Network Based Strategic Automation

A methodology to guide and facilitate collaboration

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A METHODOLOGY TO GUIDE AND FACILITATE COLLABORATION IN

NETWORK BASED STRATEGIC AUTOMATION

BY
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Network Based Strategic Automation

By Mohammad Shahabeddini Parizi

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SUMMARY

Increasing global competition and higher demand for customization and needed flexibility in manufacturing, force manufacturing companies into rapid changes in production processes by considering implementation of flexible manufacturing systems, automation solutions, and digitalization.

Implementation of the automation concepts in manufacturing Small and Medium sized Enterprises (SMEs), compared to enterprise manufacturers, requires significantly more effort due to their limited resources such as limited know-how of automation and digitalization, lacking access to proven and well-matched solutions, and lacking a structured process for automation training and assessments of the necessary competencies in the manufacturing line. That is why active collaboration through networks has received more attention by companies, where they complement their own resources with resources and competencies available in the network. However, many aspects of inter-organizational collaboration have not yet explored. Therefore, this research aims at filling this gap by providing a study to review and improve the way companies work together in automation and digitalization projects.

This study focuses on buyer-supplier collaboration between manufacturing SMEs and other stakeholders and aiming at facilitating collaboration in automation and digitalization decisions. The empirical work is based on qualitative research combined with literature study and action research elements. The cases for the study were selected among Danish firms.

Based on a behavioural analysis of buyer and suppliers at different collaboration stages, this research maps the development of buyer-supplier collaboration in automation and digitalization decisions. Following the De Bruin et al. (2005) development framework, the design principles of the automation business assessment model were identified and used as bases for the development of the Inhancer circular process model. This model provides a modular structure to facilitate integration in buyer-supplier collaboration in automation practices. Furthermore, this study focused

on the implementation and validation of a digitalized platform based on the developed model.

This research both contributes to academic and practice. On the academic side, it offers three types of conceptual contributions: 1. Extend complex buyer-supplier collaboration literature by the circular automation business assessment process model, 2. Broadens the current knowledge-based view by identifying the process domains of business assessment process model at inter-organizational level, and 3. Address the gap between literature and industrial practices within the context of this research and based on the selected case studies, yet, further studies could assess the external validity of our model by testing it in different industry settings and regions. On the practical side, this study helps to understand the drivers of inter-organizational collaboration by suggesting insights into the behaviour parameters and influential aspects in buyer-supplier collaboration development such as Knowledge Transfer among collaborators, Trust, and commitment, Communication and pattern of interaction. Furthermore, the results of this research contribute to the business success of stockholders.

DANSK RESUME

Stigende global konkurrence, større behov for kundespecifikke tilpasninger og fleksibilitet i produktionen kræver hurtige ændringer af virksomhedernes produktionsprocesser gennem investeringer i fleksible produktionssystemer, automatisering og digitalisering.

Implementering af automatiseringskoncepter i små og mellemstore virksomheder (SMV) sammenlignet med store virksomheder, kræver relativ større indsats som følge af deres begrænsede ressourcer, begrænset praktisk erfaring med automatisering og digitalisering, manglende adgang til etablerede og veltilpassede løsninger, samt mangel på en struktureret proces for træning og vurdering af de nødvendige kompetencer på produktionslinjen. Af den grund får samarbejde gennem netværk større opmærksomhed fra virksomheder, som kan komplementere deres egne ressourcer med kompetencer og ressourcer som er til rådighed i netværket. Imidlertid er der mange aspekter af det inter-organisatoriske samarbejde, som endnu ikke er blevet undersøgt. Af den grund vil dette arbejde sigte mod at udfylde det tomrum ved at undersøge og forbedre den måde virksomheder arbejder sammen i automatiserings- og digitaliseringsprojekter.

Dette studie fokuserer på indkøber-leverandør-samarbejdet mellem produktions SMV'er og andre aktører og sigter efter at facilitere samarbejdet omkring investeringer i automatiseringsløsninger. Det empiriske arbejde er baseret på kvalitativ undersøgelse kombineret med litteraturstudier og egentlige forskningselementer. De forskellige eksempler er udvalgt blandt danske virksomheder. Baseret på adfærdsanalyse af indkøbere og leverandører i forskellige faser af samarbejdet, perspektiverer dette arbejde indkøber-leverandørsamarbejdet omkring investeringer i automatiseringsløsninger. Efter udviklingsrammen, blev de retningsgivende principper for automatiseringsinvesteringer identificeret og brugt til at udvikle den cirkulære proces-model kaldet Inhancer. Denne model giver en modulær struktur til at facilitere integrationen i indkøber-leverandør samarbejdet i automatiseringsløsninger. Endvidere fokuserer dette studie på implementeringen og valideringen af en digital platform baseret på den udviklede model.

Dette arbejde har både akademiske og praktiske bidrag. På den akademiske side, tilbyder det tre konceptuelle bidrag: 1. Udvide den komplekse indkøber-leverandør litteratur gennem den cirkulære procesmodel for automatiseringsbranchen. 2. Udvide det nuværende vidensbaserede udsyn ved at identificere procesdomænet for forretningsmodeller på organisationsniveau. 3. Adressere gabet mellem litteratur og industriel praksis inden for rammerne af denne forskning og baseret på de valgte casestudier. På den praktiske side, hjælpe dette studie med at forstår mekanismerne for organisationers samarbejde ved at foreslå indsigt i adfærdsparametre og påvirkningsmekanismer i udviklingen af indkøber-leverandør samarbejdet, herunder vidensoverførsel mellem parterne gennem tillid, forpligtigelse, kommunikation og samarbejdsmønstre. Endvidere bidrager dette arbejde til den forretningsmæssige succes for ejerkredsen.

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NOMENCLATURE

DBE	Digital Business Ecosystem
NPD	New Product Development
SAFIR	Strategic Automation of Factories driven by Robotics
SME	Small and Medium Sized Enterprises

Chapter 1.

Introduction

1. INTRODUCTION

In this Chapter, the objectives of this Ph.D. project and the related research questions are presented. The research objectives and questions were presented during the EUROMA 2016, in Trondheim, Norway, on June 2016, and while preparation of the 11-month study plan, required by the Doctoral School of Aalborg University in July 2016. The comments received during the internal discussion at Blue Ocean Robotics ApS on the research scope, let to better clarify the problem to be addressed and the research goal. More after, the feedback received during the paper presentation in WOIC2016 in Barcelona, Spain, as well as discussions and reviews during the preparation of the 24-month Ph.D. project portfolio allowed the researcher to better define the research topic and advanced the objectives. Emerging approaches during the project execution along with the on-going outcome were then discussed and reviewed in international conferences, summer schools, and doctoral program presentations, collaborative projects with international academic and industry partners (EU-Projects) and the comments received during meetings with the university and company supervisors allowed the researcher to identify the research objectives and questions which are presented in this chapter as well as the overall outcome of this Ph.D. project.

1.1. RESEARCH GAP AND MOTIVATION

INTER-ORGANIZATIONAL COLLABORATION AND COORDINATION

Automation and digitalization in manufacturing is enabling technologies to enlighten the next generation of manufacturing systems. Yet, the understanding and implementation, particularly in manufacturing SMEs, is not so extensive. Increasing complexity, extended functionality and less standardized technologies generates uncertainty about organizational capabilities, new technology potentialities as well as adequate strategies. Organizations relate their activities and strategic direction to those of other firms in order to increase the business performance (Gadde et al. 2003) and cope with technology complexity. Therefore, automation and digitalization in manufacturing increase the expectation for a prevalence of inter-organizational collaboration and coordination.

It is observed that many debates are going on in the academic word on the topic of inter-organizational collaboration from different disciplines. Studies on inter-organizational collaboration and network model of business trace back to research at the Swedish University of Uppsala in the mid-1970s, where Håkansson & Snehota (1989) argued that organizations do not operate in isolation, but in complex webs of interactions with other actors and organizations, including suppliers, competitors, and customers. Industrial network approach may have important implications for the design of organizational strategies. Gadde et al. (2003) argue that it is crucial for an organization to relate its activities and strategic direction to those of other firms in order to increase the business performance. This is through the continuous combining and recombining of existing resources that new resource dimensions are identified and further developed beyond traditional firm boundaries where links actors together.

Coordination as a crucial aspect of collaboration has been considered in the literature of supply chain, to ensure that industrial collaboration efforts is both efficient and responsive to dynamic market needs.

Coordination is defined as, "the joint efforts of independent communicating actors towards mutually defined goals" (NSF 1899)

Inter-organizational collaboration constitutes of division of partners and assignment of partners with certain competencies and interests to tasks. This forms a division of partners notion of specialization. An increase of complex tasks and specialization, particularly investment in new technologies, make the question of how coordination occurs between firms with teams of diverse supplier experts. In addition, as the result of increased problem scale and scope, the industrial collaboration and coordination opportunities introduce new challenges and complexities and potentially conflicting incentives among different supply chain player (Balakrishnan & Geunes 2004). In this line, coordination mechanisms are described as administrative tools for facilitating coordination and integration among different functions within an enterprise (Crowston 1997).

Twigg (2002; 1995; 1996) with a focus on inter-organization product development, proposed a typology of inter-firm mechanism which firms are using to integrate design and manufacturing operations in product development. In this model they recommended coordination mechanisms to be classified by the four modes of interdepartmental interaction consisting of standards, schedules, mutual adaptation, and teams versus the three phases of pre-project, product and process design, and manufacturing. In their model, coordination by mutual adjustment including supplier development committee and gatekeeper, or coordination by teams comprised of a supplier development team and joint development is highly recommended in pre-project phase. During the design phase, he suggested that the coordination by mutual adjustment composed of producibility design reviews, producibility or manufacturing engineer, and guest engineer, or coordination by teams such as joint product/process design team. Having the importance role of supplier development teams, he argued that supplier development teams are built by customer organizations is to increase supplier competence to an acceptable level and to drive suppliers to maintain satisfactory performance (Twigg 2002). From the perspective of coordination work activity, Van de Ven et al. (1976) identified three modes of coordinating activities and classified them as impersonal activities consisting of plans and rules; personal activities composed of vertical supervision, and group activities comprised of formal and informal meetings. They argued that the chosen of the coordination mechanisms depends on situational factors, such as interdependency. In this line, Mintzberg (1979) proposed a classification of coordination mechanism and divided them into mutual adjustment, direct supervision, as well as standardization in terms of work processes, outputs, norms, and skills.

From the innovation perspective, suppliers are facing the challenge of clearly understanding the ambition, the goal and their task in the innovative projects, while in the customer organization the coordination challenge is mainly focused on how to identify and clearly describe the problem and how to get to a solution. Complexity and expertise diversity make coordination highly required and more precarious. Complexity of tasks often indicate novelty that undermines analysis and foresight. Diverse perspectives from collaborators brings different ideas on how to accomplish tasks (Bruns 2013). Researchers such as Bruns (2013) with focus on coordination practices within cross-domain collaboration suggested process model of coordination as to drive collaboration across domains. She explains how diversely specialized experts coordinate their work when working apart from each other and on how these efforts complete the overall process of coordination. With her suggested iterative mode of working, she suggested two critical barriers in collective work: domain differences and temporal differences. Sharing collaborative and coordination practices through the process model of joint assessment, consultation, counter projection, and alignment allowed for go beyond these differences.

The introversion role and the decision power of coordinator, while match different partners and suppliers in an inter-organizational collaboration, may be changed according to innovation complexity and information-related conditions. These conditions may well vary predictably over innovation life cycles (Von Hippel 2005). Utterback & Abernathy (1975) proposed that in the early stages of innovation cycles the process is fluid, where the relationship between process elements and partners is loose and unsettled. The system is organic and responds easily to environmental change, but necessarily has "slack" and is "inefficient". In this stage, the complexity raises, and the problem needs to be solved in collaboration of expertise diversify of suppliers. The coordination focuses around the key integration and the decision power will be centred within the coordinator, while the customer organization play a big part in sorting the matter out, in part through innovation (Utterback & Abernathy 1975; Von Hippel 2005).

Later, a dominant design will emerge with a shared understanding of exactly what a particular solution is, what features and components it should include, and how it should function (Von Hippel 2005). Therefore, innovation will shift from product to process as firms shift from the problem of how to solve the issue and what to produce to the problem of how solve the issue in an optimum way and to produce a well-understood product in ever greater volumes. From the innovation perspective and user of innovation, both functionally novel products and functionally novel processes are likely to be led by the user organization (Von Hippel 2005). In this situation, the coordination may canter around mediators, where the coordinator has the role of allowing partners and suppliers to find each other. The decision power in mainly remained within the parties with help of the coordinator as a third party.

Within the literature of industrial automation, the role of coordinator can be taken by the lead integrator. The lead integrator role has been described as a lead partner and the automation solution suppliers that perform planning, defining and implementing of an automation roadmap which often looking forward as much as five years (Gurney 2014). In addition, their collaboration is formed on a project-to-project basis.

The role of information and associated digital technologies introduced in facilitating and enabling supply chain integration (Poundarikapuram & Veeramani 2004).

Holzmüller & Schlüchter (2002) investigated the inter-organizational collaboration from the internet-based business-to-business collaboration approach, as Electronic Marketplaces (EMs). They define it as an "open electronic platforms facilitating activities related to transactions and interactions between multiple companies" (Holzmüller & Schlüchter 2002). Ganesh et al. (2004) studied the adaptive strategies and paths of adaptation of independent inter-organizational marketplaces for business collaboration. They argue the independent inter-organizational business collaboration have undergone tremendous change based on organizations business models and products/services. Internet-based business-to-business collaboration evolved from pure competitive markets that support buyer/seller aggregation, to a wider perspective, including supporting transactions, integration and collaboration among organization with existing business relationships and supply chain management to support different purchasing strategies (Grieger et al. 2003; Skjøtt-Larsen et al. 2003; Bartezzaghi & Ronchi 2004; Eng 2004; Wang & Archer 2004).

Thus, a prevalence of inter-organizational collaboration and coordination in applying new technologies may be expected. As such studying the recent practices of working with suppliers, particularly automation and robotic providers is highly interesting and relevant for the wider business environment. However, coordination mechanisms and inter-organizational collaboration have been considered extensively in literature, yet implementation of coordination mechanisms and modes of collaboration, particularly within the field of automation and digitalization is an ongoing issue. To this end and considering the role of lead integrator which, to our knowledge, have not yet been investigated in the literature, the research is focused on the phenomenon: What are the collaboration mechanisms in automation decision? How they form, in what they differ from other buyer-supplier relationship mechanisms? What is the role of lead integrator and what are the characteristics and requirements to facilitate the collaborations for more efficient strategic automation decisions?

Digitalization and digital tools have recently been introduced and adopted to the multidisciplinary organization, socio-technical networks and organizational infrastructures. Introduction of digitally mediated design, production and collaboration, facilitated a profound deviation from the traditional ways of communication, representations, knowledge sharing, organizational forms and standards (Kocaturk & Codinhoto 2009). The increasing use of digital tools and digital prototyping technologies are already enabling fundamentally new aspects of designing and coordination among the actors in design and production. Therefore, the digitalization development has the capability to enable coordination mechanisms in inter-organization collaboration. To this end, the research is also focused on the phenomenon: how a “digital platform” can be utilized to facilitate the collaborations and coordination for more efficient strategic automation decisions?

WHY/HOW AUTOMATION AND DIGITALIZATION IN MANUFACTURING SMEs?

Automation and digitalization in manufacturing have been known as enabling technologies that will enlighten the next generation of manufacturing systems, however, their understanding and implementation is not so extensive. Increasing complexity on firm levels and emerging technologies generates uncertainty about organizational capabilities and new technology potentialities as well as adequate strategies. What is automation and digitalization to SMEs? What makes manufacturing companies to adopt them? In other words, what are the main benefits of automation and digitalization in manufacturing SMEs when implemented, and what are the challenges in the automation and digitalization decisions process? The first objective of this research project has been raised from these reflections.

AUTOMATION AND DIGITALIZATION ROADMAP

In addition to understanding the new potentials from automation and digitalization for manufacturing SMEs; it is crucial for manufacturing SMEs to be aware of their current situation or state-of-development about automation and digitalization vision and therefore to identify concrete automation roadmap, fields of action, programs and projects. Benefits from the automation and digitalization adoption may differ depending on the manufacturing systems and processes they have an impact on, their strategical relevance, previous experiences and maturity level toward automation capabilities. Companies, considering their previous automation experiences and different level of digitalization maturity may expect to receive different benefits from the automation adoption, therefore, will need to prioritize investment in different digitalization projects. Automation and digitalization solutions are more complex compare to -advanced- manufacturing machineries, because they are typically less standardized and the level of contradictions while balancing flexibility is higher (Wiktorsson et al. 2016). This leads to the uncertainties companies are facing in regards to the financial effort required for the acquisition of such new automation technologies and the overall impact on their business model (Schumacher et al. 2016). Therefore, the challenge is firstly to create a base for the manufacturing company to create a clarity of the possible technical and business value generated by the implementation of automation and digitalization technologies. Then to assist manufacturing companies to evaluate the overall impact on automation decisions on their business model and define their automation strategy roadmap. Another objective of the research project has been raised related to this consideration.

CHALLENGES FROM AUTOMATION SUPPLIERS

Seen from the viewpoint of the manufacturing SMEs the overall automation and digitalization opportunities characterized by being implemented and supplied by increasingly specialized suppliers. This development imposes a critical ability to collaborate with a network of specialized suppliers in comparison with a few general contractors that could cover all needed aspects. In order to cope with these increases in complexity, new methods and approaches are needed. Such approaches are not yet in operation; therefore, the consequences are decreasing efficiency in the implementation process which leads to limiting the competitiveness of the manufacturing SMEs and automation suppliers. In the automation supply chain, in addition to manufacturing SMEs, technology and automation solution suppliers are facing challenges that are derived from the above mentioned. Most of the automation suppliers which can be categorized as SMEs, are facing increasing complexity in terms of problems in mapping the exact needs of the automation buyers. The buyers in most cases are not able to express precisely their needs and much less able to see the potentials in the new technical automation opportunities that are offered from an increasing number of more specialized suppliers.

The overall problem is therefore twofold but highly interconnected. The automation buyers and the automation suppliers both face urgent challenges in specifying solutions. These challenges are highly interconnected where both perspectives lead to a general decrease in competitiveness for manufacturing SMEs within the automation providing industry and the automation utilizing the industry.

The faster pace in technology development is making the sales process seen from the automation suppliers more complex. Automation suppliers need a higher number of high-quality leads in their pipeline: High numbers of orders create a high degree of sales uncertainty. Internationalization and the increase of sales bring more submitted orders for industrial robots for automation. Yet, the sales acquisition of such sales projects is affected by competitive actions and certain conditions so that project orders can only be successful with specific probabilities. The sales acquisition can be extended over several phases, from the initial submission of an order to the final closing of the sale. As a potential project moves through different phases, the probability of success sales increases because the unknown and uncertainties of the project are driven down with each stage and step. Both, the supplier company and the potential customer gain more understanding of the project and its requirements while the sales process proceeds. But this is a costly action for the company as it needs to spend a lot of time communicating and understanding the projects, even if the probability for a potential sale is low. In addition, this takes up time that could be spent on actual development activities. This dilemma shows the need for a system that manages the risks and removes those projects with a lower degree of probability through the sales acquisition process in an early stage. There is a need to address these challenges by assisting automation suppliers to coordinate knowledge about the automation solution between partners and communicate it to buyers, to reduce the touch time, facilitate project documentation, avoid missing information of projects and decisions, geographical market expansion and avoid unnecessary travels. It is from these requirements that the other objective of this thesis arise.

1.2. RESEARCH OBJECTIVES

An important element of this Ph.D. thesis is to review and improve the way companies work together in automation and digitalization projects. Aggressive global competition and higher demand for customization force manufacturing companies into rapid changes in production processes by considering decisions in flexible manufacturing systems, automation solutions, and digitalization. To benefit from available accumulative resources in networks and to be able to allocate sufficient resources for innovation (Håkansson & Snehota 1989), organizations, particularly manufacturing SMEs often collaborate much more actively through networks. The complexity of automation innovation, information-related conditions as well as expertise diversity of automation suppliers (Bruns 2013) highly challenge the industrial collaboration efforts to be efficient and responsive to dynamic market needs. It has been observed that automation suppliers are failing to engage in a properly organized mechanism during different stages (Ford 1980) of buyer-seller collaboration. This thesis is aiming at studying the recent practices of working with suppliers with a focus on collaboration mechanisms and tools for facilitating coordination and integration in inter-organizational collaboration, within the field of innovation projects in automation and digitalization. Therefore, the overall objectives of this research project are:

- To investigate the collaboration mechanisms of manufacturing SMEs and automation suppliers and robotics experts with focus on the role of "lead integrator". In particular, this study is aiming at advancing the collaboration mechanisms in innovation projects in automation practices to describe: how they are formed, what are their characteristics, challenges and benefits, and to identify processes and factors that can facilitate the current collaboration processes during three phases (Twigg 2002) of innovation projects and buyer-supplier collaboration stages (Ford 1980).
- To advances a process model of coordination that facilitate and drive inter-organizational collaboration in automation practices. To identify and describe the role of lead integrator in the process model.
- To implement and validate a digitalized platform based on the developed process model.

1.3. RESEARCH QUESTIONS AND STATEMENTS

Considering the research objectives have been described, this Ph.D. thesis has the purpose to deepen our understanding and improve collaboration mechanisms during buyer-supplier collaboration stages (Ford 1980), how a process model as a dynamic business assessment model (Tidd et al. 2005) is applicable to facilitate coordination and drive inter-organizational collaboration in automation practices, and whether this model contributes to enhanced business success. Therefore, the following questions are answered in this study:

THE FIRST RESEARCH QUESTION

To understand the mechanisms and processes of buyer-supplier collaboration in automation practices, it is important to start providing a definition of these mechanisms, explore how these collaborations formed and developed, the benefits and challenges they bring to the manufacturing industry and actors when developed. Considering the above-presented statements, it is important to state a Research

Question which directly addresses the Research Objectives. The first Main Research Question is:

What are the collaboration mechanisms in automation and digitalization decisions in manufacturing SMEs?

The question is grounded on the literature analysis presented in Chapter 2, where the state of the art and the state of the practice on buyer-supplier collaboration is presented, as well as empirical analysis in Chapter 4.

THE SECOND RESEARCH QUESTION

With the intention of the better foundation of the research project according to its objectives, the second set of research questions have been presented below:

How to facilitate collaborative automation and digitalization decisions?

The important element to approach this research question is the emphasize on "How"; this means that the focus area in this research is in answering "How" it is possible to build and advances a process model of coordination that facilitate and drive inter-organizational collaboration in automation practices. The details on this concern are provided in Chapter 5.

Once the collaboration mechanisms, the behavioural parameters, influential aspects and expected benefits of buyer-supplier collaboration in automation practices is understood, in order to describe how to facilitate this practice, it is essential to identify and deploy a model for automation business assessment and identify the process groups from both manufacturing companies (Buyers) and Automation suppliers' perspectives. Furthermore, the domain components associated with the process groups are essential to be identified.

Furthermore, this industrial research project aims at design, deployment, and validation of a digital platform based on the suggested model for automation business assessment. The focus is on providing a concrete example of the creation of such systems and investigates the buyer-suppliers collaboration in automation practices over a digital cloud-based platform. To do so, as part of this work, the following question is presented to be answered:

- How to create and validate a digital platform to facilitate collaborative automation and digitalization decisions?

Chapter 5 and Chapter 6 provides details on this concern. Based on the suggested automation business assessment model, the digital platform is designed, deployed, tested and validated.

1.4. THE RESEARCH DESIGN, STEPS OF THE INVESTIGATION

The following chapter provides an overview to synthesize the steps to be taken in the course of the research development. The research steps are further described in chapter 3.

The schema illustrated in Figure 1, provides a sequence of the steps to be performed (in the ovals) and the methodological approach supporting them (in the rectangles) to answer the research questions.

As it is illustrated in Figure 1, in order to achieve the research objectives which are stated in Chapter 1.2 and to answer the research questions, described in Chapter 1.3, literature has been analysed, furthermore, expert consultation and case study activities completed the methodological approach framework. The next chapter provides an overview of the chronological perspective of the research.

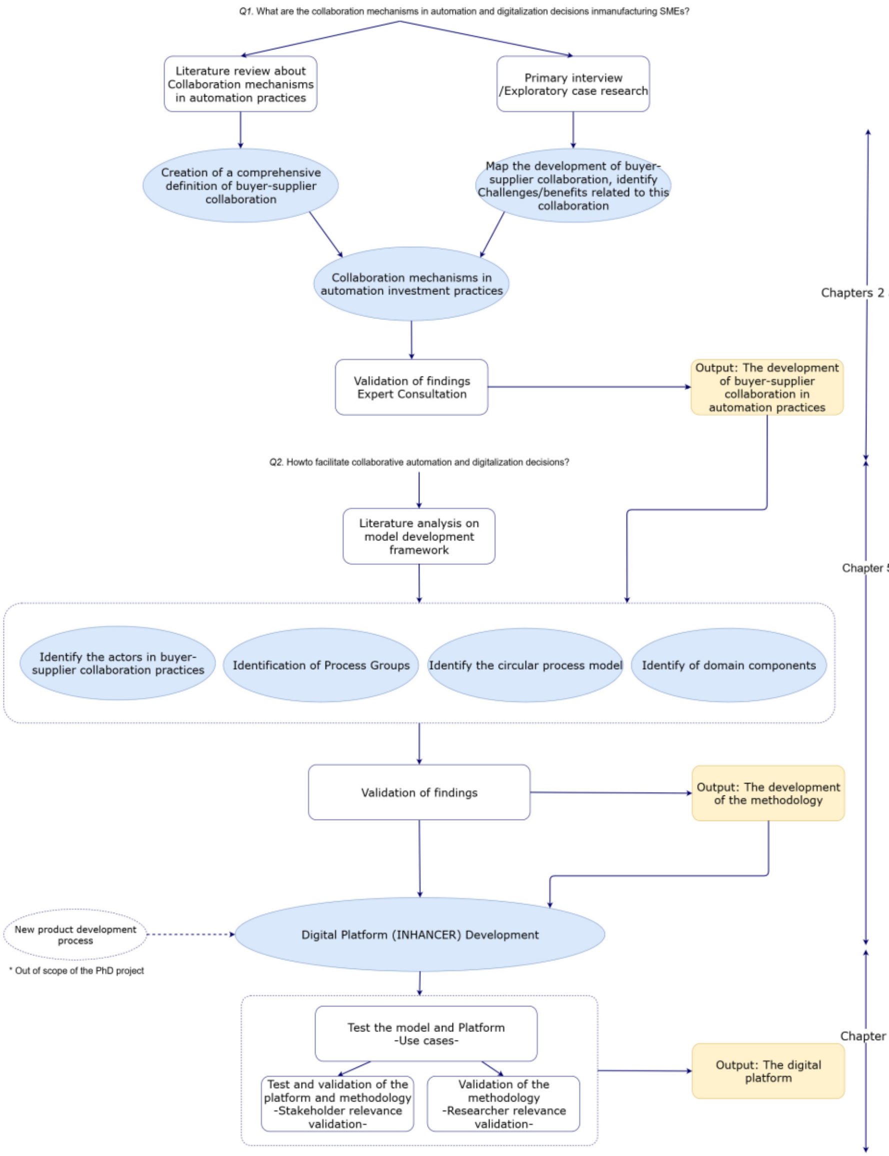

Figure 1. Research design steps of the investigation

1.5. THE OVERALL PROJECT OUTCOME AND SUCCESS CRITERIA

The project outcome is design, implementation, and deployment a flexible business assessment process model and a digital cloud-based platform for automation products to facilitate buyer-supplier collaboration in buyer-supplier collaboration in automation practices. The model and the digital cloud-based platform provide a base for information gathering, automation needs clarification, business case, and evaluate the viability of projects.

- That helps SME manufacturing companies to make substantiated (fast, low-cost, high-quality) decisions on investments and deployments of state-of-the-art robot technologies suited specifically for their needs, resulting in higher output and margins on their production.
- That helps automation suppliers and robotics experts to re-sell their expertise and state-of-the-art market technologies and solutions to most relevant manufacturing companies with less effort, increased sales radius, extend the geographical market, and hereby access the possibility to strengthen their competencies, technologies, and competitiveness within a specific niche.

The concept concentrates on a platform that is an interactive and collaborative technological network of manufacturing companies, automation suppliers and independent (international) experts, which facilitates collaborative automation decisions and problem-solving processes. The platform contains building solutions with well-defined interfaces in a so-called reference architecture. Through the platform, a manufacturing company can in a graphical, online and interactive way, rather than in a textual way, specify and document a production process (shortcoming or opportunity) in a less complex process. This is accomplished by a facilitating methodology, guidelines, and interfaces using a platform equipped smart devices such as a smartphone or tablet. Through the platform, automation suppliers will add references to existing installations that partially or completely fulfil the requirements of the production process at hand. The responses given by suppliers and experts are as done in a graphical and interactive scheme to keep their response time at an efficient level. This is executed, formatted and delivered to the manufacturing company to improve the processing speed, lower the cost and facilitates the decision-making practices from which to select and collaborate with a network of automation suppliers. Figure 2 illustrates an initial overview of the areas that the platform needs to address to achieve these aims. These areas, as well as the processes of each, will be studied and elaborate through the Ph.D. project.

Figure 2. An initial overview of the areas that the platform should address

1.6. CONTRIBUTION

This thesis offers several academic contributions to research on coordination and inter-organizational collaboration. First, investigates the phenomenon of inter-organizational and buyer-supplier collaboration in the context of automation and digitalization decisions in manufacturing SMEs. This is important, because prevailing research in buyer-supplier collaboration in advanced manufacturing technologies (Gules & Burgess 1996) largely overlooking the difference of automation and digitalization from -advanced- manufacturing machineries in the sense of being less standardized with higher level of contradictions while balancing flexibility (Wiktorsson et al. 2016). Therefore, the requirements for coordination and collaboration buyer-supplier collaboration is changed. Second, this research develops an automation business assessment process model with integration of the inter-organizational collaboration and coordination theory and a guideline on how to implement coordination and collaboration within the empirical context of this research. Therefore, the perspective of this research offers new theoretical insights on the outcomes of buyer–supplier collaboration relationships that go beyond the current explanations based on business networks (Johanson & Mattsson 2015) (Håkansson & Snehota 1989), social network theory (Gulati & Sytch 2007) (Nohria & Eccles 1992; Gulati & Sytch 2007) (Larson 1992), the relational view and special supplier (Dyer

1996) and coordination theory (Utterback & Abernathy 1975; Von Hippel 2005)(Mintzberg 1979) (Twigg 1996; Twigg 2002; Twigg 1998).

Third, this research contributes with investigates and describe the role of a lead integrator in two aspects. The imperial finding of this research further describes and qualifies the extant approaches to the role of lead integrator as a lead partner to perform planning, defining and implementing of an automation roadmap in a longer-term collaboration (Gurney 2014). Furthermore, this research proposes a dynamic view of the role of lead integrator. This view suggests a new interpretation of the role of lead integrator based on the new identified challenges and requirements in automation and digitalization decisions.

In addition to the academic contribution, the work presented in this dissertation can positively impact other relevant stakeholders such as manufacturers, automation experts, digital innovation hubs and policy makers, due to the different issues analysed in this thesis. The comprehensive literature study and exploratory case analysis presented in this research address the gap between literature and practices in buyer-supplier collaboration and the available digital technologies as the enablers of the new manufacturing environment. The practical constructs of this research can highlight the automation business assessment process model and the Inhancer digital platform (the web-application) presents a new model for facilitation collaboration between automation supplier firms and manufacturing companies via the solution selling process and involving of multiple partners in the innovation process. This methodology and suggested digital platform assist manufacturing SMEs to make well-founded decisions on investments and deployments of state-of-the-art automation technologies while supports the automation supplier in their solution selling processes. Furthermore, the commercial implications of the implemented digital platform have been considered in the course of the Ph.D. project.

Chapter 2.

Theoretical Framework

2. THEORETICAL FRAMEWORK

This chapter introduces the theoretical framework of research. In this chapter, some general considerations about new approaches to technology and product development, collaboration in buyer-supplier settings, network-based development and the emerging requirements for suppliers is presented. This chapter reviews the dynamic model and different types of collaboration that can be implemented in a buyer-supplier involvement within the context of decisions in innovative automation solutions and digitizing in manufacturing companies. In this line, the changes between different types of buyer-supplier product development collaboration from a supplier's perspective are reviewed. In addition, the concept of quality buyer-supplier collaboration is studied.

Furthermore, this chapter aims at describing the future perspective of manufacturing with considering to the concept of digitalization and new trends of automation and data exchange in manufacturing technologies, Industry 4.0 and the automation decisions in manufacturing SME.

2.1. OVERVIEW OF NETWORK THEORY

Networks have received attention in literature in a wide range from organizational literature to sociology, management and economics. From the organization perspective, networks have been considered and emerged as embedded in a web of linkage between organizations which both facilitate and constrain them by guiding their interests and ability to take actions (Powell 1990; Nohria & Eccles 1992). A wide variety of terminology and definition has been used in literature to describe the network phenomenon. Yet, based on the level of analysis, namely the individual level and the organizational level, two main areas can be identified as building blocks in conceptualizing networks (Claro 2004).

Burt (1997) introduced social capital as the contextual complement to human capital. Based on Burt (1997) definition, social capital predicts that returns to intelligence, education, and seniority depend in some part on a person's location in the social structure of a market or hierarchy. In addition, managers' social capital refers to their ability to identifying opportunities to add value within an organization, getting the right people together and coordinate them to develop the opportunities. A function of the manager's network of contacts within and beyond the firm's boundaries is to know who, when and how to coordinate (Burt 1997). The social capital view has the focus on behaviours and expectations of actors and discuss the actor’s behaviours are constrained by the degree to which their relationships are embedded in the network structure. In other study, Cross & Prusak (2002) proposed that managers rely on information from people within their network to make effective decisions. Krackhardt & Hanson (1993) studied the importance of informal networks as an information source where they can cut through formal procedures to skip long, slow-moving initiatives and meet unexpected deadlines. These studies propose the importance of social capital and information obtained from networks for controlling, monitoring and job-seeking (Claro 2004), yet, they are rather limited from the organizational scope perspective (Borgatti et al. 1998).

The second block of scholars have studied network analysis at the organizational level. The second block of scholars have studied network analysis at the organizational level. At this level, networks are studied from perspectives of alliances (Gulati 1998), strategy formulation (Jarillo 1988), strategic groups (Peteraf & Shanley 1997), organizational management (Kenis & Knoke 2002), organizational learning (Kogut 2000), international relationships (Håkansson & Snehota 1989), marketing channels (Antia & Frazier 2001), specialized suppliers (Dyer 1996), international relationships (Håkansson & Snehota 1989), Business networks (Håkansson & Snehota 1989; Ford 1990; Gadde & Mattsson 1987), marketing channels (Antia & Frazier 2001) and business relationship perspective in business networks Anderson et al. (1994; 1989). Some of the selected network definitions and implications for business are listed in Table 1.

Table 1. Network Definition and Implications

(Anderson et al. 1994)	Business Networks	A set of two or more connected actors, that exchange relation between business firms are conceptualized as collective actors. Business networks possess advantages that go beyond

		the accumulative the involved dyadic relations.
(Håkansson & Snehota 1989)	Industrial Networks	An organization-environment interface that stems originally from causal observations that business organizations often operate in environments which include only a limited number of identifiable organizational actors. These entities are involved in continuous exchange relationships with the organization with a complex set of interdependences (resources and activities).
(Thorelli 1986)	Management/ Strategic Networks	Two or more organizations involved in long-term relationships, which makes a special type of system – the one whose internal interdependencies generally change over time. Due to the intensity of interaction, two or more firms constitute a subset of one market (or several markets).
(Jarillo 1988)	Management/ Strategic Networks	The long-term, purposeful arrangements among distinct but related for-profit organizations that allow those firms in them to gain or sustain competitive advantages vis-à-vis their competitors outside the network.
(Gulati et al. 2000)	Management/ Strategic Networks	Strategic networks encompass a firm's set of relationships, both horizontal and vertical, with other organizations – be they suppliers, customers, competitors or other entities – including relationships across industries and countries. These strategic networks are composed of interorganizational ties that are enduring, are of strategic significance for the firms entering them, and include strategic alliances, joint ventures, long-term buyer-supplier partnerships and a host of similar ties.
(Dyer 1996)	Management/ Strategic Networks	Individual firms engaged in a narrow range of activities which are embedded in a complex chain of input-output relations with other firms.

(Larson 1991)	Management/ Strategic Networks	Close collaborative alliances with a limited set of suppliers and customers that enable a firm to stabilize itself while remaining flexible and responsive to a changing market
(Saxenian 1991)	Management/ Supplier Networks	Long-term, trust-based partnerships that allow for informal information flow and mobility and a blurring of the boundaries between interdependent but autonomous firms.
(Gulati 1998)	Strategic Networks	A set of nodes (e.g., individuals or organizations) linked by a set of social relationships (e.g., friendship, transfer of funds, overlapping membership) of a specified type. This could include horizontally and vertically connected firms.
(Cook & Emerson 1978)	Exchange Networks	An exchange network is a set of two or more connected exchange relations. Two exchange relations are connected to the degree that exchange in one relation is contingent upon exchange (or non-exchange) in the other relation.
(Williamson 1996)	Economic Networks	The embeddedness that matters to the transaction cost model because of the information and opportunities it offers and is considered in the institutional environment as a locus of shift parameters.
(Economides 1996)	Economic Networks	Links that connect nodes. There are one-way and two-way networks according to the economic feasibility of the links between two nodes. It is emphasized that network externalities occur when the benefits of adopting some type of technology or contract increase with the expected number of adopters. This would confer increasing returns on adoption by one party.
(Granovetter 1985)	Sociology/ Embeddedness	Networks refer to the social relations influencing economic actions. This concept explicitly considers trust, ongoing process, interpersonal relations and information exchange and reservoir of other partners. The stable (strong links with other individuals) networks are more appropriate in complex transactions.

(Nohria & Eccles 1992; Gulati & Sytch 2007)	Organizational Behavior/ Social Networks	A new type of organization that is radically different from the Weberian bureaucracy or market transactions (with) properties consisting of a fluid, flexible and dense pattern of working relationships that cut across various intra- and inter-organizational boundaries... that are made possible by advances in information technologies. Network organizations are not the same as electronic networks, nor can they be rebuilt based entirely on them. Face-to-face and social encounters are essential
(Larson 1992)	Organizational Economics/ Social Networks	A set of inter-organizational and interpersonal relationships that create social dimensions (personal relationships, reputation, trust, reciprocity norms) to the transactions and are central to the explanation of control and coordination in the exchange structure.
(Powell 1990)	Network Governance	Indefinite, sequential transactions within the context of a general pattern of interactions. Transactions are embedded in a particular social structure. Boundaries are expanded to encompass a larger community of actors and interests that would previously have either been fully separate entities or absorbed through merger.
(Antia & Frazier 2001)	Information Networks	Formal networks among agents comprise consciously planned and designed sets of relationships, while informal network ties are spontaneous and shadow formally prescribed work flow and authority relationships. This suggests that individual relationships are embedded in a context of other relationships that could have governance implications.

One of the main contributions on network research, which is specifically of interest of this research, is the business network approach. In this approach, coordination is based on both market forces and on the actors, resources and activities that are part of the relationship (Håkansson & Snehota 1989).

BUSINESS NETWORK

This study uses the business relationship theory to define business networks. This research is based on the assumption that business takes place in a network setting, where different business actors are linked to each other through direct and indirect business relationships. Therefore, the nature of business networks and firms within business networks the principal concepts for each, are examined.

A business network is defined as, “a set of two or more connected business relationships, in which each exchange relation is between business firms that are conceptualised as collective actors” (Emerson 1981), also (Blankenburg Holm 1996; Anderson et al. 1994). In this definition, connected means "exchange in one relation is contingent upon exchange (or non-exchange) in the other relation" (Cook & Emerson 1978). These actors comprise competitors, suppliers, customers, distributors and government (Axelsson & Johanson 1992). As part of a larger business network, two connected relationships of interest, can be both directly and indirectly connected with other relationships that are relevant for them. Figure 3 illustrates a focal relationship is connected to multiple different relationships that could be the supplier or the customer, some of which are with the same third parties (Anderson et al. 1994).

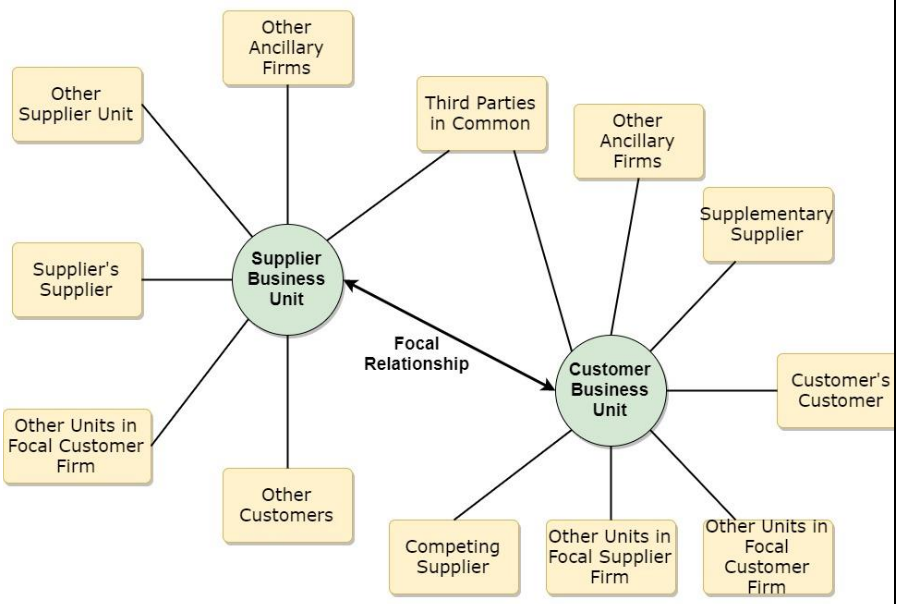

Figure 3. Connected Relations for Firms in a dyadic Relationship

(Anderson et al. 1994)

From the network point of view and considering the concept of the firm as an actor performing activities and employing resources, the business network can fulfill both *primary functions and secondary functions.* Primary functions refer to the positive and negative effects on the both partner firms of their interaction in a focal dyadic relationship while the secondary functions, which can be called *network functions*, refer to the indirect positive and negative effects of a relationship due to direct or indirect connection to other relationships (Anderson et al. 1994).

Johanson & Mattsson (2015; 2015) introduce business networks as the relationships a firm has with its customers, distributors, suppliers, competitors and government which are the actors in a business network. They argue the activities in the network enable the firm to form relationships. This allows them to gain access to resources and markets. Considering the network model, they assume a firm requires resources controlled by other firms and can be acquired through its network positions (Johanson & Mattsson 2015).

Business network and the resource dimension. The relationships with customers, suppliers, and other organizations represent strategic resources in three different ways (Gadde et al. 2003):

First: A firm's relationships are important resource. In many cases, the firm's few relationships enable most of the sales income and procurement expenditures. In the same way, companies are increasingly reliant on relationships with others in technical development activities.

Second: The relationship between companies in addition to a bridge between two actors, is a reflector of these connected relationships and their essential resources. Therefore, direct relationships connect a company to the network that the company is part of.

Third: The relationship allows to combine the physical and organizational resources of a company with other company. Consequently, a considerable amount of company's resource is beyond its ownership boundary and controlled bilaterally with other firms.

Such studies explain that, within the context of business network, actors serve each other when it draws upon its resources in its own context as a benefit (Chandler & Vargo 2011; Kogut 2000; White 2002). The main concern for a company is to optimize the benefit of the resource constellation in the network. It is essential that resources are not perceived as givens, rather, resources come with hidden and unexploited dimensions that can be declared and further developed in interaction with partners through the continuous combining and recombining in business relationships. Therefore, a business relationship is a crucial resource in itself, furthermore, it can enable modifying the use as well as the value of other resources (Gadde et al. 2003).

Business network and the activity dimension. In a business network, interaction is the main activity of a company. The interaction is established based on the exchange of products and services where the consideration in on how two companies decides to organize the flows of goods and information between them (Chandler & Vargo 2011). The activities in business network take place across the boundaries of two or multiple companies and form chains of activities, such as distribution channels (Mohr & Nevin 1990) and supply chains (Horvath 2001).

The activities constituting a chain are interdependent and related through links, which may be loose or tight. Together, the activities form an organized entity having network properties. Through interactions, companies by relating their own activities to the activities of the partner companies, can utilize the interdependencies that exist among the activities of the different actors. By linking activities between actors, companies can gain business value because it gives both companies the opportunity to rationalize operations that are valuable and extend beyond the ownership boundaries (Gadde et al. 2003). Thus, the activities of individual firms are not isolated. Its origin, progress and effects are not limited to a single actor or to a single resource, actor or activity. Regardless of limits in numbers of activities and resources, interaction between business actors, has wide, multiple and continuing effects and in turn it is affected by multiple influences across the business network. Interaction is not controlled by any of actors directly or indirectly involved or affected by it, however, many of actors may influence its direction (Ford & Håkansson 2013).

Moreover, in a business network, each company decides on its own specific pattern of interdependencies considering how it relates to its most important partner and how they set their relationship with others. Therefore, based on the industrial network perspective, it is critical for a company to build interdependencies systematically (Dubois & Gadde 2002; Hakansson & Ford 2002). Companies aim at relating their activities to those of other firms to enhance their performance. These adaptations make the company to be dependent on its partners. This shows the importance of coordination and its impacts on the productivity of a firm during activities in the network. From an industrial network perspective, it is required to build interdependencies in a systematic way, to ensure the benefits of high involvement is obtained under specific conditions (Gadde et al. 2003).

BUSINESS ECOSYSTEM AND DIGITAL BUSINESS ECOSYSTEM

The term ecosystem was only used in the content of biology (Li 2013) until 1993, by the time Moore (1993) proposed the business ecosystems theory to explain interactions between relations, interactions and co-evolutions from a business environment perspective. Moore (1993) defines business ecosystem as an economic community of loosely-coupled interacting organizations and individuals who produce valuable goods and services. A business ecosystem, similar to a biological ecosystem, can be understood as a network form of relations, a system which is formed out of large loosely coupled entities (Osterwalder & Pigneur 2010). The entities can be perceived as “the organisms of the business world” (Moore 1996). The structure of a business ecosystem has been discussed in literature from two main perspectives:

The Keystone model: comprising of a dominant large firm and many small suppliers (Iansiti et al. 2004); mainly applied to the American economic structure. In contrast to the European model, this ecosystem is highly dominated by a so-called hub firm (dominant large firm), which is having essential roles in maintaining any level of complexity within a system (Platten & Henfrey 2009). The hub firm can benefit from the lower costs because it captures economies of scale from its associated firms (Jarillo 1988).

The European model: which is more dynamic, mainly formed by SMEs but also capable of including large firms (Benguria & Santos 2008). The health and performance of the ecosystem and individuals is depended on each other being simultaneously influenced by the interaction ties and the capability of each of the actors (Hakansson & Ford 2002). Business ecosystems are not restricted to any industry, rather, they can include competitors, complementors, customers, public bodies, investors, research institutes and universities, where they are aiming at finding new opportunities beyond their industry (Moore 1998).

The other aspect of a business ecosystem is to study drives which motivate different actors to participate in the ecosystems. Since participation in a business ecosystem is voluntary, the participants seeing advantages for themselves in participating.

Therefore, self-interest represents a fundamental element in the integrational power of ecosystems and due to their very existence and the results achieved by it, the ecosystem can over the years grow to become strongly sustainable (Heikkilä & Kuivaniemi 2012). Osterwalder & Pigneur (2010) argued that the degree of commitment and the act of working towards a common business goal is another fundamental element of building a sustainable ecosystem.

Firms which exist on the marketplace among other dominant firms, face challenges of self-organizing while the "sharing / cooperation zones" from the internet also lead to the dominant actors (Dini et al. 2008). Nachira et al. (2007) suggested that political attention requires to be considered on SMEs within Europe to provide a favourable environment for them and stimulate entrepreneurial initiatives (Whitley & Darking 2006). As an extension of Moore (1993) business ecosystem and to cope with these challenges, the European Commission has developed the Digital Business Ecosystem (DBE) initiative (Whitley & Darking 2006), which is meant to support the SMEs in today's knowledge-based economy (Stanley & Briscoe 2010). While business ecosystem portrays generic organizational interdependence, DBE extends this concept by placing more importance on the centrality of digital technology.

The Digital Ecosystem creates an open community where the dynamic needs of the environment can modify leadership structure. Moreover, a Digital Ecosystem can be understood as a distribution of server functionality amongst many data systems, whose resources can be shaped into a virtual data centre which offers a platform as a Software-as-a-Service (SaaS) (Stanley & Briscoe 2010). These ecosystems can co-exist, removing the geographical barriers and providing tools for collaboration (Boley & Chang 2007). The Digital Ecosystem is formed by three main layers (Boley & Chang 2007):

Coordination layer. it consists of creating a distributed system which prevents third party observation or dependence, maintaining information privacy. For example, if a SME uses one solution provider, they are not allowed to collaborate with another SME using the same solution provider (Dini, 2008).

Resource layer. offers the usage experience of resources on the Platform-as-a-Service (PaaS), composed by resources offered by multiple participants.

Service layer. here, the resources are combined into end-user accessible services. The interaction of these services would be decided by the users, having as reasons, the business requirements.

The concept of DBE is developed by using the term "digital" (Nachira 2002) and the "business ecosystem" (Moore 1996), including the Information and Communication Technologies construct. Therefore, the co-evolution of business ecosystems with their digital representation has formed the concept of "Digital Business Ecosystems" (Nachira et al. 2007). (Nachira et al. 2007) defines DBE as a collaborative environment made up of different entities that co-create value through information and communication technologies (ICTs).

DBE has been considered from varieties of disciplines such as information systems (IS) (Graça & Camarinha-Matos 2017; Senyo et al. 2016; Tsatsou et al. 2010), computer science and risk analysis (Hussain et al. 2007) and general management (Koch & Windsperger 2017). Particularly, the attention to DBE as organisations strive suggested DBE as an enabler for organizations to leverage resources such as technology and specialised services across different industries with an innovative approach to respond to customer needs (Senyo et al. 2019). DBE go beyond traditional industry boundaries to promote open and flexible collaboration and competition. Thus, DBE comprises two main tiers (Stanley & Briscoe 2010): a) Business ecosystem, which is a network of organizations, an economic community of individuals and organizations that operate outside their traditional industry boundaries (Moore 1993). b) Digital ecosystem, which can be seen as the relationships between organizations, a virtual environment populated by digital entities such as software applications, hardware and processes (Nachira et al. 2007). As a peer-to-peer distributed technology infrastructure, digital ecosystem creates, disseminates and connects digital services over the Internet (Senyo et al. 2019; Moore 1993).

In a DBE, a close and frequent relations (Strong ties) between partners, establish a sense of cohesion (Osterwalder & Pigneur 2010). Therefore, to ensure a sustainability, it is crucial that working on specific issues may over time lead to formation of a value-based unity, on the achievement of the joint goals, in which the cohesion is strong enough to reconcile potential conflicts of interest between the actors of the ecosystem (Heikkilä & Kuivaniemi 2012).

In this study, we consider DBE as a socio-technical environment of individuals, among manufacturing companies, automation suppliers and integrators, investors, research institutes and universities, with collaborative and competitive relationships to co-create value through shared digital platforms.

2.2. BUSINESS COLLABORATION

Collaboration has been widely studied in recent years from different perspectives including sociology (Powell *et al.*, 2005), psychology (Stern and Hicks, 2000; Konczak, 2001), and test test (Stern & Hicks 2000) business networks (Håkansson and Snehota, 2006), marketing (Jap, 2000; Perks, 2000; Gadde, Huemer and Håkansson, 2003), management (Sawhney, 2002; Singh and Mitchell, 2005), and supply chain management (Holweg *et al.*, 2005). Inter-organization collaboration is turning out to be more common practice among firms (Gomes-Casseres 1994). Organizations often collaborate much more actively through networks to benefit from available accumulative resources in networks and to be able to allocate sufficient resources for innovation (Håkansson & Snehota 1989). The essential motivation behind collaboration is that a single company is not able to successfully compete by itself. Customers are more demanding; competition is escalating (Soonhong Min, Anthony S. Roath and Stefan E. Genchev, 2005), therefore, the firm's capabilities and competitive forces can be identified as the principle factors which force businesses to collaborate (Madhok 1996). Companies with advanced collaborative skills tend to gain trust and credibility (Gulati, 1995) and share risks and rewards (Lambert, D.M., Emmelhainz, M.A. and Gardner, 1999) by continuous cooperation with other companies. They aim at securing higher performance than would be achieved by operating individually. Successful firms are positioning themselves to a value creating system (Normann & Ramirez 1993) where they advance their business collaboration with suppliers, business partners, allies and customers. Inter-organizational collaboration has been studies in various literature including new product development (NPD), supplier chain management, buyer-supplier collaboration and purchasing literature; and various terms are used including production nets, networks, clusters, constellations or virtual corporations.

The new emerging challenges related to globalization in today's business environment, in addition to the rapid expansion of new information and communication technologies, has led to a high degree of knowledge diffusion across multiple public and private organizations, which encourage enterprises to innovate in collaboration with more parties (Van de Vrande et al. 2009). Hagedoorn (1995) emphasizes the increasing importance of strategic inter-firm alliances formation. New technologies are becoming more complex, and technical knowledge and skills are so distributed, that even for large enterprises it is difficult to handle innovation alone, therefore, companies try to acquire extensively dispersed knowledge through network interactions (Bougrain & Haudeville 2002). (Hakansson & Eriksson 1993) investigated the interactive nature of business and its important impacts for managers in business-to-business activities. (Hakansson & Eriksson 1993)also evaluates the challenge of a new actor to enter an existing business network in an interactive, interdependent, and interconnected business world. They argue that the fate of the new venture and its collaboration by some other business actors highly depends on the existing collaboration and relational assets which are the outcome from previous investments.

Companies that interact through networks could improve their operational performance because they have access to more sources of external knowledge (Brunswicker & Vanhaverbeke 2015; Foss et al. 2013; West & Bogers 2014). Besides membership in networks or clusters list, European SMEs are willing for internationalization due to: internal resources and capabilities; favorable government policies; economy, competitive market conditions, and industry structure (Ratten et al. 2007). McDougall & Oviatt (2000) argue that innovation and 'international entrepreneurship' activities do not happen in a vacuum. Infect, innovative actions take place within a domain of activities that include domestic and international business environments (Ratten et al. 2007). However, inter-organizational collaboration have been considered extensively in literature, yet implementation of coordination mechanisms and modes of collaboration, particularly within the field of automation and digitalization is an ongoing issue.

2.3. SUPPLY CHAIN COLLABORATION

The literature on supply chain management have had a significant impact on the study of business networks. The importance of chain and network science, and more specifically, supply chains has been identified by scholars (Omta et al. 2001).

Supply chain management represents a way that firms can pursue their objectives is by seeking cooperation in chain and raise their performance levels. Researchers have examined the elements of relationships associated with better supply chain management. Based on this, scholars approached supply chain with an emphasize on flow of value between organizations where they describe chain cooperation. Some selected definitions in this aspect, can be highlighted in Table 2:

Table 2. Supply chain collaboration definitions

(Lambert & Cooper 2000)	The integration of business processes from consumer to the original suppliers leads to product service information that has added value to customers
(Stevens 1989)	A supply chain is a system whose constituent parts include material suppliers, production facilities, distribution services and customers, linked together via the feed-forward flow of materials and the feedback flow of information and financial capital
(Salhi 1994)	A supply chain is a network of organizations involved through upstream and downstream linkages in different processes and activities that produce value in the form of products and services in the hands of the ultimate consumer

(Simatupang & Sridharan 2002)	A collaborative supply chain involves “two or more independent companies (that) work jointly to plan and execute supply chain operations with greater success than when acting in isolation”
(Zuurbier & Sauvée 1998)	By focusing on consumer needs a network will develop common activities and exchange of people, resources and information

Considering the proposed definitions, it can be argued that collaborative practices are understood crucial to the creation of firm capabilities and performances. The conceptualization of such collaborative practices in the literature emphasize on two aspects (Min et al. 2005):

a) Collaboration as an interorganizational business process: Stank et al. (2001; 2001) reviewed collaboration as a business process, where partners work together toward mutual objectives that commonly benefit the partnering firms. In this process, independent supply chain partners share information among each other (Sabath & Fontanella 2002; Stank et al. 1999) in which naturally include joint decision-making (Stank et al. 2001) and joint-problem-solving (Spekman et al. 1997).

b) Collaboration as a foundation of interorganizational relationships: Scholars such as Bowersox et al. (2003; 2003; 1996; 1992) argued that collaboration is a format of cross-organizational linkage or partnership. In this format, partners work together and share knowledge, resources, and some degrees of risk to achieve mutual objectives. They argue the functional interdependence between partner firms is funded based on the internal functional interdependence in which has initially developed across functional areas within an organization, therefore, this results in an integration of intra and interfirm activities (Min et al. 2005). Since participants become functionally interdependent, they pursue mutually advantages (Jap 2001). (Bowersox et al. 2003) suggests organizations get involve in cross-organizational linkages and agree to integrate human, financial, or technical resources in order to create a better business model.

Collaboration and knowledge transfer. Collaboration both knowledge transfer between organizations and facilitates the new knowledge creation and produce synergistic solutions (Hardy et al. 2003). Stank et al. (2001) points at the importance of transformation from standard business practice and information exchange as one of the curtail factors for successful collaboration. (Quinn 1999) identifies three factors to achieve the most benefits of collaboration: free exchange of data; operating plans; and financial information. Min et al. (2005) emphasized on the contribution of realistic, informed, and detailed information sharing on improved decision-making and supply chain efficiency. They summarize the expected outcome of supply chain collaboration as:

- Higher capabilities in supply chain, due to better demand planning (McCarthy & Golicic 2002), inventory visibility (Sabath & Fontanella 2002) and access to new knowledge and skills (Hardy et al. 2003).
- Higher supply chain efficiency, due to reduction in inventory and cost savings (Sabath & Fontanella 2002; Stank et al. 1999);
- Higher supply chain effectiveness due to improvements in customer responsiveness (Sabath & Fontanella 2002) and better access to target market segments (McCarthy & Golicic 2002).

As collaborative partners learn from the ongoing relationship, they adapt business models to better match the requirements of each other. Therefore, the partners try to keep the relationship dynamic, adaptable, and valuable to the involved parties. Outcomes of this collaboration and the interactive feedback consequence in potential business benefits which are summarized in

Table 3 (Min et al. 2005).

Table 3. Consequences of collaboration (Min et al. 2005)

Mutuality	Mutually beneficial and synergistic
Efficiency	Cost reduction Reduced inventory Shortened lead-time Streamlining supply chain process
Effectiveness	Improved customer service Increased market share Better pricing New product development
Profitability	Return on investment Sales per target segment
Reinforcement and expansion of the relationship	Trust Commitment Interdependent Mutual involvements

Key supply chain collaboration activities. Min et al. (2005) summarized the key supply chain collaboration activities, including information sharing, joint planning, joint problem solving, joint performance measurement, and leveraging resources and skills. They argue that the collaboration activities suggest the framework for successful collaboration which can be used to guide daily operations as well as longer-term strategic planning.

Table 4. Key collaboration activities (Min et al. 2005)

Information sharing	Forecasting Customer demand Materials requirement
Joint planning	Marketing planning Production capacity and scheduling Joint planning Mutual sales and performance targets Budgeting Prioritizing goals and objectives

Joint problem solving	Product development/redesign Logistics issues (shipping, routing, backhauling, pallet size, packaging, etc.) Marketing support (marketing materials, delivery schedule, store display, etc.) Quality control Cost-benefit analysis (inventory carrying cost, lead time, customer service, etc.)
Joint performance measurement	Performance reviews on a regular basis Measuring KPI (customer service, cost savings, productivity, etc.) Determining rewards and taking corrective actions
Leveraging	Resources and capacity Skills and knowledge Specialization

Most of the former research relating to supply chain collaboration and collaborative relationships concentrates on formation the set-up, roles and responsibilities, and guidelines for the operations (Rizza & Ruggeri 2017; Manrodt & Fitzgerald 2001). Some other scholars have focused on case histories of specific collaborative ventures (Batenburg & Rutten 2003), model of supply chain collaboration and supply chain collaboration activities (Min et al. 2005). One of the purposes of this study is to expand previous research findings by means of an integrative model for buyer-supply collaboration and investigation the role of lead integrator in this model with a focus on automation solution development practices.

BUYER SUPPLIER COLLABORATION

The past decade has seen a renewed importance in buyer-supplier collaboration in new product development (Andrew et al. 2010; van Echtelt et al. 2007) as key to the successful management of innovation since the buyer-supplier relationships play a critical role in knowledge development, resource mobilization, and coordination (Takeishi 2001).

Particularly, for more complex solution development, companies need a level of collaboration with supplier networks to get access to the specific knowledge of the subassemblies that suppliers offer and to get access to technologies and capabilities needed for specific development (Johnsen et al. 2006). The right suppliers provide specialized capabilities that are critical for new solution development. Furthermore, suppliers play a role as access points to a larger network of specialized suppliers, which offer a pool of technologies and capabilities which might be required during the innovation process. In the same way, among collaboration with the customer, suppliers become able to introduce their own innovations to market (Ford et al. 2011). The research around the importance of buyer-supplier interaction in innovation is not new. Preliminary studies on interaction with customer conducted in the late 1970s and 1980s by Von Hippel (1979; 1985; 1989). Followingly, the role of users as the source of innovation examined (Von Hippel 1986; Voss 1985). Some later researches have focused on the involvement of suppliers in product innovation (Takeishi 2001; LaBahn & Krapfel 2000; Hakansson & Eriksson 1993). The research has underlined the importance of early and close supplier involvement in new product development and investigates the positive performance impacts on quality, costs and faster time to market (Ragatz et al. 1997; Frohlich & Westbrook 2001; Gassmann & Enkel 2004).

Ylimäki (2014) has categorized the literature of collaboration between suppliers and customers regarding product development into two main streams: supplier involvement and customer involvement. The literature with a focus on the role of suppliers in the customer firm's product development mainly categorized in the supplier involvement stream (Johnsen 2009; Takeuchi 1986). The customer involvement literature examines customer contribution to a supplier's product development (Kaulio 1998; Alam 2002).

TYPES OF BUYER-SUPPLIER COLLABORATION

SUPPLIER INVOLVEMENT

To classify different type of buyer-supplier collaboration Petersen et al. (2005) suggested a typology that illustrates supplier involvement collaboration in three different types: black-box, gray-box, and white-box. Black-box refers to the type where the role of a supplier is the most comprehensive. In this type, design and developing of the concept is primarily done by the supplier according to the buyer's performance specifications. The second type, gray box development, refers to the situation where collaboration plays the most important role. The formalized joint activities including design and development take place in this type of collaboration where companies share facilities to smooth communication and information exchange while product development. This type of collaboration, enable collaborative companies to effectively integrate a supplier's processes in the design (Koufteros et al. 2007; Ylimäki 2014).

The third form of supplier involvement, the white-box development, referrers to the condition that customer mainly does the design. The supplier role is limited to consulting informally on the project. In this type of development, the supplier typically contributes to evaluating the possibility of manufacturing the new component (Petersen et al. 2005).

CUSTOMER INVOLVEMENT

Kaulio (1998) has suggested a similar type of classification in the field of customer involvement in product development. He divided customer involvement in product development into three categories: *design for customers, design with customers* and *design by customers*. In the first type, design for customer, products are designed on behalf of the customers by supplier's engineers. Data related to customer requirements, such as general theories and customer behaviour modes are gathered by using market research methods or studies of customers, such as interviews or focus groups. The data is used as the bases for the design process. The second type of development, design with customer, focuses more on collaboration. The product concept and solutions are developed through a collaborative effort between customer and supplier. In this type of development, an on-going dialog between customer and supplier during the product development process plays a big role. Similar to design for customer type, customer preferences data is used as a basis for the design process, yet, it includes prototypes and display of different possible concepts for further discussion and reactions around different proposed design solutions. In the third type of product development approach, customers are actively involved and contribute to the process of developing and selecting a design solution. In this type, a supplier mainly helps the customer find feasible solutions to the problems (Kaulio 1998) by guiding them toward determining of the optimum solution which fits the required cost and time frame in addition to the product needs (Koomsap & others 2013; Ylimäki 2014).

Due to many of the characteristics of supplier involvement and customer involvement Ylimäki (2014) argues the type gray-box integration of supplier involvement is similar to design with the customer in the customer involvement typology. He also argues that black-box and white-box integrations are compatible to design for customer and design by customer (Ylimäki 2014) (Figure 4).

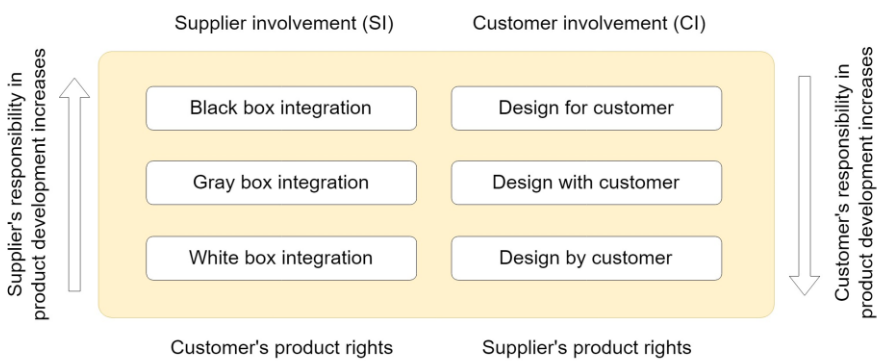

Figure 4. Types of supplier and customer involvement and their relative positions (Ylimäki 2014)

Ylimäki (2014) suggests that the selected product development collaboration follows the different business line and it depends on the type of sales of the developed product or subassembly. When the supplier in addition to the collaborative customer company is looking for the opportunities to provide the product or solution to other customers, the collaboration is inevitable of the customer involvement type. While if the supplier is delivering the product only for the collaborator customer company, the collaboration is examined as the supplier involvement type. Additionally, the ownership and products right defined the collaboration type. If a customer has the ownership of the product rights, the supplier involvement is expected as the collaboration type, while when the supplier owns the product rights, the collaboration type is expected to be customer involvement. In some cases, for instance when the collaborative supplier and customer are sharing the product rights or in situations that product rights are sold or transferred from one party to the other party the determination creates a blurred distinction between supplier and customer involvement (Ylimäki 2014).

THE DYNAMIC MODEL OF BUYER-SUPPLIER COLLABORATION

Ylimäki (2014) combined the supplier and customer involvement literature by previously discovered types of collaboration to suggest a dynamic model. Consideration the benefits of the long-term relationships for both supplier (Walter et al. 2001) and customer (Monczka et al. 1998) collaborative companies, he emphasizes on the dynamicity in product development collaboration types. The suggested framework by Ylimäki (2014) examines that the collaboration between two participants is dynamic and can be modified to meet the changing requirements of the participating companies, Figure 5.

Monczka et al. (1998) have studied the attributes of buyer-supplier collaboration from the perspective of the buyer company. They have introduced the following attributes which significantly related to collaboration success: trust and coordination, interdependence, information quality and participation, information sharing, joint problem solving, avoiding the use of severe conflict resolution tactics, and the existence of a formal supplier commodity alliance selection process.

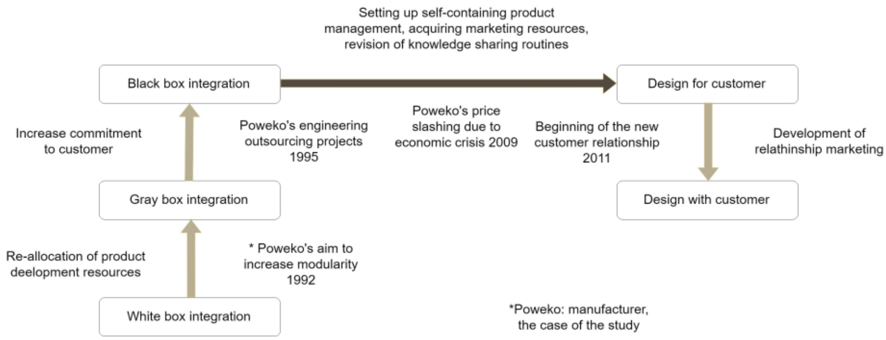

Figure 5. development of the collaboration, the critical events leading to the change in the type of collaboration and the necessities for change that the supplier faced (Ylimäki 2014)

AUTOMATION AND SUPPLY CHAIN COLLABORATION

Manufacturing enterprises needs to invest on advancing their operations to improve, or at least to maintain, their enterprises' competitive position in both domestic and international markets. To keep and increase competitiveness, automation technologies is introduced as a key for the future production by several large companies in Sweden (Wiktorsson et al. 2016). In other study, automation technologies identified as one of the means to achieve a combination of good working conditions and high labor productivity in Danish manufacturing companies (Hinrichsen 2010). Automation can be applied to reduce labor cost, increase efficiency, improve product quality or increase safety for operators (Groover 2007).

Yet, to ensure investments in the implementation of advanced manufacturing technology do not only result in marginal improvements, they need to be accompanied by initiatives that consider improvement of relationships within the whole value chain (Gules & Burgess 1996). Advanced manufacturing technology is defined as any new technique, which, when adopted, is likely to require a change not only in manufacturing practice, but also in management systems and the manufacturing approach to the design and production engineering of the product. Automation solution implementation involves knowledge and overview of the product and its requirements to be able to contribute to a production system. Therefore, manufacturing companies consider manage their businesses in different ways and investment in automation and advanced manufacturing technology. Macbeth & Ferguson (1994) identified some of the factors which drives manufacturing companies towards advanced manufacturing technologies:

- To increase quality and reliability in products
- More choice in existing product ranges
- More choice through new products
- More customization
- Faster lead time and faster satisfaction of need
- Freedom to change late in the order cycle
- Increasing level of customer service

In other study, Groover (2007) listed nine justifications that explain a transition towards automation:

- To increase labor productivity
- To reduce labor cost
- To mitigate the effects of labor shortages
- To reduce or eliminate routine manual and clerical tasks
- To improve worker safety
- To improve product quality
- To reduce manufacturing lead time
- To accomplish processes that cannot be done manually
- To avoid the high cost of not automating

Before Lindberg & Trygg (1991) study the impact of buyer-supplier relationships on buyer's implementation of advanced manufacturing technologies and suggest companies to enhance their intra-company activities, most of the early studies had focus on strengthening a company's manufacturing competitive position with concentration on improving internal efficiency through advanced manufacturing technologies implementation. Williamson (1991) pointed out the importance of the role of suppliers from the point of suppling materials, components or other inputs in the right varieties and quality at short notice, to ensure a successful and increased flexibility.

Lamming (1993) suggested that the early approaches to close relationship with suppliers focused more consideration on soft technology implementation, such as Just-in-Time (JIT) production and total quality management (TQM), due to their systemic nature of these technologies and their need to be strongly supported by suppliers. Gules & Burgess (1996) identified the relationship between the manufacturers and parts producers as a key element of the whole value-adding process. An efficient supplier-manufacturer relationship enables a smooth material flow which increase the ability to plan capacity, flexibility and respond to market fluctuations.

The production systems are facing challenges of supporting highly flexible design to ensure reacting toward short production cycles (Tan et al. 2009). Pichler & Wögerer (2011) argues that traditional industrial robots are optimized to “economy of scale”, but customization, individualization, and service-orientation drive towards new business models. Considering implementation of automation technologies, the buyer values, such as quick delivery, reliability and technical assistance, determine the buyer's purchase criteria are transmitted through their value chain. This means, suppliers need to modify their business model and their solution to fit buyers expectations, for example, suppliers are required to provide automation solutions which are flexible and can change over quickly to new product, production programs, or advance technologies to enable or facilitate design of robust components (Burt 1989; Ellram 1991). Therefore, traditional automation technologies are being replaced by new trend toward automations, such as human-robot collaboration (Olsen & Johansen 2013; Gopinath et al. 2017; Bem et al. n.d.) design concepts. This also declare the importance of the development of robots and different emerging technologies that supports new applications, with a highly consideration on performance and flexibility (Brogårdh 2007). The products which are produced in, specifically, medium sized batches and variable volumes, requiring more flexible automation solution (Heilala & Voho 2001). Automation suppliers need to design and develop intelligent automation solutions that efficiently manage the rapid product or model changes from the manufacturing companies (Scholl 2012). This might be a challenging for individual manufacturing SMEs and implies a requirement for collaboration with automation suppliers or integrators (Johansen et al. 2018).

Scholars such as Chen & Small (1994) indicated that companies need to consider their impact on suppliers, and work with closer relationships with them to ensure implementation of advanced manufacturing technologies successfully. Other scholars such as (Lamming 1993; Lamming 1992; Macbeth 1987; Carlisle & Parker 1989) argued that improving buyer-supplier relationships is highly linked to the effective implementation of manufacturing technologies, and to the overall competitiveness of the company. Decisions of automation solutions implementation and advanced manufacturing technologies involves a supply chain from the automation suppliers to the purchasers of the technology.

Based on the specific need of the manufacturing company and characteristics of the production system, automation solutions suppliers and integrators combine different technologies and engineering solutions, based on hardware, machinery and tools, covered by software and control units and electronics to complete the robotic cell to fit the production system. The robotic cell may consist of robotic arms, vision systems, grippers, control systems, additionally, services such as need analysis and solution design, development, training, installation, upgrading and maintenance. The offering from automation supplier and integrator includes a combination of hardware, software and services which also can be understood as product service systems (PSS) (Tukker & Tischner 2006) or Integrated Product Service Offerings (IPSO) (Lindahl et al.

2014). Based on the complexity of the automation solution or the offering integrated product system, number of automation solutions and integrators may require collaborating with each other to provide the final solution.

The buyer-supplier relationships in automation solution implementation is not intermittent, as Scholl (2012) argues, automation in production continuously need new customer solutions from automation suppliers or integrators. This can be developed continuously as the technologies evolves (Brogårdh 2007). Therefore, an automations solution needs to be capable of continues maintenance and upgrade efficiently in a long-term collaboration between the manufacturing SME and the automation supplier or integrator (Johansen et al. 2018). Lyons et al. (1990) studied the advantages and disadvantage of buyer-supplier relationship which is illustrated in Table 5.

Table 5.The advantages and disadvantages of the new relationship are listed for buyers and suppliers [lyons1990mixed]

Advantages and disadvantages for buyers		Advantages and disadvantages for suppliers	
Advantages	**Disadvantages**	**Advantages**	**Disadvantages**
Reduced manufacturing and labor costs	Increased dependence on supplier	Contract predictability	Cost information shared (loss of proprietary information)
Improved quality	New negotiating style	Workforce and production more stable	Pressure to assume burden of all phases from design to warranty while improving quality and reducing costs
Reduced complexity and cost of assembly and buying	Less supplier competition	Increased R and D effectiveness	Decreased autonomy
Supply assurance	Increased managerial skills	Buyer allies supporting firm's status	Increased communication and coordination costs
Cooperative relationships with suppliers	Reduced personnel mobility	Buyer assistance	Reduced personnel mobility Potential pendulum reversal
Contract predictability	Increased communication and coordination costs	Influence on buyer's future decision making	
Fair pricing assurance (open books)	Increased support for supplier	Insider information on buying decisions	
Negotiated price reductions during contract life	New reward structures	Firm becomes gatekeeper for competitors' innovations	
	Loss of direct contract with secondary suppliers		

Avoidance of bad press caused by RIFs	Information about competition

An effective inter-organizational collaboration between engineers and organizations in such an extended company network during industrialization is built on general conditions. (Johansen 2005) has identified and listed these conditions as following:

- Communication on product/solution introduction. A clear communication to define and describe the product/solution introduction and needs.
- Supports efficient collaboration. Early participation from all involved partners in the process need to support collaboration efficiently.
- Communication and information handling. A clear communication and information handling within the extended enterprise (collaboration community) -both internally and externally- is a great impact on facilitating the collaboration.
- Trust in business approaches. Trust, reliability and respect for each other's competence.
- Cultural awareness. The importance of the cultural awareness between different partners and countries, needs to be considered.

INTEGRATION MECHANISMS: R&D AND MARKETING INTEGRATION AND NPD PERFORMANCE

Market orientation includes both the concept of customer orientation and the concept of competitive orientation. Business competition plays an important role in the strategy of firms, particularly, on their innovation strategy and performance. The commercial performance of an innovation is highly linked to a strong research and development (R&D) orientation and the use of sophisticated technologies in the development of new products (Gatignon & Xuereb 1997). Consequently, many firms have considered to modify their business models and procedures to new quick response and innovative interactive models.

New product development (NPD) is the term used to describe the complete process of bringing a new product to market. Product development is critical in firm's business practices because new products are becoming the nexus of competition for many firms (Clark 1991). Due to the character and complexity of NPD, which needs input from both R&D and marketing, NPD needs involve the integration of internal and external analyses (Day 1994). Pioneer firms have been trying to establish interaction between R&D and marketing activities. A successful new product development process meets market requirements as well as an appropriate technical solution, marketing supplies the demands of customers (Griffin & Hauser 1993). Since product development is thus a potential source of competitive advantage for many firms (Brown & Eisenhardt 1995). R&D uses the firm's resources and capabilities to obtain this advantage (Day & Wensley 1988). Therefore, the first issue to consider in the inter-organization R&D and marketing is the effect that it has on NDP.

Since the purpose of the inter-organizational R&D and marketing is to develop successful new products and solutions, integration mechanisms should work to achieve this end (Hernandez 2006). In addition, the quality of the relationship between R&D and marketing has had significant influence in NPD success. Despite more conformity between R&D and marketing causes more successful NPD projects, confliction of interdepartmental relationships leads to negative consequences (Souder 1988).

Even though interdepartmental integration is part of R&D and marketing department activities, what is meant by "integration" is understood differently. Some literature has attributed to an interaction perspective, where meetings and documented information exchange predict marketing department relationships among departments. Other literature has ascribed to a collaboration perspective, where teams and collective goals are prescribed. A third group of literature has suggested that integration is a composite of interaction and collaboration. Collaboration distinguishes successful performance and promotes marketing's satisfaction in working with other departments (Kahn & Mentzer 1998). R&D and marketing personnel depend on each other for the creation of new product innovations. Yet, R&D and marketing departments have frequent misunderstanding and conflicts (Souder 1988). Managers face some challenges while characterizing this relationship: differentiation and integration, environmental uncertainty, and R&D and Marketing's perceptions (Hernandez 2006). Companies have been using six general approaches to integrate the efforts of Marketing and R&D (Griffin & Hauser 1996). The integration approaches are:

- Relocation and physical facilities design
- Personnel movement
- Informal social systems
- Organizational structure
- Incentives and rewards
- Formal integrative management processes

Reviewing the literature related to the integration among three functional units of Marketing, R&D, and manufacturing, six factors are chosen as the basic components of integration which significantly affect new product performance. These six factors and their references which are listed and cited in the Table 6 have a significant contribution to build up the theoretical framework of this research because this also examines the effect of integrating relationships between R&D and Marketing on NPD.

Table 6. Integration factors of inter-organizationcollaboration activities which impact NPD

Factors	References
Trust, Commitment and Mutual Understanding	(R. Calantone et al. 2002)(Garcia et al. 2008)(Jassawalla & Sashittal 1998)(Rodriguez et al. 2008)(Ruekert & Walker Jr 1987)(Zhao et al. 2008)

Goal agreement	(Germain et al. 2008)(Jassawalla & Sashittal 1998)(Kahn 2001) (Nie & Young 1997)(Rodriguez et al. 2008)(Song & Thieme 2006)
Information and Knowledge Sharing and Integration	(R. J. Calantone et al. 2002)(Haas & Hansen 2007)(Hung et al. 2008) (Kahn 2001)(De Luca & Atuahene-Gima 2007)(Olson et al. 2001)(Rico et al. 2008)(Rodriguez et al. 2008)(Song & Thieme 2006)(Sundgren et al. 2005)(Swink et al. 2006)(Yang 2005)
Coordination and Communication Mechanism	(Fisher et al. 1997)(Rodriguez et al. 2008)(Germain et al. 2008)(Hong & Roh 2009)(Im & Nakata 2008)(Lakemond & Berggren 2006)(Lee & Chen 2007)(Leenders & Wierenga 2002)(Love & Roper 2009)(Maltz et al. 2001)(Parente et al. 2002)(Rico et al. 2008)(Ruekert & Walker Jr 1987)(Song & Thieme 2006)(Swink & Nair 2007)(Yang 2005)(Zhao et al. 2008)
Cooperation and Collaboration	(Daniel Sherman et al. 2005)(Garcia et al. 2008)(Lakemond & Berggren 2006)(O'Leary-Kelly & Flores 2002)(Love & Roper 2009)(Olson et al. 2001)(Sawhney & Piper 2002)(Smith & Felix Offodile 2008)(Song & Thieme 2006)(Swink & Nair 2007)(Tessarolo 2007)(Zhao et al. 2008)
Technical Integration Mechanism	(Briggs & Shore 2007)(Droge et al. 2004)(Duray et al. 2000)(Ethiraj et al.

	2008)(Gupta & Kohli 2006)(Liker et al. 1999)(Parthasarthy & Hammond 2002)(Smith & Felix Offodile 2008)(Swink & Nair 2007)

SOCIAL NETWORKS, INFORMAL INTEGRATION IN INTER-ORGANIZATIONAL COLLABORATION

The increasing attention on relationship between technological changes and environmental policy is partly because the environmental impacts of social activity are significantly affected by technological change, and partly because environmental policy interventions themselves create new constraints and incentives that affect the process of new product development (Jaffe et al. 2002). However, these approaches have been used in organizations, and recent studies have tried to evaluate their efficiency, yet, other approach to integration such as Business Network (Håkansson & Snehota 1989) and informal integration such as Social Network (Borgatti et al. 1998) needs more consideration. Collaboration and integration with business network approach has been discusses earlier in this work. In the following, a social network approach around integration is studied. Employee social networks have been introduced as a potential value driver in organizational performance (Bryan et al. 2007). A social network is defined as a set of people, organizations or other social entities which are connected by a set of social relationships, such as friendship, co-working or information exchange. The analysis of social networks focusses on the analysis of patterns of relationships among the social entities of the network (Marsden 2005). Jamali & Abolhassani (2006) studies a visual and a mathematical analysis of human relationships in social networks. Provan & Milward (2010) examined the network by a focus on organizations (nodes) and their relationships (ties), the absence of those relationships, and the implications of both for achieving outcomes.

Although most results of studies illustrate that no single grand theory of network exists (Monge et al. 2003), theorizing about network-related research can help to find out facts: such as the impact of dyadic or network ties on organizational performance, more valuable types of links and relationships to individual network members, more efficient network positions, the possible changing in network position in organizations in response to changes within and outside the network or organization (Provan & Milward 2010). Grandori & Soda (1995) developed six explanations of inter-firm organizational coordination with taking together the organizational studies. They introduced the degree of differentiation, intensity and complexity of interdependence, number of units to be coordinated and flexibility as approaches and antecedents of coordination. Moreover, the quality of binary, categorizing general, categorizing with labels and categorization in line production have been analyzed as four measurement scale of social network (Ferligoj & Hlebec 1999). In other research, Provan et al. (2007) introduced in-degree and outdegree centrality, closeness interdependence, multiplicity, broker relationships, and cliques as six levels of network analysis in the terms of structural issue of inter-firm context.

Categorizing different approaches to integration and evaluate them from formal and informal approaches, we can conclude that the social network as the humanity side of inter-firm networks has the role of informal approach. Therefore, a number of variables of inter-firm informal coordination for evaluating organizational network can be identified as the following:

- Differentiation
- Closeness and interdependence
- Complexity and Multiplicity
- Flexibility
- Cliques

2.4. COORDINATION MECHANISMS IN INTER-ORGANIZATIONAL COLLABORATION

Coordination as a vital aspect of collaboration has been considered in the literature of supply chain, to ensure that industrial collaboration efforts is both efficient and responsive to dynamic market needs, because coordination is focusing on resolving the task dependencies in a complex work setting (Crowston 1997). Van de Ven et al. (1976) defined coordination as integrating or linking different parts of an organization together to achieve a collective set of tasks. In another definition, National Science Foundation (1899) introduces coordination as “the joint efforts of independent communicating actors towards mutually defined goals” (NSF 1899). Various levels of analysis and perspective have been taken to study coordination. The primary research around coordination focuses on studying the various coordination mechanisms and clarifying which mechanism to be considered under certain circumstances (Thompson 2017; Thompson 1967)(Galbraith 1973) (Mintzberg 1979)(March & Simon 1958). Research within the field of organization and management theory contributed in advancement of the conceptualization of coordination (Lawrence & Lorsch 1967; Van de Ven et al. 1976). Organization sociologists have investigated managerial coordination at the organizational level of analysis (Van de Ven et al. 1976; Blau 1968; Thompson James 1967; Heydebrand 1973). Weber (1947) studied coordination with the perspective of measuring the degrees of structural integration considering the level of complexity, centralization, formalization or socialization, while some other scholars (March & Simon 1958) and (Thompson 1967) focused on conceptualizing and measuring processes of coordination. From the other aspect, scholars within the field of operations management explained coordination in operations management and product development. Fujimoto (1999)explained strategies of coordination in the product-development process of Toyota considering information-processing theory. Inter-firm coordination mechanisms have been analysed and introduced as fundamental key dimensions characterizing supply chain management by Danese & Romano (2004; 1996). Twigg (1998) studied the mechanisms that have been used to manage the design relationships within the design chain management and suggested the “design chain” concept, with a focus on importance of coordinating across multiple organizations participating in product development.

With the emergence of supply chain collaboration paradigm and the focus on coordinating suppliers’ product development processes within a design chain, Twigg (2002; 1995; 1996) proposed a typology of inter-firm mechanism to integrate design and manufacturing operations in product development. Hines (1994) argues that the ability to coordinate suppliers’ product development design activities is can be a source of competitive advantage. The studies around supplier involvement have suggested three supplier integration strategies (Petersen et al. 2005)(Koufteros et al. 2007): white-box; gray-box; and black-box. This has been analyzed in “Supplier Involvement” section in this research.

The supplier integration strategies give a basis for the dyadic arrangement between a buyer and a supplier with consideration of specific component, regardless of the issue of the interdependent nature of developing multiple components with multiple suppliers.

Coordination mechanisms in supply chain collaboration has received some attention in literature. Twigg (1996) introduced different coordination mechanisms that a manufacturer uses within a “design chain”. Table 7 illustrates the coordination mechanisms they identified within their study.

Table 7. Inter-firm coordination mechanisms identified by Twigg (1996)

	Pre-project	Design phase	Manufacturing phase
Technological	Electronic data interchange CAD/CAM data exchange		
Organisational	Supplier development team Joint development Technological gatekeeper Supplier development committee	Guest engineer Joint product/process design team	Resident production engineer
Procedural	Cost management Supplier assessment	Producibility design reviews Sign-off Designer's tacit knowledge of manufacturing	Engineering changes Production prototypes (fit-build-test cycles) Manufacturing flexibility

Lawson et al. (2009) studied method of facilitating knowledge sharing with inter-organizational NPD teams with a focus on informal rather than formal socialization mechanisms. In other study Danese & Romano (2004) analyzed coordination mechanisms for managing business processes an inter-organizational network of suppliers.

There are some studies around coordination mechanisms with a focus on the concept of new product development and particularly, multi-organizational product development activities. Fujimoto (1999) defines product development as a cumulative process of creation and transmission of information with the purpose of converting market needs and technological opportunities into actual products. The product development processes typically consist of four stages: product conceptualization; product planning; product engineering; and process engineering. Yet, the progress of product development includes overlaps and feedback loops.

In a fully sequential process of new product development, uncertainties are resolved over time. Yet, many organizations, due to the presser on reduction in lead-time, are not able to wait to achieve required information for each step before moving to the next step and initiate downstream activities (Hong et al. 2009). This brings pressure on companies to make decisions on the time and level of accuracy of the shared information between partners (Terwiesch et al. 2002), and consequently the importance of strong coordination. In new product development, market needs are transformed into an actual product through a cumulative process of information exchange, decision-making, and problem solving among the manufacturer and multiple suppliers. Therefore, the information-processing dimension of the coordination has emerged considerably in the literature of coordination structure. In the following, different modes of coordination suggested from different scholars are explained.

ALTERNATIVE MODES OF COORDINATION

In order to identify coordination mechanisms in related to analyzing the information-processing structures, Galbraith (1977) categorize the information-processing structures in two groups: To reduce the need for information processing; and To increase the capacity to process information.

The mechanisms around managing uncertainty in the working environment, such as create self-contained tasks and standardization of work processes or outcomes (Galbraith 1977) and (Mintzberg 1979), are classified as the activities to reduce the need for information processing. In different circumstances, investments in information technology systems, establish lateral relations such as boundary spanners and co-locate resources such as using team meetings (Hoffer Gittell 2002) and (Mintzberg 1979) are considered as the activities to increase the capacity to process information.

March & Simon (1958) suggest two basic coordination mechanisms in the information-processing perspective in which organizations can be coordinated: by programming or by feedback.

Coordination by programming refers to pre-specifying multiple actions, such as the use of pre-established plans, forecasts, formal regulations, policies and procedures, and standardized information and communication systems. The coordination mechanisms by programming emphasise on the specifying of codified blueprint of action is impersonally. Therefore, the understanding from the blueprint are immediately perceives where human judgment does not get involved into the determination of what, where, when and how roles are to be articulated to accomplish a given set of tasks (Thompson 1967; March & Simon 1958). Furthermore, due to the impersonal mechanisms of coordination, minimal verbal communication among participants is needed to implement the use requires (Galbraith 1973).

Coordination by feedback refers to the mutual adjustments based on new information (Thompson 2017; Thompson 1967). Coordination by feedback consists of a less clear construct and typically initiates from roughly specified tasks. Van de Ven et al. (1976) introduced two operational modes for developing plans and applying mutual adjustments in organizations: a personal mode and a group mode. The personal mode refers to the situations that individual participants operate the mechanism for applying mutual task adjustments through either vertical or horizontal channels of communication. The group mode is considered when the mechanism of mutual adjustment is performed in a group of participants through scheduled or unscheduled staff or committee meetings.

Considering the personal mode for evaluating coordination processes in organizational, both vertical and horizontal patterns of communications have been considered in the literature. The vertical communication mechanisms, typically refer to line managers and unit supervisors (Thompson 2017; Thompson 1967), while horizontal communication channels are defined when an individual unit member communicates directly with other actors in a non-hierarchical relationship on a one-to-one basis. The non-hierarchical coordination can take place in a designated coordinator, integrator or project expeditor, where the formal authority are not specified over the individuals whose activities require coordination (Van de Ven et al. 1976).

Following March & Simon (1958) classification, Argote (1982) suggested two methods for coordination: programmed and non-programmed means. The program mean of coordination refers to the advancement of specifying the activities. Coordination methods consists of rules, scheduled meetings, and authority arrangements are categorized in programmed means, while coordination methods such as the autonomy of organization members, general policies of the units, and mutual adjustment are categorised in non-programmed means of coordination.

In the context of inter-organization collaboration, in product-development projects, programming can be specified as schedule and the deliverables for each design initiative. There are different methods to define deliverables, such as identify them based on the components in terms of physical dimensions rather than functional requirements. In this way, providing detailed specifications of the expected outcome of suppliers' development work is categorized and programs in advance. Moreover, plans and a structured process can be identified as coordination mechanisms based on programming in inter-organizational product development activities. O'Sullivan (2006) suggests implementing standardized administrative processes for each design team, in a co-designing practice with suppliers, ensure a convergent expectation on emerging designs.

Coordination by feedback in the context of inter-organization collaboration, in product-development projects involves interactive problem solving and modifying components based on new design ideas and findings (Hong et al. 2009). In this approach, the upstream phases of a project are jointly identified with the firm and its suppliers during the conceptualization phase of product architecture. In this stage the product's subsystems and their interfaces are identified. The coordination of the co-design effort is done by linking subsystem development to achieving minimum-defined product functionalities. The feedback and interface-by-interface interaction between suppliers may take place informally and on an as-needed basis. In the case of complexity of the design problem, no supplier or the manufacturer are not able to determine the components detailed specifications or interface on their own. As interdependency issues emerged, it was frequently complicated to specify which portion of the design work fits to which of any two interfacing subsystems. Therefore, suppliers prefer to discuss these issues with the manufacturer firm or other suppliers to clarify the tasks. The joint-adjustment and interactive problem-solving take place with no pre-planning (O'Sullivan 2006).

Later studies within the field of product development project management, coordination methods and product development management activities are classified into planned management and emergent management styles (Lewis et al. 2002). The confirmatory factor analysis of Lewis et al. (2002) research suggested that an emergent management style and a planned management style are distinct approaches to project monitoring, evaluation, and control. Figure 6 illustrates the contrasting styles of project management from the perspectives of emergent style and planned style.

Emergent Style		**Planned Style**
Monitoring Understandings Tracking emerging project skills, knowledge, and focus	**Monitoring**	*Monitoring Milestones* Comparing progress to predetermined standards and goals
Information Gathering Boundary spanning and environmental scanning by team members	**Evaluation**	*Formal Review* Systematic assessment of project by top managers and/or review board
Participative Control Team autonomy, discretion, and decision-making accountability	**Control**	*Directive Control* Close managerial involvement in project details, feedback, and adjustments

Figure 6. Contrasting styles of project management in product development (Lewis et al. 2002)

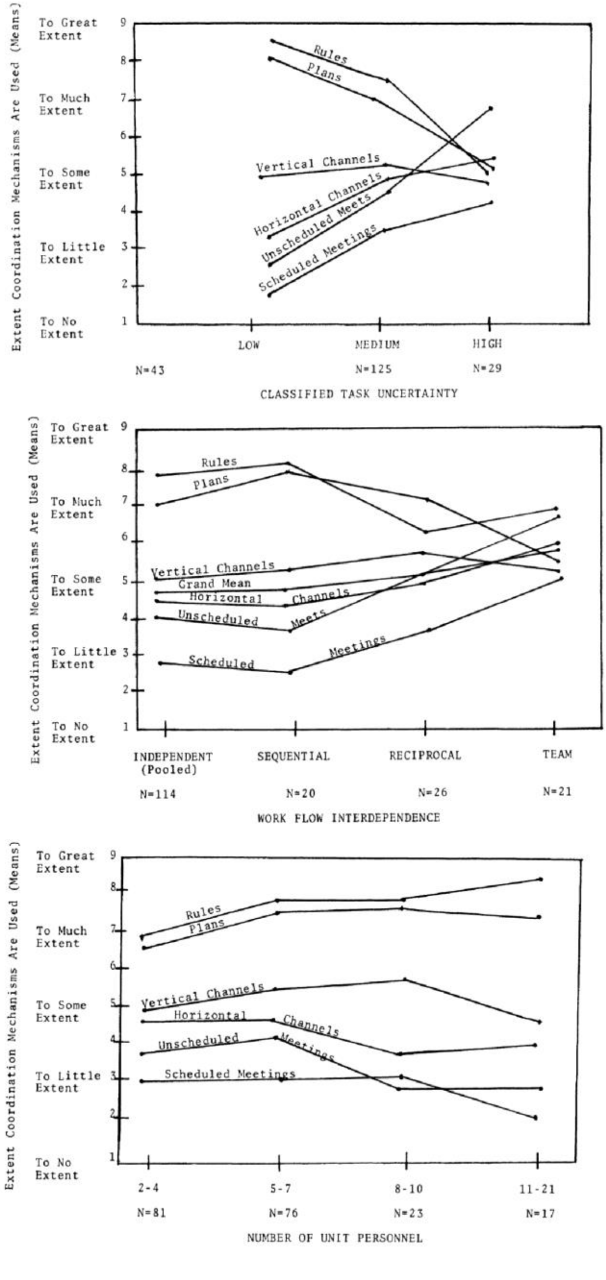

Figure 7. the profile of coordination mechanisms based on the level of each determining factor by Van de Ven et al. (1976)

Van de Ven et al. (1976) investigated variations and interactions in the use of the coordination mechanisms and modes considering task uncertainty, interdependence and unit size and argues that the mix of alternative coordination mechanisms used within organizational units is different based on the degree and kind of influence of each determining factor. Figure 7 illustrates the profile of coordination mechanisms based on the level of each determining factor.

Mintzberg (1979) suggests prescriptions take the form of job descriptions, procedures, routines, protocols, or rules. The formal constraints, on one hand, can be burdensome, where they can be a cause of apathy, absenteeism, and resistance (Argyris 2017). On the other, they support predictability, uniformity, and reliability. Therefore, organizations are facing the key decisions on how to group people into working units. Mintzberg (1979) suggests several basic options which are listed in the following:

- Function: Groups based on knowledge, skill, competence or functions they bring to the project, as in the case of academic departments or industrial units of research, engineering, manufacturing, marketing, and finance.
- Time: To define the units based on the time they perform their work, as by shift (day, swing, or graveyard shift).
- Product: Units identified based on what they produce, such as detergent versus bar soap.
- Customer: Units are formed around customers or clients they serve, as in hospital zones created around patient type, mobile service providers organized by customer (corporate, government, individual).
- Place: Units are established based on the geographical area, such as regional or international departments in corporations and government agencies.
- Process: Units are identified based on a complete work flow, as with the order fulfillment process which consists of process flow as order initiation by a customer, through the functions, to delivery to the customer (Galbraith et al. 2002).

In other research, Mintzberg (1993) introduces three basic coordinating mechanisms (

Figure 8): mutual adjustment, direct supervision, and standardization (of which there are three types: of work processes, of work outputs, and of worker skills).

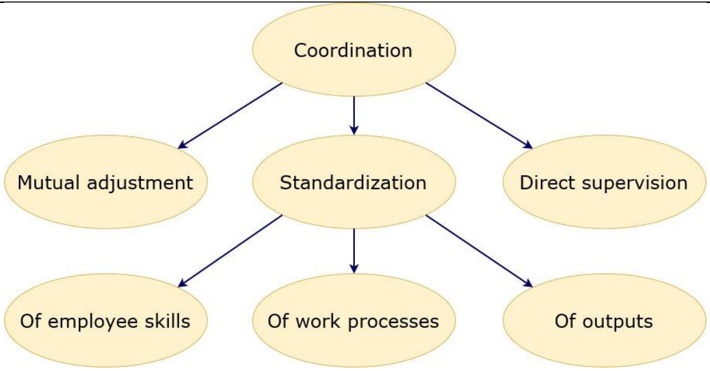

Figure 8. Three basic coordinating mechanisms by Mintzberg (1993)

Mutual Adjustment

Mutual Adjustment is based on the simple process of informal communication. Mutual adjustment typically is used in small companies, such as a 5-person robot development company, or in the case that the task is highly complicated, for instance a Mars landing project. Mutual adjustment is considered useful when no one certainly knows ahead of time how to perform the task they are doing.

Direct Supervision

Direct suppercision coordinations is accomplished when one person take responsibility for the work of the others, giving instructions and guidelines and monitoring their actions. In cases that the organization is large, it is not possible that one person take case of all the members, therefore, multiple leaders or managers will be used. In this set-up there will be a manager who coordinate the leaders.

Standardization

The coordination theroug tandardization mechanism is achieved "on the drawing board" not during the action. The coordination is pre-programmed based on one of the following ways:

Work Processes. This mechanismes is focused on standardization of the work flow or work procedures. As an example, the machinery process in a manufacturing site can be effectively standardized.

Outputs. Standardized outputs referes to specifing the characteristics which the product or work output must meet.

Worker Skills. This coordination mecanism I sbased on the the professiency of the skilled workers as they perform the tasks exactly the same way. Therefore, other employees or participants can rely on the skilled workers to do things the standard way, which allows others to coordinate smoothly with them.

The use of the coordination mechanisms based on the task complexity

Mintzberg (1993) suggests simple tasks can simply be coordinated by mutual adjustment. As the tasks become more complicated, direct supervision needs to be included and takes the responsibility of the primary means of coordination. By the time things get even more complicated, standardization of work processes, outputs or skills (or in combination) become the primary coordination mechanism. In highly complicated situations, mutual adjustment become primary coordination mechanism again. Yet this may become in combination with the other mechanisms. Figure 9 illustrates the use of the coordination mechanisms based on the task.

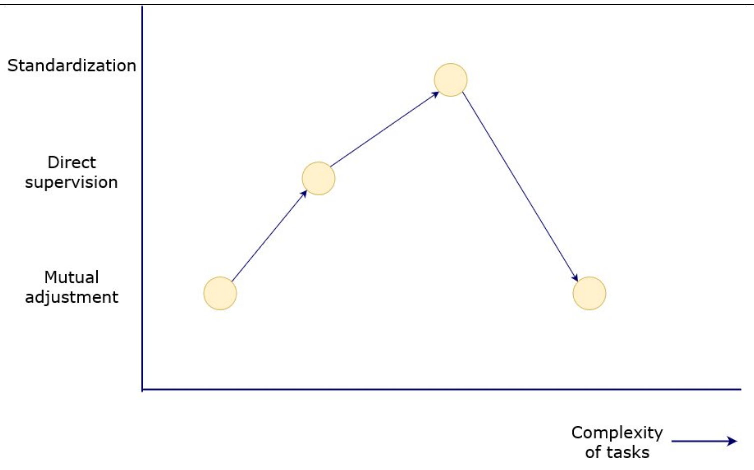

Figure 9. the use of the coordination mechanisms based on the task Mintzberg (1993)

The proposed mode from Mintzberg (1993) clarifies the dynamicity of coordination mechanisms based on the complexity of the tasks and project which is highly considered in this dessertation. Yet implementation of coordination mechanisms and modes of collaboration, particularly within the empirical context of this research is an ongoing issue.

LOCUS OF CONTROL AND DECISION-MAKING AUTHORITIES

Locus of control refers to the who owns decision-making authorities and may be centralized or decentralized and can be located at different participant roles. Price (1997) suggests a centralized structure is considered when the power of decision-making is concentrated on a focal point, while decentralized structure is considered when the decision-making authority is diffused across an organization.

To declare the centralized or decentralized coordination mechanisms, scholars such as Hart & Holmstrom (2010) emphasize on the trade-off between coordination and the private benefits of acting independently. Hart & Holmstrom (2010) argue under centralization strategies, decision makers may overlook the private benefits that division managers could realize if they act independently, while under decentralized strategies, division managers do not fully internalize the benefits of coordination. Authors such as Mintzberg (1979) introduced centralization as an effective coordination mechanism. Mintzberg (1979) argues that centralization is the strongest mechanism of coordinating decision-making in the organization.

In the context of inter-organizational collaborations, suggests that the centralized network improves the effectiveness, when integration and coordination take place from the top down.

Yet, decentralized coordination mechanisms are realized as more efficient mechanism when the decisions cannot be understood at one center or when the knowledge and expertise of local participants are under-utilized (Mintzberg 1979). Bolton & Dewatripont (2013) with a focus on the use of local information, suggest decentralization is beneficial at selecting a low-cost entrant but also results in inefficient delay and duplication of entry. Decentralization can be an incentive for motivation, in which it leaves room for flexibility to be creative and intelligent at agents (Mintzberg 1979). Furthermore, decentralization can speed up the process of decision-making and improve responsiveness to external changes while typically decision-making is slower in a centralized set-up, due to the required time to collect required information for the center (Hong et al. 2009). In the context of supply chain collaboration, locus of control can be referred to the authority or power of a manufacturer firm over the network of suppliers. Manufacturer may select centralized control mechanisms to control the design of the components that the suppliers produced or decide on decentralized control mechanisms to maintain the designing responsibility at the suppliers (Choi & Hong 2002).

Looking at the concept of information-processing capacity, the centralized mechanism suggests a company to increase the capacity of its hierarchy to process more information while a decentralized mechanism suggests a decentralized interdependence by employing lateral forms of coordination to increase the information-processing capacity (Galbraith 1974). Yet, the global competitiveness and the IT revolution which dramatically have shifted the world of business and emerged the new multidimensional perspective of organizational design (Galbraith

2012; Strikwerda & Stoelhorst 2009). Consequently, the definition of organizational design became more broadly where differentiating and integrating units have become one of the main tasks of organizational design. By increasing the coordination and complexity issues in all types of companies, there is a need for methodology to coordinate these units and in the same time, to achieve the firm's multiple strategies. Galbraith (2012) suggests three emerging coordination mechanisms to overcome the new challenges of organizations:

1. Organizations to use both types of coordination mechanisms where hierarchy is enhanced by "two-in-a-box" structures and by multi-dimensional planning and resource allocation schemes. He studies the example company as Monsanto that uses two-in-a-box management structures, in which business units are run by a general manager combination of a bio scientist and a sales/marketing person.
2. To manage interdependence is through an extensive lateral organization. Lateral mechanisms may include simple informal relationships to formal teams and, finally, to complex matrix processes. collaborative software and video conferencing, and automated business processes facilitate the lateral mechanisms.
3. Redesigned of the human side of the organization with focus on culture of collaboration. This can be done by developing shared values that guide decisions without the need for communication between interdependent units and managers, promotion processes and creating collaborative managers, rotations to create the personal networks to support things done in these multi-dimensional organizations.

The innovation complexity and information-related conditions may impact the introversion role and the decision power of coordinator while match different partners and suppliers in an inter-organizational collaboration. Von Hippel (2005) analysed the conditions and their predictability over innovation life cycles. Utterback & Abernathy (1975) proposed that in the early stages of innovation cycles the process is fluid, where the relationship between process elements and partners is loose and unsettled on an as-needed basis. The system is organic and responds easily to environmental change, but necessarily has "slack" and is "inefficient". In this stage, the complexity raises, and the problem needs to be solved in collaboration of expertise diversify of suppliers. The coordination focuses around the key integration and the decision power will be centred within the coordinator, while the customer organization play a big part in sorting the matter out, in part through innovation (Utterback & Abernathy 1975; Von Hippel 2005). Later, a dominant design will emerge with a shared understanding of exactly what a particular solution is, what features and components it should include, and how it should function (Von Hippel 2005). Therefore, innovation will shift from product to process as firms shift from the problem of how to solve the issue and what to produce to the problem of how solve the issue in an optimum way and to produce a well-understood product in ever greater volumes. From the innovation perspective and user of innovation, both functionally novel products and functionally novel processes are likely to be led by the user organization (Von Hippel 2005). In this situation, the coordination may canter around mediators, where the coordinator has the role of allowing partners and suppliers to find each other. The decision power in mainly remained within the parties with help of the coordinator as a third party.

BUSINESS MODELS

Corporation business models are made based on a plan to offer product or services to a market and to generate profits. Therefore, companies need to maintain their level of innovativeness in their respective business models with respect to new ways of creating and capturing value for their stakeholders (Sabatier et al. 2010).

Since a key value creation proposition is the technological advancement, organizations need to adjust their business models to the new technological realities (Teece 2010). One approach is to articulate the market in which the business models operate and place them within a value network of suppliers and customers (Chesbrough 2010). \Oiestad & Bugge (2014) argue that companies use business models to get an understanding and response to the market and its needs as well as to get a logical architecture behind their production and supply of a product. Business networks (Håkansson & Snehota 1989) and digitalization offer new strategies to enable new business models to be developed by adopting innovations developed under information and communication technologies (Rayport & Sviokla 1995). Companies to achieve competitive success and maintain their sustainable development within the environmental changes, need to stay more dynamic and flexible (Cavalcante et al. 2011). Recent approaches to innovative business models have an emphasize on the inter-organizational collaborations and open innovation culture (Chesbrough 2010). In this approach, companies expand their business model capacity in a knowledge economy by identifying new business opportunities in collaboration with other organizations with new ideas, techniques, products and services, and with new logics of value creation (Massa et al. 2017).

OPEN INNOVATION PARADIGM

The new paradigm of open innovation (Chesbrough 2006) has been slowly replacing the traditional model (Moore 1996). Open innovation paradigm argues that companies through the acquisition of new ideas from external knowledge sourcing adapt to changes in the complex business environment (Chesbrough 2006). Open innovation can be seen both in large enterprises and in smaller organizations. Open innovation could have a much larger influence on SMEs due to many technological challenges and their relatively small financial resources for research activities. This gives them a chance to accumulate both capabilities and resources. Van de Vrande et al. (2009) examined the main motives for pursuing co-operation in innovation in SMEs. Their conclusion shows market-related reasons such as meeting customer demands or keeping up with competitors play a more important role in collaboration formation. In addition to accumulating financial resources, SMEs, in comparison to large firms, face more challenges in attracting highly-skilled specialists (Van de Vrande et al. 2009). Small firms usually focus on core competency areas and develop their capabilities with a certain focus on these areas. Therefore, in many cases, SMEs prefer to outsource other non-core actions. Expanding networks of potential partners gives

SMEs to the possibility of finding missing capabilities and acquire more innovative resources. Organizations, specifically SMEs, that open up their boundaries have the possibility to position themselves as important players in the modern innovation landscape (Van de Vrande et al. 2009). That is why our research has examined technology exploration in the form of production process improvement through a collaborative automation project.

2.5. LEAD INTEGRATOR

As it has been mentioned, companies need a level of collaboration with supplier networks for complex solution development. This gives them access to the specific knowledge of the subassemblies and capabilities needed for a specific development. This new level of partnership, particularly within manufacturing companies and automation solution suppliers focuses on the engineering skills gap needed for production process improvement. This has led to a new model of partnership and actor definition, called "lead integrator" (Gurney 2014). The lead integrator approach has shifted the traditional buyer-supplier collaboration, where the collaboration is formed on a project-to-project basis. In the lead integrator approach, the automation solution suppliers have changed their role to perform planning, defining and implementing of an automation roadmap which often looking forward as much as five years (Gurney 2014). The lead integrator gets involved in understanding and determining the specific manufacturing processes and business drivers of the customer while utilizing the automation expertise within the process. The lead integrator performs as the controls and automation engineering arm for the manufacturer and focuses on technology developments and emerging technologies which may benefit the customer (Gurney 2014). The role of a lead integrator is investigated further in this research from two aspects. The imperial finding of this research further describes and qualifies the extant approaches to the role of lead integrator as a lead partner in automation decision practise (Gurney 2014). Furthermore, a dynamic view of the role of lead integrator is considered in this research. This view suggests a new interpretation of the role of lead integrator based on the new identified challenges, dynamicity of coordination mechanisms (Mintzberg 1979; Mintzberg 1993) and requirements in automation and digitalization decisions. In this research, the importance of the role of lead integrator as facilitator of informal communication, as mutual adjustment coordination mechanism (Mintzberg 1979; Mintzberg 1993) in buyer-supplier collaboration is investigated.

2.6. COLLABORATION QUALITY

Buyer-supplier collaboration quality can be defined as the extent to which customer and supplier groups synergistically exploit shared resources while minimizing invaluable efforts through interactive planning and execution processes during the project course (Yan & Dooley 2014). Successful collaboration in an innovative project can be related to factors such as the structure of the alliance (Suseno & Ratten 2007) and processes that promote cooperation and the transference of knowledge (Child & McGrath 2001). Such collaborations depend on mutual job-related interests. Thus, there is a requirement for intrinsic incentives to share knowledge (Swift & Hwang 2013). This knowledge sharing among companies depends on mutual respect, shared values, perceived competency (Reagans & McEvily 2003) and a level of mutual trust between partners (Das & Teng 1998). The mutual trust has received widespread attention in the literature on buyer-supplier relationships, relationship marketing, strategic alliances, business-to-business relationships, and investigations of importer-exporter relationships (Bianchi & Saleh 2010; Suseno & Ratten 2007; Morgan & Hunt 1994; Voss et al. 2006; Brenic & Zabkar 2004).

Some other studies around buyer-supplier collaboration quality mainly focus on examining the contextual issues at both interfirm and project levels which influence the effectiveness of buyer-supplier interactions. A collaborative buyer-supplier relationship is generally argued to be critical for joint project success at the interfirm level (Yan & Dooley 2014; Primo & Amundson 2002; Petersen et al. 2005). Likewise, at the project level, buyer-supplier *congruent goals* and *complementary capabilities* contribute to joint NPD success by enabling synergistic exploitation of interdependent resources in groups (Sivadas & Dwyer 2000; Rothaermel & Deeds 2004). Heimeriks & Schreiner (2002) defined collaboration quality as specificities of alliance characteristics, which have significant positive effects on alliance performance. They have introduced the key components of collaboration quality, including (1) resource configuration, (2) compatibility of partners, (3) coordination features, (4) level of trust, (5) level of commitment and (6) level of information sharing and communication. In another study, Yan & Dooley (2014) constructed collaboration quality based on the "teamwork quality" construct which was developed by Hoegl & Gemuenden (2001). Yan & Dooley (2014) model is formed based *on resource dependence theory* to formulate interfirm and project-level antecedents of buyer-supplier collaboration quality. They argued that goal congruence, complementary capabilities, and interfirm coordination positively impact buyer-supplier collaboration quality.

2.7. IMPLEMENTATION OF THE NEXT GENERATION OF MANUFACTURING TECHNOLOGIES

In today's reality, manufacturing companies are challenged with increasingly dynamic market requirements. The challenges that are fundamentally disrupting the existing competition and value-creation rules (Porter & Heppelmann 2014). The globalization and the expansion of current emerging markets affect global competition and economy. Only companies keep their substantial advantage over competitors that understand customers' changing prospects and react upon them fast with an appropriate product set (Coe & Yeung 2015; Stalk et al. 1990).

Therefore, new approaches to production and new manufacturing concepts and technologies have begun to be implemented increasingly extensively in the manufacturing industry, to comply changing business environment and market demands. Factors like changes in energy price and trade structures, internationalisation of the market and the growing sophistication of customers, Clark (1991) has increased demands for product variety while the volume per model has dropped, consequently, the product life times has been decreased. These trends are critically impacting small and medium sized (SMEs) manufacturers which are supplying larger companies with specialized solutions. SMEs in general, are more flexible in manufacturing in comparison to larger firms; which enable them to provide more customised products, with a low production volume of a wide variety, yet, to stay competitive, the SME manufacturers are forced continuously to automatize and streamline their production setup. The two major instantaneous opportunities are a. the application of flexible automation solutions, and, b. The presence of the current state-of- the-art of Industry 4.0 technologies.

Prior to 2011, use of automation as improvement driver for production performance was the focus in the manufacturing domain. Focusing on automated solutions, increasingly have incorporated computers for control of both manufacturing and administrative processes. Emerging technologies have been growing up their applicability in the manufacturing environment, due to their increase capabilities and decreased sale price and physical dimensions. Researchers and technology suppliers have realized the potentials of new technologies and made a lot of efforts in applying and implementing them in the manufacturing industry. This has led to defining a new vision of disruptive perception of manufacturing plants and factories. The recent development creates what has been called a *smart factory* which is becoming a key topic within the manufacturing ecosystem. Wadhwa (2012) proposes guidelines for flexible automation, basing on an action research approach. He suggests that the guidelines could improve foundries' responsiveness in addition to support interaction between different collaborative partners. Radziwon et al. (2014) give a review on the adoptive and flexible manufacturing and the usage of smart with respect to technology. By referring to smart factory visions with respect to both product/process technology and organization, they define a smart factory as:

> "A Smart Factory is a manufacturing solution that provides such flexible and adaptive production processes that will solve problems arising on a production facility with dynamic and rapidly changing boundary conditions in a world of increasing complexity. This special solution could, on the one hand, be related to automation, understood as a combination of software, hardware and/or mechanics, which should lead to optimization of manufacturing resulting in a reduction of unnecessary labour and waste of resource. On the other hand,

> it could be seen in a perspective of collaboration between different industrial and nonindustrial partners, where the smartness comes from forming a dynamic organization."
> *(Radziwon et al. 2014)*

Bilberg et al. (2017) conducted research on Danish manufacturing SMEs with a focus on improvement on innovation and competitive advantage through collaboration and applying new technologies. They argue with the concept of Smart Factory, SMEs require to collaborate on new products, markets, and production or supply chains within a creative organization. They also suggest that smart factory is working via an organic set-up where adjustments to new projects and customer requirements (Bilberg et al. 2017).

The term *Industry 4.0* has been introduced in 2011 for the first time and on the basis of an advanced digitalization within factories, the combination of Internet technologies and future-oriented technologies in the field of "smart" objects (Lasi et al. 2014). Since then, Industry 4.0 has been an extensive and comprehensive term, therefore, a widespread discussion has been emerged around it (Sauter et al. 2016). In the "The Fourth Industrial Revolution", or Smart Manufacturing, a virtual copy of the physical world is created by digital technology within a smart and easy process to enable decentralized decisions in the intelligent manufacturing environment and create networks related to strategic and operating values. This encourages companies to totally reconsider their business approaches (De Carolis 2017). Industry 4.0 merged the virtual and real work by integrating horizontal data flow between partners, suppliers, and customers as well as vertical integration through the organizational frame and processes, from development to product release (Hozdi'c 2015). Sauter et al. (2016) studied the impact of the industry 4.0 concept on the production-related value creation processes. They suggest in some cases the industry 4.0 concept, by creating a great decentralization and flexibility in production performance management, heavily impact the value chain as well as operative and strategic performance management (Sauter et al. 2016).

Industry 4.0 as a continuous development of the Internet of Things (IoT), enables the physical and digital worlds to converge within different layers of production to completely transform the manufacturing operations.

In addition to the possibility of connecting devices, a wide range of opportunities can be realized. The transformation in operational processes can create greater value through generating higher productivity, efficiency, quality, human factor, and flexibility which is only possible to be achieved through solutions based on a new layer of connectedness.

The new technologies get align with some new set of requirements for the automation solution suppliers who work in this evolving market. In addition to the solution suppliers and automation suppliers, the manufacturing companies are experiencing new challenges.

Today's manufacturers are transforming from being perceived as a production-centred operation to a human-centred business with a greater emphasis on creating core value for human stakeholders such as workers, suppliers, and customers being in the loop (Zelm et al. 2012). Therefore, the growing complexity of the manufacturing processes and the supply networks, the higher level of contradictions while balancing flexibility (Wiktorsson et al. 2016), cost pressures, growing user and customer expectations for quality, speed, and custom products, as well as worker safety and assistance, are some of the highlighted challenges that manufacturers are facing today, which need to be considered in implementation of the next generation of manufacturing technologies and collaboration and coordination mechanisms in this field.

Chapter 3.

Research Design Methodology

3. RESEARCH DESIGN METHODOLOGY

To address the research objectives, different research methods were applied. In the following section, the methodological departure of the study is elaborated. The consideration is on the overall research design and operationalization. Furthermore, in the following section, a detailed clarification of the methodology, data collection, and analysis applied in each study step is explained.

3.1. DEVELOPMENT OF RESEARCH THROUGH STEPS OF THE INVESTIGATION

The following section synthesizes the steps of investigation followed during the development of the research idea. In view of the research questions, some actions are required to be addressed, the schema shows the sequence of the steps performed and the methodological approach supporting them (Figure 10). The overall methodological approach followed for conducting this research required the combination of different research methodologies.

This dissertation examines the formation of collaborative automation practices and explores the characteristics of buyer-supplier collaboration in automation practices, actors and the challenges as well as the way they get facilitated through a systemized process for business assessment of innovative automation project.

It studies how an idea for an automation project is formed and evaluated at a manufacturing firm and how this evolved and get influenced through collaborations and interactions that take place between heterogeneous actors in the organized behavioural system of buyers and suppliers.

This study seeks to understand collaborations and interactions between different actors, therefore, the paradigmatic stance is to be more subjectivist and qualitative methods are used in this research work (Morgan & Smircich 1980). Furthermore, theoretical research, conceptual development and multiple literature reviews of existing knowledge will be conducted.

This thesis aims to design, implement and deploy the automation business assessment model for SMEs and a digital platform based on the model to assist manufacturing companies in exploiting automation opportunities by structured knowledge search, qualification, and decision-making (tools) and easy access to local as well as international relevant expert knowledge and suppliers. Therefore, this research aims at developing an automation business assessment process model with integration of the inter-organizational collaboration and coordination theory and a guideline on how to implement coordination and collaboration within the empirical context of this research. The perspective of this research aim at offering new theoretical insights on the outcomes of buyer–supplier collaboration relationships that go beyond the current explanations based on business networks (Johanson & Mattsson 2015) (Håkansson & Snehota 1989), social network theory (Gulati & Sytch 2007) (Nohria & Eccles 1992; Gulati & Sytch 2007) (Larson 1992), the relational view and special supplier (Dyer 1996) and coordination theory (Utterback & Abernathy 1975; Von Hippel 2005)(Mintzberg 1979) (Twigg 1996; Twigg 2002; Twigg 1998). To achieve this aim, this thesis is based on the *action research methodology* and *qualitative studies*, due to the novelty of the discussed subject and the absence of research, particularly withing the field of methods for implementing coordination mechanisms and collaboration within the empirical context of this research.

To answer the research questions and because the researcher actively participates in the automation business assessment process model development by producing knowledge for the host company, the research method is *action research*. The action research is simultaneously studying the phenomenon and creating organizational change, whereas other research methods mainly focus on studying organizational phenomena but not to change them (Heikkilä 2010). The host company has been playing the role of lead integrator by the time of the research. An automation business assessment process model, as one of the academic and practical contributions of this research, was considered as one of the phenomena to create organizational change and form a business unit within the host organization. The researcher has been responsible for developing the process model, knowledge production and exploitation within the organization and participate in the business decisions and setting up the developed process model for the host company. As in action research, the researcher and the research object in the host company has been interactively connected so that the findings of the research are created while the investigation proceeded. The researcher is actively taking part in building the automation business assessment process model within the host company which is the object of the study described in this thesis. The research worked is aiming at making determined use of propositions, models, and theories, as well as to question if they are valuable in practice. The theoretical reasoning and the research results is moved back and forth between empirical discovery, theory, test and validation. The action research methodology is described further in section 3.3.

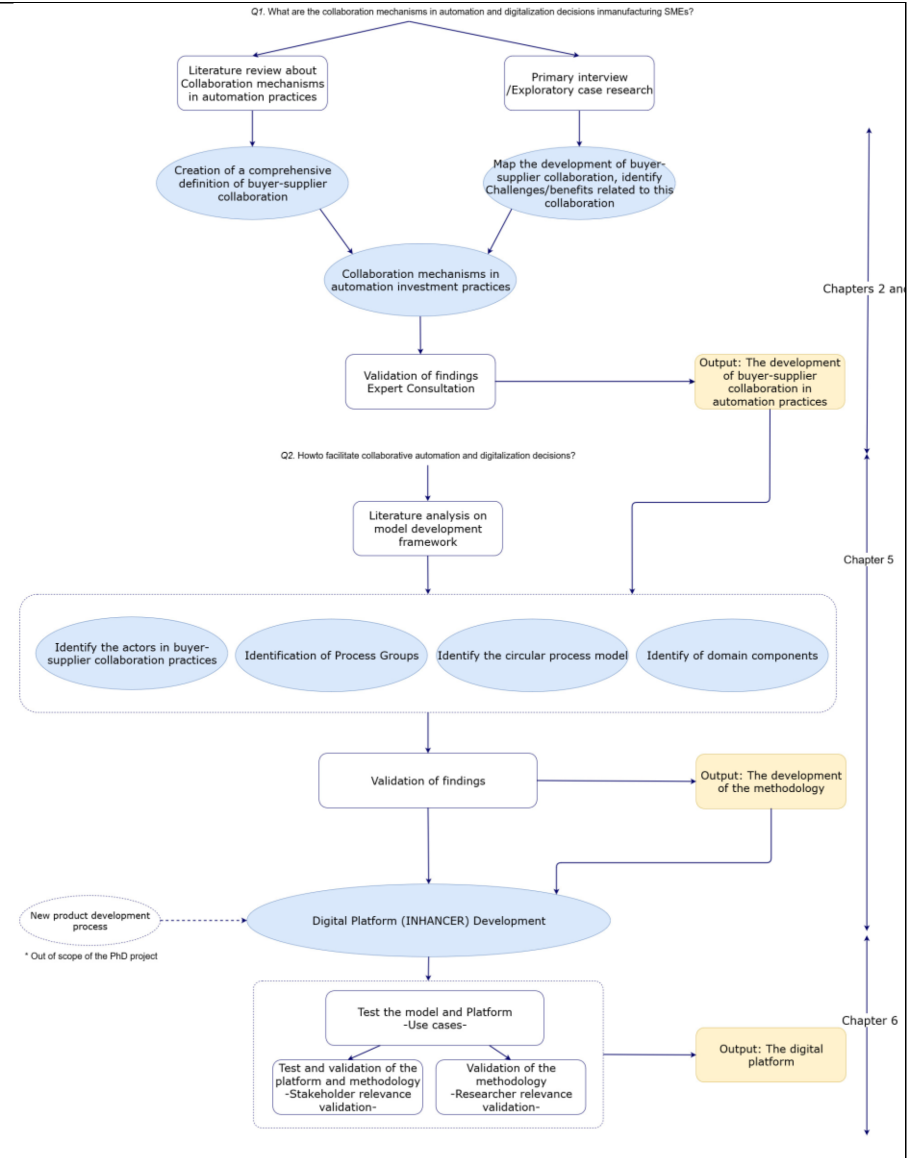

Figure 10. Development of the research through steps of the investigation

3.2. THE CHRONOLOGICAL PERSPECTIVE OF THE RESEARCH

This chapter focuses on describing how the research objectives and research questions are presented and answered through the research project in a chronological perspective of the Ph.D. project. To do so, the project schedule, including the tasks to be carried out is presented in Figure 11.

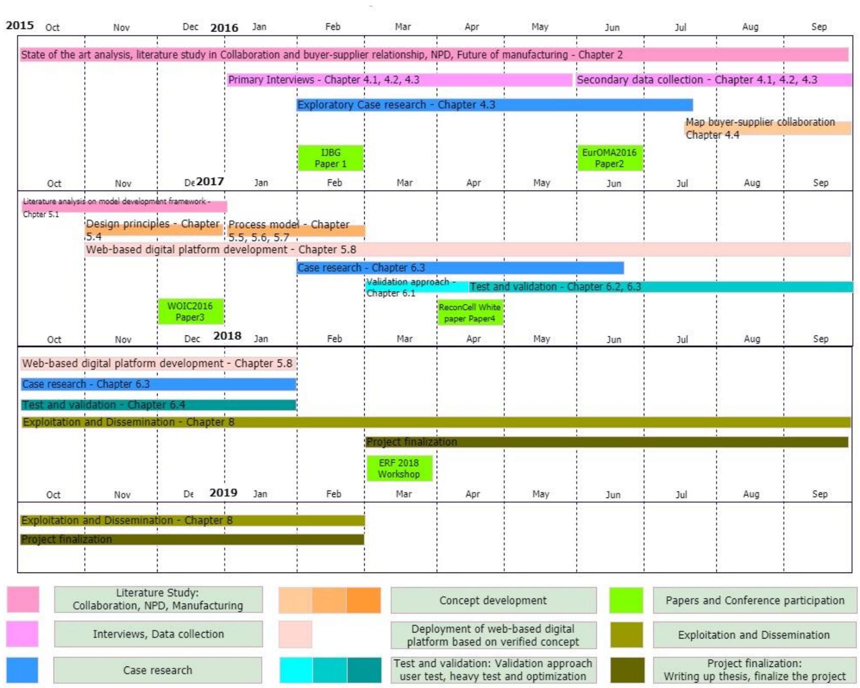

Figure 11. The tasks perfumed to carry out the Ph.D. project

The presented project task overview helps in explaining how the Ph.D. thesis was developed.

3.3. ACTION RESEARCH

According to Shani & Pasmore (1985), the main themes of action research can be captured as:

Action research may be defined as an emergent inquiry process in which applied behavioural science knowledge is integrated with existing organizational knowledge and applied to solve real organizational problems. It is simultaneously

> *concerned with bringing about change in organizations, in developing self-help competencies in organizational members and in adding to scientific knowledge. Finally, it is an evolving process that is undertaken in a spirit of collaboration and co-inquiry.*

This definition emphasizes the critical themes of action research. It is an *emergent inquiry process* which engages in an unfolding story. The focus is on *real organizational problems* or issues. Action research operates in the people-in-systems domain and *applied behavioural science knowledge*. It simultaneously aims to contributes practical problem solving in an immediate problematic situation and to expand scientific knowledge in *collaboration and co-inquiry* process, where research is constructed *with* people, rather than *on* or *for* them (Coghlan et al. 2012). The competencies of the respective actors enhance within the course of action research due to the collaborative performance in an immediate situation using data feedback in a cyclical process willing to increase the understanding of a given social situation. It primarily applicable for the understanding of change processes in social systems and undertaken among a mutually acceptable ethical framework (Hult & Lennung 1980). Furthermore, Action research and collaborative management research approach, embedded in a synergistic engagement of managers and researchers, which enhances the relevance of both for management practice (Shani et al. 2007; Coghlan 2011). The focus that has emerged in recent years to capture the distinctive collaborative processes between scholars and practitioners, organizational insiders and outsiders aimed to create actionable knowledge that is useful to practitioners and which is robust for scholars (Shani et al. 2007; Coghlan 2011; Adler & Shani 2001).

In this study, the researcher applied an action research approach perceived as a process in which academic and practical knowledge is integrated with existing organizational knowledge and combined to solve emerging problems. This approach helped in establishing a relationship with visited firms and developed an in-depth understanding of their automation challenges. Through this distinctive collaborative process between scholars and practitioners organizational insiders and outsiders researchers aimed at providing meaningful support for SMEs as well as creating actionable knowledge that is useful to practitioners, which is robust for scholars (Shani & Pasmore 1985; Coghlan 2011; Coghlan & Shani 2008).

THE ACTION RESEARCH PROCESS

Kemmis et al. (2013) have developed a simple model of the spiral nature of the typical action research process, which is illustrated in Figure 12. Each cycle has four steps: plan, act, observe and reflect.

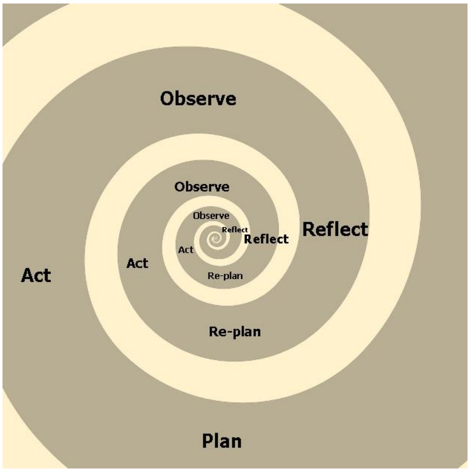

Figure 12. The action research spiral (Kemmis et al. 2013)

Action research is based on collaboration between the researcher and practitioners where they collaborate on intervening in exploring issues and identifying the problem.

Plan. Within the planning phase of the action research, data is collected for a more detailed diagnosis to identify and analyse the problem. A literature analysis was performed along with problem recognition, or the need to develop the automation business assessment. In order to develop a business assessment model for automation with a structured approach, it was decided to use and analyse a reference model that so-called buyer-supplier models.

This analysis has been helpful to identify the stages of buyer-supplier collaboration and the themes are considered for business assessment in different stages. It was decided to structure the model following the principles of the buyer-supplier relationship model, focusing on three stages of collaboration.

Do. The action plans are developed to address the issues and implement them. This is followed by a collective postulation of multiple possible solutions, from which a single plan of action emerges and is implemented. Therefore, after that, the need for this model was identified and once the related literature analysis was carried out, the automation business assessment process model was developed. In chapter **Error! Reference source not found.**, Model development, the automation business assessment process model for collaborative automation solution decisions is presented.

It is important to highlight the two objectives of the Automation business assessment process model. On one hand, the model has to determine the key business assessment and integration criteria within the process of collaborative automation solution decisions. On the other hand, to be a base to implement the digital based platform. Evaluating and selecting the appropriate tool for developed of the suggested solution is the secondary purpose of this phase.

Therefore, the automation business assessment process model was designed: firstly, the main phases performed when developing the model were identified and, secondly, the actual design of the model was developed. Therefore, a new digital platform was developed, which supports the gathering of information, useful to the application of the model, and facilitate working with the system for actual users.

Observe and evaluation. The outcome of the actions and the results of the intervention is collected and evaluated, both intended and unintended. Findings are interpreted considering how successful the action has been. Therefore, firstly, the automation business assessment process model was validated with academic and industrial experts. This permitted to evaluate the extent to which the model was complete and comprehensible. After this first step, and along with the iterative process of development the digital platform the model was applied to selected case studies, which are among the automation solution suppliers and manufacturing companies.

During this phase, it was examined the model's applicability to different kind of companies and its ability and effectiveness to support business assessment in solution selling processes.

Re-plan. The feedbacks gathered from the evaluation phase were used during the "re-plan" and "act" phase of the action research cycle, to standardize the methodology and further development of the digital platform.

The researcher relevance and stakeholder relevance validation are presented and described in Chapter 6.

Furthermore, it should be mentioned that, in order to achieve a highly "generalizable" model, it is required to have a higher volume of use cases and applications of the model to track model evolution and development. Therefore, the action cycle needs to be re-executed again and the methodology should be applied to other case studies. This may then lead to further cycles of examining issues, planning action, acting and evaluation (Figure 13).

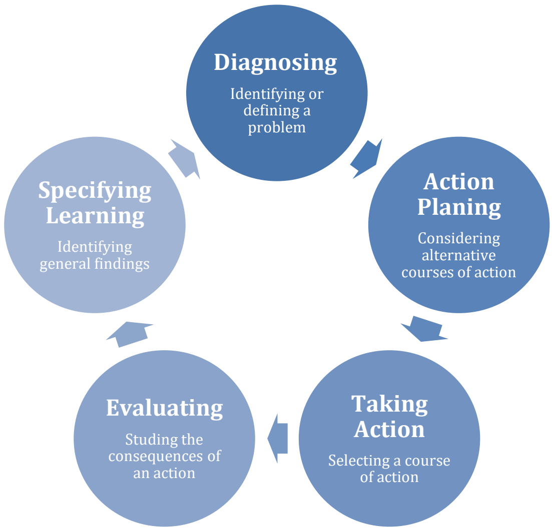

Figure 13. Detailed Action Research Model (Kemmis et al. 2013)

3.4. THE METHODOLOGY UTILIZED FOR DESIGNING THE RESEARCH

Figure 10 illustrates the structure of the research design. It is intended to illuminate a clear overview of the research objective. In order to comprehend a comprehensive answer to the main questions, this research is divided into **two steps.**

The first step of the research is focused to answer the first research question:

What are the collaboration mechanisms in automation and digitalization decisions in manufacturing SMEs?

To this concern, sub-research questions need to help to clarify the behavioural parameters, particular processes and the influential aspects in the collaborative automation decisions. The sub-research questions are the following:

1.a. Does it exist a pattern of buyer-suppliers collaboration in automation practices both from literature and from the practitioner point of view?

1.b. What are the behavioural parameters and influential aspects of buyer-supplier collaboration in automation decisions?

The second step of the research is focused to answer the second research question:

How to facilitate collaborative automation and digitalization decisions?

Once the collaboration mechanisms, the behavioural parameters, influential aspects and expected benefits of buyer-supplier collaboration in automation practices is understood, in order to describe how to facilitate this practice, is if essential to identify and deploy a model for automation business assessment and identify the process groups from both manufacturing companies (Buyers) and Automation suppliers' perspectives. Furthermore, the domain components associated with the process groups are essential to be identified. To do this the following questions have to be answered:

2.a. How the business assessment model is formed to facilitate the buyer-supplier collaboration in automation practices?

2.b. What are the "automation business assessment model" design principles?

2.c. What are the process groups that are considered in the automation business assessment model?

2.d. What are the domain components that are considered in the automation business assessment model?

2.e. What are the domain components of the digital platform for automation business assessment?

2.f. How the development and validation process of the digital platform for automation business assessment is organized?

2.g. What is the outcome of the digital platform for automation business assessment?

As already presented in Chapter 2, the research was constructed of a literature research over the key areas of the concept. Moreover, the industrial expert's consultation through interviews was utilized to support investigation steps; case studies were used for describing problems in depth and the related methodology. Phase one results in a refined problem formulation for the research. The combination of the methodological approaches for data gathering together with multiple investigators involved in the process helped us to achieve data triangulation (Eisenhardt 1989).

LITERATURE ANALYSIS

As already stated in Chapter 2, the first step performed to answer the research question was the studying of the state of the art on this topic, to develop a comprehensive understanding of collaboration and coordination mechanisms and the influential factors in automation and digitalization decisions in manufacturing SMEs.

Before selecting the proper framework to follow in order to build the automation business assessment process model, the analysis of the existing collaboration and coordination process model was performed.

The main objective of this analysis was to understand how the existing collaboration and coordination mechanisms process models are structured. It is crucial also to understand what are the main elements and influential factors that determine their structure. In addition, knowing the phases that needs to be pursued while developing process model was required which is reported in the section 5.4. The literature review in this research was conducted following a five-stage systematic literature review, based on Grounded Theory (Chong & Yeo 2015; Corbin & Strauss 1990). The five stages include (Rutter et al. 2010): define, search, select, analyse and present. Figure 19 illustrates the five-stage systematic literature review process in this dissertation.

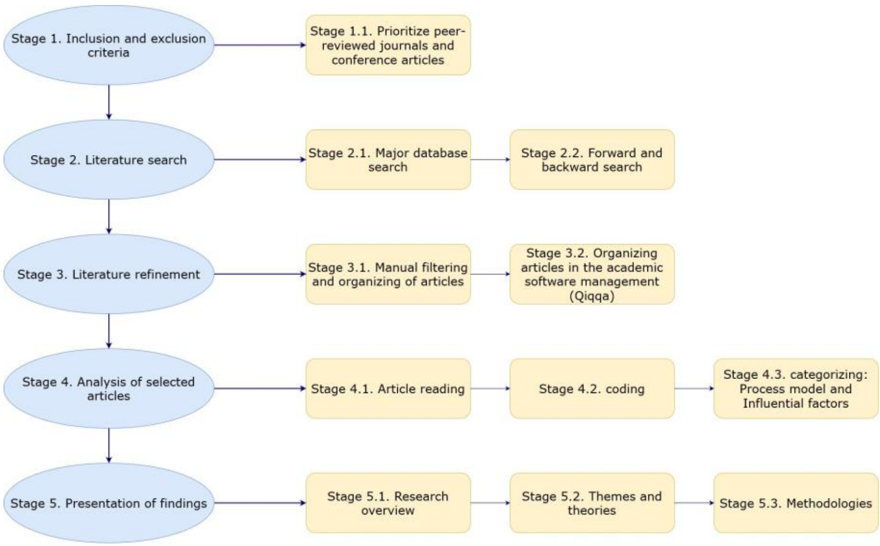

Figure 14. the five-stage systematic literature review process inspired by (Rutter et al. 2010)

Literature inclusion/exclusion criteria. The literature review has been set to ensure a quality review. To do so, literature inclusion criteria were targeted at papers from high-quality sources, mainly because the high-quality contributions in a field are primarily obtained in reliable sources such as academic journals and conferences (Webster & Watson 2002). Therefore, the prioritized references primarily were included from peer-re-viewed journal and conference articles and fewer among dissertations, books and case studies.

Literature search. The research was conducted using as searched terms as: *network theory and types of networks, business ecosystem, inter-organizational and supply chain collaboration, integration mechanisms, market and supply chain involvement and new product development, organizational coordination and coordination mechanisms, locus of control and decision-making, lead integrator concept, and collaboration in the context of automation and manufacturing.*

To ensure a complete coverage, we started the literature search from 8 major databases, namely ABI/INFORM, Emerald journals, IEEE Xplore Digital Library, SAGE, Science Direct, Scopus, Springer Link and Wiley Online Library. These databases have been selected mainly becasuse because a significant range of IS journals and conference publications are covered by them (Webster & Watson 2002). In addition, the search on the titles, keywords and abstracts has been conducted, using the identified terms. Finally, forward and backward searches have been conducted to ensure a holistic coverage of the articles selection. The reference list of the sampled articles during the backward searches has been reviewed manually, while the Google Scholar search engine has been used during the forward search to check the relevant references of selected paper. A total of 498 peer-reviewed journal and conference articles were collated for further refinement and analysis.

Literature refinement. To refine the literature, considering duplicates and relevance to the research concepts, the collected articles were reviewed, carefully sorted and filtered to down prioritized those that did not meet the inclusion criteria. The literature refinement process carried out by reviewing the title, abstract, conclusion, and the main text of the articles. The articles focusing on proposing definition, further describing the concepts of this research, e.g. categorizing and identifying the influential factors were prioritized, whereas the articles that only used the concepts of this research as an example, a reference to explain other concepts without further discussion in the main text were down prioritized. Subsequently, a total of 180 journal and conference articles were prioritized for analysis in the literature review.

Analysis of selected literature. At this stage, the selected articles were coded and tagged in the reference management software, Qiqqa based on the research interesting themes, research methodology and theories and gaps for further research. The individual articles have been reviewed to build up the fundamental for understanding and describing the research themes. For the selected research themes, open codes were developed in the first instance. Next, conceptual similarities of the open codes were analyses to generate axial codes. Based on an iterative analysis through mapping, integrating and refining of the axial codes, the selected articles were classified. The analysis stage used two types of categorization to structure the elements that had been found. The type of process model elements were then coded into phases of development of buyer-supplier collaboration in automation decision practices: pre-collaboration, early stage of collaboration, development. The elements of influential factors in inter-organizational business assessment process model: trust, commitment and mutual understanding, goal agreement, information and knowledge sharing and integration, coordination and communication mechanism, cooperation and collaboration, technical integration mechanism.

Results of literature analysis. One of the objectives of this analysis, as mentioned before, was the identification of the collaboration mechanisms in automation and digitalization decisions in manufacturing SMEs and the main elements that determine the structure of a business assessment process model. therefore, once the literature analysis was concluded, the results was presented in detail in chapter 2, theoretical framework.

THE CASE-STUDY

Case-study combined with the literature was used to ensure a comprehensive understanding of the trends of automation investments in SMEs, challenges, and benefits.

The actual issues within automation experienced by SMEs are explored by applying an inductive case study method (Yin 2009) focused on the inter-company level as a unit of analysis to uncover key challenges on the collaboration process and explore common criteria within buyer-supplier collaboration stages in automation practices. Furthermore, it provided an extensive understanding of the challenges and requirements through this collaboration process.

The following outlines the strategy of the case selection. The case selection is essential for this study because the insights gained from exploratory studies are highly dependent on the selection of interesting and information-rich cases (Strauss & Corbin 1990).

3.5. CASE SELECTION

An overall information-oriented selection strategy was applied for the primary case selection. Information-oriented selection is used "to maximize the utility of information from small samples and single cases. Cases are selected based on expectations about their information content" (Flyvbjerg 2006). The information-oriented selection is considered a determined sampling strategy for this research also because the selected information-rich cases were considered to enlighten the matter of interest. Potential firms were evaluated based on their probability to offer interesting insights and accessibility instead of focus on the possibility to represent a broader population (Stake 1995).

To find and qualify the primary selection of cases, the strategy was gradually formed based on an iterative process of empiric and theoretic inquiry. Therefore, the fundamental principle in selecting appropriate cases in different steps of the research, particularly choosing the sample of extreme cases, are information rich. The selection of cases involved using replication logic and essentially depended on the conceptual framework developed from the literature and theory as well as informal discussions.

First, an extensive search was conducted through personal networks, the network provided from the host company, and participants in innovative automation projects. The search was focused on identifying cases: **a.** Manufacturing SMEs considering automation in their production, and **b.** automation supplier companies which considering expanding their solution in a larger market. Informal discussions through email conversation, phone conversation and Skype calls were held to clear the interest of the cases to participate in the research, expected information and opportunities for access for the researcher. In the next step, the insights were compared to those presented in the literature, the case selection criteria and possible research paths were outlined. The case selection criteria which are summarized in the Table 8 had to be met in term of the firm size, sector of the case and different to expectations, the experience in automation and the possibility of future accessibility to respondents.

Table 8. Case selection criteria

Case selection Criteria	Description and Justification
SMEs	Small and Medium sized enterprise sector was chosen, as research Collaboration and Coordination mechanisms in automation decision within the SME sector is limited.
Different expectation	Due to the descriptive and explanatory nature of the research, multiple cases from manufacturing and automation supplier were used to enable access to data for comparison and process tracing in automation decisions.
Automation experiment	Businesses with previous experience in automation were chosen for this research, to be able to provide insight to the research path.

Denmark region	Businesses operating in Denmark were chosen in this study to enable explanatory data in terms of regional area and the business focus of the host company.
Accessibility to respondents	To ensure the interest of responder to participate in the research, get access to the empirical research data and validation.

The selected cases were used for the purposes of this study are further explained in Chapter 3.8. The primary research collaboration with selected firms was established during company visit and actual evaluation process of automation solutions Chapter 4.

The initial objective was to explore novel practices for Collaboration and Coordination practices in automation decisions, therefore, the search emphasized on firms experimenting collaboration in automation decisions and supplier involvement. The researcher attended multiple business conferences and exhibitions, participated in multiple collaborative research and development European based projects and took responsibility of leading a project with the focus of assisting manufacturing SMEs in automation within the host company.

Initially, multiple case companies were identified among Danish manufacturing SMEs. In the discussion and mutual assessment process and based on the potential outlined research interests, two manufacturing companies (Manufacturer 1 and 2), and three supplier companies (Supplier 1, 2 and 3) were chosen as the primary cases for the research. The primary research collaboration with these cases were established for several reasons. First, the attention to buyer supplier collaboration was a central consideration in automation decisions within all selected cases, all the selected cases have had experience with automation and they were in the process of taking decisions on applying new automation technologies (in manufacturing cases) and in the process of evaluating and offering new automation solutions to new automation buyers (in automation suppliers). In the same time, they were considering to be more engaged with buyers or suppliers through the process, where they have shown an interest to participate in the research project where the company managers were willing to provide access to empirical data for the research, participate in interview meetings which was evaluated as a unique opportunity to collect and confirm interesting data, considering the size, industry sector and innovation projects.

During the initial collaboration with the selected cases, initial interviews and informal discussions with CEOs, Production managers and Production engineers were held, historic cases were evaluated, secondary information was gathered, and the researcher participated in meetings were held between buyers and suppliers in each of the selected cases. Data collection detail and the distribution of the research encounters is described in Chapter 3.6.

3.6. DATA COLLECTION

Within the period of October 2015 to December 2018, a total 21 encounters (Table 9), and 7 site visits, conducted by the researcher, formed the empirical data collection mass needed to provide the answers for the three overarching research questions of the project (Table 11).

Table 9. Distribution of research encounters

	Manufacturer	Automation supplier	Automation Expert
Preliminary interviews			3
Targeted interviews	6	3	1
User experiment test subjects	1	3	4

The site visits and targeted interviews about exploring the buyer-supplier collaboration mechanisms in automation practices from manufacturer's preceptive rendered by the different production constituencies including CEOs, production managers, and production engineers. Interviews with automation suppliers were conducted with directors and sales representatives having the experience of working with a large number of manufacturing SMEs. Each interview was semi-structured in nature and lasted between 60 and 300 minutes and conducted in person/face-to-face respectively. Interview notes were taken based on an interview guide crafted in advance in order to ensure that answers to all critical topics were obtained from each individual. The interview notes were, however, not written up in a format suitable for external perusal. The interviews led an appropriate perspective on SMEs' challenges and helped in evaluating their needs regarding the manufacturing processes with a special focus on automation. It was aimed to investigate how SMEs realise and approach their needs to improvements on the manufacturing line and understand how they invest in new solutions to developed new manufacturing business ideas.

DATA COLLECTION MODEL

Research data was collected in the second half of 2015 and late 2017, during a multi-stage process. Different data collection strategies have been used to enable the researcher to triangulate information from different data sources (Gibbert & Ruigrok 2010).

The preliminary data of selected manufacturing companies (buyers) and automation suppliers were collected from archival information, including company web-site and public press material as well as detailed field notes of direct observations, visual documentation, during the manufacturing company visits and semi-structured interviews. Direct observations uncover the phenomenon, accordingly, are contextual, when the aim is to examine and add new dimensions for understanding a phenomenon or context direct observations serve a valuable source of information (Yin 2017).

The preliminary semi-structured interviews happened during company visits and events. Experts which have been involved in research, development, deployment, and evaluation of innovative automation solution and robotics are the target of the first part of the research, so they have been identified and interviews were contacted. The interviewer asked three questions regarding automation in manufacturing: “What makes manufacturing SMEs invest in automation and what are the main benefits related to automation implementation in manufacturing?”, “How automation projects are evaluated, and collaboration is formed?”, “What are the obstacles limiting automation investment?”. Each expert was free to touch different points and to go beyond the specific questions. Based on the agreement with experts, the concepts and suggestions are not necessary for the situation of organizations they belong to, but it is their personal vision. This phase consisted of three interviews and the interviews were noted.

Third, direct observations were made of six internal meetings, including 3 internal meetings concerning the company visits, per manufacturing company case, one after the first company visit, one after the second company visit and the third one after the third company visit together with automation provider. The goal of the internal meetings was to plan or evaluate the event. The meetings were manly hold at the host company. Participants included: the researcher as the project manager, CEO of the host company as automation expert, the student assistants working in the project, and in some cases the representative of automation suppliers. The meeting mainly focused on reviewing the collected data from company visits and interviews, review the visual material including images and videos and evaluate and organize the data in order to make them prepared to be shared with automation suppliers. The research was focused on understanding how collected data related to the automation challenges is reviewed, analysed, interpreted and organized, how communication and collaboration with automation suppliers take place to facilitate and coordinate decision process. Each meeting lasted between 30 to 50 minutes.

3.7. CROSS-CASE ANALYSIS AND DATA ANALYSIS

The next step to answer the first research question was the development of a model to map the behaviour of buyers (manufacturing companies) and suppliers (automation suppliers) within the collaboration stages with a focus on business assessment and solution selling processes. To do so, the analysis of the existing business assessment process and the collaboration staged from both buyers and supplier's perspective was performed.

The main objective of this analysis was to understand how these processes are structured, the main elements that determine their structure, and the challenges could be identified. In addition, it was required to understand how the process is performed and what could be different regarding the scope of the automation solution itself.

To do this, the analysis processes performed as a systematic combining approach, which is identified as a nonlinear process where there is an overlap between data collection and analysis (Dubois & Gadde 2002). Systematic combining as a continuous process involves "asking questions, generating a hypothesis, and making comparisons" (Strauss & Corbin 1990). The cross-case analysis strategy was deployed, following the (Eisenhardt 1989) proposed model. To discover interesting resemblances and differences, the cases were compiled and compared. To do so, the process of collaborative automation decisions was traced and compared considering different stages, influential aspects and coordination mechanisms. Notes from interviews and observations from field visits were reviewed. Important passages and interesting quotes from interviews were labelled using the informants' terms.

For example, the following quote was highlighted and initially coded as "Problem Brief" in "Pre-Collaboration Stage". (An aspect is addressed in integration mechanisms literature).

Very interesting process and fun when we have the information in place. We see that it is not only saving, and money is considered here, but also there is a lot of planning of people. I think that part should be seen that we will have an easier management process. (Production Manager, Manufacturer1)

The labels were reduced after reviewing for similarities and differences. Through a cycle between data and literature, codes were developed, and the labels were categorized. In order to identify precise codes that address the findings in the study, the researcher tapped into different literature, including that on problem framing, buyer–supplier collaboration, supplier involvement, task structure, solution selling, and interaction literature.

Coding is utilized as a strategy before drawing conclusions to reduce data prior to data display. “Codes are tags or labels for assigning units of meaning to the descriptive or inferential information compiled during a study. Codes are usually attached to ‘chunks’ of varying size – words, phrases, sentences or whole paragraphs”(Miles et al. 1994). Through the data analysis process, a data structure was built, helping to increase the level of abstraction from the embedded qualitative data. The data structure was built following the principles of the buyer-supplier relationship model. Such data structure helps to demonstrate the data analysis process (Gioia et al. 2013). Once the data structure was built, the collection of clusters used as bases to emerge and consolidate several dimensions such as automation business assessment process model domain components and the coordination mechanisms (Chapter 4.5).

Table 10. Overview Interview structure

	Affiliated	Role	Data
Preliminary interviews	Blue Ocean Robotics	Co-CEO	Recorded
	Blue Ocean Robotics	Co-CEO	Note taken
	Blue Ocean Robotics	Former SAFIR Project manager	Note taken

Targeted interviews	Manufacturer 1	production Manager	Recorded
	Manufacturer 1	Director/ CEO	Recorded
	Manufacturer 2	PTA manager	Recorded
	Manufacturer 2	Process engineer	Recorded
	Supplier 1	Project Manager and CTO	Recorded
	Supplier 2	CEO	Recorded/Note taken
	Supplier 2	CTO	Recorded/Note taken
	Supplier 3	Director	Note taken
	Blue Ocean Robotics	VP of sales	Recorded
	Manufacturer 3 (ReconCell Project)	Head of R&D department	Recorded/Note taken
	Manufacturer 4 (ReconCell Project)	Team Leader Industrialization	Note taken
	Hermiagroup (ReconCell Project)	Project Manager	Note taken
	Blue Ocean Robotics	Co-CEO	Recorded
User experiment test subjects	Supplier 4	Director	Note taken
	Blue Ocean Robotics	VP of Business Development and sales	Recorded
	Supplier 5	CEO	Recorded

	Supplier 6	CEO	Recorded
	Blue Ocean Robotics	VP of Marketing	Recorded
	Blue Ocean Robotics	Interaction Designer	Recorded
	Blue Ocean Robotics	Human-Robot Interaction Expert	Recorded

Table 11. Overview data collection structure

Data collection sources	Details	
Secondary data (Archival information)	Companies web-site and Public press material Introduction letter to the SAFIR project and processes Power point presentations Facilitation guidelines Internal document and technical document Contract Online material from second-hand sources	
Observation of event	Participant observation of the full event, from October 2015 to September 2016. In total 12 hours of observations and semi-interviews (Captured in field notes, which were subsequently, ordered and categorized)	
	#1 Manufacturer 1 site visit	Intro, Automation opportunities (recorded)

Participant observation of site visit	#2 Manufacturer 1 site visit	Analysis and valuation, detailed documentation (recorded) + Director / CEO
	#3 Manufacturer 1 site visit together with Supplier 3	Automation provider feedback (notes were taken)
	#4 Manufacturer 2 site visit	Intro, Automation opportunities (recorded)
	#5 Manufacturer 2 site visit	Analysis and valuation, detailed documentation (notes were taken)
	#6 Manufacturer 2 site visit together with Supplier 3	Automation provider feedback (notes were taken)
Participant observation of the internal meeting 6 Site visits 6 internal meetings (2 Planning and 4 evaluation meetings)	#0 Planning and model design Blue Ocean Robotic	Blue Ocean Robotic (notes were taken)
	#1 Planning meeting Blue Ocean Robotic	Blue Ocean Robotic (notes were taken)
	#2 Evaluation meeting Blue Ocean Robotic	Initial automation projects selection (notes were taken)
	#3 Evaluation meeting Blue Ocean Robotic	Roadmapping (notes were taken)
	#4 Planning meeting	Blue Ocean Robotic (notes were taken)

	#5 Evaluation meeting Blue Ocean Robotic (notes were taken)	Initial automation projects selection (notes were taken)
	#6 Evaluation meeting Blue Ocean Robotic (notes were taken)	Roadmapping (notes were taken)

3.8. CASE DESCRIPTIONS

The following section describes the host company and the selected cases of this study for data gathering and example making. This includes companies and relevant projects.

BLUE OCEAN ROBOTICS APS

Blue Ocean Robotics was founded in 2013 by the owners Claus Risager Ph.D., Rune K. Larsen M.Sc., and John Erland Østergaard Ph.D. Over the last six years, the company has spread to over five countries. Blue Ocean Robotics is specialized in creating and commercializing robots in several sectors including the Manufacturing Industry, Education Industry, and Healthcare. A number of projects have resulted in spin-out companies.

In the period of 2013 to 2016, the focus of Blue Ocean Robotics was to assist manufacturing SMEs to improve the level of automation by facilitating the processes of documentation of specific production processes, search and select competent automation suppliers, and facilitate collaboration between SMEs and automation suppliers. Here is where the basic idea of SAFIR project has emerged. SAFIR project as one of the focus cases of this study is described later in this chapter.

In the period of 2015 to 2017, Blue Ocean Robotics opened the market in three main sectors, the Manufacturing Industry, Education Industry, and Healthcare and created new markets previously not seen as being interesting. As it was stated on the company website:

> *"Blue Ocean Robotics invests resources and capital into the exponentially growing robotics industry at large through a carefully selected portfolio of robotic projects. We incubate and take lead of the projects where we develop robotic products, commercialize, and introduce the robots to the markets, and when the timing is right to sell, license- or spin-out the IPR, robots and related business-assets to new subsidiaries- or affiliated startup enterprises of ours (through equity/shares) or to existing companies in the market. After successful sell-, license- and spin-out Blue Ocean Robotics remains a closely interconnected strategic partner enabling synergies and leveraging from commercialization, international sales, and development of the next generation robots." (Blue Ocean Robotics, 2016)*

This made the company to highly focus on expanding international sales partners and joint ventures network among competitive local technology distributors and automation integrators. Figure 15 illustrates the focused business model of Blue Ocean Robotics within this period.

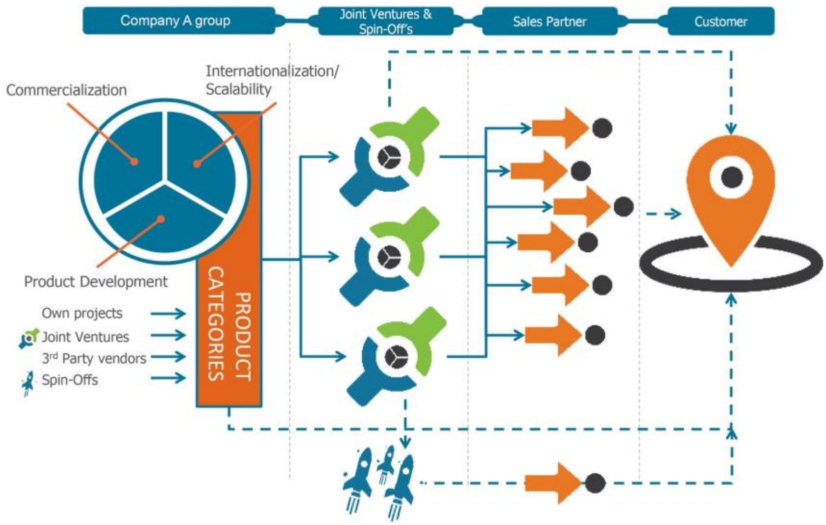

Figure 15. Blue Ocean Robotics Business model (2016)

The global presence of the company made it experience a significant expansion process and networks with subsidiaries in Lithuania, Hong Kong, USA, Sweden, Norway, Germany, and Australia. Entering to the new market the companies' role in their sales and product development collaboration with international buyer through the selling process of complex automation solutions underwent a significant challenge in communication in the network, potential projects evaluation, and alignment in sales and development processes. This was the main motivation for emerging the idea of Inhancer, the digital platform for buyer-supplier collaboration.

Late 2017, Blue Ocean Robotics proposed new collaboration model with strategic partners for creating and commercializing new generations of robots in which, the company is focusing on initiate collaboration with strategic partners typically with a strong market position where Blue Ocean Robotics takes lead on design, development, and technology while the partner takes lead on global sales, service, and production. Focus is on disruptive innovation. Here the RoBi-X program has been introduced.

"RoBi-X is a proprietary and unique model for how to engage and organize the collaboration with the partners as well as their customers and suppliers when designing and developing the robots. All partners are therefore entering into a Strategic RoBi-X Partnership. It consists of a series of 6 coupled phases:

- RoBi-Inspire. Seminars, workshops, and talks used to motivate and inspire partners and their customers.
- RoBi-Roadmap. Analise, identify and priorities the best robotic business opportunities.
- RoBi-Design. Create the robot concept, and make development-, investment- and business plans.
- RoBi-Develop. Make the robot, testing with a first customer, acquire relevant approvals/certificates.
- RoBi-GoToMarket. Intro to first 1-5 customers, validate the business case and test the robots.
- RoBi-ScaleUp. Realise global sales, establish and provide services, and set up large scale production."

By 2018, Blue Ocean Robotics by introducing of a new category of the robotic company characterized itself as a Robot Venture Factory, where the strategic focus is on create and commercialize robots based on the Spin-Out ventures business model (Figure 16).

"Blue Ocean Robotics develops, produces and sells professional service robots in healthcare, hospitality, construction, agriculture, and other global market verticals. The portfolio of robots includes brands like; UVD Robots, a mobile robot to disinfect hospitals and pharmacy industries; Multi Tower Robot, a mobile robot for safe patient handling and rehabilitation; and a handful of other service robots. All robots in the portfolio are created and commercialised based on reusable technology- and business components enabling the company to launch and scale new robots better, faster and cheaper than others. Each robot brand is set up as a venture

company in itself. Blue Ocean Robotics is thus the first of its kind - a Robot Venture Factory." (Blue Ocean Robotics, 2019)

Figure 16. Robot Venture Factory, Blue Ocean Robotics a new category of robotic company. (Blue Ocean Robotics, 2019)

Transitions between different collaboration types

The Blue Ocean Robotics over the course of this study has experienced four types of collaboration in applying robotic and automation solutions. Shifting between business strategies has been the main drive for changes between different collaboration types. The path company has taken from an intermediator to facilitate automation decision and find the right supplier, to supplier of customer-designed solutions in an international market, to a strategic partner which focuses on developing custom-made disruptive innovative solutions with less focus on sales, have had a considerable consequence on the research path of this work. That is why the blue ocean robotics case has been considered both as automation expert who takes the facilitation role in buyer-supplier collaboration as well as the robotic supplier who focuses on selling custom made solutions for automation challenges.

THE SAFIR PROJECT

As early as 2013, Blue Ocean Robotics conducted research on the potential of applying automation solution in manufacturing companies in the region of southern Denmark. This research showed that on average, Danish production companies can increase their productivity by 15.2% by applying the global state-of-the-art on robot and automation technology. By combining this with a special shape for strategic approach to automation, based on the link between internal knowledge and competence building and new advanced technologies, they conclude that Danish companies will be able to achieve a leading position, where they get advantaged over competitors in the market by creating a competitive and sustainable production in the country with more employees in new types of jobs.

According to this research results, EU Regional Founding and Region of Southern Denmark opened some funding possibilities to exploit the potential of an increase in labour productivity and production jobs as the result of using automation. Blue Ocean Robotics executed the SAFIR project under this initiative to support manufacturing companies for applying robotic and automation solution within their manufacturing line in close communication with production companies, automation suppliers and automation experts. Two other initiatives received the fund for the same purpose:

- Automation in South – technological institute, Centre for Robotic technology in Odense
- Automation South (AutoSyd), University of Southern Denmark, Mads Clauses Institute in Sønderborg.

During the period from late 2013 to late 2016 SAFIR (Strategic Automation of Factories driven by Robotics) project was executed at Blue Ocean Robotics. This has been prior and within the course of the Ph.D. work, where the researcher has been the project leader of the SAFIR project in the period of 2015 to 2016, with the responsibility of conducting the action research and apply the research outcomes and the knowledge obtained through the research work in the form of new business processes, business models and product/solution ideas.

The SAFIR project was interesting because it focuses on developing an ecosystem consists of automation customers (manufacturing companies), automation suppliers (automation and machine tools/robot suppliers and integrators) and independent automation experts which collaborate and interact through automation decision-making processes.

The SAFIR project aimed at supporting manufacturing companies to identify and document possible automation projects and evaluate them based on financial, technical, and strategical criteria to create an automation road-map. Furthermore, the

SAFIR project assisted manufacturing companies to indicate the most competitive solution provider and facilitate collaboration between participants in order to ensure they get a head start with specific project implementation activities (Parizi et al. 2014).

In addition to manufacturing companies, the SAFIR project is aiming at the involvement of automation suppliers by connecting them with manufacturing companies, to integrate the fitting solutions for the automation projects. The automation experts are integrated with this process and support the automation decision by evaluating and ensuring the quality of possible automation solutions.

The case study focuses on the perspective of SAFIR as a multi-sided service platform in an automation business ecosystem.

> *"From 2013 to 2016 SAFIR was used to describe more than 60 potential automation projects in 30 Danish SME's. Of these potential projects, more than 20 showed a return of investments in less than 3 years and more than 10 a return of investments in less than 2 years. All in all, 13 projects were initiated with a total investment of 25M Danish kroner." (Blue Ocean Robotics, 2016b)*

The SAFIR practice at each manufacturing company was a three-month event, which consists of five adjoined activities. Figure 17 illustrates an overview of the SAFIR process for the realization of an automation project:

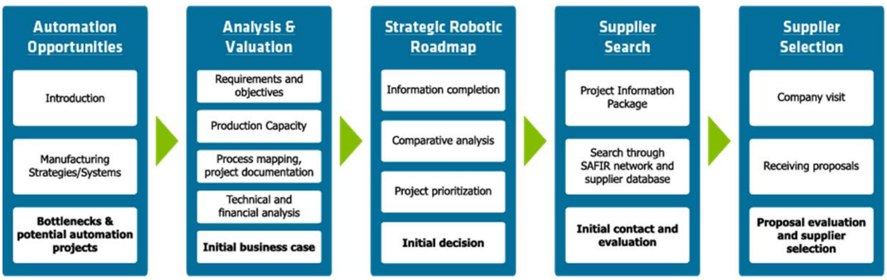

Figure 17. The SAFIR Process (Robotics 2018)

In the first three steps from ‘Automation Opportunities’ to ‘Strategic Robotic Roadmap’ the automation suppliers are not yet involved in the process.

Second event builds on the ideas and identified automation projects on the first event and serves a detailed data collection, data analysis and exchange of ideas between selected participants, representatives from manufacturing company and automation experts from Blue Ocean Robotics. Within this event initial business case is developed using the Strategic Robotics Roadmap tools. The Roadmap prepared for the strategic prioritizing meeting in next step.

The third event is strategic robotics decision and planning, aiming at discussing the roadmap results and map out the prioritized automation projects. Here, the company top managers decide on the automation projects that they want to take further attentions. Furthermore, detailed documentation of the projects and additional information (incl. pictures and videos) of the prioritized project is gathered. Here, the Strategic Automation Roadmap is reviewed.

The fourth event, focuses on finding and communicating with suppliers, where the automation suppliers get involved in the processes.

Based on the Project Brief a request for information is made and send for pre-chosen suppliers with relevant experience on prioritised project(s). The suppliers return if they find it realistic to implement the project (within the planned budget and technical constraints). Then the returned answers are incorporated into the Strategic Robotics Roadmap.

The fifth step focuses on selecting the final automation provider. Based on submitted proposal from suppliers the manufacturing company finally chooses the best matching supplier. In addition, the manufacturing company agrees with the chosen supplier about conditions for the implementation of the automation project.

The initial idea of this thesis formed during the later stages of the SAFIR project. This research project initiated as a continues of the SAFIR project with about one year of time overlap. This provided a great advantage to the researcher and the host company because the results of the work in SAFIR project were used as input to this research project. Some of the inputs were including: 1. The network of manufacturing SMEs and Automation suppliers which helped to form the initial selected cases of this research. 2. The business process formed and used in SAFIR project to take buyers through a range of analysis and automation decisions. The SAFIR business process was used as a prototype for the Business Assessment Process model. 3. A set of tools, including smart excel sheets, online forms and reporting material which used as prototype for the digital platform. For example, some of the tools from SAFIR has been used through the automation decision facilitation process of Manufacturer 1, which is reported in Chapter 4.

MANUFACTURER 1

Manufacturer 1 is a Danish privately held SME located in Kolding, Denmark. In 2015, the company experienced a turnover around 39 million Danish Krone. The company is specialized in production of steel, alloys, and titanium products where the company has been specialized in machining, certified welding, hand sanding, polishing and manual machining, quality testing using 3D measuring machines and have great experience in handling complex documentation eg. FAT documentation for the pharmaceutical industry. The main market is customers within agriculture, food, offshore industries. All manufacturing employees are considered as skilled workers. A lot of their knowledge is tacit, as there is a very low-level of standardization. The company works with few but large customers as a sub-supplier. The company produces standard parts in small batch volume. By the time of the research, the company's experience in automation and robotics was limited. 15 years prior to this event, the company had an unsuccessful investment on an automation solution working together with milling machine. 5-year period to this event, the company had an effective investment on a gantry robotic solution for the CNC machine, which encouraged the company to invest on 3 additional robots working with other CNC machines. The competition, and delayed payments by customers make some limitation in investment on robotics, still have growth by 10%.

The manufacturing line is mainly semi-automated, on cutting machine tools while there is a series of manual processes, for handling special operations, deburring processes, measurement, and control activities Figure 18. The production system at the company follows batch flow system (Miltenburg 2005) where the design of the factory layout is functional, and orders are passed from one operation to the other.

Figure 18. Overview of the company production facility

MANUFACTURER 2

Manufacturer 2 is represented as a Danish manufacturing SMEs, located in the south region of Denmark. In 2015, its turnover amounted to over 250 million Danish Krone, it employed more than 100 where 25-50% of employees are working within the manufacturing line. The company is an electronic manufacturing company produces temperature and motor controls for the business area of HVAC (Heating, Ventilation and Air Conditioning) and floor heating. Its products are sold in Europe and North America, where the company has few but important business customers. The company has had automation experience in “Assembly and test line with laser decoration” by the time of project execution. The company follows the batch flow production system (Miltenburg 2005), where many products in lower volumes of the produce are considered. Therefore, a combination of the functional and cellular layout is used. Different equipment is placed into the assembly, test, packaging, and storage departments. The equipment and tools are mostly designed and implemented in general purposes, to support the varies material flow from order to order (Miltenburg 2005).

SUPPLIER 1

Supplier 1, which was selected as an automation solution supplier for the case of this research is a Danish integrator. The company is competent in providing customer designed robotic automation solution in welding systems, material handling, assembly, and other general industry robot services. The company' main market is the Danish manufacturing industry. The funded in 2013, located in the southern region of Denmark, and employs around 25 where mainly specialized in robotic development and project management. The employees have experience of working with robots in different industries, therefore, the company offers an individual and simple solution to even the very complex tasks. To do so, by an initial meeting the company helps their customers to determine what the automation saluting could be and whether the solution will need to be developed or adapted, or if there are already standard solutions available in the market that fulfil the requirements.

SUPPLIER 2

Supplier 2, founded in 2004, is a Danish automation and software company specializing in automated Bin-Picking solutions. The core competence of the company is in handling randomly-located objects from a bin by means of enabling robot arms to see, find and grip components randomly placed in pallet-bins and boxes. Following a project, with the Danish National Advanced Technology Foundation, the first standardized Bin-Picker came into production in 2010. The company's software and gripping modules are now applicable to a wide range of existing robotics systems and delivered through a collaborative process with experienced system integration partners.

SUPPLIER 3

Supplier 3 has been selected as the other automation solution provider case in this research. The company is located in Vejen, Denmark, and since 1997 has been engaged in developing and manufacturing robot-based solutions for processes in all kinds of industrial production, food and pharma industry. The company employs 15 dedicated in idea development and project management to advanced programming, development, testing, and implementation of complete robotic technology solutions. The company today accounts for over 100 robot solutions in Danish industrial companies within gantry, palletizing, flex-picking, and other general robot applications.

3.9. THE ROLE OF THE RESEARCHER: INVESTIGATOR, SUBJECT AND CONSUMER

The approach to the action research inquiry have had a focus on the collaborative inquiries since the early articulations of the action research. The core of collaboration in action research means a true partnership between the researchers and research subjects in the formulation of research focus, research process, integration of theory and existing organizational knowledge as well as utilization of the research outcomes. In this line, some approaches around action research has been emerged, including participatory action research, action science, developmental action inquiry, intervention inquiry and appreciative inquiry. Yet, to ensure the proper action research experiment in participatory research, it is required that the knowledge that is obtained through the research work is actionable. The role of the researcher in the action research (Adler & Shani 2001). Greenwood et al. (1993) propose the key distinguishing feature of the participatory action research, as this is the combination of: a) The central principle of “participatory” or “collaborative” research, where the some members of the organization being studied should actively participate in the research process rather than just be the subjects of it, b) The central principle of action research - that there should be an intent to take action. Following this approach, the relationship between the researchers and research subjects can be described as a two-way relationship: a) The researcher gets involved in and contributes to the practitioner's world, b) The practitioner becomes involved in and contributes directly to the form of the research output (Eden & Huxham 1996).

Following this approach to the action research and collaboration aspect of it, for the case of this research, the researcher has been employed as industrial PhD fellow within the host company, with the responsibility of conducting the action research and apply the research outcomes and the knowledge obtained through the research work in the form of new business processes, business models and product/solution ideas. More particularly, the researcher got involved in and contributes to the practitioner's world by playing the role of project manager, internal consultant, and leaded the process arbitrates conflicts and adjust inputs from the other participants in SAFIR project and Inhancer design and development project. Moreover, researcher's daily collaboration and participation in management meeting, performing business processes, enabled a broad collection of empirical data which has largely contributed to form the research output.

3.10. GENERALIZATION POSSIBILITY

One of the motivations for this research was therefore to document a generalizable research outcome. Yet, the possibility to generalize the finding and possible limitations can be discussed regarding the research methodology approach, with a consideration to the action research and case study.

The purpose of case study research is to study one or a small number of cases in detail, to develop an extensive understanding of the complexity, the context and natural setting (Stake 1980). In this line, the case study is defined as a study of a bounded system which is emphasizing at the system unity and wholeness yet limiting the attention to the aspects that are relevant to the research problem at the time (Stake 1980). Following this definition, generalizability can be understood as a problem in case study, because if the case is unique in a critical field of research or contradicts existing theory, generalizability is not the purpose and the results could be very subjective.

However, Punch (2013) suggests generalizability can be resulted through cases study in two ways: a) To conceptualize which refers to concept identification with variables and factors rather than describing a situation., b) To develop propositions which refers to identifying dependencies between variables or factors. These can then be considered for the applicability and transferability of the research results to other situations. Therefore, case study research gives an extensive view of a problem and gives an understanding of the critical domains of a new or persistently problematic research area (Friedli et al. n.d.).

In the case of this research the two aspects have been considered by identifying and describing the concept of inter-organizational collaboration and coordination mechanisms in automation decisions by identifying the influential integration factors within process domains, in addition to proposing a process model for automation business assessment.

Moreover, to support the generalizability, recent scholars also proposed circular analysis methodologies where the iterative process between data collection and data analysis exists within case study, action research and grounded theory (Friedli et al. n.d.).

The construct validity can be established in the data collection and improved when multiple sources of evidence is used. A high volume of model applications, which are needed to track model evolution and development is crucial to achieve a highly standard or “generalizable” model.

The circular analysis needs to be re-executed number of times and hence the methodology should be applied to other several cases. Yin (2017) point to the importance of the construct validity, internal and external validity and reliability for qualitative research. The validation and standardization processes are elaborated in detail in “Practical validation” and “Theoretical validation” in Chapter 6.2.

The results provide support for our research model and scope; however, it is crucial to acknowledge that the focus on automation decision and Danish SMEs raises questions about the generalizability of our study beyond this industry and region. Decision is Automation solutions has several unique characteristics, including complexity, a long solution development and flexibility requirements and a resource intensive new product development process. Despite these unique characteristics within this sample, this can be argued that the results of this research might be generalizable beyond the automation decision since inter-organizational collaboration in new product development in high-technology industries appear to be playing an increasingly important role in the success and failure of individual firms (Ford & Håkansson 2013). Future research could assess the external validity of our model by testing it in different industry settings and regions.

Chapter 4.

Results

4. RESULTS

This section describes and partly analyses the selected cases of this study and examines the buyer-supplier collaboration in automation practices with involvement of automation expert as a facilitator in a specific project of the selected automation buyer.

Furthermore, based on the collaboration development stages, the behaviour of participants is analysed and the fundamentals for developing the model for the Automation Business Assessment model is uncovered.

The first case describes the process of evaluation and automation decision making and collaboration formation in a manufacturing SME. To do so, the event of the SAFIR project execution was examined in manufacturer 1 to set the basis for the ongoing research and analysis.

The second case of this study focuses on the complexity of collaborative solution selling and buying process from the automation supplier point of view. Therefore, an actual collaborative selling process of a bin-picking automation solution is studied in supplier 2.

Multiple documents, and tools, and their meaning for the case study will be stated and described. Thereafter, the conducted semi-structured interviews and their most relevant results are described. This will be followed by an analysing the process of design and implementation of the automation business assessment model and the digital tool subsequently.

Due to the action research component of the conducted research, the case study was realized parallel to real project work at Blue Ocean Robotics. Additionally, the theories from the previous literature review were mostly considered but not always referenced. They are supposed to provide a knowledge base for the context of the case study. Some of the theories will be stated in the final discussion of the research and its findings.

4.1. ANALYSING THE EXPERIMENTS

In the following section, based on the semi-structures interviews and observations, the buyer-supplier collaboration in automation practices is examined with three perspectives in mind: the manufacturing SMEs (buyer), automation suppliers and automation experts as the facilitator. The multilateral approach enhances the argument and the validation of the research and stresses the significance of the analysis collected from the qualitative research method. The aim of the empirical data collection is to build a clear understanding of how the buyer-supplier collaboration is formed in the context of automation solution decision practices to develop the model for the automation business assessment model and for counties engagement of SMEs in strategic automation. Therefore, the model of three collaboration stages is developed to be based on the empirical data collection. The three stages of collaboration are inspired by the buyer-supplier relationship in the industrial market (Ford 1980). To further elaborate on the subject, a visualizing of the research analysis is developed. Figure 19 is an illustration of the five collaboration stages, which shows the progression and path of the research

1. The pre-collaboration stage
2. The early stage of collaboration
3. The development stage

1 The Pre-Relationship Stage	2 The Early Stage	3 The Development Stage	4 The Long-Term Stage	5 The Final Stage
Evaluation of new potential supplier	Negotiation of sample delivery	Contract signed or delivery build-up scale deliveries	After several major purchases or large	In long established stable markets
Evaluation initiated by: — particular episode in existing relationship — general evaluation of existing supplier performance — efforts of non-supplier — other information sources — overall policy decision	Experience — Low	— Increased	— High	
	Uncertainty — High	— Reduced	— Minimum development of institutionalisation	Extensive Institutionalisation
	Distance — High	— Reduced	— Minimum	
Evaluation conditioned by: — experienced with previous supplier — uncertainty about potential relationship — "Distance" from potential supplier	Commitment Actual - Low Perceived - Low	Actual - Increased Perceived - Demonstrated by Informal Adaptations	Actual - Maximum Perceived - Reduced	Business based on Industry Codes of Practice
Commitment —zero	Adaptation High Investment of Management time. Few cost-savings	Increasing formal and informal adaptations. Cost savings increase	Extensive adaptations. Cost savings reduced by institutionalisation	

Figure 19. The development of Buyer-supplier relationship in the industrial market (Ford 1980)

In each individual stage, the process and behaviour at manufacturing SMEs as buyers and automation suppliers as suppliers are studied. The collaboration, special opportunities, and restrictions in each stage in compared for more detailed problem diagnosis. The results will be used to conduct the preliminary design of the concept and to define the key performance indicators (KPI) for the concept.

The researcher was deeply involved in developing and setting up of the experiment in pre-collaboration, early and development stages from scratch. The researcher was only involved at a later stage and to a lesser degree, observing and providing comments.

4.2. ANALYSING SEMI-STRUCTURES AND STRUCTURED INTERVIEWS

To analyse the Collaboration stages at buyer and supplier, the analysis processes performed as a systematic combining approach, which is identified as a nonlinear process where there is an overlap between data collection and analysis (Dubois & Gadde 2002). Systematic combining as a continuous process involves "asking questions, generating a hypothesis, and making comparisons" (Strauss & Corbin

1990). The cross-case analysis strategy was deployed based on the (Eisenhardt 1989) proposed model. The cases were compiled and compared to discover interesting resemblances and differences. To do so, the process of the development of buyer-supplier relationship and collaborative automation decisions was traced and compared considering different stages, influential aspects and coordination mechanisms. In this process, the recordings and notes from the interviews and field visits carefully reviewed. Important passages and interesting quotes from interviews were labelled using the informants' terms. For example, the following quote was highlighted and initially coded as "Problem Brief" in "Pre-Collaboration Stage". (An aspect is addressed in integration mechanisms literature).

Very interesting process and fun when we have the information in place. We see that it is not only saving, and money is considered here, but also there is a lot of planning of people. I think that part should be seen that we will have an easier management process. (Production Manager, Manufacturer1)

After reviewing for similarities and differences, the labels were combined. In a cycle between data and literature, codes were developed, and the labels were categorized. In order to identify precise codes that address the findings in the study, the researcher tapped into different literature, including that on problem framing, buyer–supplier collaboration, supplier involvement, task structure, solution selling, and interaction literature.

Coding is utilized as a strategy before drawing conclusions to reduce data prior to data display. "Codes are tags or labels for assigning units of meaning to the descriptive or inferential information compiled during a study. Codes are usually attached to 'chunks' of varying size – words, phrases, sentences or whole paragraphs" (Miles et al. 1994). Through the data analysis process, a data structure was built, helping to increase the level of abstraction from the embedded qualitative data. The data structure was built following the principles of the buyer-supplier relationship model. Such data structure helps to demonstrate the data analysis process (Gioia et al. 2013). Once the data structure was built, the collection of clusters used as bases to emerge and consolidate several dimensions such as automation business assessment process model domain components and the coordination mechanisms.

4.3. COLLABORATION STAGES AT BUYER

PRE-COLLABORATION STAGE AT BUYER COMPANY, SAFIR PROJECT AT MANUFACTURER 1

The pre-collaboration stage at customer organization refers to a combination of events which identify potential opportunities or problems to be solved and setting up a plan for changes. At the buyer side, this stage starts with the need recognition along with setting up a strategic automation roadmap. In the following, the pre-collaboration stage is examined based on the SAFIR practice at one manufacturing SME, introduced as manufacturer 1, selected as the case analysis for this study.

Automation decisions in manufacturing companies can be considered due to different reasons which could be related to production cost reduction, productivity and quality improvement, waste reduction as well as enhancing energy use. Yet, there is not always a common perception of the automation vision. Manufacturing SMEs facing uncertainties in visualizing the automation strategies, the financial requirements for applying new technology and the overall impact on their business model.

The manufacturer 1 joined SAFIR project because the company managers were inquisitive about the benefits of automation, yet they were uncertain about which project would be the most beneficial to be automated. Furthermore, due to an unaccepted result from an earlier automation investment, the owner hesitates to make new automation investments.

The SAFIR project at the manufacturer 1 aimed at assisting the company to gain a better understanding of respective organizational and technological capabilities and adequate strategies to apply automation solutions within the manufacturing line.

Through the SAFIR project, the company was supported to specify and document possible automation projects and evaluate them based on financial, technical, and strategical concerns to create an automation road-map.

The SAFIR experiment at the manufacturer 1 conducted in late 2015. Project documentation and evaluation tool mainly were prepared on the bases of Microsoft Excel.

The first meeting at the manufacturer 1 preliminary consisted of an introduction to the projects visiting the manufacturing line and discussing the manufacturing strategies. In this meeting, Rune K. Larsen and M. Shahab. Parizi (Researcher) from Blue Ocean Robotics, as automation experts and facilitator, and the production manager, and CEO of the manufacturer 1 company participated. The CEO joined the meeting a bit later.

It is an important part of the project to give all participants a shared understanding of the production facilities and an overview of the material flow within the manufacturing line.

"one challenge we have seen in manufacturing SMEs is the lack of systematic overview of material flow" (Rune k. Larsen).

In some cases, negligence of systematic overview of material flow leads to highly automated functional units in the production line, for instance, a machine unit, while the link between the structure and overview of material flow and organization is missing.

Therefore, to start the day, through an initial company visit, the production manager introduced the manufacturing line, while highlighting specific manufacturing advantages and skilled workers as well as bringing up some issues, such as complexity in production processes and space restrictions in the manufacturing line. Within the production line visit, the production manager was asked if they already had some automation possibility in mind.

After that, the event continued at one of the meeting rooms of the company. An initial broad and inclusive introduction to the SAFIR project and its processes was given by Rune. The whole process was agreed by participants.

As the next step in the process, the discussion focused on the manufacturing strategies.

We need to clarify what is the manufacturing strategy at your company. What is the reason you want to invest in automation? [we ask this because] when we start evaluating different scenarios, we evaluate them based on these [could be] potential cost reduction, potential extra production, and other potential strategic focus points. (Rune k. Larsen)

Before hands, to initiate the discussions, an index of possible general manufacturing focus points or attributes for the manufacturing outputs (Miltenburg 2005) had been prepared and brought to the meeting Figure 20.

Manufacturing Output	Measures
Cost	Unit product cost, unit labor cost, unit material cost Total manufacturing overhead cost Inventory turnover-raw material, WIP, finished good Capital productivity Capacity/machine utilization Materials yield Direct labor productivity, indirect labor productivity
Quality	Internal failure cost-scrap and rework, percentage defective or reworked External failure cost-frequency of failure in the field Quality of incoming material from suppliers Percent defective Warranty cost as a percentage of sales Rework cost as a percentage of sales
Performance	Number of standard features Number of advanced features Product resale price Number of engineering changes Mean time between failures
Delivery	Quoted delivery time Percentage of on-time delivery Average lateness Inventory accuracy Order entry time Master production schedule performance/stability
Flexibility	Number of products in the product line Number of available options Minimum order size Average production lot size Length of frozen schedule Number of job classification in the factory Average volume fluctuations that occur over a time period divided by the capability limit Number parts processes by a group of machines Ration of number of parts processes by a group of machined to total number processed by factory Number of setups Variations in key dimensional and metallurgical propertied that the equipment can handle Is it possible to produce parts on different machines?
Innovativeness	Number of engineering change order per year Number of new products introduced each year Lead time to design new product Lead tome to prepare customer drawings Level of R&D investment Consistency of R&D investment over time

Figure 20. Measures or attributes for the manufacturing outputs (Miltenburg 2005)

The production manager was asked to state how he rates the manufacturing focus points within the organization. He could state a strategic focus point get inspired from the list or state specific focus points which were not mentioned in the list. He was asked to rate them against each other by giving them the score from 1 to 5: 1 not very critical, 5: the most critical. Since the purpose was to clarify which focus point is the most critical and which one is less critical, the suggestion was to keep the average score points around 3.

Through the strategy discussion, participation and communication were built by giving the participants explanations and instances on how different strategic focus points can be understood in the company. As an example, cost reduction as a strategic focus point:

In some places, they only talk in [cost per] items, but in some places, they talk about production cost. So, we need to use the terms that you use normally internally. (Rune K. Larsen)

The talks on the strategic focus point brought some discussion on previous experiences in automation projects. Some of the experiences caused the company to hesitate about new automation decisions. Regarding quality as a critical focus point, reduction in scrap and rework is considered.

We have 3 of motorman robots here [working with CNC machines]. […] Here the system can run over 40 hours without any person to operate. In one weekend, the cooling system did not work; this damaged the cutting tool in the machine. Therefore, a lot of scraps were produced over the weekend. (Production Manager, Manufacturer 1)

We have an aim to have 56 hours of un-man operation to cover when operators go on vacation then the system should run all weekend. (Production Manager, Manufacturer 1)

Bringing up the focus point and particularly rating focused points against each other brought some internal discussion between the production manager and the CEO. In one instance, there was a debate on what the cost reduction strategy should be focused on, increasing labour productivity, unit product cost or cost of quality.

The past three investment we have done, we bought robots, one of the reasons was to reduce the labour cost. (CEO, Manufacturer 1)

That is just cost, [which ultimately] is calculated in productivity. I have given that the most critical focus point is productivity. But I don't know if you agree on that. (Production Manager, Manufacturer 1)

For me it is more overall efficiency, which is important, that is easy to say because that includes many things. (CEO, Manufacturer 1)

In many cases, there were the same understanding of the focus points and their importance.

The next step was to identify potential automation projects. This is done based on the suggestion from the company participants and review and expert evaluation from Blue Ocean Robotics participants. In the case of the manufacturer 1, three possible automation projects were identified:

1. To automate loading and unloading parts from the saw, clean chips and prevent them from spreading across the production line;

2. To automate the measurement of fabricated parts immediately after cutting processes;

3. To automate deburring processes of machined parts.

To prioritize the projects and specify the detailed requirement of each automation project, they needed to be explained in detail with the project scope and possible innovative idea on how it could be automated. For this, the SAFIR excel tool was utilized.

Initially, the CEO and the production manager had different opinions about the importance of each of these projects. The CEO believed that removing chips from the manufacturing line was very curtail, due to a better quality of products in further processes as well as cleaner and safer working environment, while the production manager was arguing that he would invest on a project to improve productivity on cutting processes to directly impact the value adding processes.

As the next practice, the company participants were asked to rate the identified projects against the overall manufacturing focus points. Here they were asked if the project would have implemented completely what would be the impact on each manufacturing focus point. The impact could be positive or negative.

In addition to the general manufacturing focus points, the company participants were asked to include any other project specific focus point and rate it. Here, for instance, environmental and housekeeping reasons, was identified as a critical focus point of the project No.1: To automate loading and unloading parts from the saw, clean chips and prevent them from spreading across the production line.

To complete the first meeting at the manufacturer 1, detailed technical information of the first project was gathered. This was including:

- The detailed manufacturing processes within the project work-cell, cycle time and material information.
- The project background with a focus on if an automation solution has been suggested previously from a potential provider.
- The company's capability to handle new technical challenges after implementing the automation solution. Which consider internal capabilities and possible external capabilities which can be obtained.
- The complexity of the project considering the complexity of the processes as a robotic task and if the required technologies are available in the market.
- The risk of the automation project with a focus on the possible impact on the production, if the implemented automation solution fail.

Furthermore, the project business information, including estimated savings and additional profit or extra cost due to the automation project is calculated. This includes:

- If the project leads to an increase in production capacity, the additional profits due to additional sales
- If the project leads to higher production quality, additional profits from the additional Sales price
- If the project leads to an improved lead-time, additional profits from the additional sales price
- Saving duo to a reduction in man hour
- Saving due to a reduction in stock and saving in inventory costs
- Saving due to a reduction in failure rate in production
- and other possible saving could be energy saving, better utilization of the space, building and other resources.

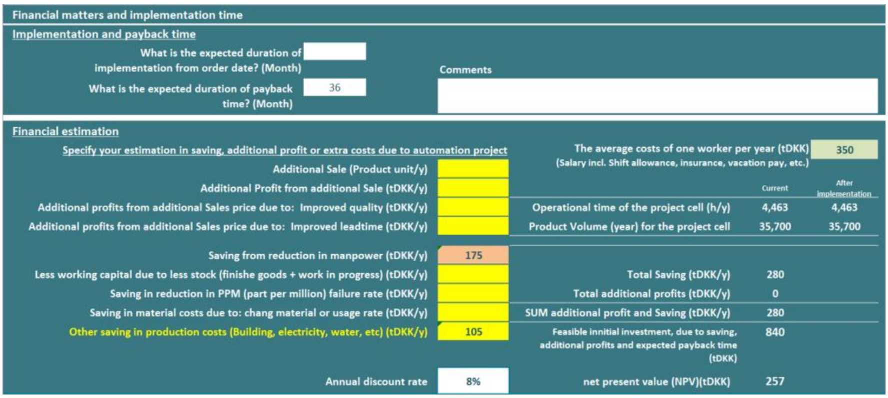

Figure 21. Financial analysis questions, SAFIR Excel tool

The business data analysis conducted by the SAFIR excel tool for financial analysis (Figure 21). The tool has been developed during the project to be used as a base for comparison analysis of different automation project from the financial point of view. To build the tool, during the internal meeting at Blue Ocean Robotics, the financial indicators had been identified and excel based calculator was built and testes. The use of the business data analysis and working with an active data analysis system provided, caused a lot of discussion on the understanding of the current situation and the different business opportunities. Furthermore, this assists the company to understand what the business benefits of the project could be. If the company has a preferred or required pay-back time on the investment project, the maximum investment rate for the project can be understood. This number only specify what could be the initial maximum investment rate if the project considered feasible financially.

The communication and effort were taken to keep the sense of performing as a joint process to identify needs and evaluate possibilities, with attention to involvement and commitment to the process. Therefore, one intention in the first meeting was to go through the SAFIR excel tool, and by giving sufficient description on the evaluate process of the first automation project, enable the manufacturing company to take the next step and continue the work with the second and third projects. To complete the first day of the company visit, participants reviewed the results of the day and discussed the next steps.

> *Very interesting process and fun when we have the information in place. We see that it is not only saving, and money is considered here, but also there is a lot of planning of people. I think that part should be seen that we will have an easier management process. (Production Manager, Manufacturer1)*

In the following week, the manufacturing company's participants had time to continue working on the SAFIR excel tool by documenting two other recognized projects and sent data to the SAFIR office at Blue Ocean Robotics. Based on the given data, a comparison analysis of three projects carried out regarding three main areas (Figure 22):

- Alignment with manufacturing strategies
- Project complexity, risk, and available capabilities to handle challenges
- Financial impact

Projects Summary and Comparison Table

BLUE OCEAN ROBOTICS - for humans

Close view

Open view

		Allience with overal comany production objectives (-10 to +10)	Specific Project Objectives (-10 to +10)	The level of automation (1-3)	Simplicity of the project (1-3)	Influence in case of failure (1: Higher negetive impact, 3: Lower negative impact)	Manucafturer capabilities to handle new technical equipment (Manufacturer point of view)	Total saving (Yearly, DKK)	Total additional profit (Yearly, DKK)	Feasible initial investment (tDKK) (Manufacturer point of view)	NPV	Priority	
NSM01	Automatic loading and unloading items from saw machine	2.00	8.00	3.00	3.00	3.00	3.33	280.00	0.00	840.00	257.37	3.00	
NSM02	Automatic measurement of materials at the measuring station immediately after processing machine	2.80	5.00	3.00	3.00	2.00	3.33	400.50	37.00	1312.50	402.14	2.00	
NSM03	Automatic deburring of machined parts	3.20	8.00	3.00	1.00	2.00	4.00	420.00	750.00	3510.00	1075.44	1.00	It is the most interesting project for the company with very high impact. And also it is the most complex. In case of finding an existing solution, that would be the first choice

Notice: The Blue Colored data bar represents the value of each evaluation item of project, compare to the other projects. The higher the value, the longer the bar.

Figure 22. Summary of projects comparison analysis

The content on the second meeting which held via Skype was focused on review, and discuss the comparison analysis and apply required modification on each project documentation. The purpose of this meeting was to prioritize projects and make an initial decision on which project should be selected for further investigation and investment.

However, in the first company visit the CEO and the production manager had different opinions about the importance of each project, through this process, a better understanding of recommended improvements and the expected benefits acquired which led to a new set of prioritizations, followingly. The second project meeting concluded on an initial automation road-map which mainly clarified the priorities of the project. *To automate the deburring processes of machined parts* was selected as the first automation project.

The selected automation project was about the automation of the deburring process of machined parts (Figure 23).

Figure 23. The deburring processes.

*** Part images are blurred due to the company restrictions.**

In the deburring work-cell, parts are carried out through the processes of picking from the pallet, deburring holes, deburring inside and outside edges and ultimately place them back to the pallet. Additionally, the process consists of using multiple deburring tools -bits- that may need to be changed in between. The project is interesting because by implementing an automation solution for the described project, the company is expecting impacts on manual work cost reduction, improvement in work environment and flexibility in operating time. Yet, the process is complex for the robotic task, due to the high level of flexibility, complex motions such as pick and place tasks and flexibility in robot tools. Therefore, fully automatization of the work-cell was challenging and find the right automation solution provider was not an easy task.

THE EARLY STAGE OF COLLABORATION AT THE BUYER COMPANY

The early stage of collaboration refers to the time when a buyer search for a potential supplier, gets in contact with them to be assisted in determining the project requirements and develop a specification of possible solutions within their relationship.

Following the recognition and determination of the improvement opportunities and automation roadmap, the right supplier must be established to maintain production. Based on the investigations and preliminary interviews, crucial data was collected regarding the tendencies of SMEs buyers when searching for a supplier to provide new technologies and solutions. During the interviews with buyers the following factors emerged:

1. Information concerning suppliers and possible solutions are achieved through networking, exhibitions, and other relevant subjects, which in the particular case of SAFIR, acts as a facilitator for the buyers.

2. Searching through search engines like Google is another method of finding the right equipment and tools.

3. Collaboration with Innovation hubs and local innovation centre.

In the case of the manufacturer 1, the SAFIR project members assessed the company to find automation suppliers specialized in the field of the selected project, to automate deburring processes. Two potential suppliers were identified and contacted. The suggested automation suppliers were found from the close network of Blue Ocean Robotics based on the former knowledge about their expertise and field of expense. They have received an initial introduction to the project through SAFIR tool, the project brief, and they were asked to evaluate the project, based on the criteria of implementation difficulty and the possibility of delivering the project within the financial frame stated from the project evaluation document. Finally, there were asked to include a short description of the previous experience relevant to the project task. The automation provider questionnaire in Appendix A.

The project brief was made in the JotForm platform, an online form builder, and sent to the selected automation suppliers before they receive the invitation to the manufacturing site. The purpose of this package was to give them an introduction to the project scope and to let them have an initial evaluation of the feasibility of performing the task. So, they could decide whether they want to take the next action and go for the company to visit or not. Additionally, the manufacturing company and the SAFIR team could have a better idea on the competence and skill set of the automation suppliers by checking their previous experiences.

The second company visit at the manufacturer 1 took place together with the supplier 3. The meeting started with an introduction presentation from the Director of the supplier 3, where he represented his company with a focus on their previous successful automation projects and frequent implemented solutions including videos and images. After that, all participants took a manufacturing line visit. The content of the visit with the automation provider was to get a detailed understanding of the project and the requirements, as well as evaluating different innovative solutions. Most of the communication was around the technical requirements where the production manager and the operator of the work-cell collaborated to answer questions about the current situation of the processes in the work-cell and possible innovative ideas. At this early stage of collaboration, participants had the opportunity to get to know each other and exchange contact information for further communication.

Two other company visit occurred accordingly, and as an outcome, the manufacturer 1 received three different innovative proposals from the potential suppliers.

THE DEVELOPMENT STAGE OF COLLABORATION AT THE BUYER COMPANY

The development stage of collaboration at the buyer company refers to the processes and circumstances which lead to a decision on evaluation and selection of a supplier and investment on the specific solution. This includes evaluating alternatives, evaluating risk, negotiation on the final solutions and success criteria as well as reach a final agreement.

Buyers use decision heuristics to evaluate and compare offers such as functionality and quality, often using surrogate measures where limited information is available, for instance, price is frequently used as a surrogate for quality (O'keefe & McEachern 1998).

The buyer may ask for trial versions and simulated version of the solution, interact with salespersons to evaluate different scenarios and questioning of previous customers in order to demonstrate the feasibility of the idea.

EVALUATION AND SELECTION

Analysing the SMEs evaluation and selection process as previously mentioned (Chapter 3.6) is executed by a range of semi-structured and targeted interviews. Buyers emphasis on a number of criteria when a decision on supplier selection is made. Recommendation from a close network and trusted specialist within the field of an identified issue, as well as the reputation of a supplier, can affect the buyer decision on supplier selection.

> *We expect that Blue Ocean Robotics makes a thorough search in the market for automation suppliers that are suitable for the project needs since we trust the experience Blue Ocean Robotics has already in this area. (PTA manager, manufacturer 2)*

> *They are very known for providing measurement equipment. (Production Manager, Manufacturer 1)*

Moreover, the following factors are considered when a solution proposal is evaluated by a buyer: high quality, service packages, and financial consequences.

> *The quality is very important for us, we need to make sure that we meet the same level or higher level of quality in production after ReconCell. The tolerances should be as stated in*

> *standards. So, we need to do the tests and make sure we have consistency in results before we use it in production. (Head of R&D department, Manufacturer 3)*

> *... what are the service packages and maintenance? We do not want to have experience with the machine, which breaks and there is no service or guarantee. Particularly about machine components. We need services to make sure upkeep the machines and if something breaks, we know that we receive the right component." (Team Leader Industrialization, Manufacturer 4)*

> *... we look at a positive business case. (Head of R&D department, Manufacturer 3)*

Furthermore, the following influential factors are preferred in some cases:

- Fulfil the general project requirements due to the production plan
- Adoptability with other currently implemented technologies
- Alignment with strategic focus points
- Leadtime and date of delivery
- User friendly and easy to operate

In the case of the manufacturer 1, the company received three different innovative proposals from potential suppliers. The proposals had been submitted in the form of the solution brief including a short description of the scenario, possible using components, overall price and time frame for delivery as well as a draft 3D model of the possible solution (Figure 24).

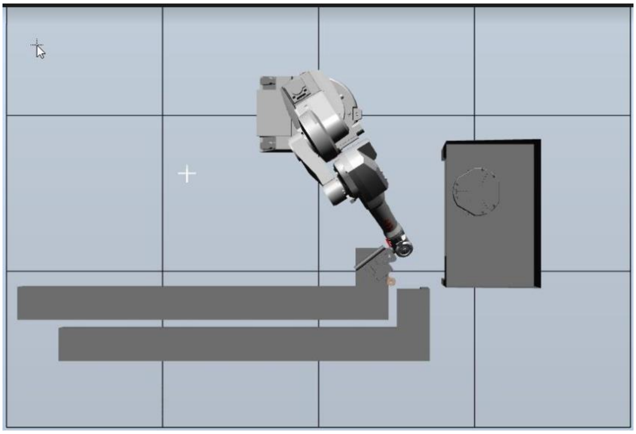

Figure 24. Draft 3D model of the solution

Even buyers are convinced on the feasibility and the proof of the solution, still, buyers are willing to calculate the risk of an investment before they take an investment decision. De-risking processes associated with complete design and demonstration of the solution, and in yet other instances, simulation of the solution which is associated with an improved cost for suppliers.

The SMEs want to calculate the risk of investment before investing in a solution, which is perfectly normal. The problem is they expect a whole solution free of charge, which no automation provider is willing to do as it expensive for them to have an engineer working to develop a solution. That is why automation suppliers prefer larger enterprises over SMEs. (Automation expert)

To avoid this Some suppliers, offer paid pre-test projects to reduce the risk.

We can prepare a quick quotation for a customer within a very short time, it can be sent per email. Preparing additionally document, text files (and modelling of the cell) can take more time.

> *It is important for us to get paid from one point on, as it gets more time intense and needs the effort to calculate and prepare an offer or to give feedback. We normally suggest to the customer [to pay for] the costs for the previous test and other things. This can be subtracted later on if an order is achieved. If a customer is not willing to pay for example 1500€ for a pre-test, which would reduce the risks, then he is not really interested. (Project Manager and CTO, Supplier 1)*

In the manufacturer 1 case, the buyer has selected the most consistent innovative solution after consulting with automation experts. The selected solution consists of a semi-automated solution where 80% of repetitive work of deburring processes will be done automatically and just 20% of the work still will remain manually. Focusing on the repetitive and not very complex robotic motions to be automated helped to reduce the complexity and the risk of the solution, as well as the associated amount of investment. Additionally, this will result in a relatively large amount of savings and additional profit to the company, estimated with about one year of a payback period.

4.4. COLLABORATION STAGES AT SUPPLIER

In this section, the author explores the pre-collaboration stage of buyer-supplier interaction from the supplier point of view. The study is based on semi-structured interviews and observations at the supplier 1 and supplier 2, two automation solution suppliers.

Supplier 2 is specialized in providing a bin-picking solution (Figure 25). Bin-picking refers to the automated feeding system for parts which are placed randomly, semi-structured or structured in bins. This technology includes vision guided robots to locate and pick a range of individual parts from bins and to feed them into machines, welding systems or fixtures. The company's tasks are mostly based on software activities, whose part-recognizing patented program has a unique value proposition.

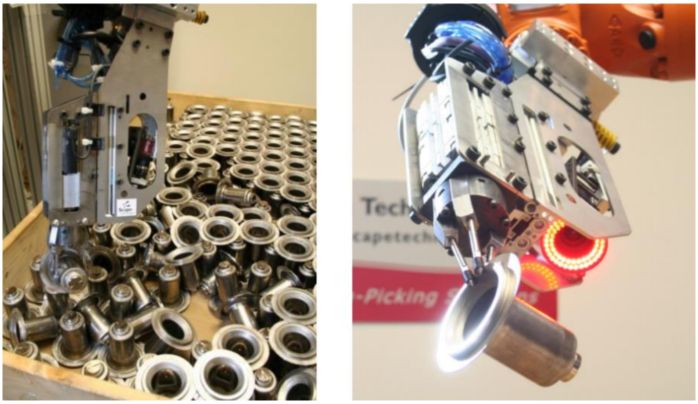

Figure 25. bin-picking technology from supplier 2

The final solution is offered to a buyer by integrating the bin-picking software solution into a standard of-the-shelf camera, along with other part handling mechanisms, depending on project case: magnets, grip hand, suction cup. The part handling system is attached to ordinary industrial robot arms. To provide a final solution, the supplier 2 needs to collaborate with other technology suppliers or local integrators, where the role of supplier 2 is to provide software and perform as a lead supplier and other partners take the role of complementary technology suppliers.

On the other hand, supplier 1 as an integrator is specialized in providing a complete solution. The company offers a wide range of applications such as welding, sorting, handling and so on. In most cases, the supplier 1 provides a solution mainly based on internal capabilities.

In both cases, to be able to keep down the cost for solutions suppliers prefer to sell the automation solution in standard versions. However, in some cases, customizations, which imply modifications to the final product is required. This does not come without additional costs generation as well as increased delivery time. Despite the advantages of customization that could be a big benefit to the customer, especially price increase negatively influences the sales.

The high degree of flexibility with respect to the technology applications as well as the non-clear targeted customer affected supplier's collaboration efforts in three stages.

THE PRE-COLLABORATION AND EARLY STAGE AT SUPPLIER

The pre-collaboration stage at provider organization refers to a combination of events which frame a portfolio of potential opportunities to offer, concerning organizational and technical capabilities as well as business strategies. In addition to that, this stage includes identifying potential contacts and conduct pre-call planning to utilize various approaches to simulate interest and establish initial contact. When the complexity of solutions, as well as a high level of adaptation to customer demands, is expected, suppliers experience new challenges.

The recent sales model of supplier 2 which is illustrated in Figure 26 follows foreign direct sale mode (Hollensen et al. 2011). The company keeps a high degree of control in the marketing and sales activity based on the internal sales team and well as a local sales partner.

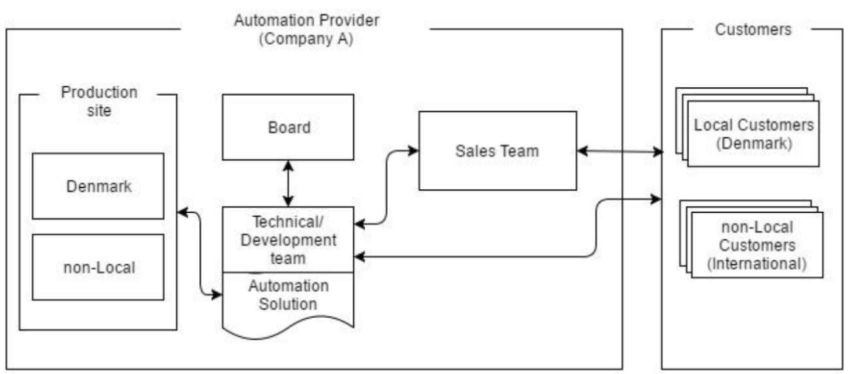

Figure 26. The recent sales model of the supplier 2

When potential customers approach the supplier company, they do not always possess the awareness concerning their actual needs, challenges, or even problem.

> *Efficient communication and exchange of information are strongly depending on the distinct customer. Thereby, some customers, for example, do not have enough time for the whole process, are not fully aware of what they are ordering, or they do not know their actual problem, or cannot explain it.*
> *(Project Manager and CTO, Supplier 1)*

In many cases they need the supplier to take the role of consultancy, may assist a part, in acquiring a better understanding of the need. In pre-collaboration stage this could be limited to an initial feasibility check on the solution as illustrated in the following supplier quote:

> *"When a customer contacts us they always are not sure what they expect. Sometimes they already have a line and they only want to automate the bin-picking process, but sometime the line is not existing and the want to design and implement the whole line. They want us to give them a quotation in let's say one week. But a bin-picking project depends on many varieties. In best case scenarios with little information on the project, we only can say yes, the project is possible, no it is not possible, and, in most cases, it might be possible. We need them to send us the parts and detailed information about the project to be able to run a test case. Only then we will be able to give them an answer." (CTO, Supplier 2)*

NOT INVENTED HERE (NIH) SYNDROME

The complexity of the solutions brings uncertainties in buyers which make them unsure if the technology could fit their requirements. In some cases, a negative attitude to the knowledge and technology that originates by the source outside of the own institution or closed network (Katz & Allen 1982) can be observed. Furthermore, "not-invented-here (NIH)" syndrome cause SMEs buyer to assume that the solution is far from the current state-of-development or it could contribute with a high cost for such a small company. This makes suppliers from the early stage of communication to face the challenge of answering the question of how the new technology could adopt current processes and internal strengths in a buyer organization.

To approach this, the sales representatives focus on similarities of the challenge in comparison to the previously solved challenges to realize the common features and specifications that would indicate a similar solution with some level of adaptation could work in the new case. Then use presentation and visualization tools such as videos and simulated models to inspiring the buyers by helping them to envision how the specific challenge can be solved by their solution.

CURIOUS BUYERS VS SERIOUS BUYERS

In both cases of supplier 1 and supplier 2, they see advantages in getting engage with potential buyers and create curiosity to drive them to want to *know more* about the offering technology. Suppliers utilize different methods to attract potential buyers such as participation in exhibitions and events, social media, seminars and webinars, networking, email marketing, and press release. The value of getting involved with curious buyers has been understood by suppliers. It not only brings the possibility of an actual realization of an automation solution but also the engaging curiosity might lead to offer something of incremental value or future return. The conversion rate from curious audiences to actual buyers is limited. Reviewing the sales statistics of suppliers shows only 20% of initially contacted visitors have a challenge which could be solved by the offering technology and they receive a quotation from the supplier. Out of this, only 10% of quality leads or only 2% of generated leads, make purchases following their visit (Figure 27).

Figure 27. The rate of successful sales from initially contacted visitors

Therefore, suppliers consider taking actions to improve the rate by focusing more on serious buyers. Therefore, they consider *qualifying* a new potential buyer in a very early stage of collaboration and only prioritized buyers with a higher chance of actual purchase. Suppliers found the best way to get to know a buyer and qualify them is to communicate with them from the beginning.

This is strongly related to direct contact with the customer, including talks. If I have a good feeling from the start, I can say if they customer is ready. (Project Manager and CTO, Supplier 1)

Suppliers consider some other criteria to qualify a lead such as budget, need and former experiences, the involvement of key decision makers, timeframe as well as the technology fit. This is usually understood during the first or second meeting with the potential buyer by asking questions and visiting the manufacturing facilities.

Trust building. Trust building for successful projects has been considered by suppliers in early stage collaboration with buyers. Trust building has been concerned from three perspectives.

Perform as an advisor: Industrial suppliers consider to be an advisor to the customers and take a proactive approach instead of interacting with them with a human sales representative who pushes the own agenda with no consideration to the challenge.

In the exhibitions we see many visitors that they seem interested in the presented solution, they take notes and pictures, but they avoid getting in dialog with us (Supplier representative)

Industrial buyers would rather do research online about technology and only get engaged with salespersons who provides new insights about their business or industry. The improvement opportunity needs to be determined by the buyer so that optimization and achievement can be obtained through purchase and later implementation of the solution.

The way they find us is through networks, previous work, and from time to time internet. What they require is naturally a solution for a certain problem, what we often experience is they want more detailed solutions and we have to be careful not giving them too much. They tend to ask multiple suppliers and sometimes take advantage of other supplier's ideas, and make the cheapest provider create them based on the offer. (Supplier representative)(Parizi & Al-azawi 2016)

Furthermore, service or guarantees are preferable in some cases.

Building a personal relationship: In the early meeting sales representative shows an interest in getting to know him/her and ask many questions about interests, hobbies, family and offer information in return. They open to other fields of communication.

Because they would much like to get to the customers themselves. They are good at making projects and convincing that I am very good at this will be a very fine project for us. If you sign, we will go fishing on Friday. And you are welcome to my party on Sunday. This is the way they do selling. (Rune Larsen, Co-CEO, Blue Ocean Robotics)

Direct communication in initial meetings and hosting social events such as banquets help the supplier selling teams to build a personal relationship with buying centre. This personal relationship enhances the rapport and trust between buyers and suppliers.

Knowledge sharing. The knowledge sharing between firms is based on mutual respect, shared values, perceived competency (Reagans & McEvily 2003) and a level of mutual trust between partners (Das & Teng 1998). To advice a buyer and evaluate their project case, getting access to detailed and, in some instances, confidential information is required.

> *In some cases, our customers are so worried about sharing information with us, specifically through online applications. They have the agreement with their customers which bond them on sharing some information specifically CAD models with third parties. Here, we need to sign NDAs which sometimes this could be very time-consuming due to the complex organizational processes at the customer side. When we know each other, or we have done projects together, this won't be a challenge. (Project Manager and CTO, Supplier 1)*

Suppliers suggested that trust which has been developed within the successful former relationship could promote knowledge creation and sharing, yet in the situations which parties are in the early stage of collaboration, official agreements should support building trust.

Building reputation: Suppliers, particularly in new businesses focus on building reputations based on transparency, stability, and consistency of their capabilities and previous results. Referring to success former collaborations and case stories is another strategy which is highly considered by suppliers within their pre-collaboration and early stage of collaboration processes.

THE DEVELOPMENT STAGE OF COLLABORATION AT THE SUPPLIER

The Development Stage of collaboration at the supplier side occurs as confirmation of business and technical requirements, the final solution, implementation plan as well as success criteria is approved, and the agreement gets to its final and solution is delivered. Following the problem recognition, mapping the requirement as well as providing an initial suggestion on the solution, the solution selling process gets to the stage of detailed solution design and implementation plan.

The investigations and preliminary interviews were focused on describing how the development stage of collaboration takes place at the supplier side and highlighted the associated challenges. In the case of the supplier 2, this has been examined by mapping the communication system within the sales process between different project collaborators. Figure 28 illustrates a typical sales process at the supplier 2.

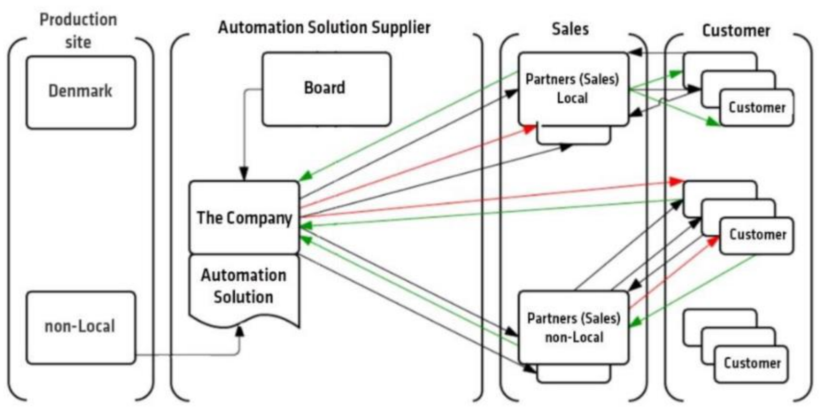

Figure 28. Typical sales process at Supplier 2 ((Badi & Spahic 2014))

According to Badi & Spahic (2014) the sales process of the company is described as follows:

1. Following the first visit at the manufacturing site and initial feasibility evaluation, the salesman initiates communication with top management and different technical experts within the organization and consults them to ensure if the automation solution can perform under potential customer's circumstances.

2. Top manager and the technical expert review the case to provide the necessary knowledge to fill the expected role. This needed to be done by giving unplanned working hours which influences their scheduled work.

3. In many cases, having not enough information on the project case, technical experts ask for more details about the project.

4. The salesman then contacts the potential buyer and asks for this information.

5. Over a time-consuming and iterative process, the salesman through a back and forth message exchanges complete the required information for complete project evaluation.

6. At further steps in collaboration, the buyer gets in contact directly to the technical experts with additional detailed information and discuss possibilities of adaptation in production to fit technology limitation. (ex. to run an operatorless night shift to overcome the negative impact of production capacity due to the higher cycle time of the automation solution in comparison to the current manual work.)

7. Subsequently, more collaborators get involved in the process as decision makers or knowledge suppliers. In which they need to get brief about the project details and formerly made decisions. Since the communication is made in the bases of e-mail, phone calls, as well as face-to-face meetings, insufficient documentation, causes a lack of understanding of the specific information that needs to be included for decision making purposes.

8. The process is continued up to the time that a decision is being made, this is contributed with wasted time and afford.

Figure 29 illustrates the number of e-mails going back and forward between different collaborators of the collaboration development stage between supplier 2 and one of the buyers. The buyer organization and internal departments are shown on the right side, where the suppliers and different departments are illustrated on the left side. The sales team represents the local sales partner which took the role of getting the initial contact with the buyer. The black coloured arrows show one-way emails, blue represents status, follow up and post visit emails, red illustrates an overview of internal communication between the supplier and the sales team, and green shows the email contain results of evaluation which communicated to the buyer (Badi & Spahic 2014).

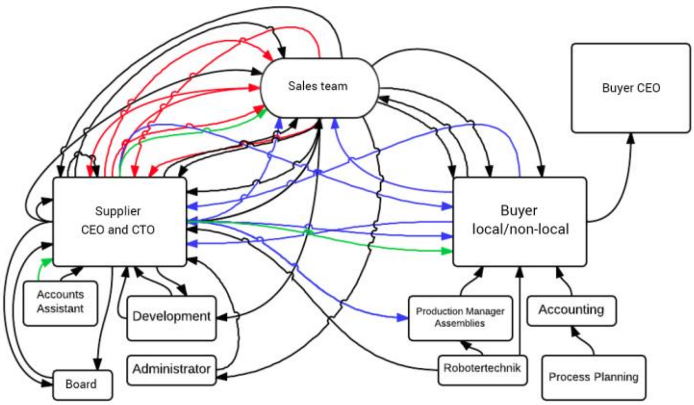

Figure 29. Communication map, e-mails going back and forward between different collaborators

Examining the complete communication map showed significant challenge with respect to the unnecessary, non-value adding communication between all the parties involved:

1. The supplier, regarding the current system for proceeding with collaboration development stage, is facing long waiting times, never-ending e-mail listings, many possible orders/customers getting unattended and an overall lack of structure. Therefore, the supplier needs to eliminate or at least reduce this waste of time (and working hours) spend during the sales process.

2. The supplier aims to continue its product promotion in international markets. That is why they are facing challenges related to the lack of market-specific knowledge and networks, the lack of technical support capacity for the international customer as well as the high cost of travels and other marketing activities.

4.5. MAP THE DEVELOPMENT OF BUYER-SUPPLIER COLLABORATION IN AUTOMATION DECISION PRACTICES

In order to obtain a solid structure of the automation business assessment model a definition of the role of lead integrator, the empirical data including key notes from interviews and observation are summarized in Table 12 and discussed further. This gives an overview map of the behaviour of buyer and supplier in different stages of the collaboration process and explains how the nature of this behaviour can be examined based on four identified aspect in relation to the three different stages of collaboration and experimental setups (Figure 30).

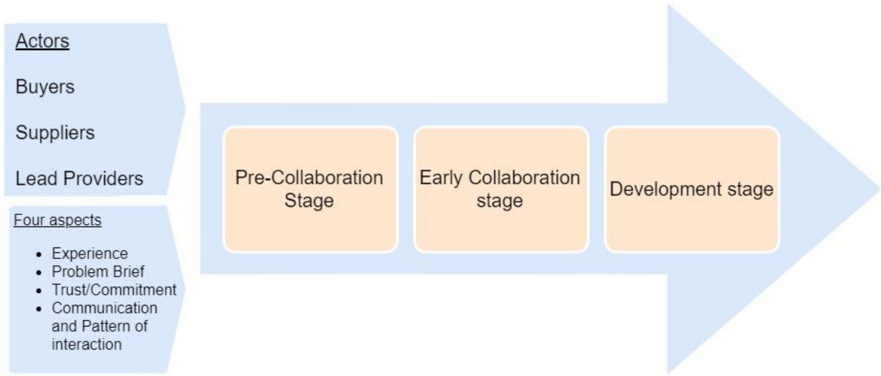

Figure 30. Map the development of buyer-supplier collaboration

Table 12. Map the development of buyer-supplier collaboration in automation decision practices

Buyer	Pre-collaboration		Early stage		Development	
Phase	Identification	Set objectives	Examination	Validation/assure / assertation	Consolidation	Investment/ Development
Objective	Vision strategy elements	Understand the requirements Create business cases Set objectives	Find solutions and components supplier	Proof of concept Refine automation vision	Discuss best terms for the solutions, price, and support	Investment realization Rollout implementation
Key activities	Defining and implementing of an	Identify and collaborate	(Co-design and) understand the solutions	Run test projects	Create deal and key terms	Execution of signed agreement

	automation roadmap	with stakeholders Gather business and technical requirement s Developed business cases and business scenarios Prioritizatio n	Early evaluation of solutions Refine requirements Options appraisal and shortlist	Implement light solutions A detailed evaluation of solutions, price, quality, and support Make recommendatio ns	Internal approvement Set the collaboration committee	Make a final investment decision
Supplier	Pre-collaboration		Early stage		Development	

	Approach	Requirements agreement	Conceptualization/ presentation	Test/ Refinement	Consultation	Sales/ Development
Objective	Identify potential opportunities and approach planning	Identify the challenge and requirement	Concept development and present	Present solution and prove capabilities	Discuss best terms for the solutions and collaboration plan	Investment realization Rollout implementation
Key activities	Marketing plan Offering portfolio Use-case and reference-user preparation	Diagnose the situation and position competitive capabilities Business case evaluation	Concept development Sales conversation preparation Propose a collaboration plan	Visualization of a possible solution and/or simulation Light implementation Performance test	Create deal and key terms Present final solution and implementation plan	Reach final agreement Sign the necessary documents

	Utilize various approaches to Establish initial contact and stimulate interest		Business case confirmation	Virtual and/or business commissioning	Set the success criteria	
Aspects						
Experience	Low	Low	Medium	Medium	High	High
Problem brief	Target: Low Path: Low	Target: Medium Path: Low	Target: High Path: Low	Target: High Path: Medium	Target: High Path: High	Target: High Path: High

Trust/Commitment	Low	Low	Increased by demonstrated references	Increased by test projects, simulation	High	High
Communicating and pattern of interaction	Internal collaboration Internet	Internal collaboration Internet Exhibition	Email Internet Phone Company visits	Email Internet Phone Company visits	Phone Email	Phone Email
Lead integrator	Pre-collaboration		Early stage		Development	
	Inspiration, Road mapping	Set Objectives	Solution Examination	Test/ Refinement	Consultation	Sales/ Development
Objective	Facilitation and	Execution strategies to implement	Concept design	Solution confirmation	Perform as the controls and	Perform as the controls and

	coordination, Inspiration Support to set the automation vision	the automation roadmap	Technology and supplier search and evaluation		automation engineering arm	automation engineering arm
Key activities	Facilitation, Inspiring seminars, and success stories Explore the business drivers and unique	Identify automation projects Technology and business case evaluation Prioritizatio n	Design the concept of the solution Bring the automation expertise to the table Refine requirements	Set standards and ensure the best fit for the manufacturing processes and the business needs	Ensure adherence to solution requirements Get involved in the implementatio n planning	Ensure adherence to solution requirements Get involved in the implementatio n planning

	manufacturing processes Evaluate state-of-development and Set automation road-map Key stakeholders identification	Set requirements	Business case confirmation		Set the success criteria	Evaluate the success criteria

THE PRE-COLLABORATION STAGE

Problem brief

The problem brief in the form of *project information package* was initially conceptualized as a problem framing, which is specified by its goal clarity, path clarity, mechanisms, and obstacle. Here, the clarity of the target refers to awareness of the end state to be achieved and clarity of path refers to awareness of the direction to achieve the target (Hirokawa 1990).

In the pre-collaboration stage at the buyer side, a high degree of flexibility with respect to the automation vision and automation path affected the buyers' preparation and involvements in automation investments efforts. This made them unsure of the determination of the manufacturing problem or the opportunity of improvement and to realize that there is a problem. Related to this, there are some cases that the firms are aware of a problem. Nevertheless, "not-invented-here (NIH)" syndrome causes them to assume that the solution might be unachievable regarding the current situation or it can become costly for such a small company, that is why they may keep the focus on growth in terms of capital, new customers and stay competitiveness in relation to the resources.

> *"We have no problems" -" … sometimes we have no work for fourteen days." - "What we could do better is maybe get more customers" (Manufacturer representor)*

Another example:

> *"…When we have challenges, we solve them of course, but we don't have problems with manufacturing…most problems are with the design of the stoves-the product-" (Manufacturer representor)*

From the perspective of the automation supplier, the SMEs are less interested in full solution development. Moreover, the work and order are not as consistent as with the larger firms.

The pre-collaboration stage at the supplier side is focused on identifying the most relative target group of the offering technologies and services and creating a plan for approaching the targeted group. Yet in approach to a potential buyer, the uncertainties about the problem brief in respect to the actual requirement, target and path made suppliers to unsure of the solution they were expected to offer.

Lead integrator in collaboration with buyers gave the indicators of setting up the roadmap and set up the objectives to the buyer. In this line, to overcome the NIH syndrome, lead integrator, through automation inspiration sessions and with sharing some automation practices, assisted manufacturing SMEs to realize that complex and high level of automation is not always the solution, rather, there are some appropriate solutions, which are more fitting for actual problems and their current state of development or there is a possibility to take smaller steps toward automation.

Moreover, the lead integrator initiated, facilitated and motivated communication between internal actors on how to evaluate and map the automation concepts to their specific domain and business strategy.

The lead integrator, in collaboration with a network of suppliers, assisted them to approach potential buyers with the requirements which could fit with their offering solutions.

The pattern of communication and interaction

In the pre-collaboration stage, the pattern of interaction dominantly follows the conversations between internal actors of both buyer and supplier companies. In collaboration with lead integrator, the pattern of communication is mainly bilateral conversation between buyer/supplier and the lead integrator where the content of interaction between buyer and lead integrator is to clarify the state of development and exploring the improvement opportunities while the content of interaction between the supplier and lead integrator is to discover the potential of the offering technology and possible business scenarios for buyers.

In the pre-collaboration stage, communication and information sharing mainly happened toward internal communication and face-to face meeting.

Experience

At the pre-collaboration stage, both buyer and supplies are in the stage of identifying and setting up the profile and specifications of a possible partner, therefore, both are likely to have very little experience of each other. The experience in previous relationships or the references in their network provides the criteria by which the potential and performance of a new partner will be considered.

Trust and Commitment

In the pre-collaboration stage, both the buyer and supplier have little or no evidence to evaluate the potential partner's commitment to the collaboration. In fact, in this stage, both partners' effort is focused on exploring the criteria to be based to judge their partner's commitment.

THE EARLY STAGE OF COLLABORATION

Problem brief

Buyers moved to the early stage of collaboration when the concreate automation road-map, fields of action, automation objectives and specific projects were determined and internally discussed. Therefore, in the early stage of collaboration, the focus of the buyer was to search and initiate communication with potential solution provider for projects with a specific target and unclear path.

In the cases of this study, the most manufacturing SMEs at the time do not possess the required knowledge of automation, which in combination with the unclear development path of the automation task, made them unsure of specific competences and suppliers to approach. Based on the observation, manufacturing SMEs, in the absence of a lead integrator, search for suppliers and solution providers via:

1. Networking, exhibitions, and other relevant subjects.

2. Looking through web-based search-engines including Google as well as industrial machinery data-bases

3. Approaching possible suppliers from similar industries.

When a potential supplier is found, the initial approach focuses on posing the problem to a supplier. In this stage, the contact persons in the supplier organization typically the sales representatives or the management in suppliers SMEs, get into a conversation with the buyer where the content of the conversations depended on the degree of clarity of the problem, form requirements evaluation and advancing the project, to simple confirmation of possible solution.

In the early stage of collaboration, the problem brief is defined in terms of target and development paths from both business and technical aspects.

The lead integrator as facilitator and coordinator plays a crucial role in this stage which is not only specifying the project requirements but also the lead integrator must determine required competences, participate in finding, communicating and evaluating suppliers with relevant competences, describe role expectations to facilitate interactive knowledge sharing and development path clarification.

Decisions and implementation of automation solutions and digitalization is categorized as highly complicated task. According to Mintzberg (1993), collaboration between suppliers is coordinated based on mutual adjustment mechanism, where the simple process of informal communication play the crucial role of coordination. In this set-up, lead integrators facilitate a rich dialog between suppliers and manufacturers who need to take a decision of the automation solution. We argue that the lead integrators have better role to lead the complexity, because there are at the level of understanding complex automation solution which is not available at the customer who need to take the decision.

Communication and interaction

When the buyer gets to the early collaboration stage, while the business and technical targets are limitedly determined, and the development paths are not specified, low clarity of the problem leads the content of the conversation to be focused on describing and advancing the project (Laursen 2017), so the project requirements are specified.

With advances in process, the project business and technical targets get to a higher level of clarity, while the development path needs to be greater clarity, the supplier initiates to evaluate the feasibility of the project based on their own competences and capabilities and well as the value they could gain from the project. The suppliers had attention to influence the buyers by presenting the possible development paths and solution concepts which matches their competences along with refereeing to previously performed projects with some degree of similarity with the given project, from their own portfolio as well as cases in the suppliers' network.

Further, in the process, where the project target and the path of development get to a clearer level, the focus of interaction is on advancing the project through test and evaluation of the possible solution and knowledge contributions.

Experience

In the early stage of collaboration, both buyer and supplier have little experience of each other where they have a limited overview of what they are expected to deliver in collaboration and the value they could gain from the project. There is no routine procedure to deal with issues such as concept development, qualification processes, and collaboration plan agreement. The issues can be solved by management engagement in the process and investment of management time.

The lead integrator contributes by facilitating guidelines, suggesting standard procedures, presentations, daily programs, summaries of takeaways and communication with suppliers.

Trust and Commitment

In the early stage of collaboration, the actual commitment of both parties is at a lower level. Yet, the perceptions of commitment are influenced by factors outside the collaboration including the brand name, the number, and importance of other partners (customers and suppliers). Further in the process, the perceptions of commitment formed based on their initial assessment of the performance, and potential competences and capabilities of the partner. The judgment of competences can be influenced by presenting the possible development paths and solution concepts with reference to previously delivered projects with some degree of similarity with the given project. Furthermore, the judgement importance of this collaboration within the partner company impacts the perceptions of commitment. Suppliers have a higher commitment to the buyers who invest time, money and expertise to build the collaboration where their managements get involve in the process.

THE DEVELOPMENT STAGE OF COLLABORATION

Problem brief

Within the development stage of collaboration, the content of the project description with the most detail of the business and technical targets as well as the development paths is clear and linked to the suppliers' technical competencies. In this stage, the suppliers clearly linked the project requirements to the internal knowledge of their organization and discuss different possible technical challenges of the project with their internal experts. Furthermore, the right experts are identified and prepared to get involved in the project.

The project briefing at this stage focuses on clarifying deliverables in detail, integration points as well as the detail of success criteria which is the bases for agreement.

Communication and interaction

At the development stage of collaboration, the interaction between participants is reflecting on the shared understanding of the project purpose and the development path. The content of the conversation focuses on the consultation of the collaboration steps. This is required to elucidate the role of the supplier in the project implementation, the collaboration process and the knowledge and expertise to be allocated to the project by them, particularly when multiple suppliers participate in project deliveries. The lead integrator could take the role and responsibility of making a meaningful collaboration pattern and integration plan.

Experience

In the development stage of collaboration, the experience between participants increases in terms of understanding the operations, decision making processes as well as norms and values of other organizations. The increased experience makes the partners to gain a better understanding on the offers they need to provide and adaptation they need to apply to fulfil the requirements from the partner company, furthermore, they will be able to evaluate their own expected value of collaboration with the partner company.

Commitment and trust

In the development stage of collaboration, partners are mainly evaluated based on their commitment to the actual solution development plan and development tasks. The effort to adopt the solution design as well as an implementation plan to meet the partner requirements is one way to show commitment. This can be demonstrated by highlighting ambitions and simultaneously apply adaptation principles to a formal contractual agreement as well as being open to the discussion for possible informal adaptations which potentially may be arranged further in the process, to deal with specific issues which escalate over the course of the development practice. For instance, a German buyer of a picking robotic cell gained a positive impression of a Danish automation supplier, Supplier 2, because the supplier adopted the design of the solution to be compatible with a specific robotic arm which was commonly used in other robotics cells in the manufacturing site, and the operation and maintenance tasks could be supported by the existing internal capabilities of the buyer company.

The way companies organize their professional communication with a partner has been observed as another influential factor for trust building and showing commitment. This refers to both involvements of the senior contact persons, the speed of response as well as the frequency of contact when it is required.

Furthermore, commitment can be emphasized by social relationship and personal involvement. As an example, it is common in Danish society to meet partners in social events to reduce the social distance.

The map of the behaviour of buyer and supplier in different stages of the collaboration process constitutes a direct input for the development and the application of the automation business assessment model where the proposed methodology built on it. Moreover, it describes the role and actions of the lead integrator as a facilitator and coordinator in this model. This map provides the basis for understanding the model principles and the aspects to be considered in the process model. In other words, the defined three stages of collaboration, and 6 steps describing the behaviour of buyer and supplier in automation decisions are built to be used as a base for building a facilitation guideline for companies for going toward collaborative automation decision practices. This framework aims to assist companies to evaluate and build up their automation vison and initiate collaboration with automation partners. The results also should be used for automation suppliers to optimize their process of collaborative solution development and solution selling. The process of model development is described in detail in Chapter 5.

Chapter 5.

Development Process

5. DEVELOPMENT PROCESS

With the aim to assist manufacturers and automation suppliers collaborate efficiently in automation decision practices, a methodology based on a digital automation business assessment model was required and so developed. The development process of the proposed methodology is presented in this chapter. The research observation and the development practice, as well as the analysis of the practice with a focus of manufacturing companies, is reported in this chapter. The inputs and consideration used as the bases for the development of the methodology proposed with automation suppliers. Furthermore, this chapter encloses the methodology as well as the development phase to build up the automation business assessment model (Inhancer) and the Inhancer digital platform.

5.1. DEVELOPMENT FRAMEWORK OF THE AUTOMATION BUSINESS ASSESSMENT PROCESS MODEL

In this section, the process of development of the automation business assessment model is described. For the purpose of this research, the methodological view of developing maturity models has been chosen to be based on the model development. Some recent studies have been published on suggesting methods for the development of maturity models. Garcia-Mireles et al. (2012), based on a review analyses, suggested a guideline to be followed for the model development. His suggested guideline consists of five activities to be performed: inception, elaboration, construction, deployment, and maintenance.

During the inception phase, the performance is focused on problem diagnosis, identifying participants, planning and identifying the scope of the targets. In the elaboration phase, the design strategy is set, and the architecture of the model is realized. Accordingly, in the construction phase, the model parameters are configured and procedures for its deployment are defined. In the deployment phase, the model is deployed and validated. If the model gets to general acceptance, within the maintenance phase the changes are evaluated and applied (Garcia-Mireles et al. 2012).

In another study, De Bruin et al. (2005) suggested a development framework which provides a comprehensive approach to different phases of model development and actions to be performed. Figure 31 illustrates the main phases of De Bruin et al. (2005) development framework.

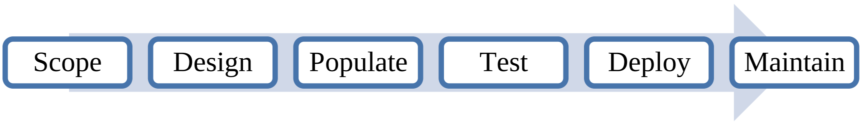

Figure 31. Model deployment phases (De Bruin et al. 2005)

The model consists of six main phases which are described in detail in the following:

Phase 1 – *Scope*. Determine the scope of the desired model is the first phase in model development. The decisions on the model scoping will influence all remaining phases in the model development framework. The decisions made in this phase involves the focus of the model and determine which domain the model would be targeted and then applied.

Phase 2 – *Design*. The second phase of the development framework is to determine a design or architecture for the model to be a base for the establishment of the model in further steps. There is a number of major decisions to be made in phase 2, which are shown in Table 13.

Table 13. Decisions when Designing a Maturity Model (De Bruin et al. 2005)

<table>
<tr><th>Criterion</th><th colspan="6">Characteristic</th></tr>
<tr><td rowspan="2">Audience</td><td colspan="3">Internal</td><td colspan="3">External</td></tr>
<tr><td colspan="3">Executives, Management</td><td colspan="3">Auditors, Partners</td></tr>
<tr><td>Method of application</td><td colspan="2">Self-assessment</td><td colspan="2">Third Party Assessment</td><td colspan="2">Certified Practitioner</td></tr>
<tr><td>Deliver of application</td><td colspan="2">Internal Requirement</td><td colspan="2">External Requirement</td><td colspan="2">Both</td></tr>
</table>

Respondents	Management	Staff	Business Partners
Application	1 entity / 1 region	Multiple entities / single region	Multiple entities / multiple region

The design of the model incorporates the identified challenges and requirements of the audience and participants and how these needs will be met in the model. The requirements of the intended audience are reflected in why value the model application creates for them, how the model can be applied to in their organizational structures and organizational decision-making process, the participants to be involved in the model application and what can be achieved through the application of the model.

The complexity of the model should be considered in the model design phase to meet audience needs. A model that is oversimplified may not sufficiently reflect the complexities of the domain and may not provide appropriate meaningful information for the participants. Whereas a too complicated model may limit interest or create confusion in the model application procedure as well as the possibility of increasing the potential for incorrect application results.

Phase 3 - *Populate* Once the scope and design of the model are agreed the content of the model is decided. In particular, it has to be identified what needs to be performed and how it can be performed in the process of the automation business assessment.

Identification of domain components, interaction types and designing the process are critical as this enables a deeper understanding of business assessment. The domain identification can be done either analysing the existing literature while in the relatively new domain it seems unrealistic to gather adequate evidence through existing literature to derive a comprehensive list of domain components. Therefore, a literature review is sufficient in providing a theoretical initiating point and other means of identification like the Delphi technique and focus group is required.

Furthermore, in the design phase the instruments used in conducting data gathering, documentation and conducting the assessment, following the design principles, need to be determined. This provides a level of reliability and consistency of response and evaluation which enables results to be easily shared and understood via the project participants network.

In the case of this research, it is important that the model and the developed digital platform provides a collaborative environment where the participants receive the valid information and valid questions in each step of the process to be able to provide valid information. The number of tasks to be performed in each step is balanced, since too many tasks may reduce the reliability of the performance by resulting in incomplete actions and sufficient responses.

Phase 4 – *Test*. Once a model is populated, it needs to be tested for relevance. It is important to test both, the construct of the model and the model instruments for validity.

Construct validity is represented by both face and content validity. Content validity is focused on evaluating how completely the domain has been represented. Face validity is assessed by whether good translations of the constructs have been achieved. Therefore, the developed model needs to be comprehensive and accurate with respect to the identified scope of the model, while it requires to cover the design objectives.

Face validity is assessed by whether good translations of the constructs have been achieved. This validation is conducted during the population phase of the model utilizing tools such as focus groups and interviews. In other words, the assessment instruments, the digital platform, have to be tested in order both to ensure that they actually perform what it was intended and to guarantee that the results obtained are accurate and repeatable.

Phase 5 – *Deploy*. Subsequent to population and testing, the model must be made available for further applications and verify to the extent of generalization. Therefore, the critical issues of the model standardization are determined in this step which can lead to the general acceptance of the model. The issues considered initially by design collaborators as primary responders are included in the deployment phase. It is likely that the initial application of the model will be with the stockholder which has provided the resources to developing and test of the model, i.e. an industry. The models which were developed for the specific domain where a single or a limited number of stockholders were involved, the identification of similar firms in different markets may supply the list of potential “next” administrations.

Phase 6 – *Maintain*. Following the deployment phase, the model needs to be maintained for its growth and use. A highly generalized model can be achieved if a high volume of model applications is realized. This will require some form of resources to track model evolution and development.

The De Bruin et al. (2005) framework by giving a comprehensive guideline to perform in each phase provides a structured approach to follow while developing an automation business assessment model.

5.2. OBSERVATION OF THE RESEARCH

In order to achieve a solid structure for developing the automation business assessment process model, literature (Chapter 2) and the empirical data (Chapter 4) has been analysed. The definition, classification, evolution, the different types, structures and scopes of inter-organizational collaboration and coordination mechanisms as well as the buyer-supplier collaboration process map in automation decision practices has been developed. This is the bases for the model development. In the following a summary of the finding from the literature analysis and empirical analysis findings is reported.

Anticipates of collaboration in automation decisions

Co-knowledge creation is taking place during the ongoing relationship and collaborative partners learn from each other, they adapt business models to better match the requirements of each other. Consequently, the partners keep the relationship dynamic, adaptable, and valuable to the involved parties. Outcomes of this collaboration and the interactive feedback consequence in potential business benefits which reported in Table 14 (Min et al. 2005).

Table 14. Consequences of collaboration (Min et al. 2005)

Mutuality	Mutually beneficial and synergistic
Efficiency	Cost reduction Reduced inventory Shortened lead-time Streamlining supply chain process
Effectiveness	Improved customer service Increased market share Better pricing New product development
Profitability	Return on investment Sales per target segment
Reinforcement and expansion of the relationship	Trust Commitment Interdependent Mutual involvements

In this line, particularly in the process of new product development and supply chain collaboration key activities are considered by collaborative partners. The key the collaboration activities the framework for successful collaboration which can be used to guide daily operations as well as longer-term strategic planning (Min et al. 2005). Table 15 draws a summary of key collaboration activities and domains.

Table 15. Key collaboration activities (Min et al. 2005)

Information sharing	Forecasting Customer demand Materials requirement
Joint planning	Marketing planning Production capacity and scheduling Joint planning Mutual sales and performance targets Budgeting Prioritizing goals and objectives
Joint problem solving	Product development/redesign Logistics issues (shipping, routing, backhauling, pallet size, packaging, etc.) Marketing support (marketing materials, delivery

	schedule, store display, etc.) Quality control Cost-benefit analysis (inventory carrying cost, lead time, customer service, etc.)
Joint performance measurement	Performance reviews on a regular basis Measuring KPI (customer service, cost savings, productivity, etc.) Determining rewards and taking corrective actions
Leveraging	Resources and capacity Skills and knowledge Specialization

An effective inter-organizational collaboration between engineers and organizations in such an extended company network during industrialization is built on general conditions. The general conditions for inter-organizational collaboration can be summarized as following (Johansen 2005):

- Communication on product/solution introduction. A clear communication to define and describe the product/solution introduction and needs.
- Supports efficient collaboration. Early participation from all involved partners in the process need to support collaboration efficiently.
- Communication and information handling. A clear communication and information handling within the extended enterprise (collaboration community) -both internally and externally- is a great impact on facilitating the collaboration.
- Trust in business approaches. Trust, reliability and respect for each other's competence.
- Cultural awareness. The importance of the cultural awareness between different partners and countries, needs to be considered.

Other aspect of an efficient inter-organizational collaboration in new product development is related to the integration mechanism between engineers and organizations which can be studied under the aspect of integration mechanisms in inter-organizationcollaboration activities which impact NPD. Based on the litreture analysis, the integration mechanisms were identified and reported as following:

- Trust, Commitment and Mutual Understanding
- Goal agreement
- Information and Knowledge Sharing and Integration
- Coordination and Communication Mechanism
- Cooperation and Collaboration
- Technical Integration Mechanism

The other aspect, was deeply analysed in the literature, was the coordination mechanisms, with a focus on inter-organization collaboration. With consideration to the design chain and process model approach, Twigg (1996) introduced different coordination mechanisms that a manufacturer uses Table 16.

Table 16. Inter-firm coordination mechanisms identified by Twigg (1996)

	Pre-project	Design phase	Manufacturing phase
Technological	Electronic data interchange CAD/CAM data exchange		
Organisational	Supplier development team Joint development Technological gatekeeper Supplier development committee	Guest engineer Joint product/process design team	Resident production engineer
Procedural	Cost management Supplier assessment	Producibility design reviews Sign-off Designer's tacit knowledge of manufacturing	Engineering changes Production prototypes (fit-build-test cycles) Manufacturing flexibility

With a more emphasize on complexity, Lewis et al. (2002) studied coordination within the field of product development project management and classified coordination methods and product development management activities into planned management and emergent management styles. Figure 32 illustrates the contrasting styles of project management from the perspectives of emergent style and planned style.

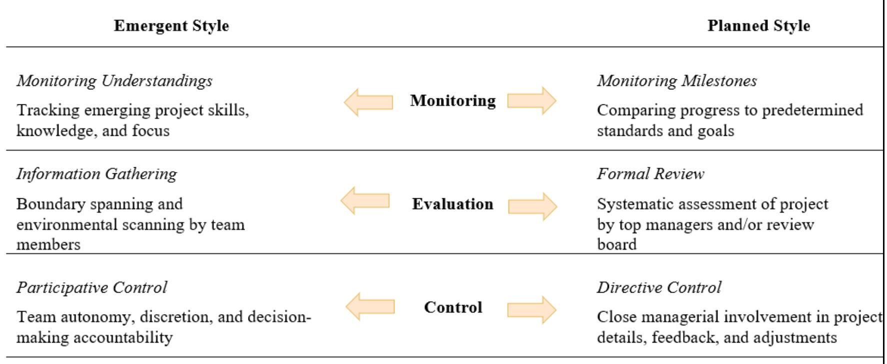

Figure 32. Contrasting styles of project management in product development (Lewis et al. 2002)

In addition, Van de Ven et al. (1976) investigated variations and interactions in the use of the coordination mechanisms and modes considering task uncertainty, interdependence and unit size and argues that the mix of alternative coordination mechanisms used within organizational units is different based on the degree and kind of influence of each determining factor.

Mintzberg (1993) in other study introduces three basic coordinating mechanisms: mutual adjustment, direct supervision, and standardization (of which there are three types: of work processes, of work outputs, and of worker skills). He suggests the coordination mechanism is shifted depends on the task complexity. Simple tasks can simply be coordinated by mutual adjustment. As the tasks become more complicated, direct supervision needs to be included and takes the responsibility of the primary means of coordination. By the time things get even more complicated, standardization of work processes, outputs or skills (or in combination) become the primary coordination mechanism. In highly complicated situations, mutual adjustment become primary coordination mechanism again. Yet this may become in combination with the other mechanisms. Figure 33 illustrates the use of the coordination mechanisms based on the task.

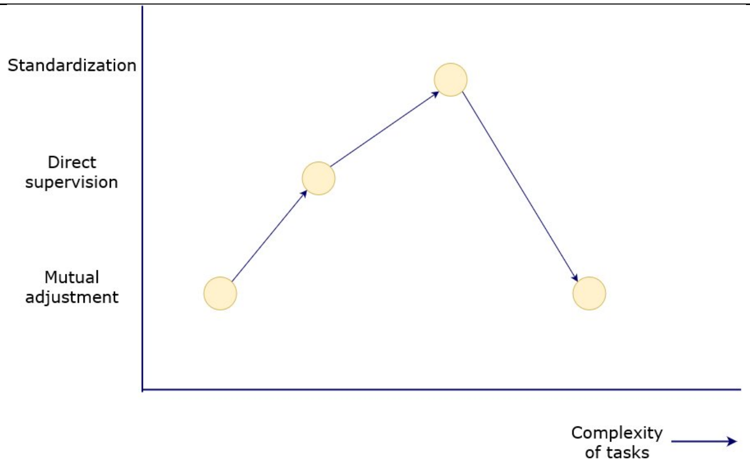

Figure 33. The use of the coordination mechanisms based on the task Mintzberg (1993)

In this research, the researcher used the concept of dynamicity of coordination mechanisms based on the complexity of the tasks as a solid fundation to the research work and focused on the implementation mechanisms of coordination mechanisms and modes of collaboration, within the empirical context of this research.

The literature also discussed that the innovation complexity and information-related conditions may impact the introversion role and the decision power of coordinator while match different partners and suppliers in an inter-organizational collaboration. Here the role of integrator and the decision power of lead integrator based on the innovation complexity of the automation project and information-related conditions was another interest of researcher.

As discussed in Chapter 4, findings from empirical data, the stages of inter-organizational collaboration identified and analysed to build up an overview map of the behaviour of buyer and supplier in different stages of the collaboration process and explains how the nature of this behaviour can be examined. This has been done based on four identified aspect in relation to the three different stages of collaboration and experimental setups (Figure 34).

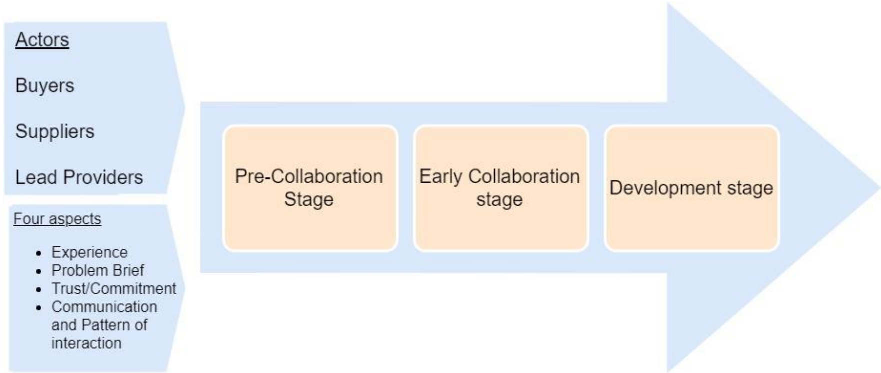

Figure 34. Map the development of buyer-supplier collaboration

The buyer-supplier collaboration development in automation decision practices describes the typical behaviour of a partner at each of the three main stages and six sub-stages, for each of the aspects of coordination and collaboration. The developed map sustains that collaborative partners are likely to evolve through the identified phases, before reaching the excellence in automation decision. These stages are reported in

Table 17. Map the development of buyer-supplier collaboration. For each level, it is indicated how the four collaboration and coordination aspects look like.

Table 17. Map the development of buyer-supplier collaboration

	Pre-collaboration		Early stage		Development	
	Identification	Set objectives	Examination	Validation/assure/ assertation	Consolidation	Investment/ Development
Buyer key activities	Defining and implementing of an automation roadmap	Identify and collaborate with stakeholders Gather business and technical requirements Developed business cases and business scenarios Prioritization	(Co-design and) understand the solutions Early evaluation of solutions Refine requirements Options appraisal and shortlist	Run test projects Implement light solutions A detailed evaluation of solutions, price, quality, and support Make recommendations	Create deal and key terms Internal approvement Set the collaboration committee	Execution of signed agreement Make a final investment decision
Supplier key activities	Marketing plan Offering portfolio Use-case and reference-user preparation	Diagnose the situation and position competitive capabilities	Concept development Sales conversation preparation Propose a collaboration plan	Visualization of a possible solution and/or simulation Light implementation Performance test	Create deal and key terms Present final solution and implementation plan	Reach final agreement Sign the necessary documents

	Utilize various approaches to Establish initial contact and stimulate interest	Business case evaluation	Business case confirmation	Virtual and/or business commissioning	Set the success criteria	
Lead integrator key activities	Facilitation, Inspiring seminars, and success stories Explore the business drivers and unique manufacturing processes Evaluate state-of-development and Set automation road-map Key stakeholders identification	Identify automation projects Technology and business case evaluation Prioritization Set requirements	Design the concept of the solution Bring the automation expertise to the table Refine requirements Business case confirmation	Set standards and ensure the best fit for the manufacturing processes and the business needs	Ensure adherence to solution requirements Get involved in the implementation planning Set the success criteria	Ensure adherence to solution requirements Get involved in the implementation planning Evaluate the success criteria
Collaboration and coordination aspects						

Experience	Low	Low	Medium	Medium	High	High
Problem brief	Target: Low Path: Low	Target: Medium Path: Low	Target: High Path: Low	Target: High Path: Medium	Target: High Path: High	Target: High Path: High
Trust/Commitment	Low	Low	Increased by demonstrated references	Increased by test projects, simulation	High	High
Communicating and pattern of interaction	Internal collaboration Internet	Internal collaboration Internet Exhibition	Email Internet Phone Company visits	Email Internet Phone Company visits	Phone Email	Phone Email

The purpose of this model was to understand where a company is, what is the focus point of collaboration and coordination mechanism, at the current moment in respect to identified phases on inter-organizational collaboration development, so that an appropriate and efficient program and process group could be carried out.

5.3. ACTION RESEARCH AND CO-DEVELOPMENT OF KNOWLEDGE

To ensure a participatory action and co-develop of knowledge with the host company, the development of the model to facilitate buyer-supplier collaboration was planned and carried out in a close interaction with the Blue Ocean Robotics.

Once the data structure was built, the development framework proposed by De Bruin et al. (2005) was applied to build up the automation business assessment model. De Bruin et al. (2005) framework gives a comprehensive guideline to perform in each phase of model development and provides a structured approach to follow while developing the model. Based on De Bruin et al. (2005) framework, the development phases of the automation business assessment model and the digital platform was defined and carried out in close interaction with the host company, Blue Ocean Robotics. Within a number of iterations, the co-development of knowledge took place, where the methodology, process model and designed digital tools were presented in management meeting and feedback collected. Findings deployed as business processed within the host company in iterations and results evaluated with respect to the commercial purposes. The process model and tools have been which released within the host company named differently due to management feedbacks, commercial purposes and Blue Ocean Robotics' strategic interest: SAFIR-e (Strategic Automation for Industrial Robotics – Electronic version) as a continues to the SAFIR project, BATool (Business Assessment Tool) and finally Inhancer. The scope and definition of the tools are described further in this chapter. The co-development of knowledge of digital platform development process and initial steps for commercialization have been done under the supervision of the researcher within the product development team of Blue Ocean Robotics throughout the following tasks:

- Transform user needs in requirements for further system implementation.

- Product development roadmap development, project planning and execution and manage product releases
- System test by applying user testing methods for data gathering in order to improve the user experience and user adoptability
- Future product development strategy – to plan the further direction of the product in the future.

In line with this, there were additional tasks to be conducted with the purpose of commercial exploitation:

- Develop Inhancer business plan as a start-up business model.
- Develop Inhancer Product promotion material including commercial web-site, flyers and user stories.
- Inhancer introduction material and presentations.
- Develop the user manuals and help module system for new user on-boarding.

All the tasks have been documented as they offered the possibility to go in depth with the system and suggest improvements which would have a significant impact within the product development of Inhancer.

Design principles and user stories for product designs established based on the user interviews and evaluation meetings. Through an evaluation process, based on inputs from developers, users and the host company managers the requirements prioritized to form the product versions. The product development process conducted based on agile project management principles, where an iteration approach was applied for planning and guiding project processes (Schwaber 2004). To help facilitate understanding of the system, flowcharts and mind maps and wireframes which were used as a discussion tool, developed using draw.io tools as well as design software such as photoshop.

5.4. MODEL DEVELOPMENT, THE AUTOMATION BUSINESS ASSESSMENT MODEL

The following chapter gives an overview of how the Automation Business Assessment model is designed. Therefore, literature findings, performance analysis of the behaviour of buyer, supplier and lead integrator in the automation decision process and considerations from academia and company experts constituted a solid basis for the construction of the new model, Automation Business Assessment, which is called Inhancer in this research. In this Chapter, firstly, the main development phases of the model and the design principles are presented. Secondly, the design of the model is illustrated and described.

MODEL DEVELOPMENT PHASES

As it has been previously described in chapter 5.1, the De Bruin et al. (2005) development framework is used as a guideline to present how the Inhancer model was developed. In the following section, the steps toward in each phase of development framework are described and illustrated in Figure 35.

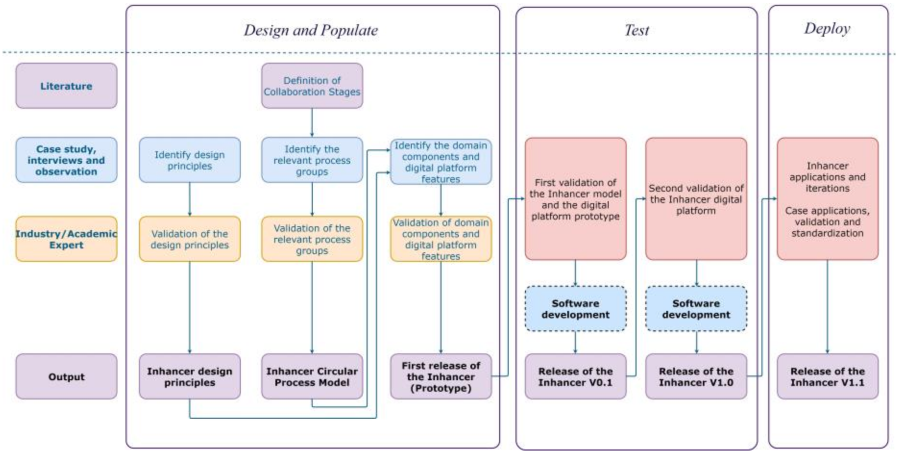

Figure 35. Development phases of the automation business assessment (Inhancer) and the digital platform

MODEL DEVELOPMENT PHASE 1: SCOPING

To determine the scope of the model, the application domain of the model was defined as the first step. The main objective of the model is to assist manufacturing companies and automation suppliers in automation decisions to enhance the level of automation and digitalization in manufacturing companies. In particular, the Inhancer model is aiming at joining several stakeholders' needs:

Automation buyers or Manufacturing SMEs which will be able to develop automation systems in their manufacturing which is supported and facilitated by having access to Inhancer model and the digital tool.

Automation suppliers including:

- Automation and machine tool/robot suppliers which can incorporate and promote automation solutions and robotic platforms as part of next generation smart production line components and solutions.
- Developers of cognitive (learning, knowledge management capability services) and automation apps for autonomous service support.
- Suppliers of cloud, simulation and computation services
- Integrators and solution suppliers that built production line solutions for SMEs and OEMs.

Automation experts such as research institutions, digital innovation hubs, and integrators with a wide spectrum of knowledge and skills to get engaged in the strategic automation roadmapping with manufacturing companies and collaborate with them through the automation decision processes.

MODEL DEVELOPMENT PHASE 2: DESIGN

The actual design of the model is based on the following aspects:

Audiences: Inhancer model suggests a multi-sided ecosystem where the audience of Inhancer are represented by the companies themselves, while the activity is different based on the role the company takes in the ecosystem. The Inhancer model guiding the manufacturing side of the ecosystem through the digital automation for technology selection and digital automation solution development and for the automation provider side enhance their capability to reach and collaborate with manufacturers.

Method of application: the model is applied by participant companies or the lead integrator using the Inhancer digital platform made based on the Inhancer model.

Respondent: The model and the digital platform is applied based on questions and answer structure for information gathering and reflect on received data from managers and relevant experts of the manufacturing company and automation provider.

In the view of the above set aspects, and over the domain modelling sessions the structure of the model was designed.

To do so, the core design principles were determined in the design phase. The design principles are described in Chapter 5.6. In addition, the main relevant process groups of automation business assessment were identified and described in a circular process model, Chapter 5.7.

MODEL DEVELOPMENT PHASE 3: POPULATE

Following the design phase, and based on the model structure and design principles, it was required to identify the domain components of business assessment in each process group and the way they should be deployed. To do so, during this phase, four main steps were performed according to Moggridge & Atkinson (2007) model of design interactions. 1. Initially, based on the identified process groups, the ideation of domain components was performed through brainstorming sessions with the participation of three to eight members form the company. 2. The pre-selected ideas of domain components described into the concrete presentation by both visualization and behavioural description, including creating story boards. 3. Followingly, during the selection session the most promising group of the domain components ideas where selected, based on three criteria: value creating for audiences, the technical possibility and required effort to be deployed in the digital platform development in further steps. 4. Subsequently, the selected domain components visualized in the form of more complete as representation, for the purpose of communication the "potential reality of the concept" (Moggridge & Atkinson 2007). To do so, the behaviour scripts in the form of user stories as well as prototypes were developed. The process has been done in iterations which were focused on both the buyer side and supplier side. Accordingly, the detailed process model was developed. The structure of the model further described in Chapter 5.8 and Chapter 5.9.

MODEL DEVELOPMENT PHASE 4: TEST

Once the domain components and the digital platform prototype were developed, the test of the model should be performed to ensure the completeness and comprehensively of the Inhancer model. Test and validation are described in detail in Chapter 6.

MODEL DEVELOPMENT PHASE 5: DEPLOY

Subsequent to test and digital platform development, the Inhancer was ready to be made available for further applications and verify to the extent of generalization. Therefore, the Inhancer model and the related digital platform were applied to a number of cases including automation suppliers and presented during the course of two European projects, ReconCell and AUTOWARE. Based on the experience and feedbacks, the model was validated. The process of validation phase is described in Chapter 6. Additionally, for the purpose of identification of similar firms in different markets and to supply the list of potential “next” administrations, the profile of audiences of Inhancer audiences was reviewed and during the market intelligence study, a market plan for further deployment of Inhancer was performed. This is further described in Chapter 8.

MODEL DEVELOPMENT PHASE 6: MAINTAIN

Following the deployment phase, the domain components, as well as the digital platform, need to continually update in interaction with audiences, best practices and available technologies in the market. This will be performed in the future, following the framework of the suggested business intelligence model from the deployment phase.

The logical representation of the performed phases for model development as well as the key participation of actors is illustrated in Figure 35. As it is illustrated as well as previously explained, the main phases of model development initially focused on determining the design principles and relevant process groups. This provides the logical structure of the mode. Further, the domain components cover the intelligence aspect of the model, which are the bases for the development of the Inhancer digital platform.

5.5. ACTORS' ANALYSIS AND PERSONAS

Based on the identified key stakeholder groups, representative personas were created. Personas represent the key audience segments for reference that might get involved in the model and use the solution in a similar approach. Furthermore, the personas give the same view in the product teams to understand the audiences' aims in specific contexts, which is principally beneficial during ideation. Figure 36 illustrates a sample persona of a production manager in a sample manufacturing SME.

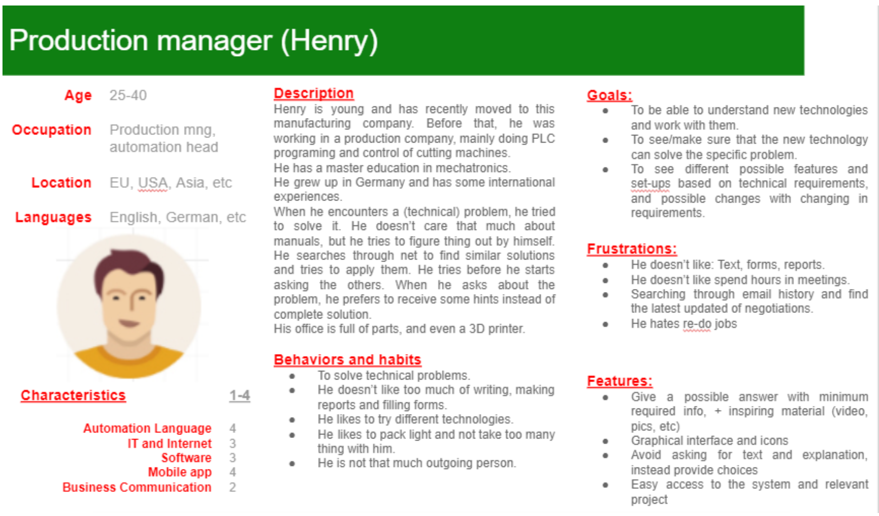

Figure 36. a sample persona of an audience of the model

5.6. DESIGN PRINCIPLES

Design principles can refer to characteristics of the planned model design (what it should look like), or of a procedural nature (how it should be developed) (van den Akker et al. 2012). Design principles are best expressed in active terms enable the stakeholders and developers to be aligned around the model.

"a good set of principles encodes that, so everyone can have this shared sense of what's important for us and what's true to us." (Zhuo 2016)

Design principles can be formed of heuristic statements such as (van den Akker et al. 2012):

"If you want to design intervention X [for the purpose/function Y in context Z], then you are best advised to give that intervention the characteristics A, B, and C [substantive emphasis], and to do that via procedures K, L, and M [procedural emphasis], because of arguments P, Q, and R." (van den Akker et al. 2012)

Design principles are often presented in the form of a list that describes characteristics of a particular product or solution. Therefore, design principles are not fixed, and they might be the consequence of the findings of a development and research experience.

To establish the design principles (Figure 37), over the course of the participant's interviews and brainstorming sessions and analysis of the results, and over the domain modelling sessions, a number of similar elements and patterns were identified. Table 18 proposes a sample of the analysis of the relevant data fragments from interviews to identify similar elements and patterns.

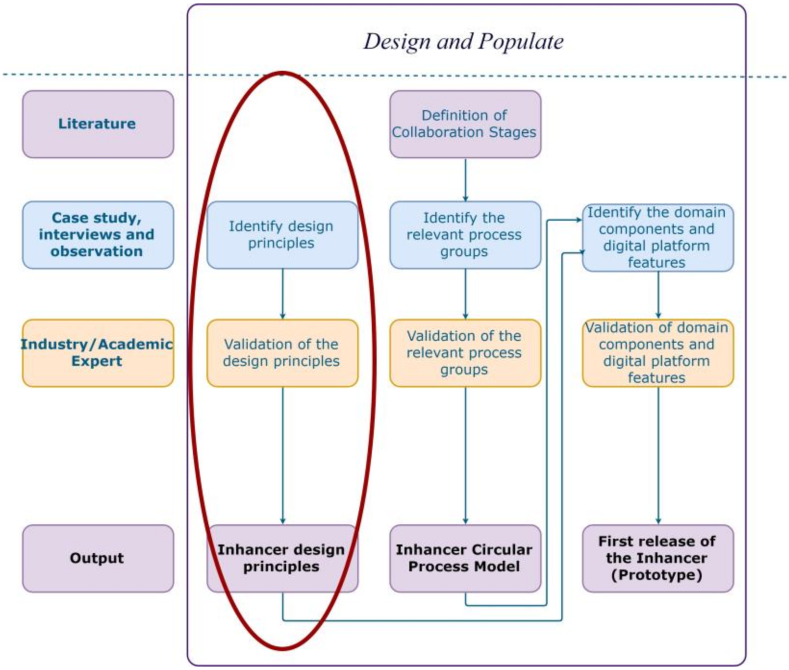

Figure 37. Identification of the design principles

Table 18. A sample of identifying the domain components and design guidelines (Appendix C)

Data Collection and Analysis Step① INSERT DATA FRAGMENTS: important words, sentences from sources that can influence our design guidelines. <u>Issues to focus on during data collection</u>: Preferences, needs, skills of users, stakeholders. Environments, values, ideas. Context of use, tools, objects. materials. Cultural situations, rules, guidelines.	Step② INSERT SOURCES Source of data fragments Can be: internet sources (web pages, videos), field study research, meetings, email/phone conversations, interviews etc.	Step④ CATEGORIZE THE FRAGMETS Give categories to the fragments. Clustering them according to what user need they belong to will help organizing the data. **Filter for the categories** for a better organized sheet.	Step⑤ DEFINITION OF DESIGN GUIDELINE: A general rule or instruction that influences feature design. If it is fulfilled, the corresponding user needs are fulfilled. Formulate on or more design guideline **for each user need category.**
① Relevant data fragments	**② Source**	**④ User need category**	**⑤ Initial Design Guideline**
Sales process, particularly within production field takes long time. There are 2 reason: 1. Investment decision in this field are taking time by nature, 2. Missing information and lack of a business case doc rise uncertainty, consequently, the time for decision	Interview with SCAPE	Business case creation Information management and data flow	The BAT tool should store the info, and facilitate business case creating
Decision makers in production companies need to make sure that the robot fulfill their requirement before taking an action.	Interview with SCAPE	State machine	To facilitate the evaluation of the projects in different stages To semi-automate some of the evaluation processes To ensure required information are provided (in an acceptable format/quality) before going to the next step
People don't like to ask push them in a way to help them, they prefer to try and test and discover if a product can solve their problem	Interview Casper, focus on Floor washer	Inspiring, motivating and involving	Provide exploring and motivating environment, without interrupting. The potential customer should be able to explore the solution capabilities and possible limitations, play videos and possible structure of the appropriate cell. Then they can register in the system for further communication.
We should avoid asking for contact information "email" in the very early stage of communication	Interview Casper, focus on Floor washer	Inspiring, motivating and involving	Provide exploring and motivating environment, without interrupting.
For floor washer robot: The hardest/most challenging part of the work is: 1. generate a lead and attract interest, 2. To motivate leads to the point they sign the contract	Interview Casper, focus on Floor washer	Persons Profile Company Profile Follow up and notification	To recognize interesting leads (potential customers) and get the contact info. To follow up with interesting leads at some points. To categorize the leads and sort them based on their progress in the selling/buying process. To visualize the pipeline
For floor washer robot: 1: technical questions are asked in the beginning to make sure the robot can cover the current situation. Questions about: the area, how many times washing/day, stairs?, ... 2. Business case related information to make the customer motivated to buy the robot, like the salary/hour, the number of workers, sick rate.	Interview Casper, focus on Floor washer	Technical data gathering Business data gathering Business case creating	Different data gathering and data analysis categories. 1. Technical info category. 2. Financial/business case category
If the area is too small with few number of wash/day or too large with number of big washing machine, then the robot cannot compete. The answer will be probably No	Interview Casper, focus on Floor washer	Initial technical evaluation Business case creation	No-Go projects: financial feasibility, technology limitation

From the analysis of the data, the elements are synthesized in the form of *design principles*. In the following the *design principles* are recommended for the incorporation of the automation business assessment model:

1. *Unity*. Hold the harmony, balance, and variety of design.
2. *Contextual overview*. Give a contextual overview of the automation project, environment and the processes with the possibility to scale up and scale down.
3. *Combined*: Combine mobile and non-mobile technologies.
4. *Communication*. Be a base for communication, data handling, and documentation.
5. *Affordances*: Exploit the affordances of the technologies
6. *Personalize*: Customized and personalized based on offering solutions and suppliers' business identity.
7. *Whenever, wherever, whomsoever*: Use the automation business assessment instantaneously, in non-traditional spaces, and both individually and collaboratively.

In the following, each of these principles is described in more detail.

UNITY

The unity of design components refers to the creation of the Inhancer domain components that support each other and all work together toward a common goal. The domain components need to look like they belong together and not be randomly chosen. This refers to both visual unities as well as a conceptual unity. The automation business assessment occurs in authentic contexts and needs to follow the process model described in "relevant process group" section. The domain components are created around the process model with the purpose to reinforce the main process flow. *"The design needs to be commercial, involving or impressive and will involve characteristics of collaboration, and interconnection*" (Rune k. Larsen). Therefore, the design of the Inhancer domain components within the digital platform is focused on proposing sequential processes and complement the key design theme. The images and icon are chosen to be used in the platform need to support communication of the design theme.

CONTEXTUAL OVERVIEW

Giving a contextual overview can be seen as the core design principle. This is aligned with the basic idea which is to optimize communication between buyer and supplier in the process of understanding the automation project opportunity and the requirements and possible solution. As it was described earlier and illustrated in Figure 29, the sales process at Supplier 2, missing well contextual information documentation caused unnecessary email communication between the automation supplier and the manufacturing company (buyer) and non-essential company visits. Manufacturing companies and automation suppliers not necessarily have the same approach to the automation challenge where they may analyse the project and technology from different level (Hansen & Madsen 2018). The manufacturing companies prefer to analyse the project and technology project from a wider level in the value chain, where operational, financial and business information is the core of focus. While the automation supplier, specifically the specialized automation suppliers evaluate the automation project from a lower order of technology system, where the focus is on details, for instance, the design of grippers, the sensors and the available light in the work cell. In many cases, the manufacturing companies or the automation buyers are not completely aware of what information the automation provider requires to evaluate a project cell. Therefore, to provide the greatest degree possible of contextual information alleviate the communication needs.

Align with this, the visual material including images and videos are a great asset to give an understanding of the project cell requirement. Yet, the way of handling visual material, particularly images, and including them in the documentation, associated with the problem that visual material in the documents seems to be not qualified enough and not showing details, moreover, exist in a vacuum such that it is not easily possible to realize where one picture is placed in the physical world compared to another picture. This may lead to repeat questions that were already aimed at being answered by using the visual material. Therefore, the visual material and images should be considered within the contextual overview.

In addition, the contextual overview of the project cell needs to provide an introduction including the environment and area. Examples include; an overview layout of the area as well as a material flow diagram to locate were specific processes are performed, and how the flow of material is into/out of cells. This should assist in creating the connections between the individual processes being performed, as well as images and other visual material to aid in the observer's understanding of where they belong.

COMBINED

Automation business assessment can be enabled by mobile technological tools and infrastructure. Mobile technologies are portable, accessible, personalized, and increasingly convergent. They are accessible and affordable while people enjoy using them. Equipped with technological components and platforms, they perform a multiplicity of functions. Wireless and telephone networks provide the required infrastructure. There are automation business assessment processes that benefit from a combination of mobile and non-mobile technologies. For the cases in this project, as it has been emphasized be the interviewees (Rune k. Larsen), the capacity of information and media capturing by using mobile devise within the manufacturing environment, as well as synchronizing information from multiple non-mobile devices, for instance, when uploading CAD files or textual material is required, adds to the adaptability of this technology where collaboration between multiple stakeholders is perceived.

COMMUNICATION

An efficient way of communication is required to overcome the need for more contextual information to identify the specific automation projects and to get a clear view of the project requirements. This principle focuses on including communication such as voice, video, messaging commenting, automated email and notifications to Inhancer application and by deploying application program interfaces.

This as it has been examined in the supplier 2 case (Chapter **Error! Reference source not found.**), enables to keep track of the communication, decisions, and messages sent back and forth between participants, and avoid the communication got lost. Furthermore, a communication system where the specific information and questions are associated with the characteristics of the automation technology, would keep questions to a minimum and make it easier to instantly understand what the questions are regarding and how to be answered, for instance, for internal transportation automation solution, the information of the path and possible obstacles. The entire communication between participants need to be stored and accessible in one system, to smoothen the communication process and information access.

AFFORDANCES

According to Gaver (1991) definition of affordance, *"...the actionable properties between the world and an actor [user]"*, this principle mainly refers to building a powerful relationship between the automation business assessment model and its audiences. This is according to determining objects' possible uses and their contribution to achieving the objectives of the model. Therefore, this enables reviewing domain components according to their perceptible properties.

This means, for instance, in some cases, it is preferred to prioritize one technology over another. For instance, Google Tango Technology generates a 3D map of the environment containing more contextual information that the images are taken by mobile phone camera. However, being accessible and much easier to use, there is a higher possibility that the mobile phone will enable the user to capture more environmental contextual information. Therefore, portability and convenience become dominant factors since the mobile phone camera could images that are possibly sufficient for the task.

Moreover, affordance refers to both financial requirements for system acquisition as well as the required effort for adaptation and deployment of the model into their business practices.

PERSONALIZE

Using a supplier's personalized automation business assessment model and its digital platform user interface ensures that many of the domain components of the digital platform are well known and perceived. Data structure and questions in the system need to follow the offering automation solution parameters. Furthermore, since the Inhancer digital platform is meant to be used as a base for communication between buyer and supplier, coloring and the graphical interface needs to be aligned with supplier company business identity. *"If we want to use it in connection with our company website, the design needs to follow a similar theme, so the user won't think that they get to a different environment." (CTO, Supplier 2)*

WHENEVER, WHEREVER, WHOMSOEVER

One idea behind the automation business assessment model is to enable manufacturing SMEs to get access and collaborate with both local and international competent suppliers. Therefore, automation business assessment, communication, and collaboration with international partners is not limited to time and space constrictions. Moreover, access to the project's information for the individual participants needs to be granted according to the confidentiality aspects.

5.7. INHANCER CIRCULAR PROCESS MODEL

For the purpose of Inhancer and having in mind that the focus of the model is to assist buyers which are manufacturing companies, and suppliers which represent automation suppliers, collaborate in the process of business assessment and decision making for automation investments. Therefore, it was important to identify the relevant processes which generate value through the management of the three collaboration phases: Pre-collaboration stage, the early stage of collaboration and development stage of collaboration. Figure 38 illustrated the method that the process groups were identified in collaboration with both academic and industry experts.

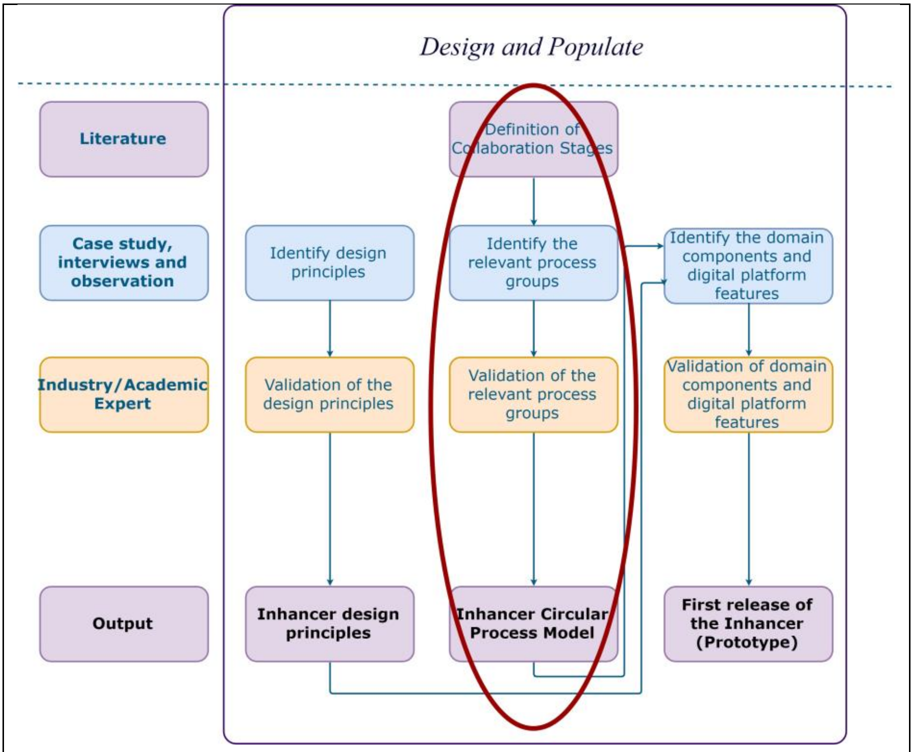

Figure 38. Identification of the relevant process groups

Based on the literature analysis and as a result from the empirical data analysis (Chapter 4.5), six main relevant process areas of collaboration development and automation business assessment from the perspective of both buyer and supplier actors were identified and modelled in a circular process diagram which reflects the dynamicity property of the model.

The model suggests that the automation business assessment be performed in a circular process instead of a linear one with an embedded decision-making framework for automation decisions.

To build up the process model, this research focused on three innovation process model including stage-gate (Cooper 2008), open innovation model (Chesbrough 2006), the simplified model from Tidd et al. (2005), and technology development perspective on entrepreneurship (Hansen & Madsen 2018).

Investment decisions for innovative automation solutions are not an easy and simple task of making choices between “clearly defined options” (Tidd et al. 2005); because the aspects associated with technology lead to extensive uncertainty (Hansen & Madsen 2018). Innovation, by its nature, is about unknowns, possibilities, and opportunities associated with doing something new, therefore, the process contains dealing with uncertainty and the innovation process aim at converting uncertainty to risk through knowledge (Tidd et al. 2005). Therefore, the process model needs to facilitate risk reduction and an increase in commitment and “lock-in” overtime to allow moving from “uncertainty to increasingly well-calculated risk management” over time (Tidd et al. 2005). Yet, the risks related to technological lock-in and path dependency (David 2001), as Hansen & Madsen (2018) considered, there is a requirement for substantial R&D investments to maintain and realize increasing performance improvements of new technologies where these investments sustain the incumbent’s dominance within the industry, yet, in a longer time frame, the further performance improvements become progressively fractional.

In a well-known market the language to describe the requirements and solution properties already exists (Hansen & Madsen 2018), while dealing with new technologies and specifically when the situation and improvement possibilities are unknows, information and the language to describe the requirement is not so easily accessible (Hansen & Madsen 2018). This raises a dilemma that in the process of automation business assessment and automation decision making some of the technical and business concerns may become clear at the later stage of the process, even during the test period or the implementation and operation process, yet they may be challenging to be remedied. It is important that these requirements and concerns are identified at the early stages of the innovation process, however, these concerns may be difficult to identify, given that the adequate information about these concerns may not be accessible, nor about how they may be obtained. Therefore, there is a need to include a process that encounters with significantly more uncertainty (Hansen & Madsen 2018). To do so, this research first considers the stage-gate approach (Cooper 2008) to decision-making attempts which aiming at minimizing risks of failure, during the innovation process. Stage-gate (Figure 39) in a simplified format consists of (Cooper 2008):

- A series of stages, where the project team under- takes the work, obtain the required information, and does the subsequent data integration and analysis
- Followed by gates – where Go/Kill decisions are made to continue to invest in the project.

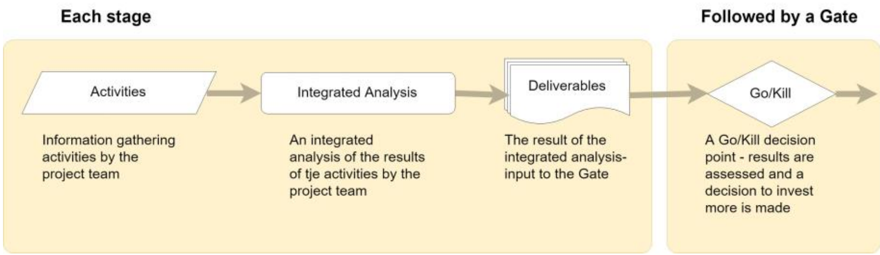

Figure 39. Stage-Gate consists of a set of information gathering stages followed by Go/Kill decision gates (Cooper 2008)

The process initiates with an ideation stage, called Discovery, and finishes with the Post-Launch review. Each stage consists of a set of required or suggested best-practice actions needed to progress the project to the next gate or decision point. The screening processes are based on certain criteria to minimize cost and to increase the likelihood of success. Typically, criteria reflect both technical and business aspects. The Stage-Gate model also includes a feedback loop to learn any business or technical practices, from the actors back to the idea generation.

It is also important to note that Cooper (2008) noted that Stage- Gate is not a linear process, where he introduces the next generation of Stage-Gate as a scalable and flexible system to handle different types and sizes of projects and he stated that the adaptable versions of Stage-Gate achieved via spiral development and simultaneous execution. Yet, Cooper (2014) is moving away from "traditional stage-gate" to "next generation idea-to-launch framework", to deal with very fast-moving trends and the dilemma of not being clear of the needs in the early stage of the process and not being possible to get a complete accurate solution definition prior to development.

Cooper (2014) points out to smart firms that adopt with the "idea-to-launch" system, where they initiate the development stage even the solution or product may be less than 50 percent defined but comes together during development; and enable the design and definition of the solution adapts to new information, customer feedback, and changing conditions on its way to deploy. Cooper (2014) suggests a Triple A system which is adaptive and flexible, agile, and accelerated (Figure 40).

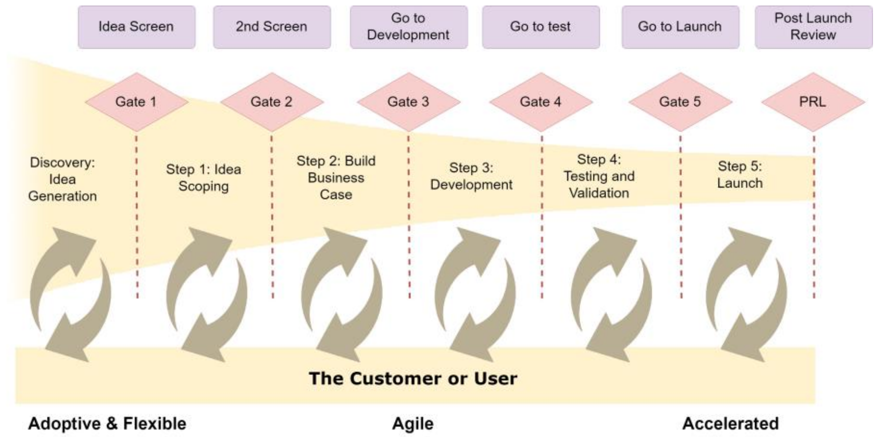

Figure 40. The idea-to-launch system (Cooper 2014)

The process is carried out in multiple spirals or iterations of development which allow experimentation and test with buyer and users.

Unlike the traditional stage-gate approach which is linear, closed to external stakeholders, the new approach to the stage-gate model has also been modified to accommodate "open innovation". The new approaches to the innovation process and new product development performance focus on the flow of ideas, IP, technology and even totally developed solutions into the company from external sources, and also the flow outward (Chesbrough 2004). In open innovation, companies look inside-out and outside-in, and across three aspects of the innovation process, including ideation, development, and commercialization to create and realize more value throughout the process (Docherty 2006). However, the open innovation model does not show how one may identify technical and business concerns in the early process of innovation and engage with them for solution design, yet, it still emphasis on being open for external stakeholders' engagement with "leverage of capabilities and expertise of others to deliver differentiated and meaningful innovation" (Perkins 2008). The stakeholder engagement could be incorporated in a process-based model of open innovation. This process-based model consists of three key elements. This model has three key elements: knowledge exploration from experts of open innovation network; knowledge retention by the innovative organization; internal and external knowledge exploitation to creating organizational and social value (Lichtenthaler & Lichtenthaler 2009). The knowledge exploration through stakeholder engagement may provide better realization of the stakeholders' requirements, and therefore can result in more accurate solution development action, consequently, bringing positive technical and financial value (Lichtenthaler & Lichtenthaler 2009). In connection with this, the approach to the value chain and engagement of stakeholder networks in innovation process has been suggested by Tidd et al. (2005). In their approach, innovation has been introduced as the core business process in a linear model which consists of four key phases (Tidd et al. 2005): search, select, implement and capture (Figure 41).

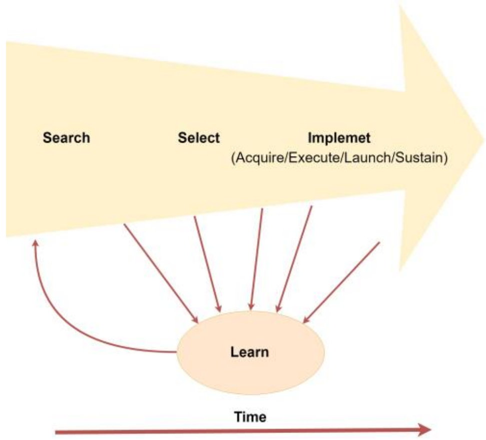

Figure 41. A simple representation of the innovation process (Tidd et al. 2005)

The introduced phases by (Tidd et al. 2005) describe the process of searching ideas and opportunities; deciding which of the idea to continue, based on the strategic view of how the enterprise can best develop; translating the ideas and potential into new experiences, implement and launching them successfully; and finally, to learn from progressing through this process so the enterprise can build the knowledge base and can improve the ways in which the process is managed. Both internal knowledge sources within the existing organizational structures, as well as external sources and competencies for effective innovation process management are emphasized by Tidd et al. (2005) where they discuss the integration of all relevant groups' involvement reduces certain risks like lack of knowledge sharing, by effective stakeholder dialogue aiming at addressing uncertainties, reducing risk and seeking solutions.

Looking at the briefly described models as well as the buyer-supplier relationship model which has been discussed earlier, the process model of automation business assessment can be generated and adopted by a circular innovation process model, having in mind to address how new technological solution may be suggested or evaluated among various actors, along with the different level of analysis based on the different actors' perspective of technology system models.

Circular process models could facilitate explicitly identifying the technical and business requirements at the buyer side (manufacturing company), and how these may be addressed in automation solution design and development.

The circular process model enables sequential and progressive stages, and still allow to regress to the previous stage due to uncertainties that may be brought to awareness at each stage. For instance, a manufacturing company during the test period of an automation solution may realize that the project scope needs to be adjusted and different vision technology needs to be applied because the lighting condition of the manufacturing site creates a reflection on the materials to be grasped.

In the case of applying new technologies for the automation solution, the concept development and solution design phase may need to be open for receiving feedback from specialized suppliers or automation experts as well as from the following stage of selection.

Furthermore, technological uncertainties and new requirements may be recognized during the implementation phase, where it not only impacts the design but also may impact the automation guidelines and respected roadmap. Therefore, the circular process model enables facilitates explicitly enable learning lessons and apply new inspirations into the adopted automation roadmap. The issues of product safety and regulatory requirements may become critical to be considered. Implementation and operation, when become associated with capture value, may pose certain concerns including intellectual property rights and licensing in actors' organizations.

Therefore, the technological and business requirement, as well as above mentioned concerns, need to be captured and evaluated for responsible actors during the process to remedy those uncertainties which are less possible to be predicted. Thus, the proposed circular process focuses on capturing, analysing and transforming information step by step as well as facilitating identifying various actors along with their concerns in the process for a deliberate automation decision-making. This research proposes an actors-oriented circular process model buyer-supplier behaviour integrate into the process of automation business assessment as shown in Figure 42.

As it is shown in the model the process groups from the buyer perspectives are:

1. Identification and Roadmapping
2. Set Objectives
3. Information Search and Examination
4. Validation and Assurance
5. Consolidation
6. Outlet Selection and Dynamic deployment

The process groups from the supplier perspectives are:

1. Approach and inspiration
2. Qualification and set requirements
3. Conceptualization
4. Validation and refinement
5. Consolidation
6. Implementation and dynamic deployment

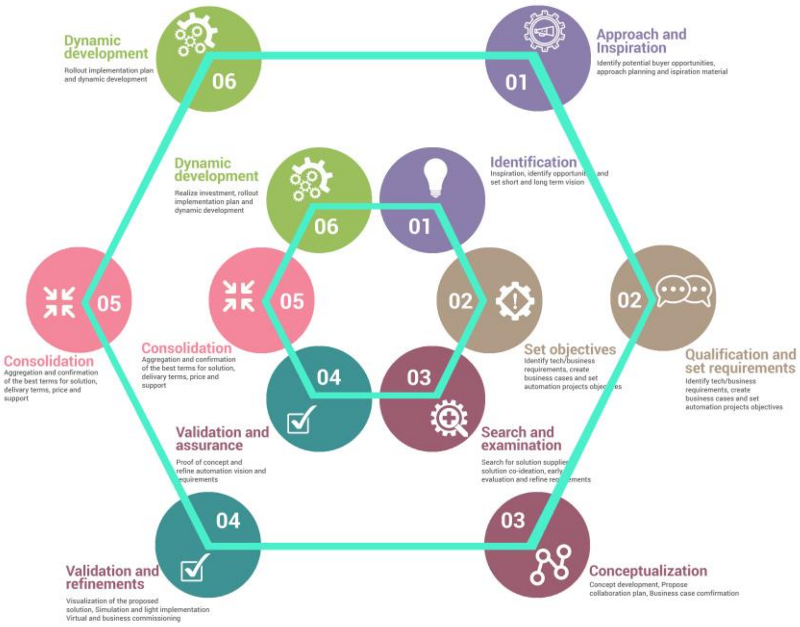

Figure 42. Circular automation business assessment process model

The proposed model explicitly illustrates an actor-oriented circular model includes identification of the potential improvements, information capturing and evaluation phases which include both internal and external actors with different levels of technology focus. The evaluation phase is clearly represented by associated domain processes relevant to the buyers and suppliers, so as to emphasize the requirement evaluation and solution match during the solutions search and concept development phase. Along with the modularity and the scalability of the model which has been explained earlier, the phases are not necessarily linearly progressive, where each stage can be retreated depending on the solved uncertainties and the decisions made in each stage. Solution development during the implementation phase suggested taking place in a dynamic pattern, where the lesson learned during the implementation may impact the design concept or be the source of adjustments in the automation roadmap.

The process domains provide a base for communication, discussion, and engagement of various actors to address potential requirements and concerns. The actors' behaviour mapping discussed above and in Chapter 4.5 could be integrated with each step. These phases effectively reflect the domains raised in buyer-supplier collaboration literature and founding from the empirical data analysis, while ensuring a circular flexible process. The structure of domain components is described in the next chapter.

5.8. INHANCER DOMAIN COMPONENTS

One of the objectives of this model is to define the domain components of Inhancer (Figure 43) through a set of macro-processes.

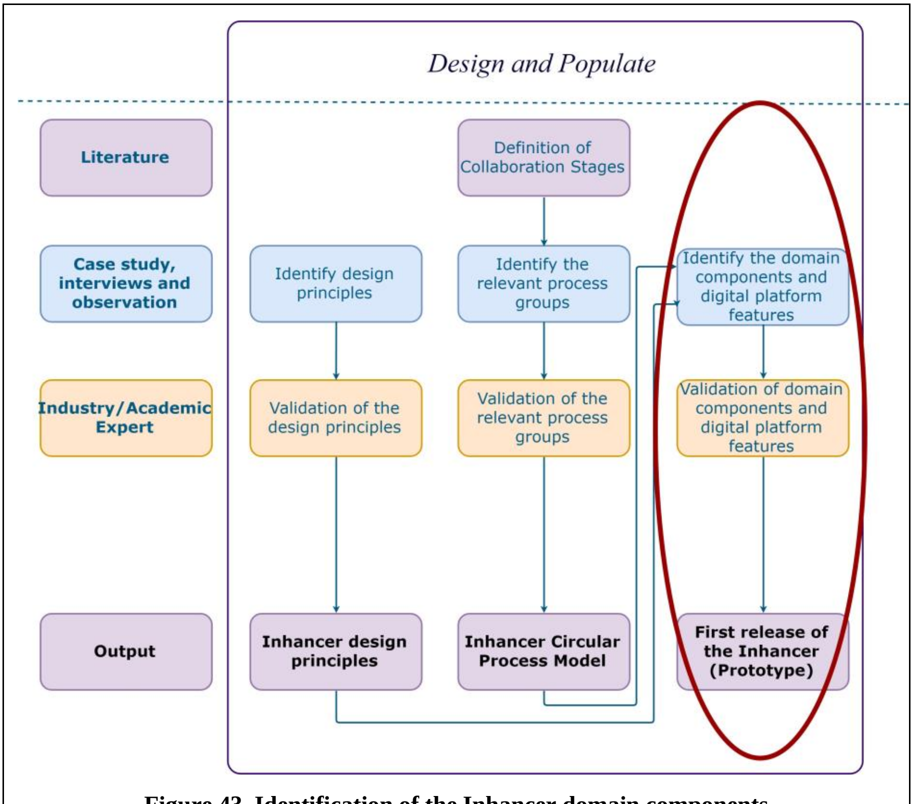

Figure 43. Identification of the Inhancer domain components

The domain components define a proper set of interactions which increase the level of integration in buyer-supplier behaviour through the automation decisions processes. The domain components of Inhancer have been described in this chapter.

The ideation domain components of Inhancer has been determined based on the inspiring principles of buyer-supplier collaboration, previously described in the literature review section, and through an interaction design process, in an iteration process and collection of participants interviews and brainstorming sessions. Each process area, introduced in the previous chapter, contains a number of *domain components*, which are defined by the single processes in the form of macro-processes and needs to be considered in the process of automation business assessment. In Figure 44, the representation of the domain components is reported. As illustrated in the figure, horizontally to the process areas, it shows the area is represented as *domain components*, from both buyer and supplier perspective, within which contains all the *micro-processes*. The lead integrator plays the facilitation role along the process. The involvement might be different depends on partners knowledgeability and capability. In case the automation projects are *urgently* important, and the *internal capability* of the buyer company fulfil the required knowledge of identification and evaluation of automation projects, the facilitation role is covered mainly by the buyer company.

Even the model structure is designed to enable the performance of self-contain module on the level of process groups, yet the domain components often are applied in the same sequence and repeated iteratively. It can sometimes seem in a less ordered sequence. Furthermore, to develop the model structure, two main properties were considered to enable the model to be used in a more general approach in different kind of companies: The modularity and the scalability. Therefore, based on the business strategy and requirements of a company, domain components can be skipped, or the new domain component can be included.

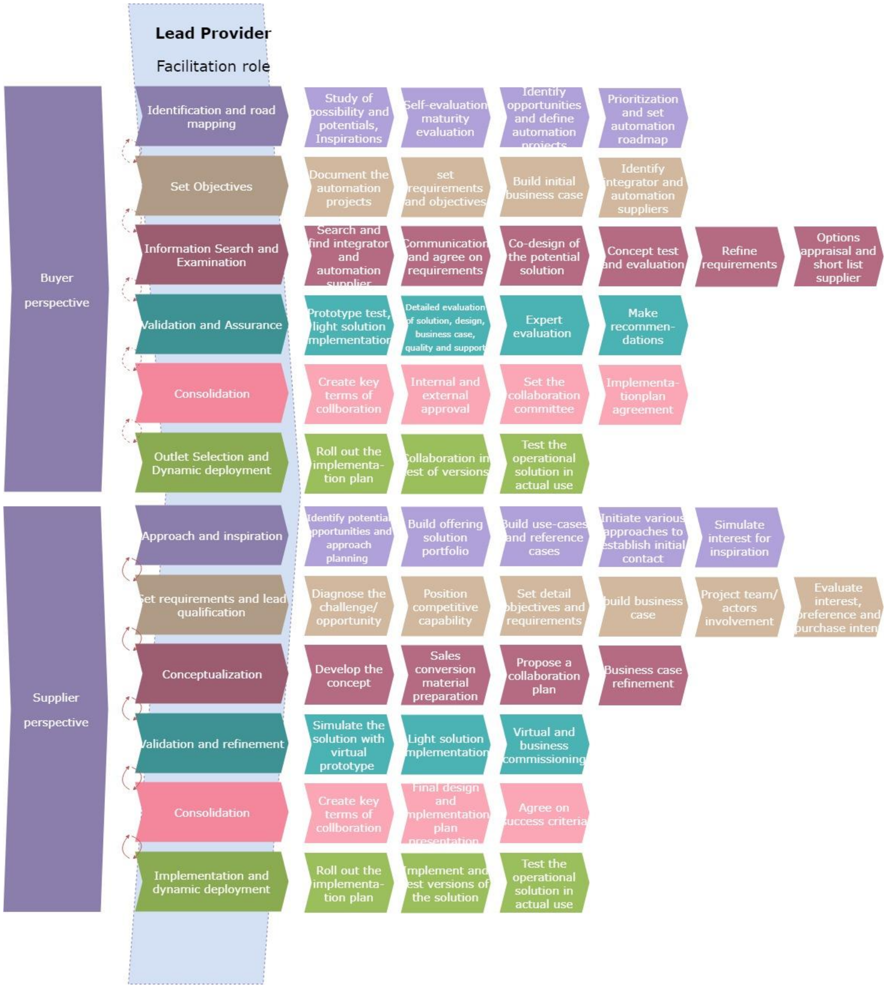

Figure 44.Inhancer domain components

5.9. INHANCER DIGITAL PLATFORM FEATURES AND APPLICATIONS

One of the objectives of this model is to identify the characteristics of a digital platform which will be utilized by actors during the process of automation business assessment. The model along with the identified domain components provide a base for digital platform development.

For the purpose of further development of the model in the form of a digital platform, the domain components were defined in the form of features. The features of the digital platform should relatively reflect macro-processes of identified domain components and be aligned with design principles described in Chapter 5.6. In Figure 45, the representation of the digital platform features with the related domain components is reported.

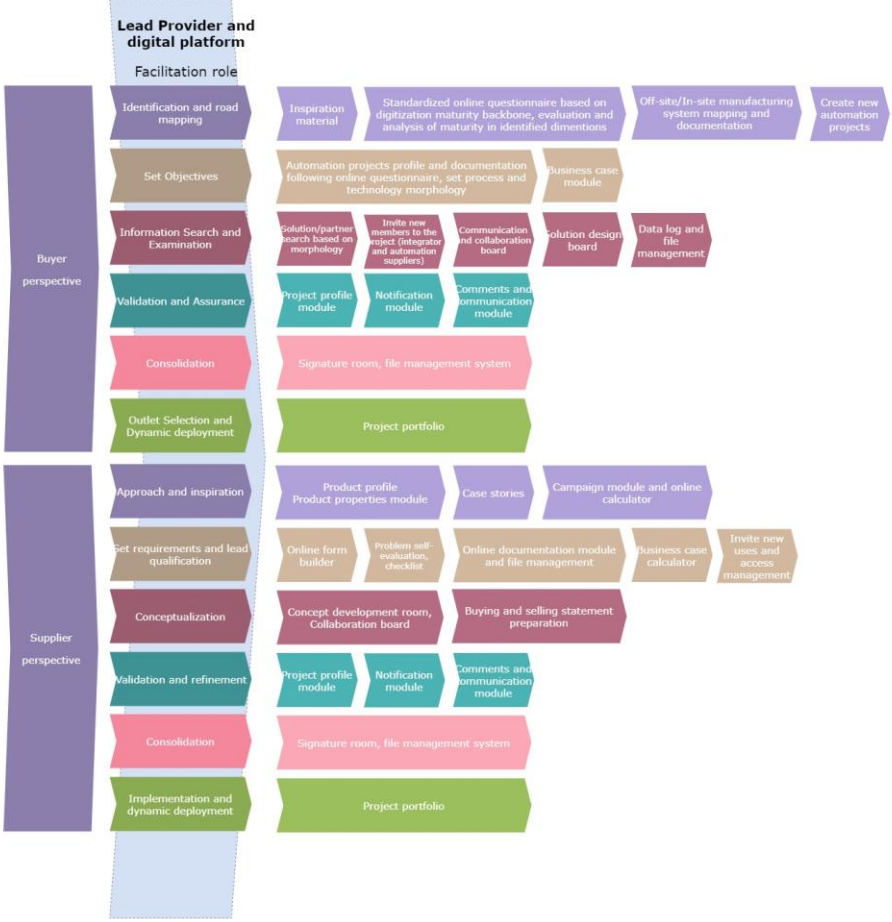

Figure 45.Inhancer features overview

In Figure 46, an overview of the suggested sequence of the Inhancer domain components is represented. As it has been mentioned, it is possible that sometimes they seem in a less ordered sequence.

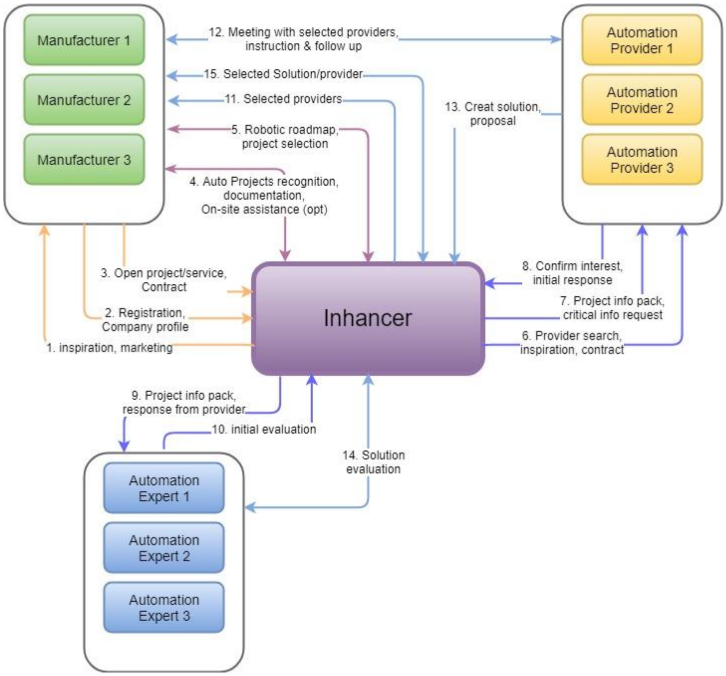

Figure 46. Automation business assessment domain components sequence

5.10. ENVISIONING OF THE DOMAIN COMPONENTS

To communicate identified domain component ideas to the development team and peers, and to apply enough clarity on the representation of them, visualization material and behavioural description were developed in the form of story boards. Since the envisioning of the model structure and domain components is too large explained entirely, therefore only the story board of an overall view Inhancer from the supplier point of view is illustrated in Figure 47.

Figure 47. Overview storyboard of supplier interaction via Inhancer

Quick storyboards helped to illustrate and evaluate the ideas for a further selection of the platform usability in the early model development and design direction. Furthermore, the storyboards provided bases for further discussion and increased the project participants involvement in the communication of the potential reality of the domain concepts.

5.11. SELECTION AND EVALUATION

An initial semi-quantitative analytical approach applied for an initial evaluation of the domain component ideas in order to select the most promising ideas for further consideration and deployment. The domain component ideas in related to the buyer side (manufacturing company), were mainly evaluated by the industry expert group from the internal team via discussion meetings. The domain component ideas in related to the supplier side (automation provider), were evaluated in collaboration with a selected automation supplier company. The participants in the selection process (Wiegers 1999) were:

- The researcher which play the role of project manager and leaded the process arbitrates conflicts and adjust inputs from the other participants.
- Automation supplier representatives, who benefit the system advantages.
- Development representatives, team technical leads, who was responsible for technical development of the digital platform in the next step and supply the cost and risk ratings.

Table 19 describes the evaluation criteria of the domain components' ideas:

Table 19. Evaluation criteria for the evaluation of domain component ideas

Ease of use	How this domain is easy for the end user to gain value from?
Impact	How much is the impact of this domain on the end user's ability to achieve their goals?

Solves problems	How much does this domain solve a problem stated by the end user?
Business impact	How much this domain commercially contributes to the business aspect of the company (automation supplier)?
Value add	How much this domain provides real added value and differentiates the product from competitors?
Technical acceptance	Will the technical evaluator accept and approve this feature?
Difficulty	How difficult is it to develop this domain?
Feasibility	How feasible this feature is?
Effort	How much effort does the development of this feature require?

The first three criteria (ease of use, impact, solves problems) were assigned to the sales department of automation supplier company, the second three criteria (business impact, value add, technical acceptance) were assigned to the management team of an automation supplier team and last three criteria (difficulty, feasibility, effort) were assigned to internal system developer representatives.

Based on an internal meeting, the criteria were weighted. Participants were asked to evaluate the domains on a scale from 1 to 9, which for the first six criteria, 1 indicating very little and 9 being the maximum possible amount. For the three last criteria, 1 indicates very difficult and not feasible 9 very easy and feasible. Table 20 shows a sample of the evaluation results.

Table 20. Sample of the initial evaluation results of the domain components

	User (Sales Department, Sales Partner, custor			Automation supplier			Development		
Domain components (features)	Ease of use	Impact	Solves problem	Business impac	Value add	Technical	Difficulty (very difficult, 10=very ea)	Feasibility (not feasible, 10=very feasi)	Effort (much effort, 10=very low)
Weighting	15%	5%	20%	10%	10%	10%	15%	5%	10%
Customized menue for different product owners	3	5	3	9	8	9	9	8	3
Calculator and synchronization with database (simple calculator)	8	10	9	8	8	10	8	7	4
Business Case creator (spreadsheet)	10	8	9	7	8	8	7	7	8
Profiles: user profile, project profile	8	8	8	6	8	9	9	9	8
Initial state machine in the way of set conditions to show or hide questions an	7	7	6	4	4	9	5	5	6
Product owner registration as customers of BAT + set up plans	4	4	3	2	2	7	8	8	7
Improved comment module, tagging system + set accessibility	9	8	9	5	7	7	7	7	7
Mentioning members in comments	8	7	7	6	5	8	5	6	7
Notification module	8	9	8	4	9	9	7	7	6
Activity module and follow up changes, Log the project	8	6	6	8	8	7	8	8	8
PDF reports	9	9	7	4	8	8	7	6	6
Distinguish between product owner environment and customer environment	9	7	5	2	3	8	7	7	6
Invite members to the project profile	9	8	8	9	8	7	8	8	8
Question types: video, image and link	10	8	8	5	9	9	9	9	8

Based on the entered estimated values the priority number for each domain component was calculated. The formula for calculating the priority was: $\sum(Value \times weight)$.

The domain components with a higher priority value were selected to be prioritized for further deployment of the model and implementation of the digital platform. Yet, the completed priority scores were reviewed by the automation supplier representatives and the development team to agree on the selected domain components and resulting priorities.

5.12. SYSTEM ARCHITECTURE, DOMAIN MODELLING, AND DESIGN

SYSTEM ARCHITECTURE

Based on the determined automation business assessment mode and the identified domain components, the next step of the project was focused on system architecture and domain modelling to build the structure of the Inhancer digital platform. To do so, the information architecture (IA) was built which demonstrated the user interaction with the system, their position in the system at each time and the information they require in related to their position in the system. Furthermore, the information architecture gives a clear overview of navigation, hierarchies, and categorizations, for instance in related to the system interface design.

This section briefly gives an overview of the domain model and the system structure. Yet, the detailed system structure, implementation documentation, and source codes are not documented in this dissertation. The backend implementation and database structure are not relevant to the goal of this thesis.

The first section briefly concentrates on the system design and the initial idea of the system flow. Subsequently, an extract of a few samples of the system components is detailed using sketches and wireframes. Lastly, one sample of system components, "the project brief structure", is defined and described. This section will bring the previous design elements together and will be used as a test bases in Chapter 6.

Following the design principles and the aim of the automation business assessment model, it is required that the digital platform provides a collaborative environment that the automation suppliers and automation buyers use it as the bases for communication in a regular basis.

The most desired path set to work towards increase numbers of created and proceeded registered and "qualified" projects in the supplier's pipeline, means more generated potential projects and fast moving through the evaluation and selling process. This is the main metric which will represent the viability of the product.

Furthermore, the digital platform from a user's perspective needs to be nice-looking and easy to use while being accessed from their computers and smart devices. Each user including supplier and buyer members gets a unique account upon a registration process. This will be used to identify users in the system and give them the right access to the information. Figure 48 shows an overview of the user interaction with the digital platform and Figure 49 represents the idea of the process flow which was the bases for system architecture in the design integration process.

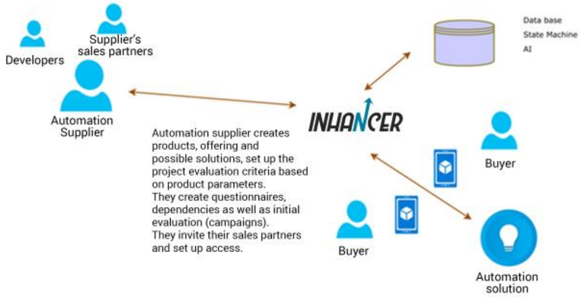

Figure 48. An overview of the user interaction with the digital platform

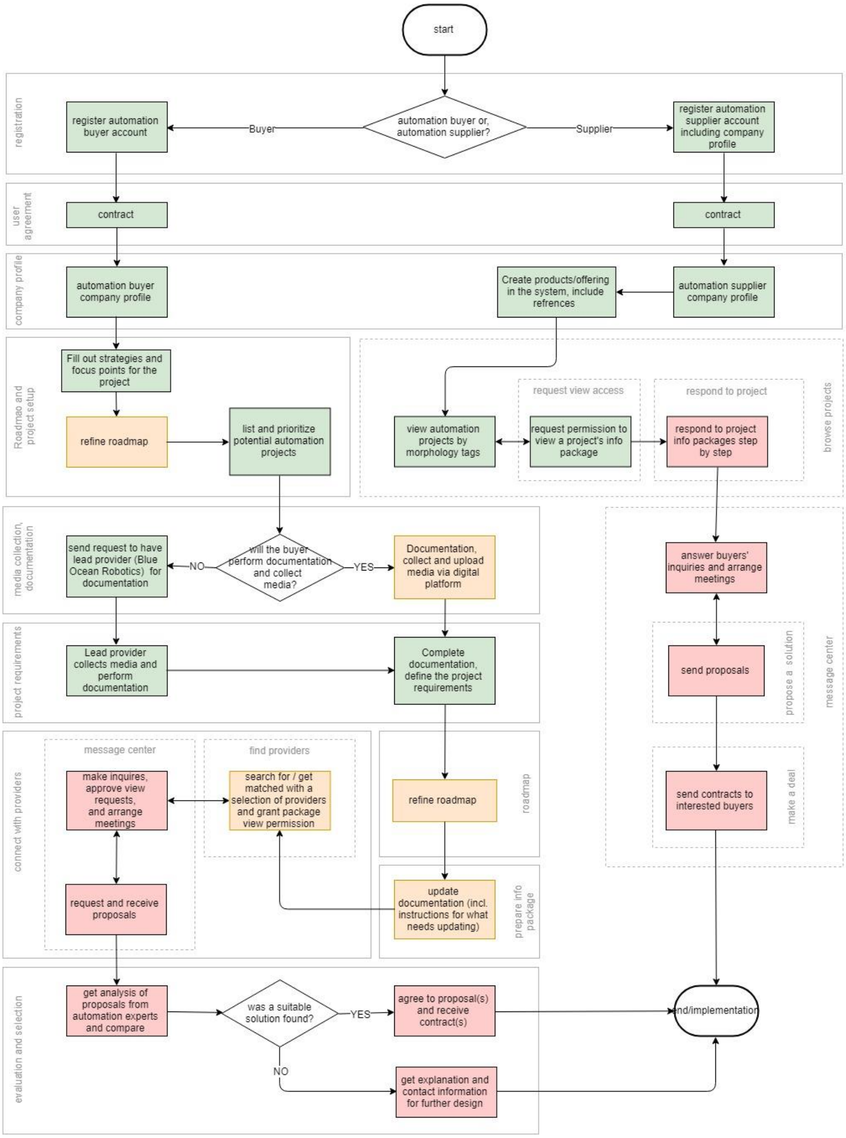

Figure 49. Process flow for information architecture

INTERFACE DESIGN

To generate ideas on how the digital platform interface, looks like, sketching and wireframing method were applied. Sketching was the way to visualize concept and ideas by hand drawing in a fast way and enabling the design and develop the team to visualize a range of design solution and decide between them. Wireframes were used to visualize a guideline to represent a page structure and the key elements in each page. Wireframes were bases for internal discussion with developers and stakeholders and were used as the backbone for prototypes.

The whole interface for the digital platform is too large to be explained entirely, therefore, some of a few samples of the system components which are more interesting and relevant are included in this section.

Figure 50. User dashboard

Figure 50 as part of an early design idea of the digital platform, on the left, portrays the layout and elements of the user dashboard when a user logs in to the system. The widget on the right explains how far the automation buyers been proceeded through the automation business assessment process and what is the next step in the process.

Figure 51 shows an idea of the general interface for the documentation of the project cell. The project documentation contains detail manufacturing process information; media material including images, videos and photospheres; detail operational information including cycle time, current manual work, operational shift etc.; implementation including information of the potential automation solution; benefits and finance including detailed financial information and business case calculation; and the contact information of the stakeholders. Figure 51 to the right, illustrates the initial creation of a set of current manufacturing processes to be documented. In the process of documenting the current state of the automation project cell, initially the overall process flow is defined, thereafter, each process is edited individually.

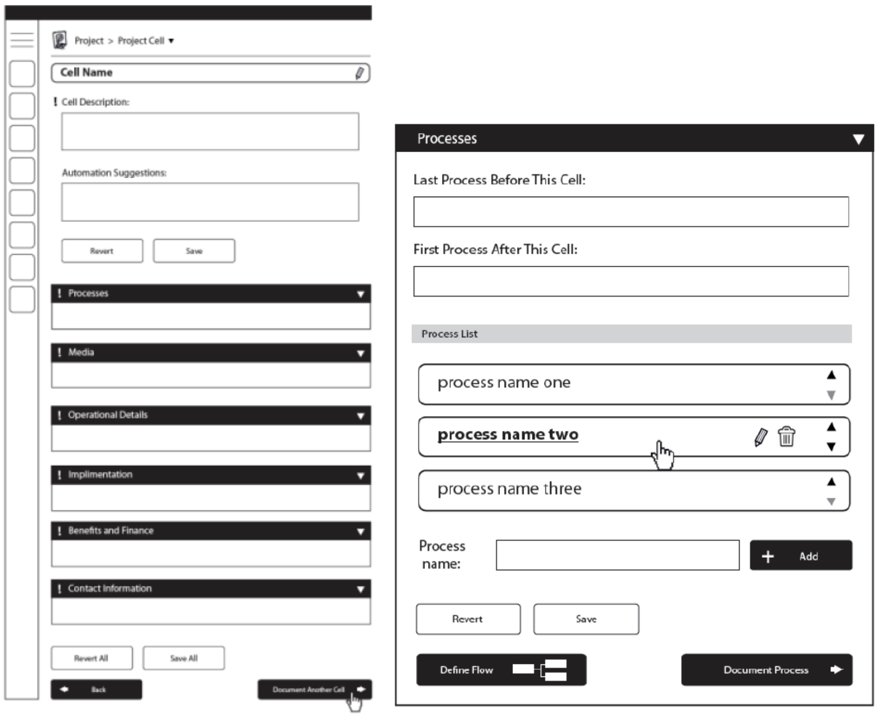

Figure 51. Project cell documentation

Figure 52 shows an example of how to set the process flow diagram to show dependencies.

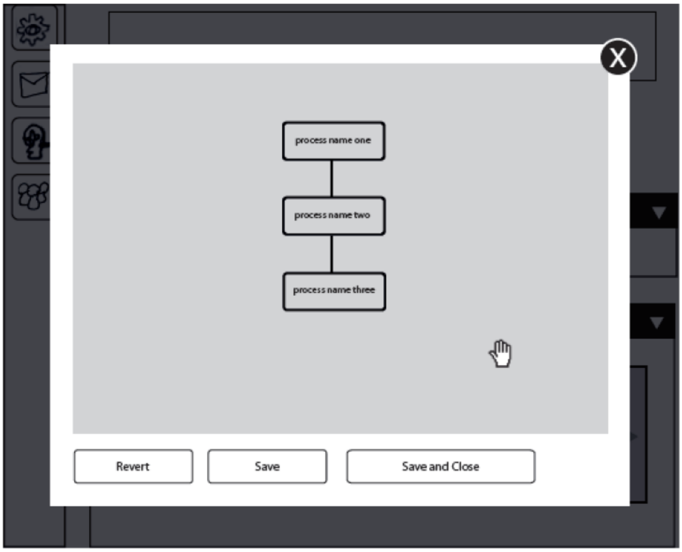

Figure 52. Process flow editor

The illustrations and visual material, as well as verbal tools and technologies, are a great way for better understanding of the status of the project cell and the processes. Figure 53 shows the design idea of how to combine the visual material and verbal tool in the process of documentation of the project cell. As it is shown in Figure 53 upon a selection of visual material, the user is able to drag an area around certain intended spots on an image and include verbal comment and description. Further design adaptation, this feature is also proposed to apply for the photospheres. A sample of this is shown in the next section.

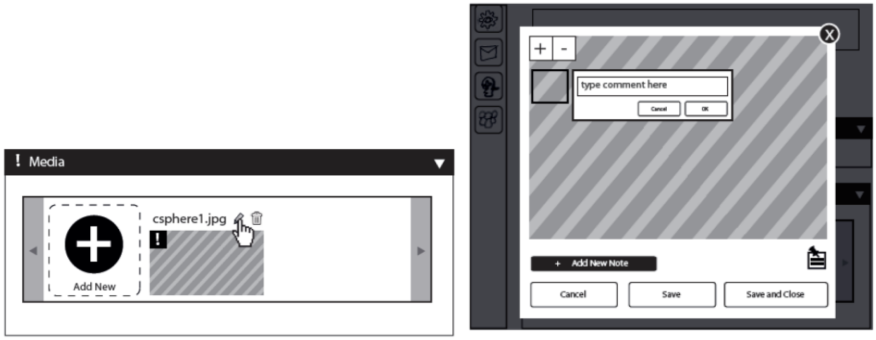

Figure 53. Images annotation

PROTOTYPING

To build a base for validation of the design idea the prototyping of the digital platform was included in the model development and design process. The prototype as an experimental model of the idea used to test the model before building the full solution, and can contribute to benefits (Engelberg & Seffah 2002):

- Cost savings in the total life cycle
- Improved usability and quality of the final application
- Permits usability testing before coding
- Improved communication of the design concept to the client and end-users, and communication of the functional specifications to graphic designers and developers.

The initial prototype focused on designing a few core components of the model and grow over multiple iterations as required components were developed. Therefore, as the first step, the *project documentation* was selected to be addressed. A snapshot of in initial system prototype to document a project work cell for communication and collaboration is illustrated in Figure 54. This prototype version is made and tested based on an identified design principle, interface ideas and inputs from user cases which will be described in Chapter 6.

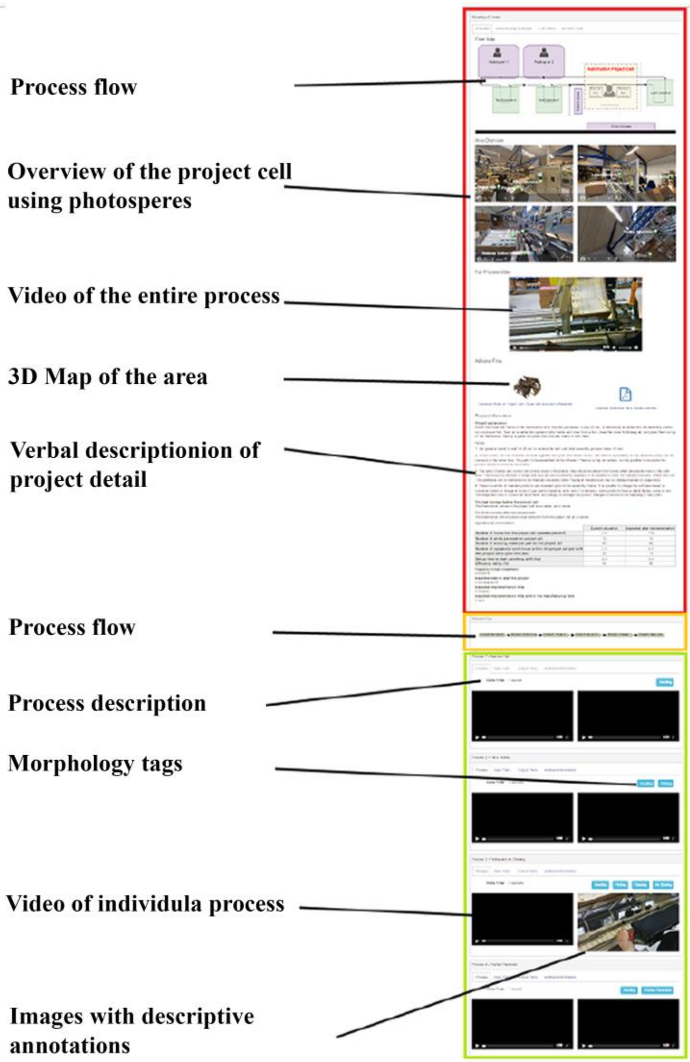

Figure 54. The first prototype of project documentation, Project brief

In this prototype version, the project cell description initiates with an overview. This section provides an illustration of the manufacturing layout which is improved by the annotation tool. Additional video of the entire process flow, the 3D map of the project work cell, to allow measurements, as well as the verbal description, aimed to give a clear understanding of the project cell for stakeholders. Therefore, the contextual information of the project cell is provided by given media items. Further sections, the yellow area, is aimed to describe the manufacturing process flow where the individual processes are broken up and separately described in the green area.

This prototype aimed to cover the core seven design principles, which were identified for project cell documentation to facilitate communication through buyer-supplier collaboration process in Chapter 5.6. The further design of prototypes and including more features took place in multiple iterations of development that permit experimentation with users to enable building an early version of each domain component of the platform, test it with users from both manufacturing and supplier companies, gather feedback to revise the design and apply adjustment in development actions. The process of test and validation of the model as well as the development iteration is described in the next chapter.

Chapter 6.

Validation

6. VALIDATION

This Chapter discusses the validation of the proposed model in Chapter **Error! Reference source not found.***5.7 and the related methodology presented in Chapter 5.8 and 5.9.*

In the scope of this Ph.D. Thesis, the developed automation business assessment model must be validated. The automation business assessment model aimed at developing a systematic problem solving and decision support system in regard to improved automation in SMEs where it supports and facilitates communication and collaboration between actors, particularly manufacturing SMEs (as buyer) and Automation suppliers (as supplier). The proposed model should support new collaborative strategies with targeting lower costs in manufacturing and add product value by focusing on applying automation solutions within the areas of product customization and reducing the lead time. Those strategies can be particularly applied in SMEs, which, through product development projects and improvement of manufacturing processes, can improve their business processes to meet the high expectations of customers and dealing with inconsistency of the market. Moreover, from the automation supplier side, the most desired path set to work towards increase numbers of created and proceeded registered and "qualified" projects in the supplier's pipeline, means more generated potential projects and fast moving through the evaluation and selling process.

Validation and its methodology, as a crucial phase in the model development research process, has been considered as a research topic and demonstrated by the different approaches in the literature. Therefore, in this report, after a short introduction to validation and review of alternative available approaches, the selected approach to validate the Inhancer is described by adopting both an empirical and a theoretical approach based on the application of the model and the digital platform on different selected cases.

6.1. APPROACHES TO VALIDATION

The validation process aims at enabling the use of models regularly, where the model is expected to be reasonably accurate representations of reality. “Reasonably accurate” refers to the need of a validation activity, no matter of the complexity of the model, there needs to be some agreement between the model results and what one actually finds in reality (Olewnik & Lewis 2005). The model to be validated can be understood as a design method. Approaching validation as a design method enables the continuing advancement of both design theory and professional practice (Frey & Dym 2006). The validation process for the case of researchers in design theory leads the development and evaluation of new methods, yet, for the case of professional practitioners, validation processes contributes in to determine which methods to apply, when and how to apply them. While some previous studies were mainly focused on techniques, methods and the challenges of representing and articulating the design knowledge (Argyris 1991), the proposed framework by Meyer (1976) gives a guideline for evaluating theories related to the professional practice. The proposed framework includes a methodological recommendation for a progressive check on internal consistency, congruence with the espoused theory, testability and effectiveness of the theory.

In this aspect, the proposed framework by Pedersen et al. (2000) for evaluating design theories related to the professional practice, approaches the validation through four parameters that are not related each other: a. theoretical structural validity, b. empirical structural validity, c. empirical performance validity, d. theoretical performance validity.

Other validation approaches give a primer focus on design method, where they look at supporting design activity. In this aspect, looking at engineering field, the institute of electrical and electronics engineers (IEEE) (Wahono 2003) defines validation as *“The process of evaluating a system or component during or at the end of the development process to determine whether it satisfies specified requirements.”* and argue that the use of validation technic should focus on 1) All project elements are properly tested. And b) All tests have a useful purpose.

The validation model proposed by (Olewnik & Lewis 2005) which focuses on designing of decision support tools, identified several criteria for a valid design–decision method. They argue that for a method to be valid, it needs to be logical, use meaningful and reliable information, and not bias designer.

The proposed framework by Enderud (1984) focused on the researcher relevance criteria and stakeholder relevance criteria for model validation. He categories the *Researcher Relevance Criteria* in three groups: a) The newsworthy criterion; b) Understanding criterion; c) Theory and knowledge development value. He identifies and categorizes the *Stakeholder Relevance Criteria* in four groups: a) "Reliable" description value, description as the respondent sees the organization; b) Provocation value; c) Self-awareness or "awareness expansion" value; d) Practice value (variance, problem solving, organizational change value).

The model proposed by Enderud (1984) provides a comprehensive and promising framework to validate the Inhancer model compare to the methodologies available in the literature.

As a conclusion, there are varieties of approaches to the validation theory. Therefore, it is required to emphasis on the proper approach for validation of the purpose of this research.

6.2. INHANCER VALIDATION MODEL

The model proposed by Enderud (1984) provides a comprehensive and promising framework to validate the Inhancer model compare to the methodologies available in the literature.

RESEARCHER RELEVANCE VALIDATION

The research relevance criteria mainly refer to novelty, innovation, and volubility of the research and results. The research relevance criteria can be evaluated in three groups:

a) The newsworthy criterion

- New recognition
- New results
- Previously unattended / underlined conditions

b) Understanding criterion

- Full picture and deep insight into the problem area
- Interpreted as a whole
- Gives deep insight into eg. players' motivation
- The material has been perceived and worked through

c) Theory and knowledge development value

- Provides or has data inspired for further development or innovation of theoretical concepts, models, "mechanisms" or contexts
- Can data lead to the development of a new theory framework that can explain several phenomena in the context
- Can data/theory deduce new/many hypotheses
- Has the scientist creatively managed to build models based on data

STAKEHOLDER RELEVANCE VALIDATION

The stakeholder relevance criteria mainly refer to the reliability, incremental value, and adoptability to the model in relationship with stakeholders. The stakeholder relevance criteria can be evaluated in four groups:

a) "Reliable" description value, description as the respondent sees the organization

- Can actors recognize themselves, others and the organization in the image that is drawn? There may be more description levels, "actual objective" description and analysis-based description (interpretation, explanation). The actor's assessment of the latter type may be characterized by emotional and interest factors

b) Provocation value

- Can the description "move" the actors without too much effort
- Can it initiate (or convey) a constructive dialogue

c) Self-awareness or "awareness expansion" value

- Contributes to greater awareness, self-awareness regarding the problems faced by the actors
- Recognize new problems
- Initiates the result further analyses, studies, dialogue in the company, role changes

d) Practice value (variance, problem solving, organizational change value)

- Can the results be used by one or more actors for changes in practice (as decision basis or problem-solving initiation)
- Variety: opens the results for a variety of action options
- Problem solving: Are there any solution suggestions that can be better in terms of the existing organization, or are suggested "shock solutions" that imply a problem-solving process between the parties
- Organizational Change Value: Can the results be used for radical changes that go beyond the existing framework (implies that the impact of alternate changes must be assessed)

To validate that the "stakeholder relevance" is comparable to verifying usability and testability in the real industrial context. To do so, multiple cases were selected for test and applying the Inhancer and the results of this analysis, confirming the "model stakeholder relevance", are presented in Chapter 6.3.

The validation of researcher relevance of Inhancer, the proposed methodology and the related digital platform were presented and discussed with researchers, academic and industrial experts who already experienced and involved in the planning and control of production systems as well as building open consolidated ecosystem and single community in automation application development in the course of two projects funded by the European Union Framework Program for Research and Innovation Horizon 2020, ReconCell and AUTOWARE.

Further details of the validation process are described in Chapter 0. The results are valid for the further development and deployment of the model. Referring to the mentioned criteria, as done during the Inhancer development, this step of validation can be considered as properly accomplished.

6.3. STAKEHOLDER RELEVANCE VALIDATION

In order to prove the validity of the proposed model and the related digital platform, directly validating that the four criteria*, a) Reliable description value; b) Provocation value; c) Self-awareness; d) Practice value*, it was decided to test apply the Inhancer and the related methodology to the number of manufacturing companies and automation suppliers.

During the validation and analysis session, each of the industrial stakeholders interviewed and were asked about the results reliability, significant value, effectiveness, and completeness. Furthermore, the evaluation and user experience test was conducted based on the digital platform and, the results of which were used to further adjustments as well as design the interface and system functionality.

In order to validate the results of the analysis run on the input collected through experts' interviews and targeted interviews, and an initial system prototype and technology test (Figure 55), two validation events were organized in collaboration with one manufacturing company (Manufacturer 2) and one automation supplier company (Supplier 1). There events took place in late 2015, in Denmark. The drivers which led to the selection of the companies were mainly because their profile was aligned with the cases were selected for the empirical research phase. Furthermore, their production and business strategy fit the topic of this research.

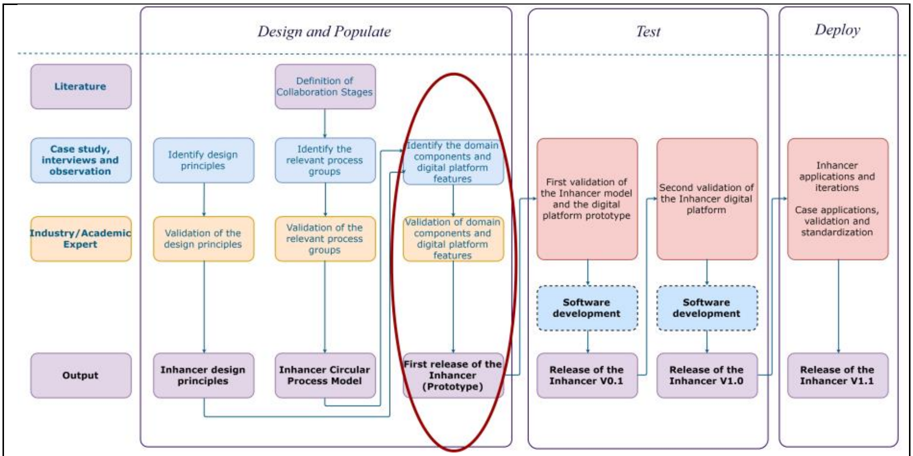

Figure 55. Inhancer stakeholder relevance validation first round

These events successfully provided a broad overview of actual activities, challenges, priorities, and recommendations on the overall suggested model and implemented prototypes. The principal characteristics of the selected cases for validation are presented in Chapter 3.8.

The second and third attempts on stakeholder relevance validation (Figure 56) for process standardization and "generalizable" model achievement carried out in iterations along with the system development process. The second and third validation round took place mid and late 2017 to validate the results of the Inhancer V0.1 and V1.1 from the usability point of view.

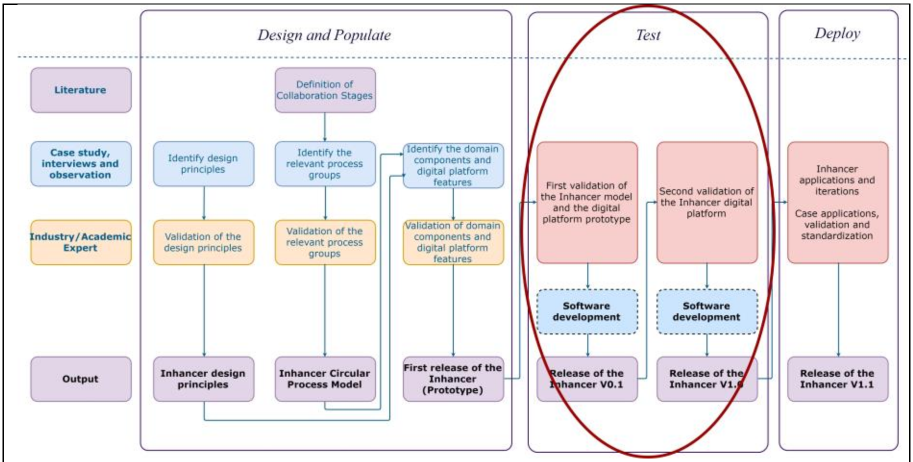

Figure 56. Inhancer stakeholder relevance validation second and third rounds

For both second and third test round four cases were selected and invited for the test, three of which were the same in both second and third test round. The selected cases had different profiles from both manufacturing company side and automation provider side. The principal characteristics of the selected cases for validation are presented in Table 21. The drivers which led to the selection of the companies were mainly regarding the similarity of their profile with the previously involved cases the empirical research phase as well as the relevance of their production and business strategy.

Table 21. Inhancer stakeholder relevance validation 2nd and 3rd round selected cases

	Case 1	Case 2	Case 3	Case 4
Industry	Software	Automation supplier	Robot development	Robot development
Role	CEO	CEO	Product Designer	Product owner
Product	Software solution	Automation component	Robotic solution	Robotic solution

Type of customers	Local	International	International	International

STAKEHOLDER RELEVANCE VALIDATION EXECUTION

The aim of this section is to present how the automation business assessment model and the digital platform was executed within the selected cases. This phase was fundamental to test, validate and gather the useful information to apply and adjust the Inhancer and the related methodology.

INHANCER AS A SEMI-ONLINE SERVICE PLATFORM-MANUFACTURER 2

Inhancer[1] performance in the case of the manufacturer 2 was focused on testing and verification of the overall designed model as well as verification of applying digital tools for documentation and data analysis to support and optimized collaboration and engagement between different participants.

"Currently, when a manufacturer considers investing in an automation solution, the process is long, complex, costly and risky. It may take up to 3-4 months with a cost range of €5.000-15.000. The decisions are often based on moderate to poor quality information, which is provided from a limited local network, thus imposing a risk to the success of the automation project. This inefficient and non-structured process hinders manufacturing SMEs to start automation projects. Automation suppliers face a huge challenge to effectively search for customers where their specific core competences and solution benefits provide a competing power. SAFIR [Inhancer] is an IT driven business model that provides an interactive and collaborative technological platform supporting manufacturing companies, automation suppliers and independent experts streamline the decisions and problem-solving processes as well as supporting resulting transactions in both local and non-local interaction system. Through the SAFIR [Inhancer] system, a manufacturing company can specify

[1] By the time of this experiment, the project was calling SAFIR.

and document a production process in 2-3 hours without any prior knowledge or expertise in automation. SAFIR [Inhancer] searches for automation suppliers with core competences in the pre-stated processes and asks them to supply references to existing installations which fulfil the requirements. World-class experts assess answers from suppliers and provide feedback and suggested approaches that could be taken. All this will be executed, formatted and delivered to the manufacturing company in under 3 days, and with a guaranteed world-class quality level, thus resulting in a fast, low-cost and low-risk decision making process. The SAFIR [Inhancer] system, with the right market deployment, will completely disrupt the whole manufacturing and robotics industry. It will substantially expedite and optimize increasing automation penetration esp. in manufacturing SMEs and with all the advantages and opportunities it holds to generate revenue and add on additional services." – SAFIR [Inhancer] EU Proposal Abstract (Not published)

The execution of the digitalization process based on Inhancer started with reviewing the documentation method, including the paper documentation, Inhancer excel tool, and simplified JotForm[1] solutions.

Identifying the challenges and problematic areas of documentation conducted based on planning and model design meeting at Blue Ocean Robotics. Rune Klausen Larsen (co-CEO) was the main resource for the interview at Blue Ocean Robotics, furthermore, Lars Andresen (Former SAFIR project leader at Blue Ocean Robotics) participated in information gathering, planning, and model design meeting. Jakob Hviid, a master thesis student, worked on the execution of the Inhancer digital platform prototype, under supervision of the author. With a software engineering background and specialty in mobile apps, virtual reality technologies and their application in new digital implementation, Jakob contributed greatly to the conversation.

[1] An online form builder platform which was used in the prototyping phase for data collection test

In the following the process and selected automation project at the manufacturer 2 is described with a focus on digitalization experiment as well as automation provider engagement. This includes the steps were performed and how it was presented to the company.

Potential automation projects were identified basically based on overall production strategy and with a focus on work environment improvement by introducing automation solutions within manufacturing. The identified automation projects were decided to be described in Inhancer and roll out through automation supplier search process. In the following, a short description of one of the selected projects is provided.

The identified project was about the automation of the assembly process to mount the cover and frame of thermostats, illustrated in Figure 57. Within this process, a thermostat is carried into the assembly station on a conveyor belt and fixed on a carrier. The operator needs to pick the cover and frame from a box and then places both on the top of the thermostat. In the last step, the parts are joined and locked together by using a pressing tool. The manufacturer 2 expects to see the results of automation in working environment improvement as well as cost reduction by saving manual work hours.

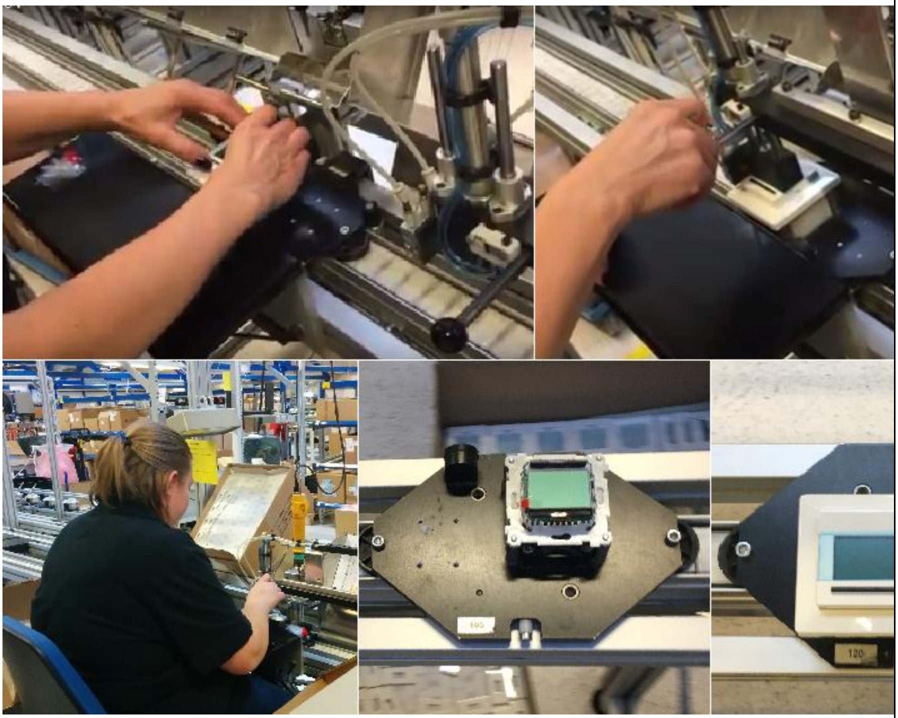

Figure 57. The assembly process of cover and frame of the thermostat

Over the course of the second company visit, the detailed information of the chosen project was collected. PTA manager and Process engineer from the manufacturer 2; the author as well as Jakob Hviid from Blue Ocean Robotics participated in this event. The second company visit involved a walk through the manufacturing facility with a further focus on the assembly work-station. In addition to the field notes, there was the possibility to take pictures, videos, create photospheres and generate a 3D map using Google Tango device, done by Jakob. This provided full visual documentation and a 3D map of the assembly working station. After the visit, the information package was constructed as a digital platform is described in the following.

DIGITIZED PROJECT BRIEF

In the Inhancer model, the efficient automation decision-making in group communication was also characterized as minimizing the need for extra communication around the automation project for an automation supplier with a purpose of making it easier and quicker to understand the status of the project cell and automation requirements without the necessity of multiple physical presences at the manufacturing site.

The *project brief* was initially conceptualized as a problem framing, which is specified by its goal clarity, path clarity, mechanisms, and obstacle. Here, as it was suggested by Hirokawa (1990), the clarity of target refers to awareness of the end state to be achieved and clarity of path refers to awareness of the direction to achieve the target. Therefore, the contextual aspects of the project brief for the automation project case of the manufacturer 2 executed in three levels and is described in the following.

The first section of the project information package was designed and focused at the third order of technological system (Hansen & Madsen 2018), where it gives an introduction or an overview to the automation project cell. This illustrates a combination of a number of manufacturing operations combined with a planning and production control viewpoint and helps to create all connections between the separate tasks being conducted. A layout and process flow help to understand the scope and location of the project cell (Figure 58).

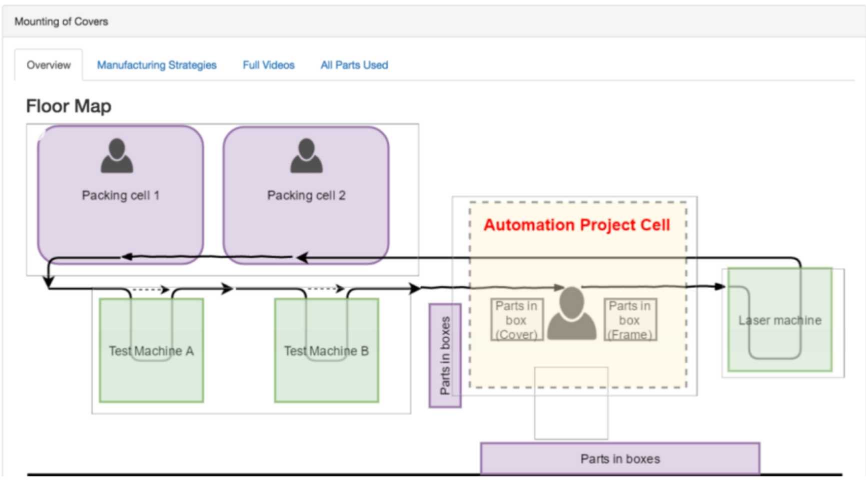

Figure 58. An overview of the layout and process flow

New technologies were used to describe contexts without adding heaps of text or tables to the documentation. Therefore, in addition to a full video of the entire processes of the project cell, a number of Photospheres -360° pictures- with annotations were included to present a more visual and realistic overview of the project cell's area and environment (Figure 59). The annotations give a clear view of the location of individual components in the project cell.

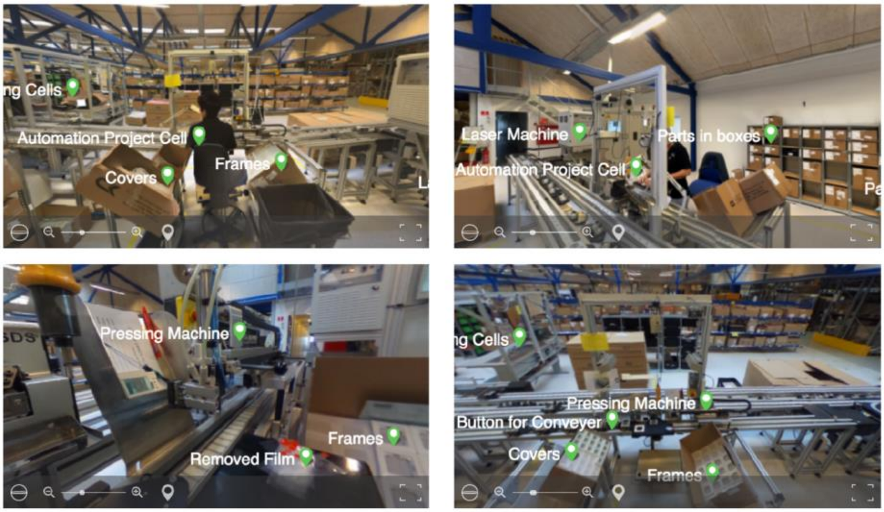

Figure 59. Photospheres -360° pictures- of the project cell and the environment with annotations

The use of the photosphere technology reduced most of the needs for textual explanation and help to include the text which still needs in context. In addition, a 3D scan of the project cell (Figure 60), made by the Google Tango technology, was included as the possibility to map the entire area, and gave the possibility to, for instance, take the measurements inside the model with sufficient accuracy, compared to the real environment.

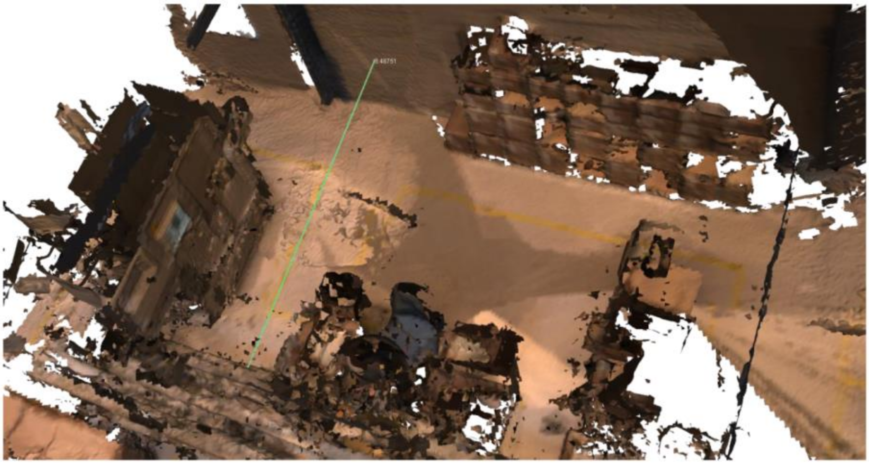

Figure 60. 3D map of the project cell

Project Information

Project explanation

Mount the cover and frame of the thermostats after the test processes. Every 25 sec, a thermostat is carried into the assembly station on a conveyor belt, fixed on a carrier. An operator picks frame and cover from a box, clean the cover by blowing air, and place them on top of the thermostat, then by a press tool press the cove and frame to lock them.

Notice:

1. the operator needs to wait for 25 sec to receive the next unit. And assembly process takes 7-8 sec.

2. In the future, two test machine will work together, the cycle time will be 15 sec. and there is a possibility of two different product on the conveyor in the same time. The parts to be assembled will be different. There is a chip on carriers, so it is possible to recognize the product before it arrives at the station.

3. The parts (frames and covers) are stored close to the station, they should be picked from boxes which are placed close to the work area. The boxes are different in shape and size and are provided by suppliers. It is possible to order for standard box size. (which add cost - the additional cost is mentioned in the financial calculation under "Saving in material cost due to: change material or usage rate)

4. There is number of standard products and standard parts in the assembly station. It is possible to change the software based on customer orders or change in product type (parts) based on order size. For instance, some products have a digital display, some do not. The shape and size of covers will be different accordingly. In average the product changes in the line in the beginning of each shift.

The last process before the project cell

The thermostat comes to the project cell on a carrier, on a convier

The first process after the project cell

The thermostat with mounted cover removed from the project cell on a convier

Operational Information

	Current situation	Expected after implementation
Number of hours that the project cell operates per shift	7.4	7.4
Number of shifts per week for project cell	10	10
Number of working weeks per year for the project cell	45	45
Number of operator(s) work hours within the project cell per shift	7.4	0.4
Ave. project cell's cycle time (sec)	25	15
Set up time to start a working shift (hrs)	0.4	0.4
Efficiency rating (%)	90	90

Feasible initial investment

310.000 €

Expected date to start the project

3 October 2016

Expected implementation time

3 months

Expected implementation time within the manufatucing field

3 days

Figure 61. Project brief in the wider value chain

To provide a wider view of the project brief, fourth order of technology system (Hansen & Madsen 2018), combine the manufacturing operations and support functions to be seen in the whole production system, and provide a brief on financial requirements, the next section of the project brief includes more detail of the project cell particularly in related to the whole production (Figure 61). For instance, it is also stated that the company expects a reduction of the number operator work hours for the project cell per shift and a decrease of the cell's cycle time. In relation to the realization of the project, the maximum budget and the expected implementation time are also mentioned to gives a statement of the financial scope that makes a feasible business case for the buyer.

The next section of the project brief is focusing on the first and second order of technology system, where single manufacturing operation and a brief description of their combination for the assembly of the parts are illustrated (Figure 62).

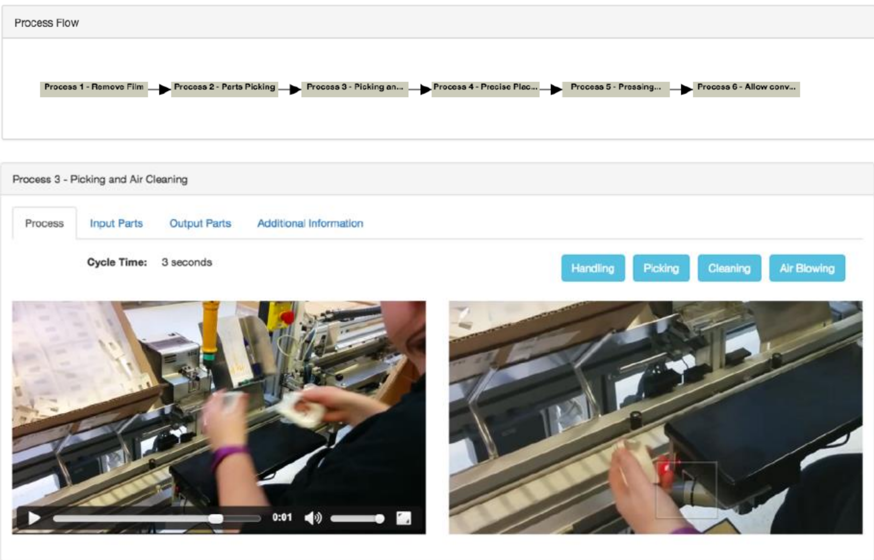

Figure 62. Simple process flow, Single process description, "cleaning by pressured air"

Thereby, the provided information for the individual manufacturing process is given in four tabs. At first, the process tab shows images and videos of the process, cycle time and uses tags and annotations for further emphasize on components in the image. The second and third tab are displaying images of the input and output parts and present information tags for the material, size, weight and other characteristics of the parts. Finally, tab number four states additional information for the related step in form of comments.

By considering all these different sections, the project brief is aiming to provide a comprehensive collection of information and visualizations that enable the project participants including automation suppliers to clearly understand the current state of the project and the requirements. Moreover, they should be able to assess if they will be able to provide an automation solution for the stated challenge completely or partially.

AUTOMATION SUPPLIERS' FEEDBACK

Based on the information from the project brief, the selected suppliers get contacted and asked to give feedback to the automation project requirements and include additional references. This allows Blue Ocean Robotics as the lead integrator and the manufacturing company to evaluate the competence of suppliers proposing a solution. Figure 63 illustrates a sample of the question which was sent to the supplier attached to the project brief.

Process #3: Parts Picking and air cleaning- Pick a cover from a box and clean it with blowing air.

How complicated is it to be automated? *

	1	2	3	4	5	
Very complicated	○	○	○	○	○	Not complicated

Does your company have any experience? *

◉ Yes ○ No

Please explain your prior experience and optionally include a link to a medi, web-page, etc.

Upload a reference

Choose File No file chosen

Max 500 MB. pdf, doc, docx, xls, xlsx, csv, txt, rtf, html, zip, mp3, wma, mpg, flv, avi, jpg, jpeg, png, gif

Do you think if it is possible to provide an automation solution at the given financial framework (310.000 €)? *

○ Yes ○ No ○ Maybe

Comments

Do you believe that the estimated following operational expectation, can be achieved after implementation of the automation project? *

	Yes	No	Maybe
Number of hours that the project cell is operating per shift (7.4 hrs)	○	○	○
Number of shifts per week for project cell (10 shifts)	○	○	○
Number of working weeks per year (45 weeks)	○	○	○
Number of operators work within the project cell per shift (0.4 hrs)	○	○	○
Project cell Cycle time (15 sec)	○	○	○
Set up time of a working shift (0.4 hrs)	○	○	○
Efficiency rate (90%)	○	○	○

Comments

Figure 63. Suppliers feedback on each process

As shown in Figure 63, the initial iteration was focused on a supplier to assess their capabilities on solve an automation task. In addition, by proposing a possible previously experience, give an inspiration for possible solution as well as a base for further evaluation.

Interview sessions

To increase the validity of insights and receive feedback and confirmation on the executed process model and the prototype tools used for project documentation and communication, the third company visit was arranged. From Blue Ocean Robotics three master thesis students in relevant topics to the project, Jakob Hviid, Dennis Stefan Boehme, who was working on the participant's engagement aspect; Silvio Iuliano, who collaborates on the morphology contents; and one designer, Theresa Nichols, participated in the interview meeting. The interview was conducted in a semi-structured manner.

The interview started with a review on the previous steps and an introduction of the next steps in the project; scope and participants. Later, the interviewers proceed with the interview showing the track of questions proposed for the interview which were mainly aimed at to understanding the experience that the team of manufacturer 2had through the process of the project and how they relate the model concept with their challenge.

In the beginning, we had problems to figure out the right use of the forms and where the different information has to be placed. It would be helpful to do it together with someone from SAFIR [Inhancer], in order to do it the right way from the beginning. This would enable us to do it ourselves the next time. (PTA manager, Manufacturer 2)

Furthermore, the interview aimed at understanding if the prototype of the platform for documentation of automation project cell in form of digital implementation and with utilizing 3D mapping and photosphere technologies provides a comprehensive explanation of the current state of the processes and automation requirements. It was aimed to understand how automation buyer think if digitalization of the project cell documentation provides better information sharing and further collaboration with automation supplier.

> *I like the approach of presenting all the information on the website and think it is done in a way that makes it easy to understand the project and to enable the suppliers to evaluate if a realization is possible. (PTA manager, Manufacturer 2)*

> *Especially, the pictures are making a big difference compared to the paper version, which leads to a much better understanding than having just a written description. This is even better than our way of describing [the production processes]. (Process engineer, Manufacturer 2)*

Moreover, the manufacturer 2 was asked for approval and allowance of the project information package to be distributed among the automation supplier network.

After that, the interviewees were asked about their expectation of Inhancer project in terms of supporting a better collaboration with automation suppliers. Here the role of *Lead Integrator* was highlighted, in this case, Blue Ocean Robotics to help the company to understand the possible automation project and its value for the company business and manufacturing strategy. Additionally, their trust in the *Lead Integrator* should ensure the manufacturing company that the selected automation supplier can solve the challenge.

> *What SAFIR [Inhancer] offers is to get information about potential automations [in collaboration with supplier], since we are not sure of what is possible to be automated and where to look for it. We expect that Blue Ocean Robotics makes a thorough search in the market for automation suppliers that are suitable for the project needs since we trust the experience Blue Ocean Robotics has already in this area. We expect that the process information they provided is specified and*

arranged in the right way for the usage in SAFIR [Inhancer] and thus, to get connected with the suppliers. (PTA manager, Manufacturer 2)

In the Inhancer project, saving time and effort in finding and communication with suppliers was considered from the automation customer.

We think SAFIR [Inhancer] can save us effort and time compared to direct collaboration with an automation provider because Blue Ocean Robotics has more experiences in this area and also a related existing network. (PTA manager, Manufacturer 2)

To complete the event, additional photosphere images and 360-degree videos of the production area were collected to complete the project documentation.

In the next step, the completed information package was sent to automation suppliers chosen by Blue Ocean Robotics (Lead integrator). Automation suppliers who have knowledge of complementary technologies were encouraged to get involved in the process of new solution development.

In the following, the process of execution of the automation suppliers' involvement is described within the course of the manufacturer 2. Two selected automation suppliers were also asked to agree to a qualitative interview, which the result is provided in the following.

TO IDENTIFY AND APPROACH AUTOMATION SUPPLIERS IN INHANCER

The process of finding and interacting with automation suppliers was executed within Blue Ocean Robotics with the engagement of Rune K. Larsen (Co-CEO), M. Shahab

Parizi (Project Leader), Dennis Stefan Boehme[1] (Master Thesis Student) and other involved employees from Blue Ocean Robotics.

To include automation suppliers in the Inhancer database, they found based on local networks, different online databases, Google search by using keywords, such as ‘Automation Integrators’, ‘Assembly Solutions’; and participants in exhibitions including AUTOMATICA and Hannover Messe.

They were called and informed about the Inhancer process and the possibility of a potential project or customer lead for them. If they showed an interest, they got an email including further information of Inhancer project, the expected value proposition for automation suppliers. The actual involvement of automation suppliers occurred when they were invited to review a relevant automation project, for the case of this study: the assembly of the thermostat cover at the manufacturer 2. Upon this, they receive an initial email contains a briefing of the automation project and the problem to be solved.

This combination of a call and email used as the first personal steps to create a relationship with new automation suppliers. The communication was also considered to be tailored for automation suppliers with different background (Brennan 2014), for instance, German speaking communication with automation suppliers from Germany. Furthermore, through the entire course, collaboration was built in structured information flow through a multi-step process, mostly by giving specific information and ask relevant questions in each step. Every step was taken to create an awareness of the expected value for the automation suppliers to be in the process, as well as creating a sense of commitment and inclusion in the project evaluation and idea generation process.

The multi-step process to build this collaboration for the manufacturer 2 represented briefly in the following:

[1] The study of automation supplier’s engagement in the Inhancer ecosystem has received a big contribution from Dennis Stefan Boehme during his master studies under supervision of the author.

- The identified automation suppliers received the invitation email including a brief introduction to the project.
- Upon their interest in the project, automation suppliers could send an access request to the project information package. To do so, they needed to agree with the terms of use as well as a non-disclosure agreement (NDA), a legal contract which outlines confidential material, knowledge, and information is generated and shared in the project course and restrictions on giving access to third parties.
- This is done by following a link and guideline provided in the initial email they receive.
- Upon this, they get access to the digital platform enabling access to detailed information of the automation project, current state, and expected requirements.
- The automation suppliers had 10 days to evaluate the project by answering questions manlily related to their perception of feasibility and preparation of automating different processes in the project cell. They also were asked to provide some references or previous experience of automating similar processes to allow the assessment of their capabilities for realizing the project. This was done by using an online questionnaire platform.
- Based on the information, the automation suppliers were evaluated and three were selected to take the further step which was visiting the manufacturing site. The selected automation suppliers received a notification that they are continuing the process and they got the required contact information to set a company visit at Manufacturer 2.
- They automation suppliers were asked to send their proposal of the solution concept via the Inhancer digital platform (prototype version) within two weeks after the company visit.

Upon and evaluation of their suggested proposal, one provider was chosen to take the next step for further collaboration with Manufacturer 2 to implement the automation project.

VALIDATION SESSION WITH AUTOMATION SUPPLIERS

In order to test and validate the process model and the prototype digital platform, Project Manager from supplier 1 and CEO and CTO from supplier 2 were interviewed, who represents the focus group of automation suppliers in this research. Each interview session lasted approximately 1 hours and 30 minutes. These two companies selected for this session because they were familiar with the project, due to their competencies they had received more automation project cases, in addition to the case of the manufacturer 2. Moreover, their geographical position and their business strategy were other drive.

During the interview sessions, initially a brief introduction on the automation business assessment study and a review on the project steps was given. After that, the open interview questions were asked, in which the aim was to understand the experience that the automation supplier team had through the process and how they relate the model concept with their challenges. The notes from the interview were analysed. In the following lines, the feedback on the model from the interview is summarized:

The business impact of the Inhancer process model and the digital platform:

- From the Inhancer project the supplier receives many interesting projects that are also relevant, but probably the investments background of the buyer and their readiness were not investigated enough or too optimistic. So, the buyers were not necessarily ready for investment.
- In related to the previous point, in some cases, the supplier felt unhappy about the collaboration with SAFIR (Inhancer) in the past because they needed to prepare a number of proposals and quotations which they did not lead any project realization.
- With just enough information about the automation project requirements, suppliers were able to realize that some automation projects were difficult for implementation and out of their scope, so, they could reject the project before they get involved in preparing a quotation.

- The communication pattern and exchange of information is not similar in different buyer organizations. Some buyers do not have enough time or capability to proceed with the whole steps and complete the automation project documentation. They require some support toward process, become more aware of what they are ordering, to know more about their actual problem, or enable to explain their requirement.
- The supplier was pleased of new potential buyers and interesting potential projects, saving sales force resources, safer to get in contact with a buyer with a more relevant project to their competencies as well as the possibility of quick feedback and quick question and answer. Yet, they had an expectation of complete or partial compensation of their expenses in the further steps, particularly in the validation and consolidation phase, where risk reduction and solution refinement take place over solution visualization, light implementation or simulation.
- Currently, suppliers find their customers by going to fairs as well as their networks of friends or partners. However, they see an advantage in Inhancer business model to get in contact with more potential buyers. Particularly if it enables them to expand their international market toward Europe or beyond in addition to the local market.
- Despite the previous point, the supplier thinks that the Inhancer model may raise the competition level higher than ever before. In fact, since multiple suppliers receive information on the automation project case, the buyer will receive multiple potential solutions. Therefore, the supplier needs to make sure that their suggested solution is competitive to get the project.
- Even though the suppliers see that the provided information by the digital platform makes a considerable difference in project evaluation, yet, they believe *the initial physical meeting* is very crucial and can impact the buyer's decisions. They are able to build up an *efficient connection* with buyers and convince them about their competencies.

> *"They would much like to get the customers themselves. They are good at making projects and convincing that they are very good, at this will be a very fine project for them. If you sign, we will go fishing on Friday" (Rune K. Larsen, Blue Ocean Robotics)*

In addition, they supplier believed that they could get some feedback from the buyer company upon their initial visit on how they are ready to invest in the project, how the critical decision makers are involved, the urgency of the challenge to be solved as well as the budget assigned to it.

- Supplier believes the process of *sharing the information of previous references* relevant to the project cell creates value in terms of giving an idea to the buyer on how the automation project can be realized. This is more convincing for them to consider the investment. Furthermore, references can be considered as an efficient method for giving information to customers, which does not need much effort for the supplier.
- Applying Inhancer may lead to *some changes in the supplier organization*, by improving the process of preparing quotations and solution proposal, the involvement of technical team from the early stage of project evaluation with not too much distortion on their daily activity plan.
- From the financial point of view, the suppliers are willing to pay for using the Inhancer.

The implementation of the digital platform and project documentation:

- *The benefit of using digital documentation* depends on the project complexity and the requirements. For more complex automation project, the digital documentation version provides a comprehensive understanding of the current state of the project and list of requirements.
- Specifically, *the videos of the process* are very helpful which is not possible to be included in the paper version of the documentation.
- For not complex projects, similar to the manufacturer 2 case, the division of the project brief into an overview, process details, and part details, could be

a bit overwhelming. It is not always necessary for many projects to get all the detailed information for initial evaluation. They might be required for further evaluation and solution development. Hence, the necessity of sharing a wide range of information is depending on the complexity of the project.

- The idea of further implementation of the *communication tool* in the digital platform, that allows asking questions for specific process or parts, was very appreciated by the suppliers. As same as the idea of keeping the information flow within the platform and visible for the participants who are involved in the project, to provide knowledge integration and to avoid that competitors have access to it.
- The platform has a considerable potential that *travelling* to the buyer side to get the project information can be eliminated.
- The 3D model of the project cell and the possibility to do measurements could be very helpful for feasibility analysis and simulations. In addition, 3D (CAD) models of the different parts would be helpful. However, creating the 3D models of the area required specific equipment which possibly all manufacturing companies do not have easy access.
- The focus of the project brief is on an existing project cell to be automated, nonetheless, in some cases, the companies are planning for building a new line or setting up a new production cell, where there is no existing project cell. In this case, the provided information in the project brief needs to be focused on describing the requirement and picture the future of the project cell in connection to the production system and manufacturing line.

The results from the interviews during the stakeholder relevance validation phase, on one hand, was important to understand if the participants agreed with the automation business assessment process model and the domain components. In this way, the feedbacks received were useful to prove the stakeholder relevance validity of the Inhancer model. On the other hand, the discussion was important to evaluate the prototype version of the Inhancer digital platform including the architecture, the features, and usability.

Based on the feedbacks received during the interviews and the discussion sessions with the companies, the stakeholder relevance validity of the model and of the digital platform was proved.

THE ACTION RESEARCH PROCESS

Following the "Action research model" cycle (reported in section 3.2 *"Methodology utilized for building the research"*), in this section the evaluation and the acting phases are reported. During the evaluation phase of the action research cycle, the Inhancer and the related digital platform were applied to the previously mentioned cases.

During these applications, it was possible to examine the model's applicability to different kind of companies and its capability to perform the business assessment. The feedbacks gathered from these applications were used for "re-plan" and during the "act" phase of the action research cycle, in order to standardize the methodology and further development of the digital platform.

During the development of the selected cases, and over each interview, feedbacks regarding the comprehension and completeness of the model and the digital platform were gathered from the respondents. Followingly, during multiple discussing sessions, based on obtained feedback, the development and implementation plan were modified.

SECOND AND THIRD STAKEHOLDER RELEVANCE VALIDATION SESSION

The second and third stakeholder relevance validation session was conducted for four weeks in mid and late 2017 to conduct user testing for Inhancer. The focus of the sessions was to test the digital platform functionality and features as well as find out the perception of stakeholders about it. Moreover, the results had to be utilized for re-planning of the domain components, which could be used for the next development action.[1]

Each session which took place at one of the Blue Ocean Robotics meeting rooms, last approximately one hour. To start the session each participant was given a brief introduction to the Inhancer digital platform, as well as the test procedure. In addition, they were introduced to the digital platform which was used for recording the test session and they were asked to comment any time they felt it was necessary. They started the test by completing the first survey, continuing with 11 tasks to perform, which walked them through the principal functions of the system. Then, they were asked to answer 10 questions referring directly to the usability and reliability of Inhancer and the value it would bring to their organization.

STAKEHOLDER RELEVANCE VALIDATION METHOD (SECOND AND THIRD ROUND)

There was a combination of methods used to perform the second stakeholder validation session. *The quantitative method* was contacted by applying two short surveys:

Before performing the tasks – participants were asked about their position in the company (considering if their position was changed between the two tests) and whether if they have used the digital platform in this period, and how. For the fourth subject, the last two questions did not make sense, because he had not participated in the previous session. So, he was asked to leave them empty.

After performing the tasks – including 10 questions referring directly to the Stakeholder Relevance Criteria (Enderud 1984) with a focus on the usability of the system and the value the Inhancer would bring to their organization. This survey was used identically in both test rounds, to enable making an analysis of if the pointed problem were solved between two sessions. To answer the questions, a 5-scale

[1] The second and third Inhancer stakeholder relevance validation session has received a considerable contribution from Ana Maria Macovetchi during her In-company project at Blue Ocean Robotics under supervision of the author.

measurement was used from 1 – Strongly Disagree to 5 – Strongly Agree. This was chosen to give the participants the possibility to have a middle point in case they were not sure or did not know how to answer the question. The survey questions are listed in the following.

1. I think I would like to use Inhancer frequently.
2. I thought the system was easy to use.
3. I believe the functions of the system fit the purpose of the system.
4. I think I can get used to using the system frequently.
5. I thought the given information about different functions on the system was helpful.
6. I think Inhancer has always done what I was expecting.
7. I felt confident using Inhancer to create an environment to communicate with our potential customer.
8. I believe that Inhancer can give me useful information about the solution selling process.
9. I think Inhancer can have a significant contribution to my organization.
10. I found this system close to other web interfaces.

The qualitative method was applied by conducting a short interview after the test, which two main questions were asked:

- *What did you most like about the system?* This question was aimed at finding out the overall positive perception about the system, and what is most motivating for the participants to use the system further.
- *What did not you like and what would you improve?* The focus of this question was to understand what the most important consideration of the system is to be fixed.

The final discussion together with the test participants enabled to summarize the testing session and give the participants the possibility to give their feedback about their experience with Inhancer.

STAKEHOLDER RELEVANCE VALIDATION DATA ANALYSIS

As mentioned, the usability test performed in two sessions for stakeholder relevance validity of two releases of the Inhancer digital platform.

The users experiment test subjects are listed in Table 10 and Table 22.

Table 22. Participants of the second and third stakholder relevance valisation, user expriment test subjects

Participant No.	Sessions	Affiliated	Role
1	Session 1, 2	Supplier 5	CEO
2	Session 1,2	Supplier 6	CEO
3	Session 1,2	Blue Ocean Robotics	Interaction Designer
4	Session 1	Blue Ocean Robotics	VP of Business Development and sales
5	Session 1	Blue Ocean Robotics	VP of Marketing
6	Session 2	Supplier 4	Director

The participants no. 1, 2 and 3 participated in both sessions. The participants no. 4 and 5 only participated in the first session and the participants no. 6 only participated in the second session. The results of the second and third stakeholder relevance validation are described in the following. In Figure 64, the average scores by questions are reported:

The average scores for the overall perception of the system usability were calculated from the final survey and illustrated in Figure 64 and Figure 65.

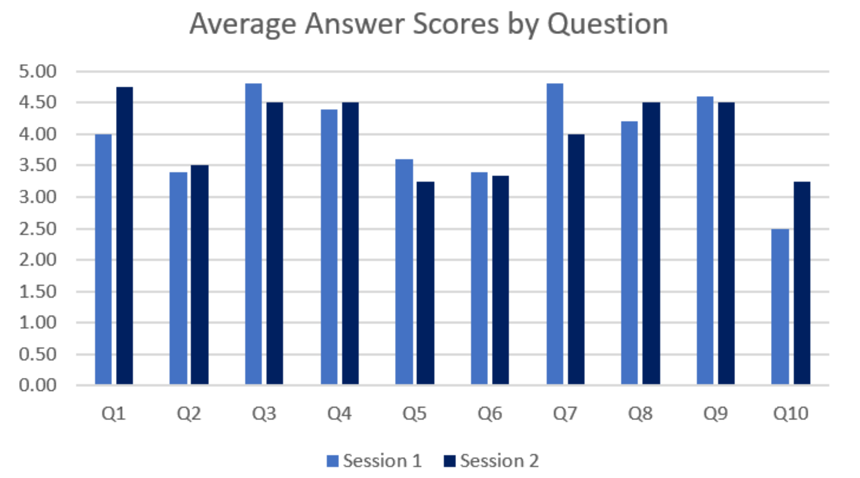

Figure 64. Average score by questions on stakeholder's relevance survey, compare the results of two sessions

To compare the average answer score by participants, it is interesting to observe that the given average scores by participants no. 1 and 2 have slightly decreased between two sessions, while the third participant scored a significant improvement. The participant no. 6 in the last test experiment registered a score of 3.3, which is slightly above the minimum acceptable score of 3. This suggest that, as a new user, it is still harder to get to know the system.

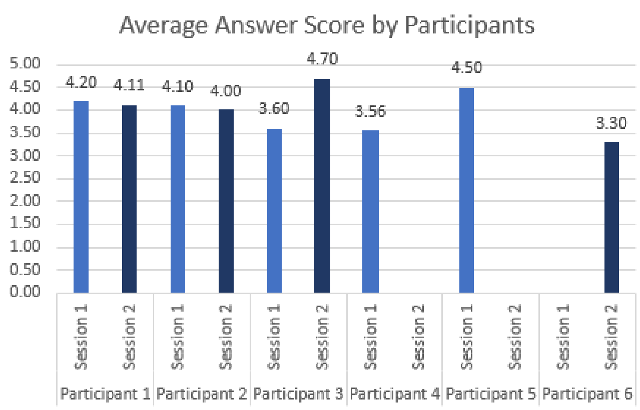

Figure 65. The average score on stakeholder relevance survay, compare the results of two sessions

Based on the results from the stakeholder relevance survey, and due to the feedbacks received during the interviews and the discussion sessions, the stakeholder relevance validity of the model and of the digital platform was *proved* one more time.

INHANCER DIGITAL PLATFORM FUNCTIONALITY TEST

For the *usability test* of the Inhancer digital platform, each participant was given 11 tasks to perform. The tasks were designed based on the implemented domain components in the system and following workflow for system preparation and set up for automation business assessment of a sample automation solution. The performance of the test participants, as well as their comments and questions during the test, were recorded and analysed using *Morae Manager*[1]. The tasks were as explained in the following:

- Task 1: Warm-up; to introduce the *Morae Manager* software which was uses during performing the tasks. It was not counted for any analysis made afterwards.
- Task 2: Registration and Log-In
- Task 3: Create a new product and edit the product profile
- Task 4: Create two info cards in with sections and new pages
- Task 5: Create a new question, type integer
- Task 6: Create a calculator question
- Task 7: Pipeline view, creating two projects and edit them
- Task 8: Gridline view, sort the projects according to their creation time
- Task 9: Accessing the finished Questionnaire, open two info cards and answer two questions
- Task 10 – Campaign module, create, edit and share the campaign link
- Task 11 – Logout of the system

[1] Available to be downloaded from: https://www.techsmith.com/morae-features.html

After each session, recorded data in the form of videos and comments were reviewed and coded. Data analysis were manly aimed at pursuing the following:

- The usability of the system as a whole and per function
- To identify the functions and domain components with the most issues
- To suggest a prioritized list of the issues to be addressed for further consideration, either to be solved or implemented.

Data coding conducted based on the type of comments the participants made, as follows:

- O (Observation): Observation made by the moderator during testing
- Q (Quote/comment) – Comment made by the participant
- H (Participant needed help) – In case that the task was not clear and the participant needed help to conduct the task.
- P (Participant prompted): this was used any time the participant needed more information to understand the functions of the system
- X (Error) – when there was an error/bug in the system.

The data was coded and categorized based on functions and domain components. Between two sessions, some of the issues were solved, yet, some other issues appeared. I addition, the parameter of the intensity of the issue is included. The intensity of the issue refers to the importance of the issue and the number of times the problems were mentioned. For this, a scale of 0: Severe, 1: Medium and 2: Minor was used. The data analysis was further summarized and resulted in 27 features to be implemented or improved in the Inhancer digital platform. In Table 23, a list of resulting features is displayed.

Table 23. Further features to be implemented in Inhancer

#	Inhancer digital platform feature
1	The system should make it clear for the user who is creating the project
2	The system should contain a brief explanation about the project value

3	The system should show what can you do on the product profile and how would that influence other functions
4	The system should have clear naming of the 2 functions and a brief explanation, so it does not create confusion (Questionnaire and Campaign)
5	The system should categorize the types of form elements, and specifying which are for information (like the Editor) and which ones are for other purposes
6	The system should have clear naming of the distinct functions and a brief explanation, so it does not create confusion (Info cards, product, project, sections, etc.)
7	The system should be clear in naming, so each function has an intuitive name
8	The system should use the same language for a command, for the element it creates, and the dialog box which appears for that command/element
9	The system should use simple words for simple functions
10	The system should clearly show how to create complex elements, such as a Calculator question
11	The system has to show, through a video, how to create a complex element (e.g. the Calculator question) and explain what information goes in there
12	The system should resize images to look nice depending on the information on the final questionnaire
13	The system must highlight the functions buttons, so it is intuitive for the user
14	The system should have the option of choosing between distinct color templates, depending on what the user likes most
15	The system should have a sharing shortcut to different social media platforms and/or email
16	The system should make it possible for the user to set up the currency
17	The system should have an edit option on any page
18	The system should offer the "Add description" as an optional field and also describe where and for whom it will be visible
19	The system should not show any other projects than the ones related to him
20	The system should have preview options
21	The system should offer the possibility to copy questions between pages, cards, products
22	The system has to run smoothly, without requiring refreshing the page after each action the user is doing
23	The system has to provide a logical sequence of actions from the beginning
24	The system should provide an info page which presents a summary of the data for a specific project

25	The system has to have some warnings. Letting the user know when something goes wrong
26	The system should not give editing access for the calculated field in the questionnaire
27	The system should have a button for finishing a process

In further iterations, the identified features were partially and completely implemented into the Inhancer digital platform.

The outcomes of the stakeholder relevance validation sessions gave valuable information about the actual stakeholder needs and their perception about the Inhancer model and the functionalities the digital platform provides, as well as future implementation suggestions. The result made it possible to, firstly, understand if the model and the digital platform addressed the relevant aspects of the processes and identified issues; if the responders can recognize themselves and their organization in the image which is represented by the model and them show an interest to the suggested model (confirming the fact that the model is based on reliable information).

Secondly, it was possible to test the goodness of the methodology and the digital platform via testing if the platform provides a descriptive methodology which motivate the actors to move and adopt to it without too much effort and if it can initiate and support constructive dialogue and communication around it (Provocation value). The results showed that the suggested methodology was able to provide an overall provocation value, yet, most of the identified issues in the system were encountered with the naming of features and need for some wizards to create a better level of understanding and guidelines while applying the digital platform.

Furthermore, it was possible to test the methodology in terms of understanding the extent to which the company agreed with the facilitation of the automation business assessment as well as efficient communication with other actors via the platform, and if the result of applying the methodology will positively impact the business implications of the organization. Therefore, to identify strengths and weaknesses and the suggested opportunities to evaluate if the methodology would be possible to be applied in other possible automation suppliers and manufacturing companies with similar challenges (confirming self-awareness and practice value).

Finally, a number of test cases of Inhancer has decided to apply the Inhancer into their business processes. At the time of this report, four subdomains of Inhancer are active. A total number of around 20 projects are being evaluated through Inhancer. There are around 50 users work with Inhancer in their daily business activities. Figure 66 illustrates the number of active users on Inhancer in one sub-domains within the period of 1 July 2018 until 30 March 2019.

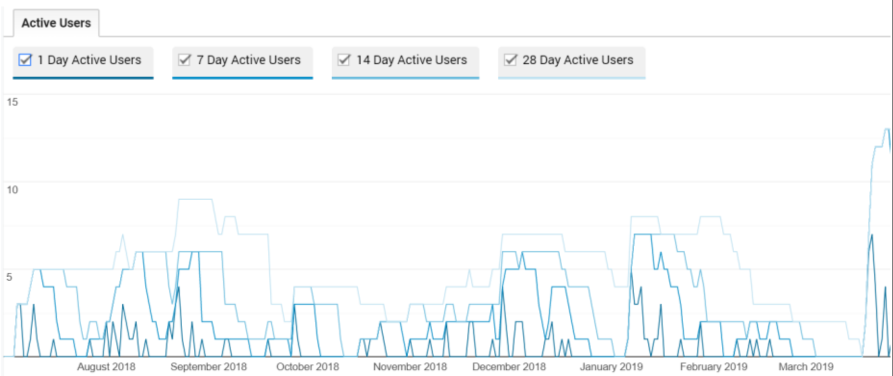

Figure 66. Number of active users in one sub-domains of Inhancer

BUSINESS IMPACT AND EFFICIENCY INCREASE

Efficiency has been considered as one of challenges in inter-organizational collaboration which were reflected as one of the motivations of this research. The challenge was formulated as “limited efficiency in the implementation process leads to limiting the competitiveness of the manufacturing SMEs and automation suppliers”. Therefore, efficiency enhancement in inter-organizational collaboration is required to be discussed to validate if the platform coming to live, the efficiency is improved. To measure efficiency, the researcher has conducted a business case analysis with a focus on the business KPIs in related to the sales performance of the automation supplier 2.

In average automation supplier 2, gets in contact with 500 leads per year, through sales partners, marketing campaigns, participation in automation exhibitions and cold calls. This includes finding potential customers and approach them, identify projects and agree on needs. In average 20% of leads, are considered as quality leads, which the automation supplier can formulate and send a quotation for an automation solution. This includes expectations, selecting process, prepare an offer and refine the offer and proceed through negotiation processes. In average 10% of these ends to a successful contract. In average, 25% of the automation solution sales price is used for lead generation, traveling to the customer site, create the quotation etc (Figure 67).

Figure 67. Lead conversion rate in supplier 2 (before Inhacer)

It is expected that the implementation of the Inhacner process model and the digital tool affect this structure in multiple ways, categorized in two scenarios:

Scenario 1. Increase in number of quality leads and successful sales:

1. Increase lead generation by 40%: Due to standardization of the processes and facilitate communication. This means 200 more leads.
2. Increase the number of qualify leads, due to efficient filtering and easy conversion. This means 12 more qualify leads.
3. Increase successful leads, due to higher number of qualify leads, faster move through the sales pipeline, highly fit with the business and technology criteria.

Scenario 2. Saving in time during automation decision and sales process:

1. Saving time in lead generation and qualify leads by 45%, due to facilitation of the processes. Reduction in required time to find and qualify a lead from 22 hours to about 10 hours.
2. Saving time in automation decision and closing a deal with the buyer by 80%, due to the higher communication capacity between partners, transparency in problem brief, trust and commitment within the customer organization. This means the required time to make an automation decision and close a deal is reduced.

The following a brief business case analysis is presented and the expected addition business revenue due to the above-mentioned scenarios is calculated (Table 24).

Table 24. Inhancer business case analysis for automation supplier 2

No. 1	Scenario 1		
No. 2	INPUT:		
No. 3	Current number of company's clients	50	
No. 4	The annual revenue of the company (€)	1000000	
No. 5	Number of lead to be generated to create a qualify lead	5	
No. 6	Number of qualify leads to be generated to create one new client	10	
No. 7	Number of years the company keep a client in average	5	
No. 8	OUTPUT:		
No. 9	The value of a lead for the company (€)	2000	(No.4 / No.3) / No.5 / No.6 X No.7
No. 10	The value of a qualify lead for your company	10000	(No.4 / No.3) / No.6 X No.7
No. 11	Additional lead generated per year	200	No.3 / No.7 X No.5 X No.6 X 140% - No.3 / No.7 X No.5 X No.6
No. 12	Additional qualify leads generated per year	12	(No.3 / No.7 X No.5 X No.6 X 140% X (1 / No.5 X 80%))-(No.3 / No.7 X No.5 X No.6 / No.5)
No. 13	Additional successful deals per year	4	(No.3 / No.7 X No.5 X No.6 X 140% X (1/No.5 X 80%)) X (1 / No.6 X 120%)-(No.3 / No.7 X No.5 X No.6 / 5 / 10)
No. 14	**Additional revenue per year (€)**	**400000**	No.4 / No. 3 X No.7 X No.13
No. 16	Scenario 2		
No. 17	INPUT:		
No. 18	Required hours (Sales and development) to generate and qualify a lead	22	
No. 19	Required hours (Sales and development) to close a deal	50	
No. 20	Hourly rate (€)	15	
No. 21	OUTPUT:		
No. 22	Reduction in required hours to generate and qualify a lead	12.1	No.18 X (1 - 45%)
No. 23	Reduction in required hours to close a lead	10	No.19 X (1 - 80%)
No. 24	Saving in generate and qualify a lead (€)	181.5	No.22 X No.20
No. 25	Saving in close a deal (€)	150	No.23 X No.20
No. 26	**Yearly saving due to time saving in qualify lead generation (€)**	**90750**	No.3 / No.7 X No.5 X No.6 X No.24
No. 27	**Yearly saving due to time saving in closing deals and automation desicion (€)**	**1500**	No.3 / No.7 X No.5 X No.6 / 5 / 10 X No.25

The business case analysis has been discussed within the host company and the supplier 2 and feedback received. Yet the validity of the expected results needs to be analysed when the platform become completely operational.

6.4. RESEARCHER RELEVANCE VALIDATION

In order to prove that the Inhancer and the proposed methodology is novel, innovative and provides interesting research results, they were presented as discussed with an international scientific community made of researchers, academic and industrial experts during two presentation and collaboration in course of two projects funded by the European Union Framework Program for Research and Innovation Horizon 2020, ReconCell and AUTOWARE.

ReconCell is a European funded project, which aims at designing and implementing a new kind of an autonomous robot workcell, to be applicable for both large production lines but also for few-of-a-kind production, which often takes place in SMEs. The ReconCell workcell is based on novel ICT technologies for programming, monitoring and executing assembly operations in an autonomous way to automatically reconfigured to execute new assembly tasks with a minimum amount of human intervention. The backup business case analysis shows that the ReconCell system is economically viable also for SMEs (Anon n.d.).

AUTOWARE is an EU funded project, H2020-FOF-2016, focuses on wireless autonomous, reliable and resilient production operation architecture for cognitive manufacturing. One of the objectives of AUTOWARE is to form a multi-sided ecosystem to leverage a number of SME enablers; e.g. augmented virtuality, reliable wireless communications, CPPS trusted auto-configuration, smart data distribution, and cognitive planning to ease cognitive autonomous systems; as well as to leverage digital automation investments (Molina et al. 2017).

RESEARCH RELEVANCE VALIDATION SESSIONS

The first presentation and discussion of Inhancer took place at the ReconCell project general meeting which was held at the University of Göttingen, 11-12 Sep 2017. Subsequently, the following discussion took place during the next project meeting, Vienna Jan 2018 and the results were presented and further discussed at European Robotics Forum (ERF) 2018, March 2018.

The purpose of the presentation and the discussion was to identify and discuss challenges in advancing the vision of Business Model development in the context of open cloud-based service platforms for Smart Manufacturing (SM) systems. Two sides of the business model vision were the field of interest of the discussion: a) Organizing: includes all the activities associated with developing the automation solution (design, supply materials, manufacturing, and construction, etc.). b) Functional: includes all the activities associated with solution selling (finding and reaching customers, transacting a sale, distributing the product, or delivering the service.). The project ReconCell has chosen to use the Product Service System (PSS) (Baines et al. 2007) approach to business model development. Therefore, ReconCell PSS is a layered concept where the service layer will be maintained by ReconCell ltd (the ReconCell supplier company by the end of the project) identify potential target groups based on a synthesis of own and market possibilities. Selected groups are contacted and together with customers begin with building functional case intention against suitable concept variants by modelling and analysing for the assembly case needs both for technical and business requirements. Therefore, the objectives of the presentation and discussion were to: a) To help evaluate and analyses the complexity of collaboration and commutation with buyers. b) To inform the Inhancer model and the future steps as well as the digital platform brief. c) To offer information to the project management board and stakeholders on business model integration to discuss the theoretical contribution of Inhancer and its integration with the ReconCell business intelligence model.

ReconCell business requirements are characterized by the products and services that are envisioned to be delivered to the business environment, with a focus on two layers: Business layer with functional, composition describing needed functions and functional behaviour of the planned Product Service Support system; and the organization layer with which is understood the construction perspective that is characterized by the processes in which the products and services are brought about. The product service system of ReconCell is developed to enable integrating various customer orders, their execution and results in evaluation needs with the solution design. This requires efficient integration of functional requirements with the organizational process knowledge. System intention is thus the synthesis of changing needs and requirements with constantly developing possibilities and can be used to constantly improve the value proposition.

Experiences from the discussions were used for planning of integration of Inhancer with the ReconCell business model, and system modules and concepts accordingly (Figure 68).

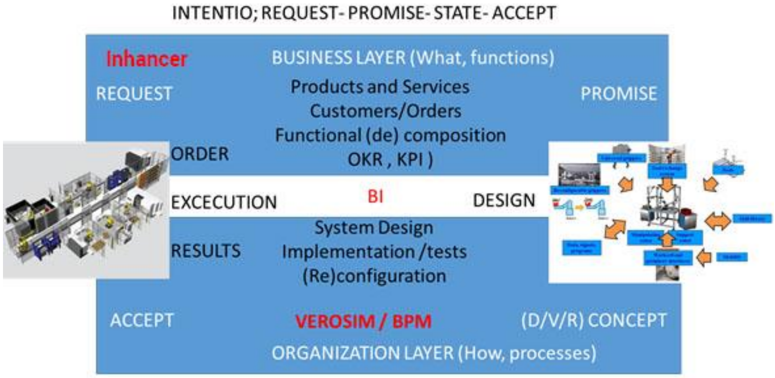

Figure 68. Inhancer integration with ReconCell business model

As it is illustrated in Figure 68, the agile collaboration environment which consists of a set of shared processes, ICT tools, technologies and partner network, is created for identifying the potential customers, contact them, establish the need and provide an exact set of service offers provided by multiple partners. To be adequately agile and reliable a well-established, transparent and accurate and tested system is created in integration with Inhancer, agreed on and efficiently implemented. The added value and improving performance were intended to be included on fast evolving competences, capabilities, knowledge and collaboration case by case. In the ReconCell approach, tools, integration of the system, experiences derived from real cases and discussion of future directions.

The approach and potentials of the platform economy and digital platforms for complex manufacturing system deliveries from point of view of especially SMEs were discussed. First findings indicate the need for created improved contact process, as well as the potential for reduction of integration cost and time with improved quality and system efficiency. Further reduction of costs of the hardware and software can be achieved by improved modularization, knowledge sharing and benchmarking with improved reuse and sharing of resources.

Within real projects cases, we have planned the system to verify the concepts potential to learn and teach and thus improve. Fast creation and update of shared models allow the collaboration with customers and partners for current and future needs and affects to OKRs and KPIs. First experiences of the created collaborative business platform where the roles of customers and suppliers can change and potential to create shared knowledge and meaning with a mutual view on the applicability of the offered solution and business contents over intended system life-cycle.

"Business Assessment System (Inhancer) developed by BOR. Inhancer is a system that connects a ReconCell Solution with its potential customer base at an early stage. It helps a business developer (sales person) with initial customer communication."

Kai Salminen, Project Manager, and Researcher at Hermiagroup

Following the presentation meeting, user requirements of various identified user groups and development ideas and system needs were collected first together with participating industrial use case companies of the ReconCell, ELVEZ, and Logicdata. Thereafter, the Inhancer applied as the application platform for additional case-companies in the period of Dec 2017-Mar 2018 to be based for gathering the user requirements and automation project evaluation (Figure 69).

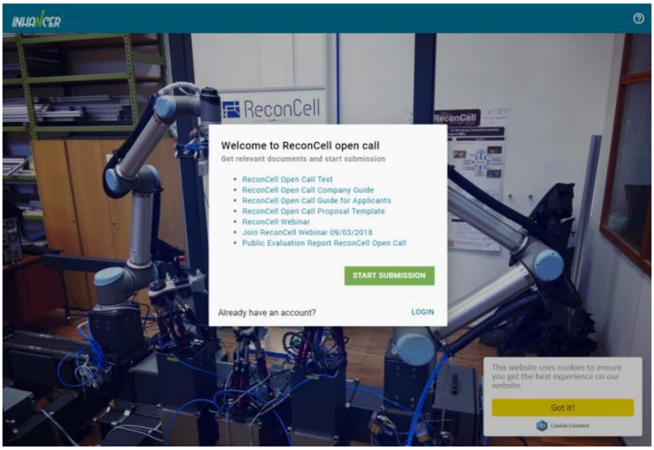

Figure 69. Inhancer for ReconCell open call applications

System development is also based on previous research projects and supported by thorough literature review, benchmarking and collaboration with other similar EU projects.

RESULTS OF THE RESEARCH RELEVANCE VALIDATION SESSIONS

The main outputs obtained from the Inhancer presentation and discussion during the course of the ReconCell project was that researchers, academic and industrial experts, who already had experience on automation solution development, digitalization process and automation decision processes, that attended the event confirmed the validity of the methodology structure, focus, execution process and digital platform completeness (proving it uses meaningful and reliable information).

In addition, Inhancer was evaluated as a complimentary link to the Product Service System approach of the business model during and after the meeting. Where the compatibility and performance of the model have been evaluated and validated subsequent of the initial meeting, during development ideas and system needs for the ReconCell project use cases and next following project meetings. This proves the value of the Inhancer goal and of its structure. At the end of the comparison exercise, it was possible to state that Inhancer is complementarity to the Product Service System

(PSS) business layers in the overall scope of digitalization and Smart Manufacturing. Thanks to the collection of this information, the Inhancer was theoretically validated.

In the next chapter, the results obtained using the main output of this Ph.D. dissertation are discussed and summarized.

Chapter 7.

Concluding Discussion

7. CONCLUDING DISCUSSION

In this Chapter, the overall Research presented in this Ph.D. thesis is discussed. The results obtained through performing the research and using the main output of this Ph.D. Thesis are summarized. According to the Research Questions presented, the key output of this Research is the methodology based on automation business assessment model, the Inhancer, to facilitate and guide manufacturing companies and automation suppliers, strategically, identify and evaluate the automation possibilities, in order to set the ground for next actions which aim at collaborative automation solution deployment reaching the breakthroughs projected. The findings based on performed analysis on use cases of this research and through the proposed methodology is reported. Furthermore, the conclusions and suggestions for future works presented in this chapter.

The evidence emerged from the research project

To discuss the evidence emerged from the research project, the answers to the research question are described. The Main and secondary Research Questions, namely the Research Questions presented, are here stated for further clarity of the results:

What are the collaboration mechanisms in automation and digitalization decisions in manufacturing SMEs?

1.a. Does it exist a pattern of buyer-suppliers collaboration in automation practices both from literature and from the practitioner point of view?

1.b. What are the behavioural parameters and influential aspects of buyer-supplier collaboration in automation decisions?

How to facilitate collaborative automation and digitalization decisions?

2.a. How the business assessment model is formed to facilitate the buyer-supplier collaboration in automation practices?

2.b. What are the "automation business assessment model" design principles?

2.c. What are the process groups that are considered in the automation business assessment model?

2.d. What are the domain components that are considered in the automation business assessment model?

2.e. What are the domain components of the digital platform for automation business assessment?

2.f. How the development and validation process of the digital platform for automation business assessment is organized?

2.g. What is the outcome of the digital platform for automation business assessment?

7.1. ANSWERS TO THE FIRST RESEARCH QUESTIONS

What are the collaboration mechanisms in automation and digitalization decisions in manufacturing SMEs?

SUB-RESEARCH QUESTION 1.A.

The research question 1.a is answered by the literature review reported in Chapter 2. Inter-organizational collaboration, consequences and anticipations have been studies in detail in this chapter. The literature study, initiated with an investigation of the network theory and previous studies, definitions and consideration particularly around the business networks. This included network from perspectives of alliances (Gulati 1998), strategy formulation (Jarillo 1988), strategic groups (Peteraf & Shanley 1997), organizational management (Kenis & Knoke 2002), organizational learning (Kogut 2000), international relationships (Håkansson & Snehota 1989), marketing channels (Antia & Frazier 2001), specialized suppliers (Dyer 1996), international relationships (Håkansson & Snehota 1989), business networks (Håkansson & Snehota 1989; Ford 1990; Gadde & Mattsson 1987), marketing channels (Antia & Frazier 2001) and business relationship perspective in business networks Anderson et al. (1994; 1989).

One of the main contributions on network research, which is specifically of interest of this research, is the business network approach. In this approach, coordination is based on both market forces and on the actors, resources and activities that are part of the relationship (Håkansson & Snehota 1989). A business network is defined as, "a set of two or more connected business relationships, in which each exchange relation is between business firms that are conceptualised as collective actors" (Emerson 1981), also (Blankenburg Holm 1996; Anderson et al. 1994). In this path, to multiple different relationships between network partner, including supplier or the customer, and the third parties (Anderson et al. 1994) was studied. It was discussed that the interaction between business actors, has wide, multiple and continuing effects and in turn it is affected by multiple influences across the business network. Interaction is not controlled by any of actors directly or indirectly involved or affected by it, however, many of actors may influence its direction (Ford & Håkansson 2013). In more focus on digital business ecosystems and business collaboration, the research has focused on the definitions and aspects of the collaboration in supply chain. In Chapter 2, the researcher discussed that as collaborative partners learn from the ongoing relationship, they adapt business models to better match the requirements of each other. To elaborate more on this, the outcome of supply chain collaboration can be: Higher capabilities in supply chain, due to better demand planning (McCarthy & Golicic 2002), inventory visibility (Sabath & Fontanella 2002) and access to new knowledge and skills (Hardy et al. 2003); Higher supply chain efficiency, due to reduction in inventory and cost savings (Sabath & Fontanella 2002; Stank et al. 1999);

Higher supply chain effectiveness due to improvements in customer responsiveness (Sabath & Fontanella 2002) and better access to target market segments (McCarthy & Golicic 2002). Therefore, the collaboration partners try to keep the relationship dynamic, adaptable, and valuable to the involved parties. The reasons and patterns companies initiate collaborations, particularly in automation and digitalization decisions in manufacturing SMEs, as identified by Min et al. (2005) have been described as Mutual benefits; Efficiency (cost reduction, Reduced inventory, Shortened lead-time, Streamlining supply chain process); Effectiveness (Improved customer service, Increased market share, Better pricing, New product development); Higher profitability; and The reinforcement and expansion of the relationship (Trust, Commitment, Interdependent, Mutual involvements). Companies typically collaborate through the mechanisms (Min et al. 2005) as Information sharing (Forecasting, Customer demand, Materials requirement); Joint planning (Marketing planning, Production capacity and scheduling, Joint planning Mutual sales and performance targets, Budgeting, Prioritizing goals and objectives); Joint problem solving (Product development/ redesign logistics issues, Marketing support, Quality control, Cost-benefit analysis); Joint performance measurement (Performance reviews on a regular basis, Measuring KPI, determining rewards and taking corrective actions); Leveraging (Resources and capacity, Skills and knowledge, Specialization). Successful inter-organization collaboration in automation decisions depends on some conditions including (Johansen 2005) Communication on product/solution introduction; Supports efficient collaboration and early participation from all involved partners in the process; Clear communication and information handling both internally and externally; Trust, reliability and respect for each other's competence in business approaches; and Cultural awareness between different partners and countries.

Furthermore, to reveal the coordination mechanisms, influential factors and conditions, in the literature review, Chapter 2, the researcher analysed different approaches to coordination mechanisms, with a consideration to early involvement of supplier in the new product development process. In this path a deep literature analysis has been conducted to identify the integration factors of inter-organizationcollaboration activities with impact new product development processes. The factors have been reported as Trust, Commitment and Mutual Understanding; Goal agreement; Information and Knowledge Sharing and Integration; Coordination and Communication Mechanism; Cooperation and Collaboration; and Technical Integration Mechanism.

Coordination mechanisms and the dynamic approach to the coordination mechanisms have been reviewed from different approaches and reported in Chapter 2. Twigg (1996) introduced different coordination mechanisms that a manufacturer uses within a "design chain" in three phases: Pre-project, Design phase and Manufacturing phase. Lewis et al. (2002) suggested that an emergent management style and a planned management style are distinct approaches to project monitoring, evaluation, and control. Moreover, the research Van de Ven et al. (1976) and Mintzberg (1979) conducted to identify variations and interactions in the use of the coordination mechanisms, have been used to study the coordination modes and identify the influential factors that determine the mix of coordination mechanisms in this study. The coordination mechanisms introduced by Mintzberg (1979), mutual adjustment, direct supervision, and standardization (of which there are three types: of work processes, of work outputs, and of worker skills), and the use of the coordination mechanisms based on the task. Mintzberg (1993), is referred as a bases for this study, where the researcher described the role of different participants and the locus of control in different phases of inter-organizational collaboration, particularly the role of lead integrator when the factors of task complexity and problem urgency are evolved.

SUB-RESEARCH QUESTION 1.B.

The results from the literature analysis, followed by the analysis has been done to answer the research question 1.b. The answer to the research question 1.b. also evaluated based on the expert's consultation and evidence reported through case research described in Chapters 4. Findings from empirical data, the stages of inter-organizational collaboration identified and analysed to build up an overview map of the behaviour of buyer and supplier in different stages of the collaboration process and explains how the nature of this behaviour can be examined. The relevant emerged points from the analysis of the case studies mainly describe the process of emerging an innovative collaboration, consideration, challenges and possibilities which lead to the development of efficient automation solutions for production optimization.

The buyer-supplier collaboration development in automation decision practices describes the typical behaviour of a partner at each of the three main stages and six sub-stages, for each of the aspects of coordination and collaboration. The developed map sustains that collaborative partners are likely to evolve through the identified phases, before reaching the excellence in automation decision. These stages are reported in Chapter 4, the map of the development of buyer-supplier collaboration. Based on the behaviour analysis of buyer-supplier collaboration in automation decisions and the influential aspects the finding can be summarized and discussed in the following areas:

- Automation opportunities and need recognition as a dynamic action
- The role of the lead integrator in a dynamic action
- Commitment and involvement in the buyer-supplier collaboration
- Behavioural analysis in the buyer-supplier collaboration in automation investment
- Innovative automation solutions in SMEs and new business models
- Digital business ecosystem

AUTOMATION OPPORTUNITIES AND NEED RECOGNITION AS A DYNAMIC ACTION

Manufacturing companies, particularly SMEs, regardless of their current level of automation are facing different types of challenges. Decisions in automation are a long, complex and costly process, preventing a successful result for many manufacturers. There is a real lack of technology-based tools to support manufacturing companies in identifying and evaluating their automation projects and in facilitating collaboration with automation suppliers in a smart and efficient way.

More specifically, the notion of shifting market demand, increase the demand for flexibility and adaptability in manufacturing SMEs to increase the capability of producing more customized products.

To achieve a flexible, efficient and world-class production system there is a need to frequently recognize and evaluate the impact of the various forms of automation solutions on their production system to support their flow production system. The selection of optimum automation solutions follows the decision on the best solution for a production system. Therefore, evaluation the automation opportunities and specify the requirements for automation projects need to be done in iterations, yet, the need for automation road-map where defines goals and desired outcome of automation projects to envision the vision of the production system is demonstrated.

LEAD INTEGRATOR AS A COORDINATION MECHANISM IN A DYNAMIC ACTION

Emerging new technologies continue to evolve quickly, while many manufacturers SMEs are limited in engineering competencies in automation and digitalization.

> *"Even though they are flexible, they do often not have the resources to research automation solutions" (Automation Expert)*

Therefore, the need for dynamic evaluation and evolvement in technology highlights the role of lead integrator as a coordination mechanism. This study proposes the lead integrator as kind of personalized coordinator mechanism. Lead integrator takes the role of coordination between different suppliers in inter-organization collaboration to ease the challenges may occur during the collaboration process. The role of the lead integrator in automation projects, unlike the traditional buyer-supplier relationship where the efforts are focused on a project-to-project basis, is on a more continues bases with the engagement of the lead integrator from an earlier stage of planning automation. The lead integrator not only initiate, facilitate and motivate communication between actors at the buyer company to give the indicators of setting up the roadmap and the automation objectives, but also the lead integrator make a commitment to stay up to date on technology developments and keep a focus on technologies the manufacturing SMEs could benefit from. This study explored the role of lead integrator as coordination mechanism and a facilitator in the automation business assessment process model where the lead integrator assists the buyer in determining the required competences and participate in finding, communicating and evaluating suppliers with relevant competences, describe role prospects to facilitate interactive knowledge sharing and development path clarification. Moreover, the lead integrator role can contribute by facilitating guidelines, suggesting standard procedures, demonstrations, summaries, takeaways and communication with suppliers. It is fundamental to note that in some cases the lead integrator role can be associated with the main automation contractor, where on the bases of automation capabilities and assigned technical resources, they take the responsibility of making a meaningful collaboration pattern and integration plan and contribute to the deployment process of automation solutions and take the lead by integrating all aspects of the automation project. This results in a faster and more efficient start-up.

COMMITMENT AND INVOLVEMENT IN THE BUYER-SUPPLIER COLLABORATION

Several studies have specified that the commitment of top management is important for the success of buyer-supplier collaboration in development activities. (Johnsen 2009) Nevertheless, the studies have not clearly focused on how to attain top management commitment to this collaboration.

This study has built up on the current discussion on buyer-supplier collaboration by proposing a behavioural analysis on how the collaboration is developed and exploring the behavioural parameters including the trust and commitment formation and communication pattern in the processes. As such the study bring forward the difference in behavioural pattern and different considerations in buyer organization, in contrast to supplier organization through each stage of collaboration.

Based on the analysis from manufacturing company cases and in mostly all the analysed automation suppliers, what realized is that involvement and fast responding in the buyer-supplier collaboration processes can be affected by *Problem clarity, The urgency of the automation project.*

The problem clarity or project brief is specified by its goal clarity, path clarity, mechanisms, and obstacle. Clarified project brief illustrates the required competencies and capabilities to provide immediate contributions to a project. An important aspect when involving and forming commitment in supplier organization is to convince top management and business development department since they will have the commitment to assign qualified resources to engage in the future course of the innovation projects. The research widens the understanding of how to tap into project brief specifically by illuminating how to describe an automation project supported by technical and business aspects to facilitate and enhance mutual understanding and support communication in supplier organization and the buyer firm.

The urgency of the automation project. In cases that the realization of the automation project has an early and considerable impact on the business performance of the buyer organization, the involvement of the buyer company is expected to be at a higher level of participation. The results showed that when there is a demand in the manufacturing companies due to orders from prioritized customers where the realization of the automation solution potentially supports the order delivery, or when considerable business impact and production improvement is predicted, they have more committed on involvement in the buyer-supplier collaboration and automation assessment model. Furthermore, when the potential for automation solution is identified and prioritized in the manufacturing strategy, the involvement in the buyer-supplier collaboration is expected to be at a higher level. The research examined how to evaluate and create an automation roadmap based on the evaluation of the automation projects and utilize elements of business and technical assessment.

BEHAVIOURAL ANALYSIS IN THE BUYER-SUPPLIER COLLABORATION IN AUTOMATION DECISION PRACTICES

The research investigated the buyer-supplier behaviour in complex decisions focused on digitalization and automation projects. The challenges and opportunities have been recognized and analysed via different stages of buyer-supplier collaboration. The role of different stockholders and the expected contribution has been analysed. The behavioural analysis has been focused on identifying the particular processes and possible "consistent behaviours" to "merge successful approaches into a pattern of actions that could become the strategy" (Mintzberg 1987), consequently, identify synchronization mechanism through the process.

While the buyer-supplier collaboration model has been scrutinized in e.g. literature on new product development (Yan & Dooley 2014) and quality of collaboration, also, in industrial context (Ford 1980), the emergent strategies which may impact the realization of strategies has been overlooked, where mainly the linier or semi linear model of buyer-supplier collaboration model has been examined. The research based on actor's behavioural analysis and studding the behavioural parameters in the collaborative automation assessment and decision process (Chapter 4.5), suggests an iterative and circular process model for the buyer-supplier collaboration (Chapter 5.7) where the dynamicity and flexibility of the solution involved, and the type of collaboration is considered. Furthermore, to facilitate the collaboration, the communication setup has been studied to provide a bases for e-synchronizer utilizing the digital platform (Chapter 5.9).

UNDERSTANDING INNOVATIVE AUTOMATION IN SMEs

In some manufacturers, clear identification of innovative automation projects align with their manufacturing strategies is the point of challenge and interest. Some manufacturing companies have shown that grasping the overall idea of digitalization, automation as well as the overall idea of Industry 4.0 (Erol et al. 2016) and concepts hereof could be substantial problematics because the manufacturing companies have challenges to relate the automation opportunities to their specific domain and their particular business strategy (Schumacher et al. 2016). The experiments and observations in this research from several case studies are in line with the stated results from Schumacher et al. (2016). The results from our research show manufacturing SMEs are uncertain about the financial requirement for the acquisition of new automation technologies and the overall impact on their business model. SMEs are flexible and more innovative in new areas, in many cases, the founder(s) is the inventor. They have a high level of understanding and knowledge about the product which makes SMEs flexible and adoptive regarding different demands from customers. Yet, they are facing challenges in determining and evaluation their state-of-development in related to the Industry 4.0 vision to identify concrete fields of action, to answer: what to automate? and how to automate?

One of the focus areas of this research was to provide methods and tools needed to create guidelines and support to align business strategies and operations.

Only a limited number of SMEs have enough capacity to realize the whole innovation process by themselves. This constrains their competences of conducting regular R&D projects as well as hold them back from pursuing new investment that is not directly related to the scope of their core competencies (Parizi & Radziwon 2017). To overcome this challenge, one approach is to collaborate with other firms (Edwards et al. 2005) and source knowledge from outside of the organization. This could help SMEs to clarify their improvement opportunities and benefit from external capacity in order to strengthen or increase their internal technical capabilities (Parizi & Radziwon 2017). Therefore, one practical contribution of this research work with the focus on this requirement, is to provide a model and the supportive digital platform enabling a manufacturing company to rigorously collaborate with external partners within the process of evaluating their automation development, reflect the fitness of business strategies as well as managing the dynamics of co-operation in industrial innovation.

INNOVATIVE AUTOMATION SOLUTIONS IN SMES AND NEW BUSINESS MODELS

The other aspects of industrial innovation in SMEs refers to the specifications of the automation solution applicable to manufacturing SMEs.

SME’s tend to equip their production with the required solution when they start growing and the capacity starts to vary, while they tend to stay very flexible. In many cases, the automation solutions offered by large companies or global automation suppliers do not necessarily meet SMEs requirements properly. It mostly happens because large companies are not fully aware of the manufacturing needs of SMEs. Moreover, some of the existing solutions include 'unnecessary features', which often make the product way too expensive. As illustrated based on the selected case of this research, the suggested solutions offered by an external provider are tailored to meet the specific requirements of the company. The solution is more aligned with the particular firm's manufacturing system and better integrated with the overall manufacturing strategy than the 'one size fits all' solutions.

Furthermore, the limited capital/cash flow makes SMEs be very conservative about changes, and afraid of bringing something new to the company. In many cases, this makes them focus their attention on the day to day survival of the company rather than radical changes which make them think short-term. Therefore, in the view of this research result, developing a strategy of long-term incremental improvements with the boundary conditions of the payback period – not longer than two years is highly recommended. Correspondingly, new business model to offer automation solutions such as Product Service System (PSS) (Baines et al. 2007), is recommended, to embrace a service-led competitive strategy, environmental sustainability, to simply offer 'less capital investment'.

7.2. ANSWERS TO THE SECOND RESEARCH QUESTIONS

How to facilitate *collaborative* automation and digitalization decisions?

SUB-RESEARCH QUESTION 2.A.

The research question 2.a. is referred to the next part of the research, introduced by the development of the Inhancer, the automation business assessment model to facilitate buyer-supplier collaboration in automation practices. In order to give a proper answer, the development framework has been evaluated to clarify the model development steps described in Chapter 5.1. The De Bruin et al. (2005) development framework is used as a guideline to present how the Inhancer model was developed. The development framework proposes six main process area: Scope, Design, Populate; Test; Deploy; and Maintain.

Phase 1: Scoping. The scope of the model has been determined by considering the model objectives which is to assist manufacturing companies and automation suppliers in automation decisions to enhance the level of automation and digitalization in manufacturing companies by joining several stakeholders' needs: Automation buyers or Manufacturing SMEs; Automation suppliers including; and Third party such as automation experts.

Phase 2: Design. The design of the model was based on multiple aspects including Audiences; Method of application; and Respondent. In the view of the aspects, and over the domain modelling sessions the structure of the model was designed, core design principles were determined and followed by the main relevant process groups of automation business assessment were identified and described in a circular process model.

Phase 3: Populate. During this phase, four main steps were performed according to Moggridge & Atkinson (2007) model of design interactions. 1. Ideation of domain components, 2. The pre-selected ideas of domain components described into the concrete presentation by both visualization and behavioural description; 3. Select the most promising group of the domain components ideas, based on three criteria: value creating for audiences, the technical possibility and required effort to be deployed in the digital platform development. 4. Visualization of domain components in the form of more complete as representation, for the purpose of communication the "potential reality of the concept" (Moggridge & Atkinson 2007). Create user stories and prototypes. Iterates with focus on both the buyer side and supplier side. Develop the detailed process model. The structure of the model described in Chapter 5.1, Chapter 5.8 and Chapter 5.9.

Phase 4: Test. Once the domain components and the digital platform prototype were developed, the test of the model has been performed to ensure the completeness and comprehensively of the Inhancer model. Test and validation are described in detail in Chapter 6.

Phase 5: Deploy. To deploy the model, the Inhancer model and the related digital platform were applied to a number of cases including automation suppliers and presented during the course of two European projects, ReconCell and AUTOWARE. Based on the experience and feedbacks, the model was validated. The process of validation phase is described in Chapter 6. Additionally, for the purpose of identification of similar firms in different markets and to supply the list of potential "next" administrations, the profile of audiences of Inhancer audiences was reviewed and during the market intelligence study, a market plan for further deployment of Inhancer was performed. This is further described in Chapter 8.

Phase 6: Maintain. Following the deployment phase, the domain components, as well as the digital platform, need to continually update in interaction with audiences, best practices and available technologies in the market. This will be performed in the future, following the framework of the suggested business intelligence model from the deployment phase.

The framework to develop the development of the Inhancer, the automation business assessment model is illustrated and further described in Chapter 5.4.

SUB-RESEARCH QUESTION 2.B.

The research question 2.b. is answered by identifying the design principles of the automation business assessment model. The design principles refer to characteristics of the planned model design (what it should look like), or of a procedural nature (how it should be developed) (van den Akker et al. 2012). Design principles are best expressed in active terms enable the stakeholders and developers to be aligned around the model. Over the course of the participant's interviews and brainstorming sessions and analysis of the results, and over the domain modelling sessions, a number of similar elements and patterns were identified. A sample of the analysis of the relevant data fragments from interviews to identify similar elements and patterns is presented in Appendix C. From the analysis of the data, the elements are synthesized in the form of design principles of the automation business assessment model have been identified which are summarized in the following:

1. *Unity*. Hold the harmony, balance, and variety of design.
2. *Contextual overview*. Give a contextual overview of the automation project, environment and the processes with the possibility to scale up and scale down.
3. *Combined*: Combine mobile and non-mobile technologies.
4. *Communication*. Be a base for communication, data handling, and documentation.
5. *Affordances*: Exploit the affordances of the technologies
6. *Personalize*: Customized and personalized based on offering solutions and suppliers' business identity.
7. *Whenever, wherever, whomsoever*: Use the automation business assessment instantaneously, in non-traditional spaces, and both individually and collaboratively.

The method to identify the design principles, as well as the detail description on the principles, is presented in Chapter 5.6.

SUB-RESEARCH QUESTION 2.C.

The research question 2.c. is answered by identifying the main process groups that form the Inhancer circular process model from both perspectives of manufacturing companies (buyer) and automation supplier in Chapter 5.7. These processes have been grouped into six process area represented and provide a modular structure that allows integration in buyer-supplier collaboration in automation practices.

The focus of the model is to assist buyers which are manufacturing companies, and suppliers which represent automation suppliers, collaborate in the process of business assessment and decision making for automation investments. Therefore, the relevant processes which generate value through the management of the three collaboration phases have been identified: Pre-collaboration stage, the early stage of collaboration and development stage of collaboration. Based on the results from the literature analysis and as a result from the empirical data analysis (Chapter 4.5), six main relevant process areas of collaboration development and automation business assessment from the perspective of both buyer and supplier actors were identified and modelled in a circular process diagram. This reflects the dynamicity property of the model. Referring to three innovation process model, stage-gate (Cooper 2008), open innovation model (Chesbrough 2006), the simplified model from Tidd et al. (2005), and technology development perspective on entrepreneurship (Hansen & Madsen 2018) the process model was built. The model suggests that the automation business assessment be performed in a circular process instead of a linear one with an embedded decision-making framework for automation decisions. The technological and business requirements are captured and evaluated for responsible actors during the process to remedy those uncertainties which are less possible to be predicted. Thus, the proposed circular process focuses on capturing, analysing and transforming information step by step as well as facilitating identifying various actors along with their concerns in the process for a deliberate automation decision-making. This research proposes an actors-oriented circular process model buyer-supplier behaviour integrate into the process of automation business assessment as shown in Figure 42.

As it is shown in the model the process groups from the buyer perspectives are:

- Identification and Roadmapping
- Set Objectives
- Information Search and Examination
- Validation and Assurance
- Consolidation
- Outlet Selection and Dynamic deployment

The process groups from the supplier perspectives are:

- Approach and inspiration
- Qualification and set requirements
- Conceptualization
- Validation and refinement
- Consolidation
- Implementation and dynamic deployment

The proposed model gives an actor-oriented circular model includes identification of the potential improvements, information capturing and evaluation phases which include both internal and external actors with different levels of technology focus.

Chapter 5.7 presents a detailed description of the method to develop, as well as the detail description on the circular automation business assessment process model and its main process groups from both perspectives of manufacturing companies (buyer) and automation supplier.

SUB-RESEARCH QUESTION 2.D.

The research question 2.d is answered by proposing a map of detailed and modular domain components. This describes the process groups of the Inhancer circular process model to be used for understanding the key aspects and processes through a set of macro-processes to focus on through the assessing an automation opportunity and toward the buyer-supplier collaboration of practice of a certain system. In addition, the domain components define a proper set of interactions which increase the level of integration in buyer-supplier behaviour through the automation decisions processes. The lead integrator facilitation role is described along the process with specifying the coordination mechanisms and the locus of control. The involvement of the lead integrator might be different depends on the problem complexity and urgency as well as partners knowledgeability and capability. In case the automation projects are urgently important, and the internal capability of the buyer company fulfil the required knowledge of identification and evaluation of automation projects, the facilitation role is covered mainly by the buyer company.

The model structure is designed to enable the performance of self-contain module on the level of process groups, yet the domain components often are applied in the same sequence and repeated iteratively. It can sometimes seem in a less ordered sequence. The modularity and the scalability properties were considered to enable the model to be used in a more general approach in different kind of companies.

The domain components of Inhancer have been described in this Chapter 5.8 and summarized in Figure 44.

SUB-RESEARCH QUESTION 2.E.

The research question 2.e focuses on the scope and dimensions of the digital platform. This question is closely related to research question 2.d, where it focused on converting the domain components of the model process group to more practical features and applications can be presented toward a web-based digital platform of Inhancer.

In order to guide structure productivity improvements, this research project provided a digital platform which can be a base for building up the automation digital business ecosystem. In the view of the researcher, the automation digital business ecosystem supported by the technology morphology covers the basic needs for search automation solutions for SMEs. On such a digital platform, SMEs are able to search for possible existing solutions in the market and get inspired by the relevant solutions, have addressed similar problems. Moreover, they become able to search for groups of specialized automation suppliers with existing solutions or matching competences for automating similar processes. The SMEs have the possibility to upload an experienced issue to the web-based digital platform where automation suppliers and other researchers in the related area can discuss the issue and give new suggestion.

The automation digital business ecosystem, from an automation suppliers' approach, become an environment to promote their automation solutions, skills, and technologies, as well as to get familiar with SME's actual needs, trends and expectations in regard to automation improvements. The automation digital business ecosystem and an open-based platform for technology morphology can also provide a space for academic researchers to extend their studies in the area of manufacturing, which is particularly relevant for small businesses. In the view of research, the technology morphology is the enablers for technology search. To create a morphology that is generic enough to cover the needs of the vast segmentation of the production businesses in the SME sector, the following criteria are suggested (Parizi & Radziwon 2017):

- manufacturing system
- manufacturing application groups
- specification of components of product
- complexity and level of automation.

Each criterion is identified by a more specific area, which SMEs can use to classify the automation opportunity. Moreover, automation suppliers are able to submit their solutions or new ideas to the posted problems. Upon a solution search, the rated possible solution and solution suppliers to compliance with the automation problem specifications can be reached.

The web-based open innovation platform for automation contributes to creation of an interactive space for both SMEs and automation suppliers. The platform helps SMEs in developing their internal technical capabilities while benefiting from external capacity. Creation and delivering business value assure the sustainability of the ecosystem. For the purpose of development of the business assessment model in the form of a digital platform, the domain components were presented in the form of features. The features of the digital platform should relatively reflect macro-processes of identified domain components and be aligned with design principles described earlier. The digital platform features with the related domain components is reported in Chapter 5.9 and summarized as Inhancer feature overview in Figure 45.

SUB-RESEARCH QUESTION 2.F.

The research question 2.f which is answered widely in Chapter 6 focused on validate the model and the digital platform. The validation model in this research, follows the model proposed by Enderud (1984) and encompasses both stakeholder relevance (Chapter 6.3) and researcher relevance aspects (Chapter 6.4). The criteria selected for the research relevance validation mainly refer to novelty, innovation, and volubility of the research and results. The stakeholder relevance criteria considered in four groups: a) “Reliable” description value, description as the respondent sees the organization; b) Provocation value; c) Self-awareness or “awareness expansion” value; d) Practice value (variance, problem solving, organizational change value). The research relevance criteria presented in three groups: a) The newsworthy criterion; b) Understanding criterion; c) Theory and knowledge development value.

The “stakeholder relevance” validation is comparable to verifying usability and testability in the real industrial context. To do so, multiple cases were selected for test and applying the Inhancer and the results of this analysis, confirming the “model stakeholder relevance”, are presented in Chapter 6.3.

During the validation and analysis session, each of the industrial stakeholders interviewed and were asked about the results reliability, significant value, effectiveness, and completeness. Furthermore, the evaluation and user experience test was conducted based on the digital platform and, the results of which were used to further adjustments as well as design the interface and system functionality.

In order to validate the results of the analysis run on the input collected through experts’ interviews and targeted interviews, and an initial system prototype and technology test, two validation events were organized in collaboration with one manufacturing company and one automation supplier company. These events successfully provided a broad overview of actual activities, challenges, priorities, and recommendations on the overall suggested model and implemented prototypes. The second and third attempts on stakeholder relevance validation for process standardization and "generalizable" model achievement carried out in iterations along with the system development process to validate the results of the Inhancer V0.1 and V1.1 from the usability point of view.

The outcomes of the stakeholder relevance validation sessions gave valuable information about the actual stakeholder needs and their perception about the Inhancer model and the functionalities the digital platform provides, as well as future implementation suggestions. The result made it possible to, firstly, understand if the model and the digital platform addressed the relevant aspects of the processes and identified issues; if the responders can recognize themselves and their organization in the image which is represented by the model and them show an interest to the suggested model (confirming the fact that the model is based on reliable information).

Secondly, it was possible to test the goodness of the methodology and the digital platform via testing if the platform provides a descriptive methodology which motivate the actors to move and adopt to it without too much effort and if it can initiate and support constructive dialogue and communication around it (Provocation value). The results showed that the suggested methodology was able to provide an overall provocation value, yet, most of the identified issues in the system were encountered with the naming of features and need for some wizards to create a better level of understanding and guidelines while applying the digital platform.

Furthermore, it was possible to test the methodology in terms of understanding the extent to which the company agreed with the facilitation of the automation business assessment as well as efficient communication with other actors via the platform, and if the result of applying the methodology will positively impact the business implications of the organization. Therefore, to identify strengths and weaknesses and the suggested opportunities to evaluate if the methodology would be possible to be applied in other possible automation suppliers and manufacturing companies with similar challenges (confirming self-awareness and practice value).

Finally, a number of test cases of Inhancer has decided to apply the Inhancer into their business processes. At the time of this report, four subdomains of Inhancer are active. A total number of around 20 projects are being evaluated through Inhancer. There are around 50 users work with Inhancer in their daily business activities. An initial business case evaluation describes the potential business impact and increase efficiency in inter-organizational collaboration and automation decision which were reflected as one of the motivations of this research. The business case analysis has been discussed within the host company and the supplier 2 and feedback received. Yet the validity of the expected business impact results needs to be analysed when the platform become further operational.

The validation of researcher relevance of Inhancer, the proposed methodology and the related digital platform were presented and discussed with researchers, academic and industrial experts who already experienced and involved in the planning and control of production systems as well as building open consolidated ecosystem and single community in automation application development in the course of two projects funded by the European Union Framework Program for Research and Innovation Horizon 2020, ReconCell and AUTOWARE.

The first presentation and discussion of Inhancer took place at the ReconCell project general meeting which was held at the University of Göttingen, 11-12 Sep 2017. Subsequently, the following discussion took place during the next project meeting, Vienna Jan 2018 and the results were presented and further discussed at European Robotics Forum (ERF) 2018, March 2018. Following that, the Inhancer applied as the application platform for additional case-companies in the period of Dec 2017-Mar 2018 to be based for gathering the user requirements and automation project evaluation.

As result of the Inhancer presentation and discussion during the course of the ReconCell project, researchers, academic and industrial experts, who already had experience on automation solution development, digitalization process and automation decision processes, that attended the event confirmed the validity of the methodology structure, focus, execution process and digital platform completeness (proving it uses meaningful and reliable information). Furthermore, Inhancer was evaluated as a complimentary link to the Product Service System approach of the business model during and after the meeting. Where the compatibility and performance of the model have been evaluated and validated subsequent of the initial meeting, during development ideas and system needs for the ReconCell project use cases and next following project meetings. This proves the value of the Inhancer goal and of its structure. At the end of the comparison exercise, it was possible to state that Inhancer is complementarity to the Product Service System (PSS) business layers in the overall scope of digitalization and Smart Manufacturing. Thanks to the collection of this information, the Inhancer was theoretically validated. Detailed description of research relevance validation is presented in Chapter 6.4.

SUB-RESEARCH QUESTION 2.G.

The research question 2.g mainly focuses on the research output and contributions of the research from both practical and academic perspectives. The answer to this question is roughly touched within the validation phase in Chapter 6 and in more detailed structure in the following, Chapter 7.3.

7.3. RESEARCH CONTRIBUTION

The research carried out adds several important academic contributions and practical implications. In the following the research contribution from the both perspectives are presented.

ACADEMIC CONTRIBUTION

The research contributes to the o the body of knowledge in multiple areas including buyer-supplier collaboration, supplier involvement, and lead integrator role literature. In the following, the aggregate contributions are discussed:

- Map the development of buyer-supplier collaboration in automation decision practices
- Circular automation business assessment process model
- Business assessment process model domains
- The gap between literature and industrial practices

Map the development of buyer-supplier collaboration in automation decision practices

This research is believed to contribute to the business network literature (Håkansson & Snehota 1989; Ford 1990; Gadde & Mattsson 1987) and the dynamic relationship between firms by mapping out the partner firms and stakeholders in an inter-organization automation decision practices. The research described how the primary functions (Anderson et al. 1994) of the relationship between supplier business unit and customer business units is formed, in addition, other network functions considering the other relationships in the network is analysed.

This research with a focus on firms' interactions during the process of developing a buyer-supplier collaboration, the roles of partner firms, expected values and access to markets contributes contribute to the supply chain collaboration literature (Lambert & Cooper 2000), interorganizational collaboration as a business process (Stank et al. 2001) and joint-problem-solving (Spekman et al. 1997).

This research contributes to the industrial network systems and internationalization literature (Johanson & Mattsson 2015) and (Gadde et al. 2003) by giving an analysis on gaining access to required resources by firms in an inter-organizational collaboration and the control over resources based on the role and position of the organization in the network.

In this research, by reviewing the challenges of manufacturing and automation suppliers in automation decisions, and well as analysing the facilitating factors in inter-organizational automation decisions, contributes to the literature of anticipate, consequences and requirements of a successful inter-organization collaboration such as better demand planning (McCarthy & Golicic 2002), inventory visibility (Sabath & Fontanella 2002), access to new knowledge and skills (Hardy et al. 2003), reduction in inventory and cost savings (Sabath & Fontanella 2002; Stank et al. 1999), improvements in customer responsiveness (Sabath & Fontanella 2002) and better access to target market segments (McCarthy & Golicic 2002).

Deep analysis of information flow, automation problem brief, automation data documentation and access to data through the inter-organization automation decision process, and considering the interaction establishment based on the exchange of information, products and services contributes to the literature of organizational set-up, information and good flow between companies (Chandler & Vargo 2011).

With detailed literature analysis on integration factors of inter-organization collaboration activities in new product development and mapping the development of buyer-supplier collaboration in automation decision practices, with considering the influential aspects in each stages, this research highly contribute to the literature of buyer-supplier collaboration (Takeishi 2001), supplier involvement (Petersen et al. 2005), integrating relationships between R&D and marketing in NPD (Hernandez 2006) and (Griffin & Hauser 1996) and specifically the development of Buyer-supplier relationship in the industrial market (Ford 1980).

This research, by declear the role of partner firms, particularly the definition and decribing the dynamic role of lead integrator has widely contributed to the litreture of lead integrator (Gurney 2014).

Circular automation business assessment process model

This research is believed to contribute to the buyer-supplier collaboration in new product development literature (Andrew et al. 2010; van Echtelt et al. 2007) by extending the previous established buyer-supplier collaboration thinking into the emerging topics of innovation process (Tidd et al. 2005) and (Hansen & Madsen 2018), new product development performance focus on the flow of ideas, automation and digitalization technology and in particular by considering all these topics within the context of a business ecosystem, which is beyond the traditional company boundary (Figure 70).

In this way, performing an analysis of the behaviour of buyer, supplier and lead integrator in the automation decision process and considerations from academia and company experts, constituted a solid basis for the construction of the new model for “Circular automation business assessment” process model. The circular approach to the automation business assessment contributes to the idea-to-launch system (Cooper 2014) model where the factors of adaptivity, flexibility, agility, and acceleration ability are highlighted in the context of this research. This contributes to the development of the buyer-supplier collaboration and provides insights for academic and practitioners on illustrating an actor-oriented circular model. The modularity and the scalability of the model provide insights and illustrates how solution development during the implementation phase takes place in a dynamic pattern, where the lesson learned during the implementation may impact the design concept or be the source of adjustments in the automation roadmap.

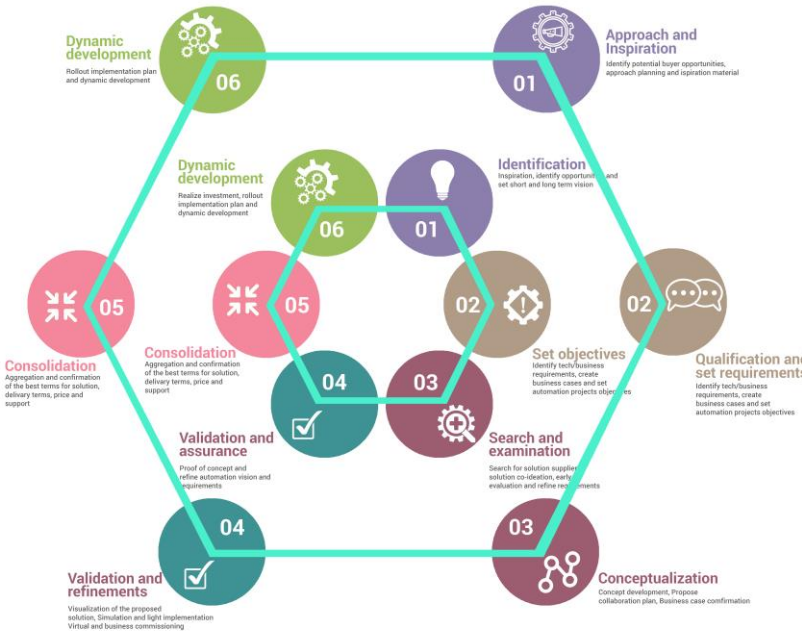

Figure 70. Circular automation business assessment process model

Business assessment process model domains

This research has addressed the architecture of the business assessment process model with identifying the process domains in a business ecosystem with modular logic. The propositions have been developed which could be used for both developments of the features and applications of the Inhancer digital solution, as well as future research described.

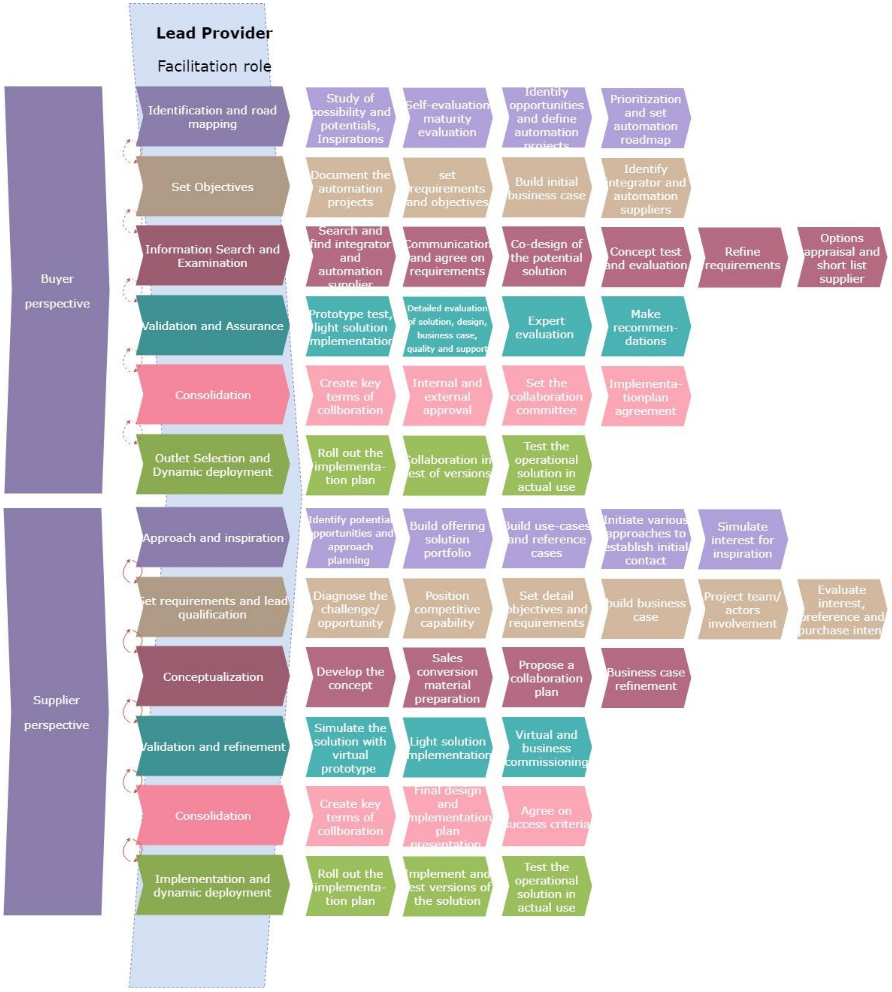

Figure 71. Inhancer domain components

The process model and proposed modular dimensions, specifically contribute to the dynamicity of coordination mechanisms from Mintzberg (1993) where the factors such as complexity of the tasks and project and the impact of it on selecting the coordination mechanism in the context of this research is evaluated. In addition to the task complexity, this research introduces other influential factors on the use of coordination mechanism, such as the eurgency of the probblem and the internal automation capability of the manufacturing compeny.

The proposed modes from Mintzberg (1993), Lewis et al. (2002) and Twigg (1996), clarify and introduced different coordination mechanisms which are highly considered as bases for identifying the Inhacner domain compenents in this dessertation, yet, the implementation of coordination mechanisms and modes of collaboration, particularly within the empirical context of this research is an ongoing issue which this research is highly contribute in this area. In addition to the academic contribution, this can be considered as the gap between literature and industrial practices and the practical implications of this research.

Considering the complexity of the buyer-supplier collaboration in the business ecosystem, identifying its boundaries is a complex task, therefore, it is important to deconstruct the process model to capture the in-depth implications of designing and managing the process domains. As a result, this research has proposed a modular architecture, including Buyer and Supplier perspective. This research puts more focuses on multiple levels analysis and proposes a network structure with the introduction of the connections among supplier, buyer and the lead supplier with acts the facilitation role which contribute to the literature of business ecosystem (Moore 1998) and (Hakansson & Ford 2002), ecosystem sustainability (Heikkilä & Kuivaniemi 2012); and the digital business ecosystem proposed by the European Commission and (Whitley & Darking 2006).

The gap between literature and industrial practices

This chapter aims to provide an overview of the central points, where the results extend current theory and evaluate the distance between industrial practices and current literature. This research through the analysis of the available state of the art literature in buyer-supplier collaboration (Lambert & Cooper 2000) and the available digital technologies as the enablers of the new manufacturing environment, claims a gap between the state of the art and the state of the practice, which results from case analysis and the industrial experts' consultation.

The current state-of-the-art in production technology such as flexible automation (Wadhwa 2012) and smart factory concept (Radziwon et al. 2014) which mainly driven by advances in manufacturing efficiency takes place on the individual firm rather than overall buyer-supplier collaboration. Furthermore, however, the development of automation and digitalization solutions happened rapidly, the market ready solutions are still not completely adopted by the actual needs of the industrial companies.

While some manufacturing companies have shown that grasping the overall idea of digitalization, automation as well as the overall idea of Industry 4.0 and concepts hereof could be substantial problematics because the manufacturing companies have challenges to relate the automation opportunities to their specific domain and their particular and dynamic business strategy. Therefore, industrial manufacturing companies, on one hand, need better understand the potentialities of automation technologies and on the other hand, technology suppliers have to put their effort in order to identify the actual requirement and opportunities as well as reduce the technological complexity and barriers that are preventing digital technology adoption in a dynamic and flexible development.

The developed recent research tentatively neglected that many companies particularly manufacturing SMEs still are not ready in basic steps of digital technologies and automation evaluation and implementation, both from the organizational and strategical point of view and from the application of simple automation solutions. These aspects express the practical gaps which often have not been fulfilled in research works because the practical applicability has been poorly focused in previous research work.

This consideration mainly realized form the analysing of the automation decision process and discussion sessions at manufacturing company research cases (Chapter 4.3). The industrial participants in the research shown their interest in receiving suggestions from research in a number of key functions:

- Manufacturing companies, as buyers of automation solutions, after the discussion and evaluation of the automation opportunities and opportunities for improvement conducted in this research work, demonstrated interest on results to be based for internal discussion and further decisions, furthermore, they asked substantially to initiate working together on the most prioritized projects.

- During presenting the developed methodology and sample case of documented automation project to automation supplier participants (Chapter 6.2) participants asked practical information for defining and conducting the proper actions in order to analyse and give their evaluation on the project cases for further collaboration. Therefore, research enterprise cases were highly involved within the investigation of overcome the “applicability” gaps which has been aligned with the purpose of the industrial Ph.D. research project.
- The research involvement within the initiatives of the EU H2020 Framework Program, in particular, the ReconCell project and AUTOWARE Ecosystem build-up, is of great utilization of research contribution in order to fill the gap between Research and Industry in the future.

PRACTICAL IMPLICATIONS

The nature of this Ph.D. project has been industrial, pursuing an understanding of a phenomenon, application in the industry set up with a commercialization approach. During the Ph.D. journey, I was frequently asked to share the developing studies with experienced professionals, such as industrial robotic business owners, manufacturing companies, consortiums of projects within the EU H2020 Framework Program, and actors from the European network of Digital Innovation Hubs (DIHs). These sessions declare that the research offers several practical implications. The heterogeneity of managers and their context gave the opportunity of diverse, yet, complementary practical implications. From these sessions four core important insights were constantly realized:

- Automation supplier managers and robotics experts
- automation buyers, manufacturing industry

- European projects and automation strategic partners
- Company business implication

Automation supplier managers and robotics experts

The automation business assessment process model and the Inhancer digital platform presents a new model for facilitation collaboration between automation supplier firms and manufacturing companies via the solution selling process and involving multiple partners in the innovation process. It reveals an exclusive format and a new set up to attract and select participants, which makes it possible to knowledge sharing, case evaluation and creation of the foundation for innovation projects. Focusing on the automation solution selling process, it shows how to systemize strategic communication and alignment across teams and organizations opening the opportunity of optimizing the solution selling processes and move the strategic collaborative to a strategic level. It gives insight into how an automation supplier can promote their automation solution toward a larger group of potential partners, where enhances the possibility of re-selling their expertise and state-of-the-art market technologies and solutions to most relevant manufacturing companies with less effort, increased sales radius and the possibility to strengthen their competences, technologies and competitiveness within a specific niche.

Automation buyers, manufacturing industry

The automation business assessment process model assists manufacturing SMEs to make well-founded (fast, low-cost, high-quality) decisions on investments and deployments of state-of-the-art automation technologies and from that gain higher output and margins on their production. They gain from the strategic and business assessment of the automation opportunities to answer questions of What to automate? and How to automate?

Manufacturing companies gain access to experts' knowledge and suppliers that without expensive and risky developments can implement and deploy global state-of-the-art commercially available technology and solutions suited specifically to their needs to become more competitive.

European projects and automation strategic partners

The studies provide insights and selected to support some tasks and activities of two international projects funded by the European Commission. The study and the provided digital platform provide a base for an interactive multi-sided business ecosystem, where: 1. Across robotic and cloud-based competence domain, acting as a glue that attracts potential manufacturing companies, automation suppliers and skills developers for business development, more efficient service development over harmonized automation architectures 2. Promote and leverage automation and digitalization enablers within SME; e.g. augmented virtuality, reliable wireless communications, smart data distribution, and cognitive planning to ease cognitive autonomous systems.

Company business implication

The automation business assessment process model and the Inhancer digital platform as an industrial Ph.D. project gives a potential for commercialization and fast market up-take for Blue Ocean Robotics. The efficiency of the Inhancer platform is expected to encourage automation suppliers to base their sales and collaboration with buyers on Inhancer, which creates an interesting business opportunity. Considering the business model of the Inhancer and further market penetration and exploitation plan a very positive business opportunity around the digital platform is expected which also assure the sustainability of the business and further exploitation of the study results.

7.4. SUGGESTIONS FOR FURTHER CONSIDERATION

The presented research opens several other avenues for further research, pointed out in the following list over a brief description:

Further research possibility within the open innovation area.

The findings of this research contribute to a valuable discussion on collaborative innovation which linking the research area toward other research disciplines of open innovation, such as automation, sales, and marketing, supplier involvement.

Research activities to keep Inhancer continuously updated.

Future research can enlarge our findings on collaboration processes and the application within the digital platform set-up. It could be interesting to examine the competences needed to configure the automation collaboration for different projects and industry areas, counting the required competences, skills and use cases to be added in the process and how they are prioritized, implemented and consolidated.

Literature and state of practice in terms of available technologies and process management practices, automation and digitalization, smart manufacturing and collaboration need to be continually reviewed and included in the Inhancer domain components in order to keep it updated.

Specific action research to let the Inhancer be used with a comparative purpose.

One of the purposes of this research was to provide a base for manufacturing company for understanding their current situation in terms of strategic automation and to identify the prioritized automation projects for further improvement.

The proposed model of this research suggests the company business strategies and general manufacturing strategy to be based for building automation strategy and robotic roadmap through collaborative practice. Yet, the suggested application provides a base for maturity evaluation for digitalization following the maturity models for manufacturing digitalization as another source for building automation strategy and robotic roadmap.

By including the digitalization maturity assessment, the manufacturers will be able to understand their current situation in terms of digital readiness against standard digitalization maturity models (De Carolis 2017) in order to identify and prioritize the main actions for improvements as well as the current state in comparison with the other companies with similar profile operating in the same industry.

Therefore, further development of this research, in addition to the specific company business and manufacturing strategy, might consider including standard self-assessment digitalization maturity model as well as comparison to other similar profile companies, to assist manufacturing SMEs with an analytical and structured benchmarking capability.

Inclusion of skills as Artificial Intelligence (AI) based analysis dimension

Based on the test results and user feedback, implementation of Artificial Intelligence can be suggested as one of the future considerations of the research for further applicability of the results. Two main scenarios can be suggested to benefit from artificial intelligence are: to assist automation suppliers to build up the collaboration environment; and use of artificial intelligence for solution design and decision-making processes.

The use of AI facilitates the automation suppliers in building up the collaborative working environment where they will be able to select the optimum set of questions related to the automation solution characteristics. In this scenario, the automation suppliers will be able to add the automation solution into Inhancer and by giving some information such as the specific industry and the manufacturing process groups it addresses, the AI module suggests templates for creating the collaboration platform environment and question lists for assessment of the potential customer's projects. The *fuzzy logic* programming could also be suggested for the AI to offer suggestions, even when the data about the automation solution is not sufficiently completed.

The suggested templates by AI are editable in the way that automation suppliers are able to select the suggested template, yet to adjust them depending on the specific automation solution characteristics. While the process of modification by the user and the given input will be the source for further provided templates for the next cases. The use of AI in this scenario facilitates the automation suppliers in using the application and would give the user the feeling of getting easier every time they use the system. Therefore, most of the issues related to understanding the system, found through the testing sessions, would be solved, thus the experience with the system becoming more positive and successful.

In the second scenario, using the AI for solution design and decision-making process is aiming at offering the automation supplier with solution proposals which they can send to automation customers. In this scenario, after sharing some initial information by the potential automation customer, the AI, depending on specific parameters, suggests the automation supplier if they should move on with this specific customer. The most relevant support from AI here should be if the customer request fits with the offering solution capabilities and limitation and if the automation supplier's business terms. Therefore, if there is any possibility to provide him with a solution. More after, by using *intelligent agents,* the AI could provide a summary of the gathered data and based on the feedback received from the customer, it will able to offer recommendations for the automation supplier. Depending on the complexity of the provided solution, within an iterative process, by utilizing *machine learning,* AI intervenes to provide multiple recommendations of a final solution, which the automation supplier is able to select, modify and prepare to send to the automation customer. This scenario will highly support the solution selling process by making it easier, faster more automated and supportive for decision-making needs.

The two scenarios of utilizing AI is expected to boost the applicability of the Inhancer, by integrating intelligent systems to facilitate communication within a collaborative automation solution selling. Additionally, this brings significant advantage for Inhancer over other online applications, which provide surveys or alternative solutions for data gathering.

Chapter 8.

Exploitation and Dissemination

8. EXPLOITATION AND DISSEMINATION

In this Chapter, the dissemination and exploitation of the results of this Ph.D. work are presented. The developed automation business assessment process model and the Inhancer digital platform, have been applied in a number of national and international initiatives. This confirms the existence of a requirement to be approached and the valuable role of this Research results to do it. Exploitation activities also focused on building a supportive business model together with a reliable set of early adopters as the key to success market.

8.1. DISSEMINATION AND EXPLOITATION ACTIVES

The exploitation and dissemination of the results of this research have happened during the project in multiple initiatives with are listed in Table 25.

Table 25. Dissemination and exploitation activities

Date	Activity
Journals and Conferences	
Jan 2016	Network-based automation for SMEs, Int. J. Business and Globalisation, Vol. 18, No. 1, 2017
Jun 2016	Expansion of innovative automation solutions: A study in Danish automation suppliers, EUROMA 2016, Trondheim, Norway
Dec 2016	The Integration of R&D and Marketing for Successful Innovative Automation Solutions: An Open Innovation approach, WOIC (World Open Innovation Conference) 2016, Barcelona, Spain
April 2017	ReconCell Business Assessment Tool white paper
Mar 2018	European Robotic Forum (ERF 2018), Workshop: Adapting robotics and related Industry 4.0 technologies for SMEs, Solution Selling Processes in early stages of automation decisions

Trade fairs and exhibitions	
Sep 2016	Elmia Exhibition, Trade fair in Jönköping, Sweden
Jun 2016	AUTOMATICA Trade Fair for Smart Automation and Robotics
April 2016	Hannover Messe Industry 2016
April 2017	Hannover Messe Industry 2017
Aug 2017	MADE Open Lab: Digitized Automation with Robots 2017
Jun 2018	AUTOMATICA Trade Fair for Smart Automation and Robotics
Master thesis projects supervision	
Jun 2016	Company supervisor of the master project: Technology morphology in automation solution, Silvio Iuliano
Jun 2016	Company supervisor of the master project: Using Mobile Sensing to Map Industrial Processes to facilitate Digital Robot Automation Communication, Jakob Hviid
Sep 2017	Company supervisor of In-Company project: User experience via platforms supported by AI.
Other dissemination and exploitation activities	
Apr 2017	Business Assessment Tool web-site.
Sep 2017	INHANCER.io web-site. (The new website, launched 1 Oct 2017)
Sep 2017	Presentation material, promotion material and video material
July 2017	Collaborate with Your Customers in a Buyer Driven World, Business Assessment Tool the α version release announcement
Jan-Mar 2018	Multiple demonstration and presentation on the model and the application toward automation supplier companies

Feb 2018	Webinar in collaboration with I4MS and ReconCell: To engage knowledgeable customers into a collaborative sales activity, focusing on complex robotic solution Link
R&D Project Proposals	
	SAFIR-e, Strategic Automation of Factories driven by Robotics and Web-Services; EU Call: H2020-SMEINST-1-2014
Jan 2016	AUTOWARE, Wireless Autonomous, Reliable and Resilient Production Operation Architecture for Cognitive Manufacturing, EU Call: H2020-IND-CE-2016-17
Mar 2017	BATool, Business Assessment Tool, Innovation Fund Denmark, Strategic growth technologies
Aug 2017	CHAMPS, Championing Social Value in Industrial Research and Innovation, EU Call: H2020-SwafS-2017-1
Mar 2018	I40 Inhancer, an enabler to guide manufacturing companies toward smart manufacturing
Master thesis projects supervision	
Jun 2016	Company supervisor of the master project: Technology morphology in automation solution, Silvio Iuliano
Jun 2016	Company supervisor of the master project: Using Mobile Sensing to Map Industrial Processes to facilitate Digital Robot Automation Communication, Jakob Hviid
Sep 2017	Company supervisor of In-Company project: User experience via platforms supported by AI.
Business plan build-up	
August 2018	Inhancer ecosystem business plan and business canvas

August 2018	Inhancer business case for automation supplier

8.2. COMMERCIAL EXPLOITATION

To ensure a sustainable and continues initiative, Inhancer was persuaded to be exploited as a commercial solution and performs within a business unit or be prepared for the opportunity of creating a start-up company. The project exploitation strategy took place in Blue Ocean Robotics by the researcher and in close collaboration with test cases and early adopters.

The exploitation plan for realizing this has occurred in 3 phases:

COMMERCIAL EXPLOITATION PHASE 1: MODEL VALIDATION & PROOF OF CONCEPT

The proposed model and the developed digital platform was validated and analysed concerning their exploitation potential. The technology is evaluated to be at TRL 7 - System prototype demonstration in a space environment- (Mankins 1995) at the end of the project. The key stakeholders and primary end-users, the price indicators, possible competition and the related advantages of the Inhancer elements have been identified. The solution has been demoed to test cases to collect their feedback on the benefits and usability of the technology. These user tests and analyses helped to prioritize the technology according to market and user needs. Furthermore, the total number of potential customers based on the current trends of the market has been identified. Furthermore, competitor analysis has been performed.

COMMERCIAL EXPLOITATION PHASE 2: BUSINESS INVESTIGATION

Towards the end of phase 1, a business plan has been created with a focus on: product description, use scenario and workflow, a more detailed market overview, a detailed business case showing the costs, benefits and the payback for the Inhancer use cases, a go-to-market plan, business process and potential organization of a start-up company as well as a financial overview, including 5 year projections of the financials (Appendix E). This makes Inhancer ready to be considered for finding funding sources such as investors, business angels, public investment fund, etc. Furthermore, the marketing material, including the commercial web-site[1] (Figure 72), introduction video[2] and flyer material has been prepared.

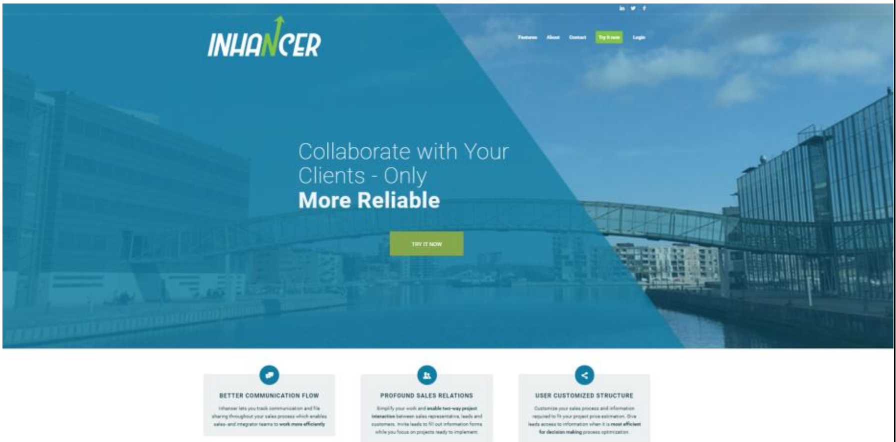

Figure 72. Inhancer commercial web site, front page (inhancer.io)

In addition to the executed and on-going activities and projects described earlier, other possible exploitation channels can be considered to further exploit the proposed methodology. The initiatives mainly referred to further commercialization of the results and Inhancer application in collaboration with strategic partners, yet, the procedures collaboration set-up, as well as the economic details, still need to be defined. The strategic partners are mainly considered from local Digital Innovation Hubs where allow Inhancer to be introduced and further be experienced by their network manufacturing companies and automation suppliers. They would also like to utilize the methodology to assess some of their manufacturing companies' members to assist them in building their automation roadmap and thought the execution phases.

[1] http://www.inhancer.io/

[2] https://youtu.be/jJdX3gBNP_U

COMMERCIAL EXPLOITATION PHASE 3: INHANCER AS A START-UP COMPANY

This includes the traditional establishment of sales, development, support, management and more as well as the further prototype versions and complete release versions of the Inhancer will be launched in the market.

Phase 1 and 2 took place within the course of the Ph.D. project, Phase 3 was expected to take place after the projects end based on exploitation discussions have been taken place during the project lifetime. Yet, since the strategy of Blue Ocean Robotics has been changed and the focus of the company is on being a “Robot Venture Factory”, to “create and commercialize robots”, the phase 3 of exploitation is not within the scope of Blue Ocean Robotics business strategy.

However, it might be that the Inhancer early adopters will try to attract additional public funding from various national and European sources to further extend the functionality or matureness of Inhancer and the services around it.

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Appendix

10. APPENDIX

TABLE OF CONTENT

APPENDIX A. THE PROJECT INFORMATION PACKAGE

The deburring project profile and automation provider questionnaire.

BLUE OCEAN ROBOTICS
- for humans

Project Information Package

Manufacturer company information

The main business area
Steel, Alloys and titanium industry

Location
Southern Denmark

Last year turnover (tDKK)
39 000 tDKK

Number of employees
21-50

Number of working shifts per week
15

Exprience with Automation
First move: 15 years ago, the ABB robot had been bought on milling machine. The project was not successful due to users and items; Next move: 5 year ago, the Gantry robot bought and installed for the CNC machine; Last summer 3 robots have been bought.

Next

Automation project information

Project's name

To automate deburring processes of machined parts.

General description of the project

To automate processes in deburring room. The parts should be picked from a box or be placed into the machine, and the machine runs (pre-programed) deburring processes, which are including deburring internal and external edges. The process should be very precise. The finished items should be placed in a box after finishing the process.

The last process before the Project cell

Placing the pallet with parts in on the table

The first process after the Project cell

Placing the pallet with parts in on the table

Weight and Dimension of input items

max: 750 gr, 10*10*10 cm3

Weight and Dimension of output items

max: 750 gr, 10*10*10 cm3

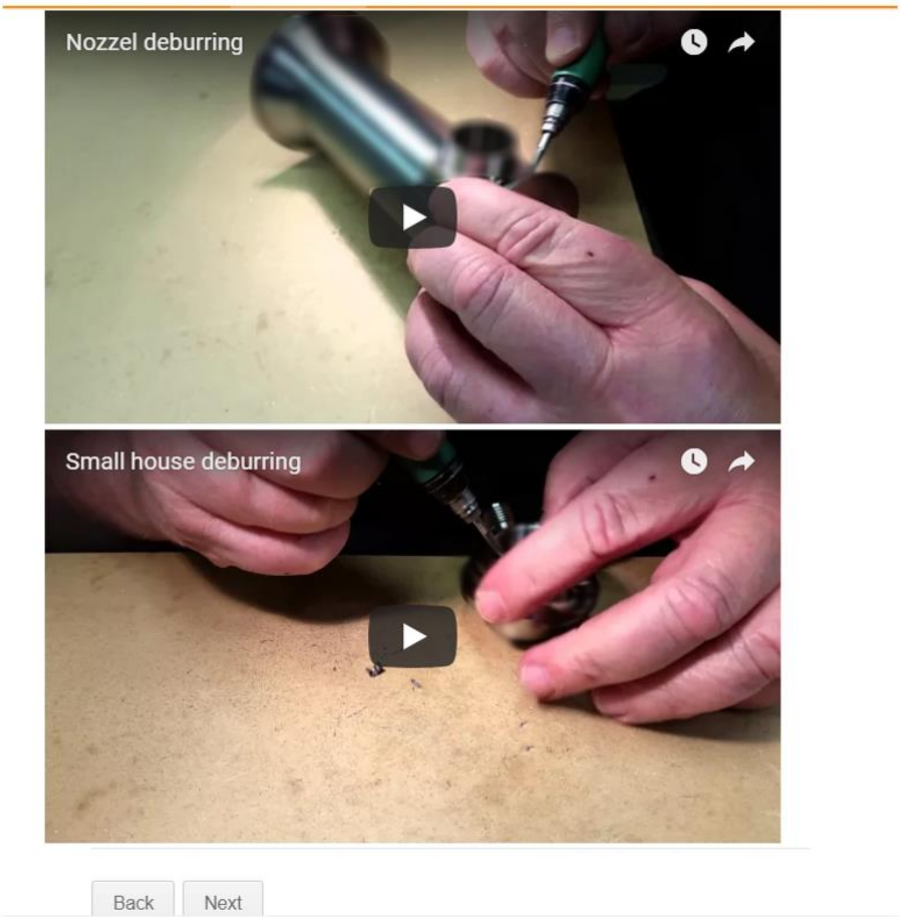
Approx. variety of items

4 items. It is possible to have more variety in case of automation.

Approx batch size

Currently 100. It can be higher.

Back Next


Nozzel deburring
Small house deburring
Back
Next

The current processes of the project cell

1. Pick one item from pallet

Current cycle time (sec)

15

How difficult is it to be automated?

	1	2	3	4	5	
Not complicated	○	○	○	○	○	Very complicated

Does your company have any experience?

○ Yes
○ No

If yes, please explain

Add reference

Upload a File

Max 500 MB. pdf, doc, docx, xls, xlsx, csv, txt, rtf, html, zip, mp3, wma, mpg, flv, avi, jpg, jpeg, png, gif

Add reference link

2.Grind all holes

Current cycle time (sec)

90

How difficult is it to be automated?

	1	2	3	4	5	
Not complicated	○	○	○	○	○	Very complicated

Does your company have any experience?

○ Yes
○ No

If yes, please explain

Add reference

Upload a File

Max 500 MB. pdf, doc, docx, xls, xlsx, csv, txt, rtf, html, zip, mp3, wma, mpg, flv, avi, jpg, jpeg, png, gif

Add reference link

3. Grind all internal endges

Current cycle time (sec)

60

G. Project objectives

This part explains the manufacturer purposes of investment in the automation projects. You shuld give your evaluation on the project achievements after implementation.

Please evaluate the impact of the project after impelementation in address to each objective. -2: Very negative impact, +2: Very positive impact.

Automation Project Objectives

	NA	-2	-1	0	+1	+2
Cost reduction-Increase in labor productivity	○	○	○	○	○	○
Quality improvement-Reduction in scrap and rework	○	○	○	○	○	○
Ergonomics	○	○	○	○	○	○
Flexibility-Minimum order size	○	○	○	○	○	○
Human flexibility	○	○	○	○	○	○

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Operational hours and cycle time

The deburring cycle time is different from one item to the other one. If we assume the rough average cycle time is 3 minutes, currently, the efficient time on deburring is about 475 hours/year. It is expected that the efficient deburring time will get 2-2,5 times higher, after implementation. Consequently, it is expected that the current work load be done in 2-3 hours and extra operational time be used to proceed extra orders. It is expected that manufacturer will be more competitive in deburring and will receive more orders. Currently, there are 4 main products to be proceeded. The batch size is about 100 pieces. But it can be raised to higher numbers.

	Current situation	Manufacturer expectation after implementation
Number of hours that the project cell is operating per shift:	8	8
Number of shifts per week for project cell:	5	5
Number of working weeks per year:	45	45
Number of operators work within the project cell per shift:	2	1
Project cell's Cycle time (min):	3	3,5
Set up time of a working shift (min):	5	20
Efficiency rate (%):	45	70
Volume per shift (unit):	71	92

Do you believe that the estimated above items, can be achieved after implementation of the automation project?

	Yes	No	Maybe
Number of hours that the project cell is operating per shift:	○	○	○
Number of shifts per week for project cell:	○	○	○
Number of working weeks per year:	○	○	○
Number of operators work within the project cell per shift:	○	○	○
Project cell Cycle time (min):	○	○	○
Set up time of a working shift (min):	○	○	○
Efficiency rate (%):	○	○	○
Volume per shift:	○	○	○

comments

Back Next

I. Requirements for implementation Please explain any specific requirements before implementation. Detailed information are NOT required in this step. For instance for a logistic robot, the path shall be free & min. 1 meter wide and the floor shall be even.

1. Space / Environmental requirements ○ Yes ○ No

If yes, please explain

2. Energy / Supply power ○ Yes ○ No

If yes, please explain

3. Integration with other equipments ○ Yes ○ No

If yes, please explain

4. Other ○ Yes ○ No

If yes, please explain

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Cost frame

The maximum amount of total investment that make the project feasible for the manufacturer (tDKK)

3500

Do you think if it is possible to provide an automation solution at the given financial framework?

- Yes
- No
- Maybe

Comments

Back Next

Automation Provider General Information

Company Name

Number of Employees

- 0-20
- 20-50
- 50-100
- >100

Main competencies and skills

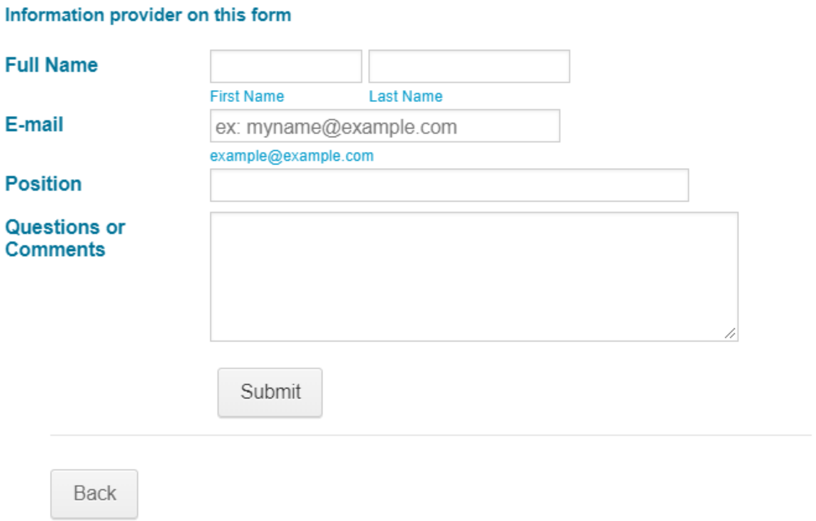
How does the company prefere to work with manufacturer

Type a question

- Meet up directly with the manufacturer
- Partnership with local parties

Comments

Back Next



Information provider on this form

Full Name

First Name | Last Name

E-mail

ex: myname@example.com

example@example.com

Position

Questions or Comments

Submit

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APPENDIX B: SAMPLE OF THE SAFIR AUTOMATION SUPPLIER DATABASE

# ID	Company Name	Link	Country	Type / Area
#000001	SCAPE Technologies- Mini Picker	http://www.scapetechnologies.com	Denmark	Part Handling
#000002	Rethink Robotics	http://www.rethinkrobotics.com/	USA	Part Handling
#000003	e.m.s. - automationstechnik	http://www.ems-a.de/index.html	Germany	Assembly, Mating
#000004	ASS Maschinenbau GmbH	http://www.ass-automation.com/en/2	Germany	Gripper components, robot hands (EOAT), automation systems
#000005	TranTek Automation	http://trantekautomation.com/	USA	builds automated welding, material handling and assembly solutions
#000006	Actemium	http://manufacturing.actemium.nl/	Netherlands	not in english
#000007	ATS Automation Tooling Systems Inc.	http://www.atsautomation.com/en/Te	Canada	a lot of different expertise areas; joining technologies, pressing
#000008	Baumann GmbH	http://www.baumann-automation.cor	Germany	handling, assembly
#000009	BÄR Automation GmbH	http://baer-automation.de/en/	Germany	Assembly
#000010	Evana Automation	http://www.evanaautomation.com/	USA	Assembly
#000011	Dr. HAFNER Montage- und Produktionssysteme GmbH	http://www.drhafner.de/de/	Germany	Handling, assembly
#000012	Yaskawa Europe GmbH	http://www.yaskawa.eu.com/en/	Germany (+ DK)	handling, assembly
#000013	Gibotech A/S	http://www.gibotech.dk/en/	Denmark	handling, assembly
#000014	Remtec Automation, LLC	http://www.remtecautomation.com/	USA	handling, assembly
~~#000015~~	~~GB Innomech Ltd~~	~~http://www.innomech.co.uk/~~	~~UK~~	~~handling, assembly~~

Automation supplier’s database (Boehme 2016)

APPENDIX C: INHANCER DESIGN GUIDELINE

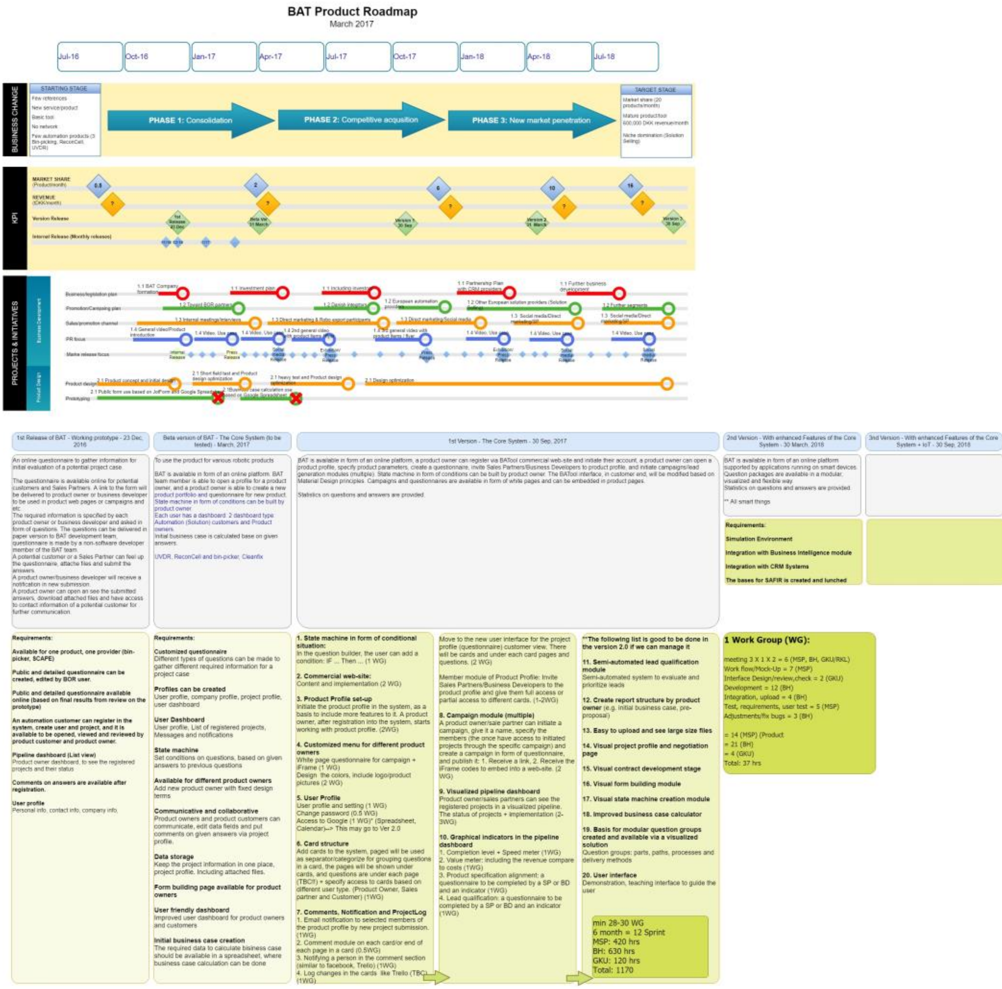
Data Collection and Analysis **Step① INSERT DATA FRAGMENTS:** important words, sentences from sources that can influence our design guidelines **Issues to focus on during data collection:** Preferences, needs, skills of users, stakeholders. Environments, values, ideas. Context of use, tools, objects, materials. Cultural situations, rules, guidelines.	Step② INSERT SOURCES Source of data fragments Can be: internet sources (web pages, videos), field study research, meetings, email/phone conversations, interviews etc.	**Step④ CATEGORIZE THE FRAGMETS** Give categories to the fragments. Clustering them according to what user need they belong to will help organizing the data. **Filter for the categories** for a better organized sheet.	**Step⑤ DEFINITION OF DESIGN GUIDELINE:** A general rule or instruction that influences feature design. If it is fulfilled, the corresponding user needs are fulfilled. Formulate on or more design guideline **for each user need category.**	
① Relevant data fragments	**② Source**	**④ User need category**	**⑤ Initial Design Guideline**	**Comment**
Sales process, particularly within production field takes long time. There are 2 reason: 1. Investment decision in this field are taking time by nature, 2. Missing information and lack of a business case doc rise uncertainty, consequently, the time for decision	Interview with SCAPE	Business case creation Information management and data flow	The BAT tool should store the info, and facilitate business case creating	
Decision makers in production companies need to make sure that the robot fulfill their requirement before taking an action.	Interview with SCAPE	State machine	To facilitate the evaluation of the projects in different stages To semi-automate some of the evaluation processes To ensure required information are provided (in an acceptable format/quality) before going to the next step	
People don't like to ask push them in a way to help them, they prefer to try and test and discover if a product can solve their problem	Interview Casper, focus on Floor washer	Inspiring, motivating and involving	Provide exploring and motivating environment, without interrupting. The potential customer should be able to explore the solution capabilities and possible limitations, play videos and possible structure of the appropriate cell. Then they can register in the system for further communication.	
We should avoid asking for contact information "email" in the very early stage of communication	Interview Casper, focus on Floor washer	Inspiring, motivating and involving	Provide exploring and motivating environment, without interrupting.	
For floor washer robot: The hardest/most challenging part of the work is: 1. generate a lead and attract interest, 2. To motivate leads to the point they sign the contract	Interview Casper, focus on Floor washer	Persons Profile Company Profile Follow up and notification	To recognize interesting leads (potential customers) and get the contact info. To follow up with interesting leads at some points. To categorize the leads and sort them based on their progress in the selling/buying process. To visualize the pipeline	
For floor washer robot: 1: technical questions are asked in the beginning to make sure the robot can cover the current situation. Questions about: the area, how many times washing/day, stairs?, ... 2. Business case related information to make the customer motivated to buy the robot, like the salary/hour, the number of workers, sick rate.	Interview Casper, focus on Floor washer	Technical data gathering Business data gathering Business case creating	Different data gathering and data analysis categories. 1. Technical info category. 2. Financial/business case category	
If the area is too small with few number of wash/day or too large with number of big washing machine, then the robot cannot compete. The answer will be probably No	Interview Casper, focus on Floor washer	Initial technical evaluation Business case creation	No-Go projects: financial feasibility, technology limitation	
If the robot is not able to handle the request, the next step can be Robi-design OR just receiving the newsletter	Interview Casper, focus on Floor washer	Persons Profile Company Profile	Keep the requests records for further communication, sending newsletter, updating about the new product development and sending oder relevant product offer	
Challenge: 1. The contact person is not CEO or decision maker	Interview Casper, focus on Floor washer	Users in same group with same access	Different people at a customer company have access to the project profile	
Challenge: 2. The information is separated between different people in the customer company, for ex. different persons have different info about how often the robot wash, the layout and the salary level. We need to push the contact person to gather information from different persons in the customer organization	Interview Casper, focus on Floor washer	Add info to project profile by different users	Corresponding people at customer company be able to add some information into the project profile	
Challenge: 3. The decisions are made via board meetings, quarterly or annually. We need to make sure the case is considered in the board meeting, the right decision related information is available at the meeting.	Interview Casper, focus on Floor washer	Reports in different views	The report "PDF" format of the business case, offer, and possible installation should be prepared and be available through project profile. The notifications and following up email should be prepared by order to be sent to the corresponding people.	
Challenge: 4. The process is time consuming, the BD forget who had/provided what information. Therefore, he needs to go to the customer site sometimes to gather/update the info	Interview Casper, focus on Floor washer	Project profile Keep information in one place	The project profile with the latest updates should be available.	
Requirement: A business case should be created and the system should support creating it in collaboration with us, or the customer make it by themselves.	Interview Casper, focus on Floor washer	User friendly Training Confidentiality	A simple, understandable frame for creating a business case should be available. + confidentiality matter should be considered. Competitors should not be able to receive detailed information of the offer	
A barcode/QR code is attached to the robot/BD's business card/videos/PR material, a user scan it and is guided to a web site or mobile application, where then can evaluate the robot solution	Rune's suggestion	Easily accessible	Different ways to enter to the system: 1. QR code on the robot 2. Links within PR material 3. Banners in different websites	

Data Collection and Analysis **Step① INSERT DATA FRAGMENTS:** important words, sentences from sources that can influence our design guidelines **Issues to focus on during data collection:** Preferences, needs, skills of users, stakeholders. Environments, values, ideas. Context of use, tools, objects, materials. Cultural situations, rules, guidelines.	Step② INSERT SOURCES Source of data fragments Can be: internet sources (web pages, videos), field study research, meetings, email/phone conversations, interviews etc.	**Step④ CATEGORIZE THE FRAGMETS** Give categories to the fragments. Clustering them according to what user need they belong to will help organizing the data. **Filter for the categories** for a better organized sheet.	**Step⑤ DEFINITION OF DESIGN GUIDELINE:** A general rule or instruction that influences feature design. If it is fulfilled, the corresponding user needs are fulfilled. Formulate on or more design guideline **for each user need category.**	
① Relevant data fragments	**② Source**	**④ User need category**	**⑤ Initial Design Guideline**	**Comment**
To somehow clarify how customer is ready to invest 10%, 20% or higher chance to invest and When the customer is ready. In addition, if the customer is just curious to know more or if they really need a solution for an important problem. If the customer have money to invest. "What is the chance of investment in the project if it costs this and with this payback time?"	Interview Erik Petersen, Dan Robotics - 19 April 2016	Company profile	To clarify the readiness of the customer to invest. It can be a link to databases of last year turnover of manufacturing companies, sorting their production strategies, etc. A company profile of automation customers should be made	
If the customer have money to invest, and if the project is a priority?	Interview Erik Petersen, Dan Robotics - 19 April 2016	Company profile	To clarify the readiness of the customer to invest. It can be a link to databases of last year turnover of manufacturing companies, sorting their production strategies, etc. A company profile of automation customers should be made	
Is it on the budget, what is your budget to invest on the production improvement in this year? What is the investment priorities? Why do you think it is the priority no. 1? Because ...., Is it important? YES it is very important... Or ... To recognize the reasons they want to invest.	Interview Erik Petersen, Dan Robotics - 19 April 2016	Company profile	To clarify the readiness of the customer to invest. It can be a link to databases of last year turnover of manufacturing companies, sorting their production strategies, etc. A company profile of automation customers should be made	
The back invests/helps when they see a benefit in a very short time period.	Interview Erik Petersen, Dan Robotics - 19 April 2016	Business case creation	To create a business case	
The initial quotation/evaluation (free) is including: the suggested robot arm, gripper, cycle time, roughly cost of the solution. For not complex robotic project.	Interview Erik Petersen, Dan Robotics - 19 April 2016	Give an initial possible solution	as an initial evaluation/answer, an approximate price + possible solution should be provided	
One hour is required to make a quick quotation via email, 2-3 hours in a Word file. If we make a form, fill up some information, it can make the quotation development process faster.	Interview Erik Petersen, Dan Robotics - 19 April 2016	Give an initial possible solution	pre-made format to create initial quotations	
"The quotation needs time to be prepared. For the simple solution, I can imagine the solution in my mind and then prepare the quotation easily. For more complex projects which is not easy to instruct a solution in my mind, it takes more time to prepare the quotation, because the risk is matter. Therefore, I cannot give the to one of the dummies to make a quotation. It should be me (an experienced person), to make the quotation. I should be able to imagine the solution and its complexities."	Interview Erik Petersen, Dan Robotics - 19 April 2016	Give an initial possible solution Ask additional questions and additional comments	the detailed proposal, should be prepared when the customer shows an interest, they go to the next step. An automation provider (product owner) can decide it the next step is paid or they will do it for free.	
For a next level of evaluation, for a test project, the customer should pay.	Interview Erik Petersen, Dan Robotics - 19 April 2016	Payment procedure in some steps	the detailed proposal, should be prepared when the customer shows an interest, they go to the next step. An automation provider (product owner) can decide it the next step is paid or they will do it for free.	
If it ends up to a contract this can be subtracted, because it is also in provider's interest.	Interview Erik Petersen, Dan Robotics - 19 April 2016	Payment procedure in some steps	the detailed proposal, should be prepared when the customer shows an interest, they go to the next step. An automation provider (product owner) can decide it the next step is paid or they will do it for free.	
"If we make a quotation for 30000 euro and the customer doesn't pay for 5000 euro for a pre-test to take out the risk, it is not an interesting customer."	Interview Erik Petersen, Dan Robotics - 19 April 2016	Payment procedure in some steps	the detailed proposal, should be prepared when the customer shows an interest, they go to the next step. An automation provider can decide it the next step is paid or they will do it for free.	
"I would like to shoot a -approximate- price in the first level of evaluation. Because I will be able to commit the customer -or to evaluate the commitment level of the customer" and see if they are really interested. It prevents spending time on the next steps.	Interview Erik Petersen, Dan Robotics - 19 April 2016	Give an initial possible solution Business case creation	Give an initial price, to check if the customer is really interested and serious or they are just curious. The initial price can be given automatically. To calculate the price, an automation provider (product owner) should decide on how to calculate it. This can be based on: 1. the complexity level, or 2. the previous installations, 3. price of standard products, 4. required components and features, etc. Business case creation	
"For old customers, one third of quotations and up to a contract. This is about 10%-15% for new customers."	Interview Erik Petersen, Dan Robotics - 19 April 2016	Persons Profile Company Profile	To stay in touch with old customer, keep them updated about further development	
Basically because they are not ready for investment: "they may have spare time and they don't know what to do, then they just ask, try to figure out what it is out in the market"	Interview Erik Petersen, Dan Robotics - 19 April 2016	Give an initial possible solution Business case creation	Initial evaluation of the project, and provide possible installation/business case	
Dan Robotics prefers to have the first connection with customer face-to-face. "The first interview give an impression on how the customers are ready, how is the chance to become a successful sale. "	Interview Erik Petersen, Dan Robotics - 19 April 2016	Give an initial possible solution Give related reference solutions Business case creation	TRUST formation. To convince: 1. the provider understand the challenge, 2. have a solution and 3. have references	

Data Collection and Analysis **Step① INSERT DATA FRAGMENTS:** Important words, sentences from sources that can influence our design guidelines. **Issues to focus on during data collection:** Preferences, needs, skills of users, stakeholders. Environments, values, ideas. Context of use, tools, objects, materials. Cultural situations, rules, guidelines.	Step② INSERT SOURCES Source of data fragments Can be: internet sources (web pages, videos), field study research, meetings, email/phone conversations, interviews etc.	**Step④ CATEGORIZE THE FRAGMETS** Give categories to the fragments. Clustering them according to what user need they belong to will help organizing the data. **Filter for the categories** for a better organized sheet.	**Step⑤ DEFINITION OF DESIGN GUIDELINE:** A general rule or instruction that influences feature design. If it is fulfilled, the corresponding user needs are fulfilled. Formulate on or more design guideline **for each user need category.**	
① Relevant data fragments	**② Source**	**④ User need category**	**⑤ Initial Design Guideline**	**Comment**
The references are convincing. On certain solutions -which are very similar to project case-.	Interview Erik Petersen, Dan Robotics - 19 April 2016	Give related reference solutions	Provide possible installation, and references from previous cases	
"Normally if you make a good simulation (it takes between 3-8 hours) they you have whole cell modeled, every passed thoughts. Then the customer can see everything". Simulation tool: Robotstudio from ABB.	Interview Erik Petersen, Dan Robotics - 19 April 2016	Attach additional files and documents	For further sales step, a detailed design of the cell is required. There are some pre-made solutions for it. The BAT make it possible to attach the file, pictures and videos.	
"A simulation shows how parts coming into the cell and going out, what operator does, what robot does. It can be presented as a video, or other files. You can zoom in - zoom out". It is costly.	Interview Erik Petersen, Dan Robotics - 19 April 2016	Attach additional files and documents	For further sales step, a detailed design of the cell is required. There are some pre-made solutions for it. The BAT make it possible to attach the file, pictures and videos.	
"If we receive many leads and no contract, I don't spend more time using the system." (In this case old SAFIR was mentioned in the interview, where Dan Robotics had received about 40 cases to provide quotations and no contract)	Interview Erik Petersen, Dan Robotics - 19 April 2016	Give an initial possible solution Give related reference solutions Business case creation	To reduce the cost of evaluation and make it more efficient. Trust forming.	
"Many the people we talk to at the initial level of evaluation are not decision makers, they are technical directors, making an idea on how to make improvements. When they receive the initial answer, they can go to their bosses. They say we have this good idea, it costs this amount, then the boss makes the decision."	Interview Erik Petersen, Dan Robotics - 19 April 2016	Give an initial possible solution Give related reference solutions Business case creation	To provide some reliable and valuable material to be used internally at automation customer side.	
The automation provider (product owner) needs to know: what is the budget level, what is the organizational level of the people they talk to, what is the level of talks (is it something that the customer really want to invest or if it is in the exploratory level and the customers want to know what can be done and what are the possibilities.	Interview Erik Petersen, Dan Robotics - 19 April 2016	To create a profile for company and for user. Gives an understanding on how ready the company is to invest.	To create a profile for company and for user. Gives an understanding on how ready the company is to invest.	
The sales procedure "is a 6 months to 3 years time frame to make it to something, from idea to a project" - "We have a project it has been taken 6 years and it is still in progress".	Interview Erik Petersen, Dan Robotics - 19 April 2016	Persons Profile Company Profile	Keep the project information in one place. Project profile. Keep the dialog	
The documented project from OJ Electronics, in SAFIR, "is easy to understand in few hours. It gives a better overview compare to paper version if you wanted to know more. For the first quotation you don't need this much information"	Interview Erik Petersen, Dan Robotics - 19 April 2016	Attach additional files and documents User friendly Training	To gather the information in steps and provide detailed info in further steps	
"Sometimes, particularly for larger projects, in addition to the projec cell itself, it is important to know the other stuff around the project cell, also the floor map and the material flow"	Interview Erik Petersen, Dan Robotics - 19 April 2016	User friendly Training	To provide a guideline for documenting the project cell, itself and surrounding.	
For the OJ Electronics case, "the video was enough to give the good understanding about the project."	Interview Erik Petersen, Dan Robotics - 19 April 2016	Take and include video and pictures	To document the project cell The questions should be easy to understand, easy to answer, available via smart device, visualized Video of the cell should be taken and attached Video is very important	
Sometimes it is important "to give the customer some info and get the confirmation." For instance: "to give them the required floor space and then ask them for their confirmation"	Interview Erik Petersen, Dan Robotics - 19 April 2016	Confidentiality	Some information should be confirmed. In BAT, a confirmation request should be sent for automation customers for some of the feedbacks Explanation: When an automation provider (product owner) receives the submission and answer to some questions, they analyse it and come up with some feedback. They need to confirm the results by automation customers. They should be able to send a request for confirmation	
"The questions and answers should be private between providers and customers." "We don't want our competitors see the communication between us and customers."	Interview Erik Petersen, Dan Robotics - 19 April 2016	Confidentiality	The communication between provider and customer should be confidential.	
Communication and information should stored in one place. It creates value.	Interview Erik Petersen, Dan Robotics - 19 April 2016	Project profile Keep information in one place	The project profile should include all information about the project and communication history	
"Photospheres make sense to be there. 3D modeling stuff is good. It provides some measurements." particularly when making the simulation.	Interview Erik Petersen, Dan Robotics - 19 April 2016	Attach additional files and documents	To document the project cell Take and attache photospheres (360 pictures)	
"The 2D layout is very useful. They normally have it in the production line."	Interview Erik Petersen, Dan Robotics - 19 April 2016	Attach additional files and documents	Attache the 2D layout	
From scale 1-5, it is 4 for simulation, to have 3D model.	Interview Erik Petersen, Dan Robotics - 19 April 2016	Attach additional files and documents	Attach the 3D model of the cell, (Optional)	
The flow description, and the processes shows an overview. But from a robot perspective, it is important to know what exactly the human does, how the place the items, why the do it, is it because the parts are not qualified enough and have different tolerances or what are other reasons. Some of this information is gathered through interviews.	Interview Erik Petersen, Dan Robotics - 19 April 2016	Easy data entry Available via smart devices	To include and store detailed information of the project cell gathered through meetings or site visits. To attache other relevant material	

Data Collection and Analysis **Step① INSERT DATA FRAGMENTS:** important words, sentences from sources that can influence our design guidelines **Issues to focus on during data collection**: Preferences, needs, skills of users, stakeholders. Environments, values, ideas. Context of use, tools, objects. materials. Cultural situations, rules, guidelines.	Step② INSERT SOURCES Source of data fragments Can be: internet sources (web pages, videos), field study research, meetings, email/phone conversations, interviews etc.	**Step④ CATEGORIZE THE FRAGMETS** Give categories to the fragments. Clustering them according to what user need they belong to will help organizing the data. **Filter for the categories** for a better organized sheet.	**Step⑤ DEFINITION OF DESIGN GUIDELINE:** A general rule or instruction that influences feature design. If it is fulfilled, the corresponding user needs are fulfilled. Formulate on or more design guideline **for each user need category.**	
① Relevant data fragments	**② Source**	**④ User need category**	**⑤ Initial Design Guideline**	**Comment**
"You need the normal production flow, parts list, mixed parts list, flow calculation for each station (That is the output from that cell, that is the output from the other cell), Oh I need that buffer there because I cannot get the output from that cell", There are systems and specialists for simulating this. "	Interview Erik Petersen, Dan Robotics - 19 April 2016	Project profile Keep information in one place Attach additional files and documents	To include comments on given information To "STAR" important decisions coming out from comments/discussions and "TAG" them. Prepare report of stared/tagged comments Keep the history of discussions and suggestions on process improvement (with time/date)	
"It is interesting to know the 3D model of the parts, 3D Model of the placing parts, splicers, clearance and guiding between parts." "How accurate do you pick it up?" You ask this questions afterward to know if you need an additional station or not.	Interview Erik Petersen, Dan Robotics - 19 April 2016	Attach additional files and documents Easy data entry	3D model of parts to be attached. Large files should be zipped while attaching. A small JPG shows the content of the zipped file, without downloading and unzipping the file.	
Many of the information is required to ask in the second or third level of evaluation, some is asked via communication or an interview. Many of the questions are not repeated and different from one project to the other project.	Interview Erik Petersen, Dan Robotics - 19 April 2016	Communication between stakeholders Ask additional questions and additional comments	To include comments on given information To "STAR" important decisions coming out from comments/discussions and "TAG" them. Prepare report of stared/tagged comments Keep the history of discussions and suggestions on process improvement (with time/date)	
For the first contact, breaking down the process in the way that is was broken down for -OJ Electronics case- is over killed. But it make a lot of sense for the second level of iteration.	Interview Erik Petersen, Dan Robotics - 19 April 2016	Easy data entry	To document the project cell The questions should be easy to understand, easy to answer, available via smart device, visualized Video of the cell should be taken and attached Video is very important	
Using the kind of system sometimes forces the customers to think about the challenge	Interview Leif Thomsen, RoboTool - 31 August 2016	Easy data entry Guiding through the process Data gathering frame	To document the project cell To help customer understand the challenge and specify the problem. The structured way of asking questions, and give them hints and short inspiring material like videos to show how to investigate challenge in the production site, which kind of information to be provided	
You have to understand the buying process, which is different from case to case. This is what we understood after many years of sales.	Interview Leif Thomsen, RoboTool - 31 August 2016	Reports in different views	Being flexible and providing reporters in different view for automation customers	
We are skilled and competent. we know how to implement a solution in an efficient way.	Interview Leif Thomsen, RoboTool - 31 August 2016			
We prefer to build the robot here, internally, we ship it to the customer site, and we send our people to install it at the customer site. We prefer local partners only focus LEAD generation first, and then services/maintenance, instead of building the robot or installation	Interview Leif Thomsen, RoboTool - 31 August 2016			
We prefer to visit the customer many times. It doesn't matter how many time. It is important that our potential customer trust our product and convince that our solution can help them to solve their challenge	Interview Leif Thomsen, RoboTool - 31 August 2016	Inspiring, motivating and involving	Trust formation through personal communication. The call me button, automatic request for meetings at some point and skype meeting requests	
There are many competitor in the market, we prefer to focus on food industry, because we have built many products in this field and we are specialized in this field	Interview Leif Thomsen, RoboTool - 31 August 2016	Inspiring, motivating and involving	Company profile Evaluate based on company working area	

APPENDIX D: INHANCER PRODUCT DEVELOPMENT ROADMAP



APPENDIX E. BUSINESS PLAN FOR INHANCER BUSINESS ECOSYSTEM

Value proposition

Introduction

The current trend of automation and data exchange shows, that new technologies are transforming industrial production. INHANCER, as a cloud based flexible business assessment tool, has been developed for collaborative selling of complex solutions supporting the Industry 4.0 trend. It is supposed to support collaboration with manufacturing customers with a specific need for an existing Industry 4.0 solution and thereby enables an automation provider company to identify the right target group. This not only enhances the chance to increase sales for the solution providing company it also refines the company's marketing strategy and accelerates the product improvement. The INHANCER can also be used by manufacturing companies to evaluate solutions for their business and find the most suitable solution to innovate their business models. It enables even small or medium sized enterprises, that might not have the capacity or expertise to evaluate potential Industry 4.0 solutions, to access new and ground-breaking options for efficient and automated production.

INHANCER in Industry 4.0 ecosystem

INHANCER is defined as a web-based platform which supports automation solution selling processes in a buyer drove business environment, by using smart checklists and databases, online questionnaires, or other similar tools. All of this is based on the need of specific automation solution parameters. Therefore, INHANCER enables automation suppliers to introduce and promote their solution in an online platform considering the solution parameters, where automation customers and other ecosystem actors will be able to search and evaluate a solution based on their specific field of use. Furthermore, they will be able to contact the relevant provider using the marketplace environment for the next step collaboration. By using the INHANCER, automation suppliers will be able to improve the handling of huge pipelines for complex products, collaboration with manufacturing companies and development partners to improve their offered solutions. This results in a more efficient alignment in the sales network and facilitates the solution selling process.

The current version of the INHANCER enables manufacturers to get inspiration for potential Industry 4.0 solutions within their field of interest. A range of inspiration is given by offering the latest projects and inventions including technical information as well as, technical and business advantages, drawings, benefits, and usability of the solution. The INHANCER provides an easy-to-use interface in which manufacturing companies can search for possible solutions and solution suppliers within their local region or internationally. Based on the documented project or intentions a technology morphology index enables companies to find the right solution to their need by selecting classified parameters. Since the INHANCER will also be used as communication and dissemination platform of knowledge. Experiences and challenges can be shared and solution for a specific issue can be requested and offered by all involved parties. This accelerates the learning for the platform and improves quality within the process of finding and offering the right Industry 4.0 solution, thus promoting automation within the industry.

Together, the interactions between the automation solution suppliers and the manufacturing companies form an ecosystem with INHANCER in the centre as illustrated in figure 1. Within the ecosystem all participating companies and institutions will be able to benefit from communication and knowledge-sharing, thus increasing their competitiveness and capability of performing efficient business. This provides the following value propositions:

- Increasing automation in Europe by matching automation solutions and Industry 4.0 suppliers with manufacturing companies.
- Boosts the use of automation and new technologies in manufacturing companies to make manufacturing more efficient.
- Creates innovation and intensifies the development of new automation and Industry 4.0 solutions.
- All based on an ecosystem centered around INHANCER

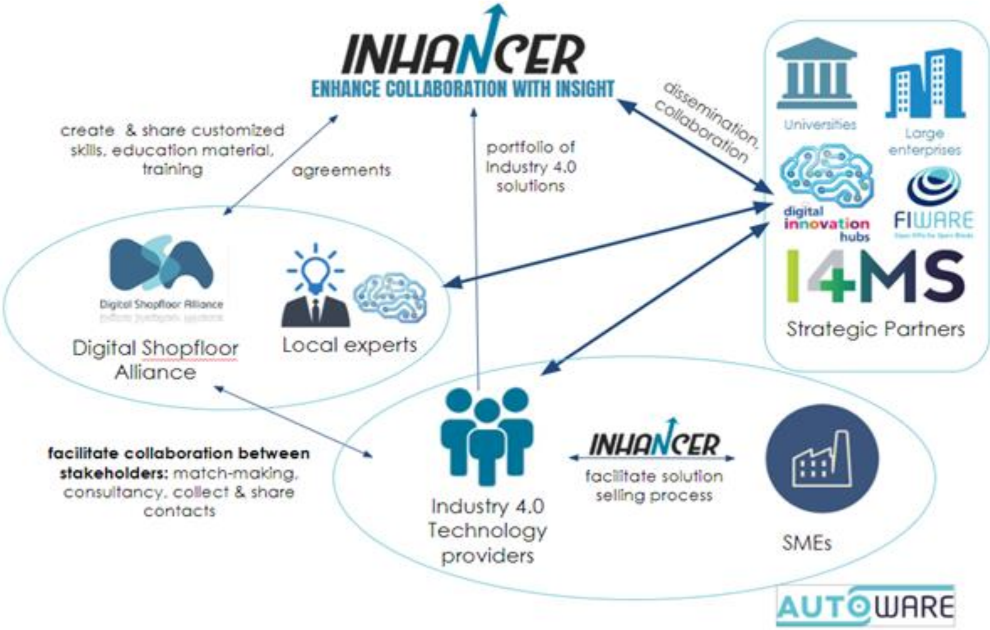


Figure 1 - The INCHANCER Ecosystem

Market

Manufacturing companies in Europe

The targeted users of INHANCER are on one side, manufacturing companies and on the other side the suppliers of Industry 4.0 solutions. In Europe 2.6 million enterprises operate within the manufacturing industry which employs 40 million people.[1] Manufacturing companies are the biggest users of robots and automation solutions. The European manufacturing industry operates with more than 300.000 robots, of which half are within the automotive industry.[2] Of the 2.6 million manufacturing companies approximately 2.5 million are SMEs, which is the desired target of the project.[3]

Automation solution suppliers and Industry 4.0

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[1] Organisation for Economic Co-Operation and Development: https://stats.oecd.org/

[2] World Robotics, Industrial Robots 2014 - International Federation of Robotics Annual Report

[3]https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Key_tab5_size_class_indicators,_Manufacturing_(NACE_Section_C),_EU-28,_2014.png

The market for robots and other Industry 4.0 solutions are growing fast. 12% of SMEs have acquired robots and are generally indicating interest in further adopting automation solutions. The total revenue of industrial robots totals more than 14bn dollars a year, and the expected yearly market growth is 10-20% towards 2025. Some areas within the industry are experiencing even higher growth rates. This is especially true for the market of collaborative robots, which is expected to grow by 60% in the following years. This technology is also expected to accelerate the use of robots and automation solutions, especially in smaller enterprises.[1]

By 2020 Europe is projected to account for more than a third of the global industry 4.0 investments. The market is in total expected an annual growth rate of 22% and is expected to reach a value of 287bn euros in 2020. The frontrunners are Germany, Ireland, Sweden and Austria. 41% of European companies expect to increase their IT-outsourcing, suggesting an increase in demand for companies offering Industry 4.0 solutions.[2]

Addressable Market

It is assumed that some of the technology suppliers will also be manufacturing SMEs. It is estimated that approximately 20% of the roughly 2.5 million manufacturing SMEs in Europe can be considered technology suppliers, which totals 0.5 million manufacturing technology suppliers. These are mainly situated in Germany, Spain, France, Italy, the UK, and Poland.[3] Other technology/solution suppliers are the technical universities of Europe, as these contribute to new knowledge and technologies. There are approximately 200 technical universities in Europe.[4]

Table 1 - Addressable Market

Addressable Market	**Number of enterprises**
Manufacturing SMEs	2.000.000
Technology suppliers	500.200
Manufacturing technology suppliers	500.000
Technical universities	200

1 Region Syddanmark - Robotter og automatisering - Styrkepositioner, udfordringer og udviklingspotentiale (2017)

2 https://www.cbi.eu/market-information/outsourcing-itobpo/industry-40/

3 https://ec.europa.eu/eurostat/documents/3433488/5582000/KS-SF-08-031-EN.PDF/eb619993-065f-47c2-9c76-7674bf55c6fa

4 https://www.topuniversities.com/university-rankings/university-subject-rankings/2018/engineering-technology

Total	**2.500.200**

When analysing the total addressable market in regard to the Inhancer, it is interesting to look at how manufacturing companies cluster together. In Europe, 109 clusters exist based on a cooperation of extraction of resources, transport, and manufacturing.[1] 20% of these clusters have more than 200 members. When looking at clusters focusing on core production, 38 relevant clusters exist of which half have more than 100 members.[2] These 38 clusters are the most relevant, as their ecosystem does not already include other actors than manufacturing companies, which means that we can target the entire cluster. It is notable that these clusters are not only defined geographically but also separated in industries (e.g. wood production, automotive production, etc.), which differs from the strategy of Inhancer to include companies across industries. This means that, when targeting the market, we are not limited to targeting existing clusters but are able to create a unique ecosystem across industries.

Competition

Ecosystems compete for resources and try to obtain competitive advantages like independent companies.3 According to some of the latest research on business networks, 'insidership' within a relevant network with the ability to cooperate and knowledge-share can be a source for competitive advantages on its own.[4] This means that the various ecosystems compete against each other on their ability to knowledge-share and do business within the network. Therefore, the ecosystem's environment needs to enable knowledge-sharing to try and obtain competitive advantages. There should be a strong political foundation, as the base of doing business is regulated by governments. The automation and Industry 4.0 solution suppliers will provide the knowledge to share together with the demand for solutions from the manufacturing companies. These factors will together enable innovation and provide the foundation of a strong competitive ecosystem.[5] INHANCER will function as the centre of the Ecosystem and provide the technical features to enable interaction and knowledge-sharing between the actors.

[1] https://www.clustercollaboration.eu/cluster-list

[2] https://www.clustercollaboration.eu/cluster-list

[3] Project Manager, Odense Robotics, 20th august 2018

[4] Johanson, J., & Vahlne, J.-E. (2009). The Uppsala internationalization process model revisited: From liability of foreignness to liability of outsidership. Journal of International Business Studies(40), pp. 1411-1431.

[5] Range, M., & Etzkowitz, H. Triple Helix Systems: An Analytical Framework for Innovation Policy and Practice in the Knowledge Society.

This ecosystem will be in competition with similar ecosystems if any exists. Most of the data on ecosystems is centered around startup hubs and innovation, while not much data is found on manufacturing companies in ecosystems. Several clusters of manufacturing and automation solution suppliers exist within Europe. These clusters are often defined geographically. It is noteworthy that except for Germany, none of the top clusters within manufacturing and digital companies are situated in the same country.[1]

Today, the task of matching manufacturing companies' needs for automation solutions with the right solution from the providing companies is most likely done by agents from the companies concerned or by independent agents. These services can be seen as substitutes or competition against the INHANCER system. But the strategy of launching INHANCER is not to replace and exclude the agents but instead to include them in the ecosystem and provide them with the tool to handle their business better.

The goal of the project is not only to try and create our own ecosystem, but also to offer the INHANCER tool to existing clusters and ecosystems. Therefore, it is relevant to look at competitors of the INHANCER tool:

	CRM-Systems	**Online Form-Builders**	**Decision Tree Builders**	**INHANCER**
Description	Costumer database, task management and lead qualification	Online forms and questionnaires where customers can ask questions	Systems where one question leads to another based on the previous answer	Ecosystem for Collaborative Solution Selling of Complex Automation and Robotic Solutions
Flexibility	Low	Medium	Low	High
User collaboration	Low	Medium	Medium	High
Data processing	High	Medium	High	High
Pros	Able to gather and analyze customer data. Enables evaluation of solutions.	Able to ask questions and flexible.	Involves users and provides data for analysis.	Enables communication between actors. Can be configured and adjusted. Saves costumer data for further use.
Cons	No communication between actors. Inflexible.	No actual communication between actors.	No communication and inflexible.	Requires a higher volume of user cases and applications.

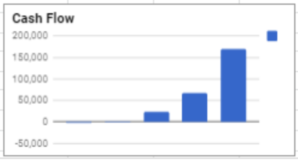
As it appears in the above table, the main deficiency of the existing solutions is their lacking option of providing communication between solution suppliers and customers. CRM-systems are good at handling data, and the form-builders and decision trees are great tools for one-way communication. The INHANCER tool adds further flexibility by being configurable and adjustable, makes communication

[1] https://ec.europa.eu/growth/smes/cluster/observatory/cluster-mapping-services/mapping-tool_en

possible and therefore enables collaborative solution development while still offering the possibility to process data. The INHANCER tool is based on the users, thus it requires a high volume of user cases and applications to function. This is why creating an ecosystem or selling to existing clusters is a favourable way of obtaining and maintaining users.

5 years of business plan

Estimated Market & Overall business case (5 years)		year 1 (Jun 2017	year 2	year 3	year 4	year 5
Pipeline number (how many we approach, test use,...)		400	4,000	26,000	76,000	192,000
# of active European automation product owners		20	200	1,000	3,000	8,000
# of active non-European product owners				300	800	1,600
# of products are supported by INHANCER (per product owner)		2	3	3	3	3
# of projects are created and evaluated per year (projects per product in one year) (Red List)		180	240	240	240	240
# of product are supported by INHANCER		40	600	3,900	11,400	28,800
# of projects are created and evaluated per year (project per product) (#created and evaluated projects*#Products)		7,200	144,000	936,000	2,736,000	6,912,000
# of projects end up to a contract and implementation through INHANCER (Yearly) (% of solution reques	1%	72	1,440	9,360	27,360	69,120
Fee table						
Product owner fee for INHANCER for services, training and impelementation per hour (DKK/hrs)		500	600	700	800	1,000
Required hours for services, training and impelementation per product (hrs)		60	20	15	10	5
% of products that requires service, training and impelementation	%	60%	50%	30%	15%	10%
Product owner fee for subscription (Product owner membership) (DKK/year)		1,000	1,000	1,000	1,000	1,000
Product owner fee per new product (Product owner membership) (DKK/year)		3,000	3,000	3,000	3,000	3,000
Product owner fee per project submission (DKK)		10	10	10	10	10
Automation customer fee per project sent for solution request through INHANCER (per Submission) (DKK)		0	0	0	0	0
Product owner fee per project that concludes as a contract (DKK)		0	0	0	0	0
Revenue Table						
Revenue stream from services, training and impelementation (tDKK)		720	3,600	12,285	13,680	14,400
Revenue from subscription fee (Product owner membership) (tDKK)		20	200	1,300	3,800	9,600
Revenue from new product added (Product) (tDKK)		120	1,800	11,700	34,200	86,400
Revenue from Product owner for projects submissions (tDKK)		72	1,440	9,360	27,360	69,120
Revenue from automation customer for projects submissions (tDKK)		0	0	0	0	0
Revenue from project that concludes as a contract (tDKK)		0	0	0	0	0
Total Estimated Revenue stream (tDKK)		932	7,040	34,645	79,040	179,520
*The annual cost for one product owner can be calculated: 1000+3*3000+3*240*10+(500*60*60%)=**17200**+18000=35200		0.9	3.8	11.0	10.7	9.0
Cost Table		year 1 (Dec 2017	year 2	year 3	year 4	year 5
Full-time Service employees to support product owners	1600 working hrs	1	4	11	11	9
Full-time development employees		2	2	2	2	2
Full-time marketing and sales employees		1	2	2	3	3
Total No. of fulltime employees		4	8	15	16	14
employee Cost + 100% OH (tDKK)	-550	-2,200	-4,400	-8,250	-8,800	-7,700
Total costs of development, technical support, marketing, etc (tDKK)	1.3	-2,860	-5,720	-10,725	-11,440	-10,010
Cash flow		-1,928	1,320	23,920	67,600	169,510
	Year	year 1	year 2	year 3	year 4	year 5
	Cashflow	-1,928	1,320	23,920	67,600	169,510
	cumulative cashflow	-1,928	-608	23,312	90,912	260,422
	Cost of Capital	3.0%				
	Discounted Cash Flow Analysis					
	Pay back period	25 month(s)				
	Net Present Value of the investment (NPV) (tDKK)	227,545				
	Internal Rate of Return on investment (IRR)	411%				



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