 gives several insights regarding LADM as a tool for structural analysis. The LADM standard describes many useful 'off the shelf' tools for modelling the example situation(s). The paper has included notions of class diagrams (Figure 8) and object diagrams (Figure 9 and Figure 10), the latter to describe two specific situations related to the case, viz. the situation immediately before resp. immediately after the cadastral decision regarding subdivision. As Section 3.4 already mentions, object diagrams have not been utilized in the same

way as in the property subdivision example illustrated in Figure C.38 in the LADM (ISO, 2012).

For structurally analysing two situations of the example process, the LADM offers the possibility to represent formally (and with high precision) various RRRs of different parties in relation to each other and to land. The extension to the LADM classification proposed by Paasch et al. (2015) offers even higher level of precision, for example making it possible to model the right-of-use to the well on the neighbouring property (i.e. $s_{w,o}$ in Figure 9) as an *LA_PartyToPropertyRight* or perhaps an *LA_PropertyToPropertyRight* (see Figure 11 in Section 4). Since the focus of the LADM is conceptual rather than technical, and the standard was designed to give room for national implementations that adhere to different legal traditions, there are several degrees of freedom to its application, and the examples discussed in the standard sometimes give limited guidance. For example, Section 3.4.1 utilized the RRR subclass Restriction to model the servitudes in Figure 9 and Figure 10. However, since the paper refers to the owner of u_o (resp. u_D) having a right to access the well for water, it might be perceived as more natural to model this with an instance of the Right class (attached to the dominant property) than an instance of the Restriction class. The paper refrained from this for two reasons. First, in order to follow the example C.21 of the LADM standard, and secondly, since the RestrictionType code list has an entry *servitude*, while the RightType code list has not. It is not clear from the description of the standard if any of the two options should be preferred, so it appears that the servitudes could have been modelled both as (subclasses of) *LA_Right* and *LA_Restriction*, perhaps depending on perspective. This freedom may be a benefit for a conceptual analysis, but at the same time a challenge when approaching technical implementation. Due to this and to the focus on concepts and static situation descriptions, the LADM support for further automation of land administration processes is rather limited.

Note that the two BA_Unit objects u_R and u_N in Section 3.4.2 originate from u_o , and that the two LA_SpatialUnit objects in Figure 10 together constitute the original LA_SpatialUnit object in Figure 9. These relationships could be represented in the diagram by means of a *LA_RequiredRelationshipBAUnit* and a *LA_RequiredRelationshipSpatialUnit*, respectively. These relationships could be very important in various context, but were omitted from Figure 10 to reduce the complexity.

As demonstrated, the LADM with extensions can be used to structurally with high level of granularity model different categories of (e.g. public and private) RRRs, and how they are attached to different parties and administrative units. As Section 3.5 shows, the structural analysis can be complemented with a logical analysis that adds better support for legal reasoning. Through the analysis a deeper insight is gained into how to (with very high precision) state basic legal positions of different parties regarding some state of affairs or event in logical language. By doing so, it is possible to exhaustively formalise the leeway of the agents involved in the decision situation, and thus take another step towards increased automation of legal decision processes. Consider again, for example, the simple types of legal

relations (5), (6) and (7) regarding the condition *using the well on* u_N (abbr. w_N) in Section 3.5:

Privilege & Counter-privilege & not:Claim & not:Counter-claim &
Power & Counter-power & Immunity & Counter-immunity. (5)

not:Privilege & Counter-privilege & not:Claim & not:Counter-claim &
not:Power & Counter-power & not:Immunity & Counter-immunity. (6)

Privilege & Counter-privilege & not:Claim & not:Counter-claim &
not:Power & not:Counter-power & not:Immunity & Counter-immunity. (7)

Before subdivision, (5) is the type of legal relation between a_S and a_N with regard to a_S 's using the well on u_N , (6) is the type of legal relation between a_B and a_N with regard to the same event, and (7) is the type of legal relation between a_B and a_N with regard to a_B using the well on u_N . The difference between (5) and (6) is due to the existing servitude that gives a_S a right-of-use (manifested as a Privilege, a Power and an Immunity) that a_B does not have. The reason for the difference between (5) and (7) is that a_S does have legal capacity regarding his/her own use of the well on u_N , thanks to the well servitude, but not regarding a_B 's use of the well. (The servitude does not give a_S the right to permit another person to use the well.)

Regarding the condition *subdividing* u_O into u_R and u_D (abbr. $s_{O,R,D}$), some of the suggested simple legal relations in Table 4 are rather straightforward, while others are not. It is not evident, for example, how to understand the notions of Power and Counter-power in this case. In the current situation, does a_S versus a_C have 'legal capacity' (power) regarding that a_C subdivides u_O ? As for Counter-power, does a_S versus a_C have capacity regarding that a_C does not subdivide u_O ? In Table 4 it is suggested that both Power($a_S, a_C, s_{O,R,D}(a_C)$) and Counter-power($a_S, a_C, s_{O,R,D}(a_C)$) hold.

The analysis in terms of simple legal relations may be translated to logical language through Table 2. Note, however, that the conditions *using the well on* u_N (w_N) and *subdividing* u_O into u_R and u_D ($s_{O,R,D}$) are unary conditions, i.e. conditions on one agent x . Kanger's logical explication of the fundamental jural relations (Section 2.5) originally presupposes binary conditions, i.e. conditions on two agents x and y . Thus, by generalising to unary instead of binary conditions, as in Table 3 and Table 4, the formalism is stretched a bit. This is not a limitation, since the main purpose of the logical analysis was nothing more than demonstrating how to put the logical language to work, but should be kept in mind when interpreting the result of the translation. For example, in the situation before subdivision, it seems reasonable to say that

$$\text{Counter-claim}(a_N, a_B, w_N(a_B)) \quad (9a)$$

or, in other words,

$$\text{Claim}(a_N, a_B, \text{not}:w_N(a_B)) \quad (9b)$$

holds, i.e. that a_N (versus a_B) has a claim regarding that a_B does not use the well on u_N . On the other hand, equally reasonably, it holds that

$$\text{not:Claim}(a_S, a_B, \text{not}:w_N(a_B)), \quad (10)$$

i.e. it is not the case that a_s (versus a_b) has a claim regarding that a_b does not use the well. However, the generalised explication of (9ab) is

$$\text{Shall Do}(a_b, \text{not}:w_N(a_b)), \quad (11)$$

while the generalised explication of (10) is

$$\text{not:Shall Do}(a_b, \text{not}:w_N(a_b)), \quad (12)$$

i.e., there is a logical contradiction. Thus, when generalising the logical explication of simple types of legal relations to unary conditions, either the rights-bearer or counterparty may ‘disappear’ from the logical analysis, which may be potentially problematic. Regarding the interpretation of Power and Counter-power in Table 4, the generalised explication of $\text{Power}(a_s, a_c, s_{O,R,D}(a_c))$ is $\text{May Do}(a_s, s_{O,R,D}(a_c))$, which may be interpreted as ‘it may be the case that a_s sees to it that a_c subdivides u_o ’. The fact that a_s has the right to have u_o subdivided (provided that all necessary prerequisites are fulfilled) seems to already be adequately modelled by the simple type Claim, and what it would mean in the present situation that ‘ a_s sees to it that a_c subdivides u_o ’ is not wholly clear. The explication of $\text{Counter-power}(a_s, a_c, s_{O,R,D}(a_c))$ is $\text{May Do}(a_s, \text{not}:s_{O,R,D}(a_c))$; ‘it may be the case that a_s sees to it that a_c does not subdivide u_o ’. In this case, one might perhaps say that a_s has the right to withdraw the subdivision application, and thus may see to it that a_c does not subdivide u_o . (See also the example in Section 2.4.)

It could be argued that by performing a logical analysis of this simple decision situation, one takes a sledgehammer to crack a nut. In fact, the complexity of mapping out all the legal positions of different parties with respect to different conditions in the decision situation seems to be way out of proportion to the complexity of the actual decision. Besides, sorting out this complexity by hand is likely a very difficult and time-consuming task. These are valid objections, but it should be kept in mind that the aim here is to take a first step towards developing the theoretical and conceptual framework for digitalization and automation of the urban planning and cadastral process. By one step at a time applying the analysis tools to a number of situation case studies, this domain becomes more and more familiar, and at the same time the strengths and weaknesses of the applied tools become more evident. The rapid development of modern machine-learning techniques potentially offers a new kind of tools that for example makes it possible to derive formal descriptions of the normative systems that regulate the property formation decision-making from unstructured or semi-structured legal text and/or descriptions of real subdivision cases. A prerequisite for employing such approaches, however, is a thorough understanding of the domain, regarding both structure and logic.

An interesting question is how the two analysis tools relate to each other, i.e. how they ‘fit together’? Since they have different purposes, i.e. conceptual and structural vs. logical analysis, they can be regarded as complements to each other rather than competitors. It is natural to ask whether it would be possible (and, if so, useful) to add support in the LADM for expressing RRR’s as atomic types of legal relations, in order to allow for even more fine-grained analyses and smoother co-existence and integration of the two formalisms.

4 Discussion

The analyses in Section 3 focus on a subset of the domain and a subset of the legal positions that hold in the selected decision situation. (A more comprehensive analysis of the selected decision situation and/or decision process is beyond the scope of this paper, and thus left for future work.) This approach might seem limiting, but it should be noted that the legal positions of different parties in specific situations are rarely explicitly written down in legal text like laws or other normative systems. In the process of formulating a normative system that is internally consistent and precise, it may certainly be helpful to be able to formally express (some or all of) the legal positions that hold in a particular situation. However, Lindahl and Odelstad (2013, p. 547) argue that a set of sentences that contain individual names is not an appropriate representation of a normative system, since normative systems express general rules where no individual names occur. (Lindahl & Odelstad, 2013, p. 547) The application of a particular normative system to a particular situation usually does not require being able to map out all legal positions 'by hand'. Instead, the specific legal positions of the parties with respect to different states of affairs or events should follow from application of general regulations to the specific situation. What is needed for automated application of normative systems is therefore (i) a theory of representation of normative systems consisting of individual general norms, together with (ii) a mechanism for deducing specific legal positions of different agents by applying general norms to specific situations, (iii) a mechanism for checking the compliance of the agents' actions with these legal positions, and (iv) a computational framework for instrumentalisising these components into executable code. One example of how to deal with items (i) through (iv) is briefly discussed below.

Individual items of a normative system, i.e. what is here referred to as norms, are often formally expressed as conditional sentences of the simple form

$$P \text{ implies } N(Q),$$

where P and Q are descriptive sentences, often conditions on a number of agents, and N is a norm-creating operator. If the left part P of the implication holds, then the right part $N(Q)$ is in effect, and potentially regulates the behaviour of some agent(s). The norm-creating operator N may be a deontic operator such as Shall and May, or an operator based on atomic types of legal relations (see Sections 2.5 and 3.5) or one-agent types of normative positions (see Table A1). Odelstad and Boman (2004) employ an algebraic version of the theory of normative positions, based on the notion of a condition implication structure (*cis*). In the *cis* approach to the formal representation of normative systems (item i), a conditional norm is represented as an ordered pair $\langle p, Nq \rangle$ where p (the 'ground' of the norm) and q are descriptive conditions and Nq (the 'consequence') is a normative condition on a number of agents. Applying an individual norm $\langle p, Nq \rangle$ is done through instantiating the ground p with the parties x_i involved in the particular situation, and checking if $p(x_1, x_2, \dots, x_n)$ holds in this situation. If so, the following derivation scheme (see

Odelstad & Boman, 2004, p. 146) is used to infer a consequence in the form of a normative n -ary condition instantiated with n agents:

$$\frac{p(x_1, x_2, \dots, x_n) \quad \langle p, Nq \rangle}{Nq(x_1, x_2, \dots, x_n)}$$

The last step is to check whether the agents' actions comply with the normative consequence $Nq(x_1, x_2, \dots, x_n)$. Hjelmblom (2015) demonstrates possible mechanisms for norm instantiation and rule checking, i.e. items (ii) and (iii), instrumentalised into a computational framework (item iv).

It can be noted that norms of the more complex form

$$P_1 \text{ implies: } P_2 \text{ implies } N(Q),$$

occur frequently in law; not least in normative systems containing intermediate concepts (see Section 2.2). For example, P_1 could denote that there is a servitude attached to the property unit u_o regarding right-of-use of the well on u_n , P_2 could denote that a_s is the owner of u_o , and $N(Q)$ could denote the atomic legal relation (5) in Section 3.5.1. The consequence of P_1 is itself a conditional norm, since it is conditional on P_2 , the intermediate concept *being the owner of u_o* . Jurists often call such consequences *hypothetical legal consequences*. For a discussion of the formal treatment of norms with hypothetical consequences, see for example (Lindahl and Odelstad, 2000) and Odelstad (in press).

During its development as well as after its publication in 2012, the LADM has been the subject of numerous research activities, with topics ranging from technical implementation issues and the registration of real property to legal and organisational aspects. Liedholm Johnson et al. (2015) showed that it is relevant to use a standardized approach for obtaining an overview of, and thus comparing the multifaceted nature of, private and public interests in land. A survey (Paulsson & Paasch 2015) showed that there has been limited focus on research on legal and organisational matters, such as how to organise and manage interests in land. The rather coarse classification in the LADM today could benefit from a higher level of specialisation by adding an extended classification, as mentioned in Paasch and Paulsson (2015) and Paasch et al. (2015). Both discuss a proposed development of the LADM, an extension focusing on expanding the standard's terminology for providing a more detailed classification of land use than possible in the original standard. Figure 11 shows a possible extension of the LADM's legal right class, showing an extended classification for privately and publicly imposed rights.

An interesting line of work would be to examine the possibility (and usefulness) to extend the LADM even further with support for expressing RRR's as simple types of legal relations with regard to some state of affairs or event, for example by adding more subclasses or more developed property code-lists.

The logical analysis presented in Section 3.5 was based on Kanger's typology of atomic types of legal relations. As mentioned in Section 2.5, this typology was developed by Lindahl (1977) into three systems of types of *normative positions*. Recently, this theory has attracted attention within computer science and has been

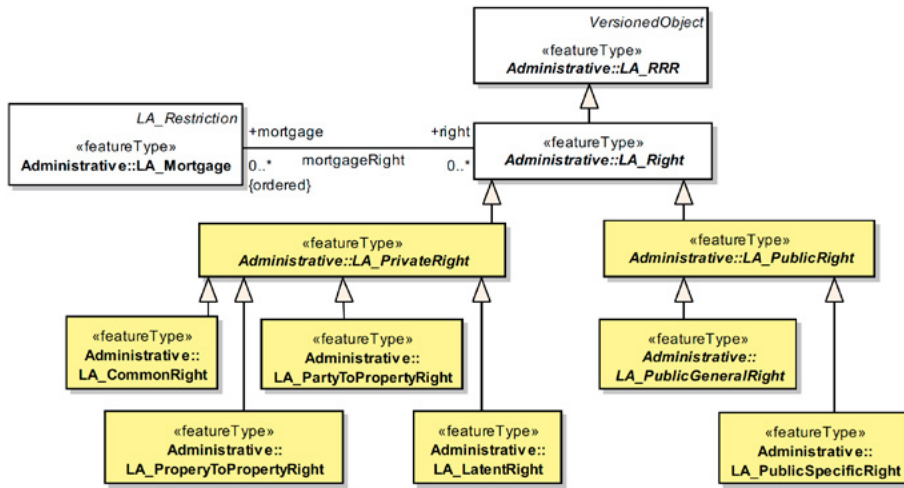


Figure 11. Specialization of the LADM's legal right profile (white) with an extended classification of privately and publicly imposed rights (yellow) (Paasch et al., 2015, p. 684).

been put to work by, e.g., Jones and Sergot, Krogh and Herrestad, and Odelstad and Boman (see for example Sergot, 2013, Krogh & Herrestad, 1999, and Odelstad & Boman, 2004). As already mentioned, the latter work is based on an algebraic version of Lindahl's system of *one-agent types of normative positions* (see Table A1). In the algebraic approach, a normative system in its simplest form is represented as a so-called Boolean joining system where conditional norms are represented by ordered pairs ('joinings') which correlate descriptive conditions with normative conditions. It is straightforward to perform the analysis in Section 3.5 in terms of one-agent types of normative positions instead of atomic legal relations, and formulate corresponding normative systems as algebraic entities. Together with the work by Hjelmblom (2015), which demonstrates how to instrumentalise this approach into executable code, this prepares the ground for automated decision-making.

When developing automated decision-making systems within such complex areas as the urban planning and building process, and in particular property formation, it is important to consider and analyse in detail both technical, legal and organizational aspects. Ongoing projects seem to mainly focus on technical, and to some extent organizational, issues (Ekbäck, 2019), which makes it even more important to consider the legal aspects. The urban planning and building process consists of many different decision processes and includes different kinds of decisions. Some of them (such as the surveyor's cadastral decision as an example, or a building permit approval by a municipality) are related to specific cases and are taken by individual officials, while others (for example establishing municipal detailed development plans or comprehensive plans) are made by local assemblies. What these decisions processes all have in common is that they are directed and constrained by a legal framework which in the Swedish setting

includes laws such as the Real Property Formation Act, the Planning and Building Act, the Joint Facilities Act, the Administrative Procedure Act, the Environmental Code, the Land Code, etc. This legal framework constitutes a normative system with which all decisions must comply, i.e. the law must always be obeyed, but the latitude given by the legislation can vary considerably. In the case of the cadastral decision discussed in this paper, the scope of action for the cadastral surveyor is very narrow: if the formal requirements for property formation are fulfilled, then the surveyor must approve the application. In other cases, for example regarding establishing local regulations or municipal development plans, the scope of action given by the legislation can be much wider, with room for making political choices (based on different preferences or ideological stances) between several options. Ekbäck (2019) discusses how digital processes could handle the many qualitative assessments that are required by law, where the variables that must be evaluated are neither quantifiable nor well defined, or may be based on normative political positions. He claims that change of property ownership and property transactions would be somewhat easier to make automated since no particular qualitative assessments are needed, but raises the question whether or not it would be possible to design the technology to handle the balance between different public and individual interests. This paper hopes to further contribute to this discourse, by suggesting that these neither quantifiable nor well-defined variables are to be understood as open intermediate concepts (see Section 2.2), and by discussing the theory of such concepts and their role in the decision-making process. Ground-open intermediate concepts are of special significance, and require special attention, since they function as ‘decision points’ in a decision process (Odelstad, 2019, pp. 106f). In the property subdivision process, for example, the cadastral surveyor must aggregate information of different sorts in order to decide on whether the factual grounds of, e.g., the previously mentioned condition *being enduringly suited to its purpose* apply in the specific case²⁰, and thus its legal consequences are in effect. This potentially includes weighing together different legal facts and balancing sometimes conflicting interests. (This approach to open intermediate concepts, analogous to that of weighing together different aspects in a multi-criteria decision problem, is outlined in Odelstad, 2002, ch. 12-3.)

Thus far, the paper has discussed one potential approach to the logical analysis and automated application of normative systems within the land administration domain, based on the algebraic approach to norms by Lindahl and Odelstad (2013) and its instrumentalisation by Odelstad and Boman (2004) and Hjelmblom (2015). Naturally, there are other interesting approaches to the formal representation and instrumentalisation of normative systems, such as Input/output logic (see the overview by Parent & van der Torre, 2013). Two recent examples within the land administration domain are the work by Lee et al. (2016) and Malsane et al. (2015) on formalising and digitalising building requirements and regulations. However, a particularly interesting feature of the work by Lindahl and Odelstad

²⁰ I.e., that there are no legal impediments to forming the new property, as regards its suitability.

is that it is an application of their so-called Theory of Joining Systems (TJS). Since one of the aims of the development of this theory was “to provide tools for a rational reconstruction of a legal system with intermediaries” (Lindahl & Odelstad, 2013, p. 625), TJS and its application to normative systems containing intermediate concepts has the potential to be a useful part of the framework for digitalization and automation of the urban planning and building process.²¹ Further development of the theory includes developing an algebraic version of the system of n -agent types of normative positions (Lindahl, 1977), to potentially address some of the limitations (briefly discussed in Section 3.6) of the simple one-agent system, and investigating the formal treatment of norms with hypothetical legal consequences. Further work (including computational logic considerations) on the instrumentalisation of the theory into executable logic programs is also of interest.

This paper has presented a simple case on property formation and a starting point for how an automated decision process could be achieved. However, when adding more complexity, as often is the case in real life situations, and including the assessments made by various authorities in several steps, additional considerations would have to be made. The required information and documentation as a basis for the assessment and decision-making has to be more standardized. In many cases, a combination of automation and manual assessments of more qualitative aspects might be necessary, at least during the initial phases before further development of the automated system. For example, formal analyses as performed here, together with analyses of relevant normative systems regarding the occurrence of open intermediate concepts, may lay part of the groundwork for semi-automated decision-making where a computer identifies decision points and presents a complex decision situation (and possibly suggest or recommend a particular decision) to a human decision maker, who then makes the necessary judgments and trade-offs. This, in turn, is an important step towards further automation of complex decisions.

5 Conclusion

This paper uses two different analysis instruments to perform structural and logical analyses of two specific snapshots of a fictitious property subdivision case in Sweden, focusing on the legal relations between different entities and parties involved in the specific situations. The structural analysis used the LADM ISO standard formalism, and the logical analysis was based on Kanger’s atomic types of legal relations. By (i) combining two perspectives on formalisation and classification of legal relations within the urban planning and building domain, (ii) discussing some of the strengths and weaknesses of the two tools regarding the formal representation of RRRs of different parties in this domain, and (iii) discussing how the tools can be aligned, the paper has presented one way to analyse

²¹ Lindahl and Odelstad (2013, p. 546) argue that “[a] theory of representation for normative systems will be incomplete unless attention is paid to the role of *intermediate concepts* within the system (for example, the role of legal concepts such as ownership)”.

and describe the land administration domain at a higher level of abstraction and formalization using different analysis tools.

Furthermore, the paper has provided suggestions of future research in several directions, including to model the general subdivision process by mapping out the (kinds of) different parties involved in or affected by the process and analysing what kind of decisions emerge where in the process. Another direction is to analyse further the normative systems (such as Swedish laws, regulations and municipal development plans) that regulate the process and how they form networks or strata of intermediate concepts.

Similar analyses of a wider range of subdivision process snapshots as well as analyses of other property formation processes are one suggested future research path. The paper has highlighted the need for more basic research on the theoretical tools themselves, such as to explore possible extensions of the LADM standard, and to further develop the Theory of Joining Systems (TJS) and put it to work within the land administration domain. Another suggestion for further work is the instrumentalisation of TJS into executable prototypes, and investigation of the possibility to use machine-learning approaches within the theoretical and conceptual framework developed here. This paper has taken one step towards a deeper understanding of the domain, and outlined some of the work needed to proceed even further, in the hope of providing better conditions for more efficient and transparent use of geospatial information, and increased automation of the property subdivision process and other related civil processes.

Acknowledgements. This research was financed by J. Gust. Richert stiftelse (The J. Gust. Richert Foundation). Project name: Efficient and transparent decision making in urban planning. Project-id: 2018-00456. The authors are indebted to Prof. Peter Ekbäck at KTH Royal Institute of Technology, and Prof. Jan Odelstad at the University of Gävle, as well as to the anonymous reviewers, for valuable comments and suggestions improving this paper.

References

AL (1973). Joint Facilities Act [in Swedish: Anläggningslag, AL]. SFS 1973:1149. With later amendments.

Bergström, S. (1956). Om begreppet äganderätt i fastighetsrätten (in Swedish). *Svensk Juristtidning* (in Swedish), 1956, 145–162. Reprinted in Ekbäck, P., Kalbro, T. & Mattsson, H. *Fastighetsteknik* (in Swedish), 2005, (pp. 49–63). Stockholm, Sweden: KTH Royal Institute of Technology.

Boverket (2019) Får jag lov? (in Swedish) Available at: <https://www.boverket.se/sv/byggande/uppdrag/far-jag-lov/> Accessed 23 January 2019.

Ekbäck, P. (2009). Private, Common, and Open Access Property Rights in Land – An Investigation of Economic Principles and Legislation. *Nordic Journal of Surveying and Real Estate Research*, 6(2), 57–74.

Ekbäck, P. (2019). Mot en digitaliserad samhällsbyggnadsprocess – Analys av rättsliga strukturer vid förändring av fastighetsindelning, äganderätt (markägare) och markanvändning (in Swedish). TRITA-ABE-RPT-1839. Stockholm, Sweden: KTH Royal Institute of Technology.

- FBL (1970). Real Property Formation Act [in Swedish: Fastighetsbildningslag, FBL]. SFS 1970:988. With later amendments.
- FL (2017). Administrative Procedure Act [in Swedish: Förvaltningslag, FL]. SFS 2017:900. With later amendments.
- Garner, B. (Ed.). (1891). *Black's Law Dictionary*. (Abridged Eighth Edition 2004). USA:Thomson/West.
- Gifis, S. H. (1984). *Law Dictionary*. USA: Barron's.
- Hjelmlom, M. (2015). Norm-Regulation of Agent Systems: Instrumentalizing an algebraic approach to agent system norms. Doctoral thesis. Department of Computer and Systems Sciences, Stockholm University.
- Hohfeld, W. N. (1913). Fundamental Legal Conceptions as Applied in Judicial Reasoning. (Note: part 1). *Yale Law Journal* XXIII, 1913, 16–59. Republished in Cook, W. (Ed.), *Fundamental Legal Conceptions as Applied in Judicial Reasoning*. 1964, (pp. 23–64). New Haven, USA and London, England. Yale University Press. <https://doi.org/10.2307/785533>
- Hohfeld, W. N. (1917). Fundamental Legal Conceptions as Applied in Judicial Reasoning. (Note: part 2). *Yale Law Journal* XXVI, 1917, 710–770. Republished in Cook, W. (Ed.) *Fundamental Legal Conceptions as Applied in Judicial Reasoning*. 1964, (pp. 65–114). New Haven, USA and London, England. Yale University Press. <https://doi.org/10.2307/786270>
- Honoré, T. (1987). *Making Law Bind*. Reprinted 2002. England: Oxford University Press.
- ISO (2007). ISO 19132:2007. Geographic Information – Location-based services – Reference model. Geneva, Switzerland: International Organization for Standardization.
- ISO (2012). ISO 19152:2012. Geographic Information – Land Administration Domain Model, LADM. Geneva, Switzerland: International Organization for Standardization.
- JB (1970). Land Code [in Swedish: Jordabalk, JB]. SFS 1970:994. With later amendments.
- Krogh, C., & Herrestad, H. (1999). Hohfeld in cyberspace and other applications of normative reasoning in agent technology. *Artificial Intelligence and Law*, 7(1), 81–96. <https://doi.org/10.1023/A:1008367514393>
- Lantmäteriet (2019) Private exchange. 9 January 2019.
- Larsson, G. (2010). *Land Management as Public Policy*. University Press of America.
- Lee, H., Lee, J.-K., Park, S., & Kim, I. (2016). Translating building legislation into a computer-executable format for evaluating building permit requirements. *Automation in Construction*, 71, 49–61. <https://doi.org/10.1016/j.autcon.2016.04.008>
- Libecap, G. (1989). *Contracting for Property Rights*. Cambridge: Cambridge University Press 1993. <https://doi.org/10.1017/CBO9780511664120>
- Liedholm Johnson, E., Paulsson, J. and Paasch, J.M. (2014). Classification and co-ordination of conflicting rights for sustainable land use. *Nordic Journal of Surveying and Real Estate Research* (Vol. 10, issue 2, 2014, pp. 61–81).
- Liedholm Johnson, E., Paulsson, J. and Paasch, J.M. (2015). Comparative Studies on Land Use Rights – Methodological and Standardization Aspects. *Journal of Comparative Law* (Vol. 10, issue 1, 2015, pp. 1–26).

- Lindahl, L. (1977). Position and change: a study in law and logic. Synthese Library, Vol. 112. Dordrecht, Holland: D. Reidel Publishing Company. <https://doi.org/10.1007/978-94-010-1202-7>
- Lindahl, L. (1985). Definitioner, begreppsanalys och mellanbegrepp i juridiken (in Swedish). In Rationalitet och Empiri i Rättsvetenskapen. Juridiska Fakultetens i Stockholm skriftserie, nr 6. Stockholm: Juridiska Fakulteten.
- Lindahl, L. (2006). Hohfeld relations and spielraum for action. *Analisis Filosófico*, 26(2), 325–355.
- Lindahl, L., & Odelstad, J. (2000). An Algebraic Analysis of Normative Systems. *Ratio Juris*, 13(3), 261–278. <https://doi.org/10.1111/1467-9337.00155>
- Lindahl, L., & Odelstad, J. (2013). The Theory of Joining-Systems. In D. Gabbay, J. Horthy, X. Parent, R. van der Meyden, & L. van der Torre (Eds.), *Handbook of Deontic Logic and Normative Systems* (Vol. 1, pp. 545–634). London: College Publications.
- Malsane, S., Matthews, J., Lockley, S., Love, P.E.D., & Greenwood, D. (2015). Development of an object model for automated compliance checking. *Automation in Construction*, 49, 51–58. <https://doi.org/10.1016/j.autcon.2014.10.004>
- Odelstad, J. (2002). Intresseavvägning. En beslutsfilosofisk analys med tillämpning på planering. (in Swedish) Stockholm: Thales.
- Odelstad, J. (2017). Om beslutsteoretiska verktyg vid tillståndsprovning av vindkraft (Technical report, in Swedish). Gävle: Gävle University Press.
- Odelstad, J. (2019). Joining conceptual systems – three remarks on TJS. *Filosofiska Notiser*, (1), 77–131.
- Odelstad, J., & Boman, M. (2004). Algebras for Agent Norm-Regulation. *Annals of Mathematics and Artificial Intelligence*, 42(1), 141–166. <https://doi.org/10.1023/B:AMAI.0000034525.49481.4a>
- Olsson, P., Axelsson, J., Hooper, M., & Harrie, L. (2018). Automation of building permission by integration of BIM and geospatial data, *ISPRS Int. Journal of Geo-Information*, 7, 307. <https://doi.org/10.3390/ijgi7080307>
- Paasch, J. M. (2012). Standardization of Real Property Rights and Public Regulations. Doctoral thesis. KTH Royal Institute of Technology, Stockholm, Sweden.
- Paasch, J. M., van Oosterom, P., Lemmen, C. and Paulsson, J. (2015). Further Modelling of LADM's Rights, Restrictions and Responsibilities (RRRs). *Land Use Policy* (Vol. 49, pp. 680–689). <https://doi.org/10.1016/j.landusepol.2014.12.013>
- Paasch, J.M. and Paulsson, J. (2015). Classification of Land Use: Further development of the ISO Standard for Land Administration, ISO 19152. In *Homo Oeconomicus* (Vol. 32, no. 1, pp. 53–75). Accedo Verlagsgesellschaft, Munich, Germany.
- Parent, X., & van der Torre, L. (2013). Input/output Logic. In D. Gabbay, J. Horthy, X. Parent, R. van der Meyden, & L. van der Torre (Eds.), *Handbook of Deontic Logic and Normative Systems* (Vol. 1, pp. 499–544). London: College Publications.
- Paulsson, J. and Paasch, J.M. (2015). Land Administration Domain Model – A literature survey. *Land Use Policy* (Vol. 49, pp. 546–551). <https://doi.org/10.1016/j.landusepol.2015.08.008>

Sergot, M. (2001). A Computational Theory of Normative Positions. *ACM Transactions on Computational Logic*, 2(4), 581–622. <https://doi.org/10.1145/383779.383786>

Sergot, M. (2013). Normative Positions. In D. Gabbay, J. Horthy, X. Parent, R. van der Meyden, & L. van der Torre (Eds.), *Handbook of Deontic Logic and Normative Systems* (Vol. 1, pp. 353–406). London: College Publications.

Smart Built Environment (2019) Smart planering för byggande (in Swedish). Available at: <https://www.smartbuilt.se/projekt/standardisering/informationsfoersoerjning/smart-planering/> Accessed 24 January 2019.

Snare, F. (1972). The Concept of Property. *American Philosophical Quarterly*, 9(2), 200–206. Reprinted in P. Ekläck, T. Kalbro, & H. Mattsson, (Eds.), *Fastighetsteknik – En antologi om markanknutna rättigheter* (in Swedish). 2005, (pp. 23–33). Stockholm, Sweden: KTH Royal Institute of Technology.

Umbeck, J. (1981). *A Theory of Property Rights*. The Iowa State University Press.

UN (2015). *Transforming our world: the 2030 Agenda for Sustainable Development*. United Nations resolution A/RES/70/1. United Nations.

Vaskovich, M. (2012). *Real Property Processes: An explorative study of property institutions in Belarus*. Doctoral thesis. KTH Royal Institute of Technology, Stockholm, Sweden.

Appendix 1

Table A1. Lindahl's set of one-agent types of normative positions.
(Standard logical connectives are used for conjunction and negation.)

\mathbf{T}_1	$\text{May Do}(x,F) \wedge \text{May}[\neg\text{Do}(x,F) \wedge \neg\text{Do}(x,\neg F)] \wedge \text{May Do}(x,\neg F)$
\mathbf{T}_2	$\text{May Do}(x,F) \wedge \text{May}[\neg\text{Do}(x,F) \wedge \neg\text{Do}(x,\neg F)] \wedge \neg\text{May Do}(x,\neg F)$
\mathbf{T}_3	$\text{May Do}(x,F) \wedge \neg\text{May}[\neg\text{Do}(x,F) \wedge \neg\text{Do}(x,\neg F)] \wedge \text{May Do}(x,\neg F)$
\mathbf{T}_4	$\neg\text{May Do}(x,F) \wedge \text{May}[\neg\text{Do}(x,F) \wedge \neg\text{Do}(x,\neg F)] \wedge \text{May Do}(x,\neg F)$
\mathbf{T}_5	$\text{May Do}(x,F) \wedge \neg\text{May}[\neg\text{Do}(x,F) \wedge \neg\text{Do}(x,\neg F)] \wedge \neg\text{May Do}(x,\neg F)$
\mathbf{T}_6	$\neg\text{May Do}(x,F) \wedge \text{May}[\neg\text{Do}(x,F) \wedge \neg\text{Do}(x,\neg F)] \wedge \neg\text{May Do}(x,\neg F)$
\mathbf{T}_7	$\neg\text{May Do}(x,F) \wedge \neg\text{May}[\neg\text{Do}(x,F) \wedge \neg\text{Do}(x,\neg F)] \wedge \text{May Do}(x,\neg F)$