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**DESIGN OF AN INTER-FIRM ELECTRONIC COLLABORATION PLAT-
FORM FOR SMES BASED ON AXIOMATIC DESIGN THEORY**

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ABBREVIATIONS

AD	Axiomatic Design
C	Constraints
CMS	Customer Management System
<i>DP</i>	Design Parameters
DCN	Digital Collaboration Network (DCN)
ERP	Enterprise Resource Planning
ESF	European Social Fund
EU	European Union
<i>FR</i>	Functional Requirement
ICT	Information and Communication Technology
MIS	Management Information Systems
MIT	Massachusetts Institute of Technology
PV	Process Variable
OECD	Organization for Economic Co-operation and Development
OSS	Open-source Software
RWB	Responsive Web Design
SC	Supply Chain
SDG	Sustainable Development Goals
SME	Small and Medium Enterprise
UML	Unified Modelling Language
UN	United Nations

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ABSTRACT:

Small and Medium Enterprises (SMEs) account for 99% of all Businesses in Europe (OECD, 2017). Although having limited resources, they need to compete with bigger institutions. The pressure on the international market force them to find competitive and flexible business solutions. Additionally, due to the digitization of business processes, they need innovative solutions in handling cooperation and networking inside their own company and with their external partners. A notable solution is to seek for opportunities to cooperate with other organizations and to become part of a business network (Casals, 2011: 118–124).

This thesis, which is part of EU funded Pisku project, explores the underlying needs that SMEs face when they strive to engage in inter-firm collaboration. It also aims at designing a prototype of an electronic inter-firm collaboration platform to support their business processes.

A mixed strategy research method that includes qualitative and axiomatic design theory is used. The theoretical framework analyses the SMEs collaboration in a digital area and how it affects their performance and growth. It also highlights internal and external reasons to collaborate and the collaboration process framework as well.

The empirical part consists of questionnaire designed for the SMEs participating in the project. The aim of the questionnaire is to identify their challenges in general and their needs regarding an inter-firm collaboration platform by using mainly the axiomatic design theory.

The finding of this research is divided into two parts. The first part is to identify and list the needs and challenges faced by SMEs when collaborating. The second part consists of mapping these needs into requirements and parameters to design an inter-firm e-collaboration platform

KEY WORDS: Inter-firm collaboration, Intra-firm collaboration, Axiomatic design, Collaboration platform, E-collaboration, SME

1 INTRODUCTION

Digitization and globalization are changing business processes today. Ever before in the pass, have companies invest heavily in tools, technics and approaches that can help them to remain competitive and grow. The nature of their work and activities involve not only their employees, but partners, consultants, customer and other businesses from over the world. Small and medium size enterprises (SME) accounting for 99% of all businesses in Europe play key role in the overall European economy (European Commission, 2019). A look on the employment market in Europe show a vital and non-negligible role they play. This is illustrated in the percentage share of SMEs regarding employment in eight countries in Europe: Germany (59.9%), Spain (81.1%), France (63.4%), Italy (78.7%), Netherlands (60.9%), Belgium (56.2%) and Luxembourg (71.0%) (Soumitra Dutta, 1999: 239–251). In 2017, SMEs accounted for 66.4 % of total employment and 56.8 % of the value added generated by the nonfinancial business sector in the twenty-two European Union (EU) states (Annual Report on European SMEs, 2018).

However, SME's lifecycle is dotted with thorns and risks that affect them seriously. When compared to larger firm, SMEs tend to perform poorly as to “profitability, higher staff turnover, lower rate of survival, less success in the field of innovation as well as lower capacity to invest in staff development and training” (Szczepański, 2016). Although they have limited resources and get less external support, they face fierce competition from well establish bigger firms and businesses that have more resources and market share (Casals, 2011: 118–124). In view of these problems, SMEs need to innovate, be flexible and find avenues that can help them to survive. A popular approach used by most of them is to cooperate with other businesses (Casals, 2011: 118–124). According to Hagedoorn, right from the 90s, companies from various industries started to enter into inter-firm relationship (Hagedoorn, 2002: 477–492). In the other hand, due to globalization, companies in general and SMEs in particular need to build strong relationship and partnership by means of collaboration which is defined as when two or more people or firms work together towards achieving the same goal (Martinez-Moyano, 2006: 69).

1.1 Background and significance of this research

This research is part of "PISKU - Pieni Iskuri" project (Project ID S20867) funded by the European Social Fund (ESF). Four institutions of higher education in Finland (Turku University of Applied Sciences in Turku, Aalto University in Helsinki, University of Vaasa in Vaasa and Lapland University of Applied Sciences in Lapland) are partners and bring their expertise in various areas. The main goal is to evaluate and optimize SMEs collaboration by mapping their needs related to teamwork, practices, productivities and work welfare. It also aims at advancing networking and cooperation with digital solutions as well as increasing profitability. Thirty-five SMEs were selected from four regions in Finland representing four business sectors where the project's steering higher education institutions are located: Energy industry in Ostrobothnia, wellbeing industry in Uusima, tourism in Lapland and metal industry in the Southwest region.

1.2 Research gap, question and objective

Studies reveal that a part from having limited resources, SMEs are not able to capitalize on their internal assets (Gabrielsson & Kirpalani, 2004: 555–571). Furthermore, in order to remain competitive, it is important for them to build relationship and partnership by means of collaboration. There are advantages in working with other firms. Some benefits are the possibility to access new markets, improve their competences and performances, network with peers and share risks while investing in some projects and activities (Bititci, Turner & Kearney, 2006: 23–26).

A successful collaboration creates benefits and allows SMEs to focus on their key competences and core businesses. Additionally, inter-firm collaboration platforms serve as a tool that bring companies together in working toward achieving a common goal.

With the development and proliferation of IT tools in companies, it is now important that SMEs though sometimes small in size and with limited resources find ways and capability to shift to the digitization of their processes. One approach has been the implementation of Enterprise 3.0 collaboration platforms that provide enterprises with an ecosystem of employees, partners, suppliers, and customers who collaborate to develop capabilities by

collectively generating, sharing and refining business knowledge (Soriano, Lizcano, Cañas, Reyes & Hierro, 2007: 62–68).

Notwithstanding an extensive and diverse literature, there is limited knowledge on how these platforms can address tailor made specific needs of SMEs. The objective of this study, therefore, is to use axiomatic design theory to design an inter-firm electronic collaboration (e-collaboration) platform that integrate technologies needed for (i) the collaboration within an enterprise (intra-firm) and (ii) collaboration with external partners or firms (inter-firm). Prior to that, the needs and wishes of SMEs involved in this research are analyzed. The research questions this thesis will address are:

- *What are the needs and the challenges SMEs face in their endeavor to collaborate and improve their business processes?*
- *How can axiomatic design framework be used for the development of a comprehensive online platform towards SMEs collaboration and growth?*

The first research question was answered by delving into the data gathered from interview conducted with SMEs. Insight from it helps to apprehend their needs when it comes to intra-firm and inter-firm collaboration. An axiomatic design theory approach was used to answer the second research question. This theory was instrumental in developing *Design Parameters* based on the expressed needs.

1.3 Definitions and limitations

The European Union (EU) recommendation 2003/361 defines two main factors that can categorize an enterprise as an SME: (i) staff headcount (<250) and (ii) either turnover or balance sheet total (\leq € 50 m for turnover and \leq € 43 m for balance sheet total). Furthermore, SMEs are divided into medium-sized, small and micro based on criteria mentioned above. The Table below shows the different categories (European Commission, 2019).

Company category	Staff headcount	Turnover	or	Balance sheet total
Medium-sized	< 250	≤ € 50 m		≤ € 43 m
Small	< 50	≤ € 10 m		≤ € 10 m
Micro	< 10	≤ € 2 m		≤ € 2 m

Figure 1. Factors determining an SME.

For better competitiveness and efficiency, SMEs need to collaborate both internally and externally. Thus, the concept of intra-firm and inter-firm collaboration. Studies pointed out a trade-offs between inter-firm (i.e. collaboration between various functional unit and departments of different firm) and intra-firm (i.e. interaction between functional units within the same firm) collaboration when it comes to products and service development (Schleimer & Faems, 2016). However, for the purpose of this thesis, the intra-firm and inter-firm collaboration will be limited to SMEs operating in the EU space only. Furthermore, the concept of collaboration platform will focus only on an electronic or digital platform.

1.4 Structure of the study

This thesis has six main chapters arranged in a logical way. All parts were interrelated and gave a general overview about the topic at hand from the existing theories to the results.

The first chapter dealt with the reason behind the whole project. Research gap needed to be filled thus triggering more investigation into the selected topic. The theory part was covered in the literature review in the second chapter. A light was shed on the mutation in the business practices over the years regarding collaboration issues. Consequently, small size firms try to look for avenues to innovate in order to increase competitiveness. Moreover, the chapter three talked about the research method used. The chapter four focused on the technical design and the design theory used. The chapter five covers the

platform prototype design and the test for validity and reliability. It also highlighted the design concept. The last part is about discussing all findings and drawing conclusions.

2 LITERATURE REVIEW

A report by the Organization for Economic Co-operation and Development (OECD) highlighted the major role SMEs play in EU. Not only they account for 99% of all firms in the OECD area, they are the main source of employment with 70% jobs on average. The **Figure 1** below showed their value creation in terms of sources of job in the business sector (OECD, 2017).

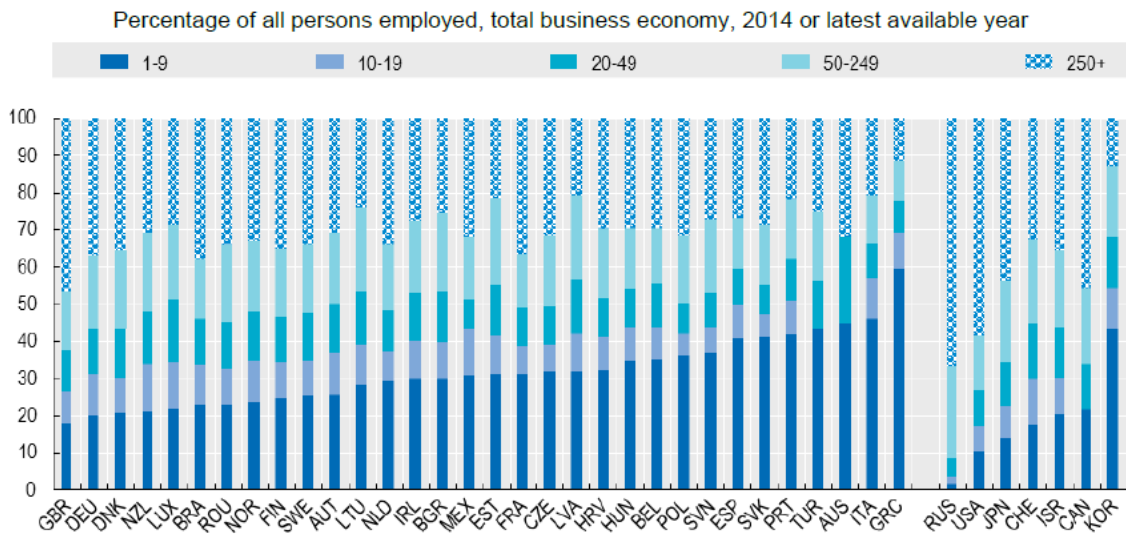


Figure 2. SMEs as the main source of jobs in the business sector in EU (OECD, 2016).

The competitive environment in which SMEs operate is an incentive to come out with better strategies that help them to survive. Additionally, they participate in all levels in reaching the Sustainable Development Goals (SDGs) defined by the United Nations (UN). That is the reason why the 2017 OECD report made it clear that adapting to an ever-changing business environment and getting involved in the digital transformation is key to their success and growth (OECD, 2017).

The globalization made it crucial for companies no matter how big or small they are to open up to the world. They need to build relationship and partnership by means of collaboration. Collaboration is defined as the process of two or more people or organizations working together to complete a task or achieve a goal (Martinez-Moyano, 2006: 69).

In the other hand, open systems development and information sharing are factors that contribute to better collaboration (Kanter, 1994: 98–108). With the development and proliferation of IT tools in companies, it is now important that SMEs though sometimes small in size and with limited resources try to shift to the digitization of their processes.

2.1 Business collaboration between SMEs

A successful collaboration creates benefits and allows SMEs to focus on their key competences and core businesses. Additionally, inter-firm collaboration platforms serve as a tool that bring companies together in working toward achieving a common goal. Depending on the sector, there are different type of collaboration.

2.1.1 Supply chain (SC) collaboration for a competitive business

Wang and Archer defines collaboration as an effort by two or more organizations to work towards a common goal and the results they cannot achieve by working alone (Wang & Archer, 2007: 113–126). Over the past decades, firms have been looking for opportunities to build partnership and collaborative network with supply chain (SC) partners to be able to satisfy their customers and ensure competitiveness (Cao & Zhang, 2011: 163–180). The aim is to reduce the development cost and at the same time enhance product development and quality in dynamic business environment. Other researchers (Walter, 2003: 721–733, Crook, Giunipero, Reus, Handfield & Williams, 2008: 161–177) emphasized that when firms collaborate independently and share their expertise with others, they could gain more than, if they operate alone. Factors that drive the SC collaboration are as follow:

- ***Commitment:***

It is about the desire from the partners willing to collaborate to put in effort and build a win-win relationship (Walter, 2003: 721–733, Fynes, Voss & de Búrca, 2005: 339–354).

- ***Collaborative communication:***

It refers to the communication channel among the parties. It focuses on the frequency, the type and the mode of communication been adopted (Cao et al., 2011: 163–180, Forslund & Jonsson, 2009: 77–95).

- ***Enabling technology:***

These are the IT tools used such as Management Information Systems (MIS), Enterprise Resource Planning (ERP), Decision Support System (DSS), Customer Management System (CMS) (Angerhofer & Angelides, 2006: 283–301, Lee Palekar & Qualls, 2011: 568–578).

- ***Strategy and goal compatibility:***

It talks about how each party in the collaboration perceive his own objectives in relation to the defined goal of the SC collaboration. Goal compatibility or congruence is the “degree to which objectives of two entities are compatible” (Cao et al., 2011: 163–180, Tan & Smith, 2006: 238–246).

- ***Information sharing:***

It refers to the exchange of sensitive information between SC members by means of secured communication channel (Cai, Jun & Yang, 2010: 257–268, Cao et al., 2011: 163–180).

- ***Incentive Alignment***

This is about sharing costs, risks and profits among all parties (Cao et al., 2011: 163–180, Simatupang & Sridharan, 2005: 44–62).

- ***Difference in culture and organizational culture:***

Organizational culture is a set of rules, norms and belief that help to better apprehend the way an organization function and thus provide behavioral norms. The culture difference is the way people’s minds are programmed and which make the difference between the members of different groups. Cultural and organizational differences could create difference in people’s attitude or bring conflict of interest (Jin & Hong, 2007: 544–561).

- **Trust:**

It is when one party believe, hope and expect that the action of the other party in the collaboration will be satisfactory (Kwon & Suh, 2004: 4–14, Nyaga, Whipple & Lynch, 2010: 101–114).

Furthermore, Barat defines two types of SC collaboration: *horizontal collaboration* and *vertical collaboration* as illustrated below (Barratt, 2004: 30–42).

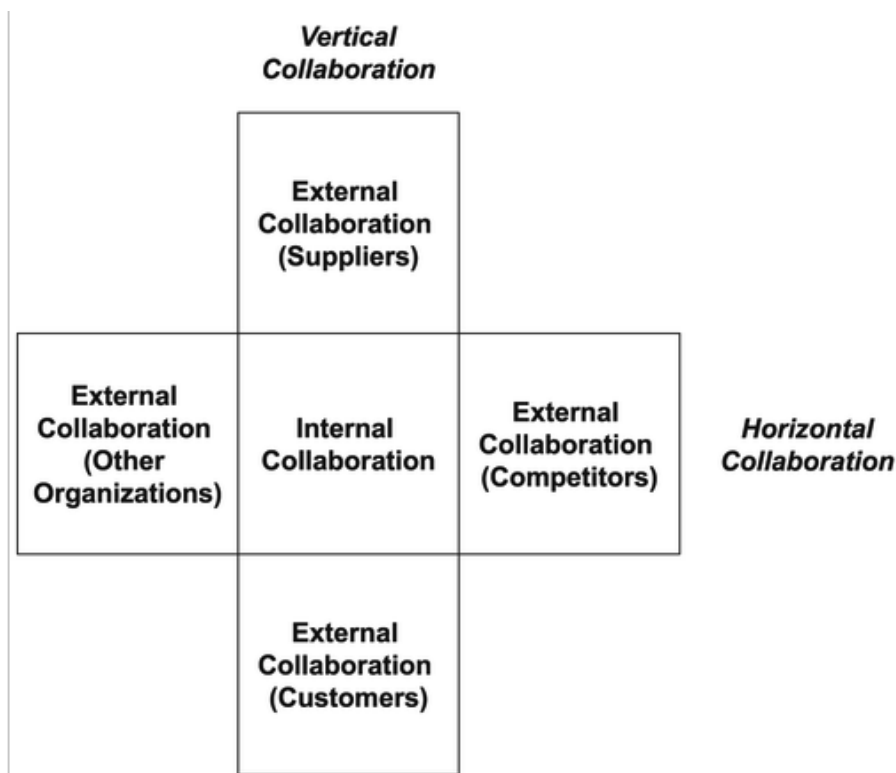


Figure 3. Types of collaboration (Barratt, 2004: 30–42).

As seen in the picture above, these collaborations involve customers, suppliers, competitors and other organizations. They are as follow:

- **Horizontal collaboration:**

This collaboration happens when parties involved identify and exploit win-win situation among firms that operate at the same level of the supply chain (Chan & Prakash, 2012: 4670–4685).

- ***Vertical collaboration:***

It takes place when two or more companies from different levels or stages in the supply chain share their resources and responsibilities and serve the same customer. This refers to companies that operate at different stage of the SC, yet they collaborate together with the aim of benefiting each other (Chan & Prakash, 2012: 4670–4685).

Although these factors and type of collaboration are specific to SC management, it can be applied to SMEs in all business sectors.

2.1.2 SME collaboration platforms and intermediary organizations

Collaboration platform can be an organization, a tool or a digital platform that works across the interface of two or more companies. It serves as a tool to combine and help to facilitate cooperation between different teams. Riskko who studied that issue in the first part of this project in relation to SMEs in Finland, gave more explanation about intermediary organizations and other collaborative platforms such as (Risikko, 2017):

- ***Internationalization platforms and organizations:***

In Finland, some of these intermediary organizations (i.e. Team Finland, Finpro, Tekes, Finnvera) play the role of collaboration platform that help firms in general and SMEs in particular to export their product to the international market. They are funded by the government (Team Finland , 2019).

- ***Seminars, fairs and events:***

SMEs can display their products and build new networks by attending seminars, fairs and other business events. *Messukeskus* is the largest venue for organizing these fairs and some other business-related events in Finland. They organize 65 trades and consumer shows, 1,500 meetings and congresses every year and attract up to 10,000 media representatives and bloggers (Messukeskus, 2019).

- ***Research projects and other development programs:***

This platform brings researchers from different SMEs to work on researches and developmental projects. That help to innovate and come out with new ideas and products. In Finland, TEKES (Finnish Funding Agency for Technology and Innovation) plays that role (European Commission - Research & Innovation, 2018).

- ***Regional developmental organizations and technology centers:***

In Finland, there are regional development organization that support firms. They understand the local business environment very well and can provide tailor made advices. The major task they handle include but not limited to marketing and business development. SEKES (Association of Finnish Development Companies) embodies the development organizations owned by cities. Its mission is to boost local enterprise's competitiveness and growth (SEKES, 2019). A typical example of a regional developmental organization is VASEK based in Vaasa. Their goal as stated on their official website is to "promote regional business, help SMEs to grow and market the region" (VASEK, 2019)

- ***Social Media Platforms:***

According to Kaplan, social media "is a group of internet-based applications that builds on the ideological and technological foundations of Web 2.0 and that allows the creation and exchange of User Generated Content" (Kaplan & Haenlein, 2010: 59–68). Social media are playing a major role today as a marketing and communication tool.

- ***Electronic platforms***

Electronic collaboration platforms are good options for SMEs that try to use digital solutions to facilitate their business processes. According to Barrat, the implementation of complex and large software packages can be challenging (Barratt, 2004: 30–42). That is why in Finland, a digital collaboration platform called Jakamo strive to act as an electronic platform that connect customers and suppliers across the supply chain (Jakamo, 2019).

2.2 SME's collaboration in a digital era

The use of information and communication technology has greatly changed the way individuals and companies interact. Living in the era of mass communication, there is a need to access and share information in real time. Internet and soon the 5G network will increase the need to handle business and companies' activities and processes electronically. Relying on computers, smart phones and other similar devices, collaboration among employees in the same firm or with other partners becomes more effective by mean of e-collaboration. According to Kock (2009), six concepts define e-collaboration:

- the collaborative task (Zigurs & Buckland, 1998: 11–21),
- the e-collaboration technology (DeSanctis & Poole, 1994: 121–147),
- the individuals involved in the collaborative task (Gefen & Straub, 1997: 389–400),
- the mental schemas possessed by the individuals (Kock, 2004: 327–348),
- the physical environment surrounding the individuals (Ned, 2001: 267–285), and
- the social environment surrounding the individuals (Carlson & Davis, 1998: 335).

2.2.1 E-collaboration or collaboration using online platform

Unlike Web 1.0 that was mainly used for browsing the internet, Web 2.0 refers to websites oriented towards user-generated contents and content sharing internet (Blank & Reisdorf, 2012: 545). Social media networks, video sharing sites, web applications and other online-based tools have become part of how firms operate and do business. That leads to the adoption of Enterprises 3.0 and Industrial 4.0 features. The current digital transformation of the industry and business processes move firms to opt for innovative ways to communicate, to collaborate between team members and to handle company's activities by means of information and collaboration technology thus the adoption of e-collaboration (Riemer, Steinfield & Vogel, 2009). However, it must be noted that some technologies used in the e-collaboration such as group decision support system, collaborative writing tools and teleconferencing are prior to the advent of internet in 1990 (Dasgupta, Granger & McGarry, 2002: 87–100).

2.2.2 Trends that drive the advent of e-collaboration

There are some market drivers that enable companies in general and SMEs in particular to review how they collaborate both internally and externally. Nowadays, organizations expand their activities in new areas and therefore need to setup new organizational structure or alliances (Riemer et al., 2009). Additionally, the accessibility of the information to all make it difficult for a firm to own all knowledge needed in product or service development. Consequently, firms are working together with external collaborators to innovate in their knowledge creation process (Powell, 1987: 67–87). Moreover, businesses

are moved to either experiment and /or build alliances if they want to satisfy their customers that are demanding and always looking for a customized service and product (Franke, 2001: 43–67).

The concept of collaboration is also applied internally. A typical example of such collaboration is explained by Schmalzl, Imbery and Merkl as an office-sharing concept whereby employees book workspace over the internet (Schmalzl, Imbery & Merkl, 2004). In some companies, it is rather based on first come first served principles as an employee takes the next desk available. It has also become common practice to work from home or remotely. Sometimes, this is because some employees are working from a branch office of a particular company in another geographical location. The working environment is therefore becoming virtual. Due to the mobility and special distribution, coordinating tasks and working efficiently become easy by means of e-collaboration. Riemer et al. (2009) draws a picture (**Figure 4**) that illustrates how market drivers and organizational trends contributed to the advent of e-collaboration.

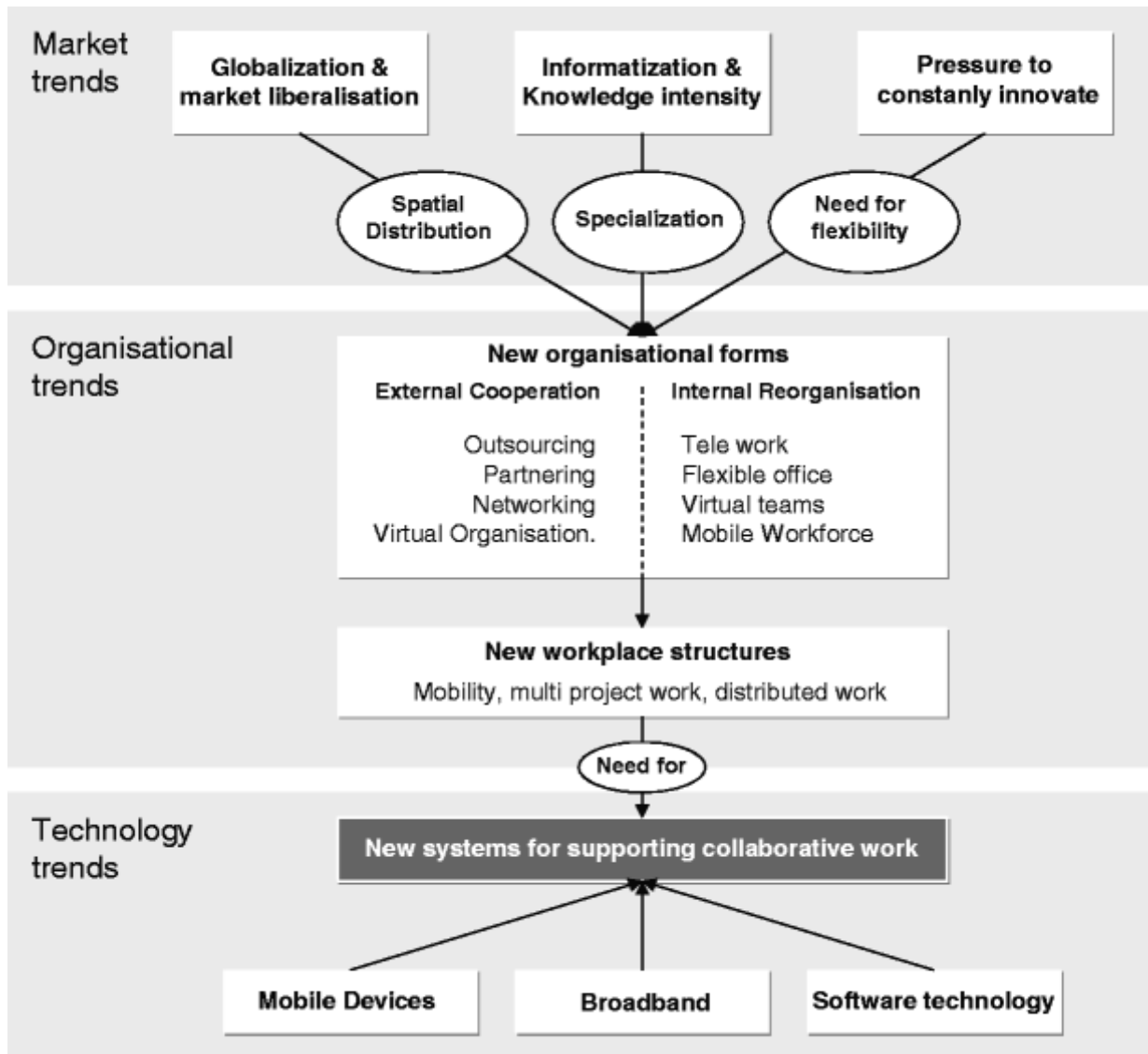


Figure 4. Trends driving the emergence of e-collaboration.

The picture shows three major trends that drives the emergence of e-collaboration:

- ***Market trend:***

Globalization and market liberalization, informatization and knowledge intensity, pressure to innovate continually.

- ***Organizational***

New organizational forms and new work place structures.

- ***Technology trend***

Mobile devices, broadband, software technology.

2.2.3 E-Collaboration features and system building blocks

E-collaboration is possible via ICT (Information and Communication Technology) technology, which brings together various parties involved. A study on collaboration tools subsume three main features (Lomas, Burke & Page, 2008: 11–21):

- ***Strong Communication Capability:***

This is done via communication channel, which could be video, audio and text.

- ***Easy-to-Understand Interface:***

An interface or common platform, which list tools for pick up and to be used easily. There are a lot of application or software at the disposal of the user. Sometimes this can bring confusion and deter him from using them. A well thought platform with tools needed for a targeted audience brings better user journey and experience

- ***Capability and Expectation of Collaboration:***

This help to motivate users and get input from them thus leading them to become active participants in the collaboration.

Although these tools were meant for collaboration in general, they can be applied to E-collaboration as well. In the other hand, before the spread of internet, a group of researchers pointed to the main forms of interaction as collaboration, coordination and communication) in a hierarchical order as seen in the figure below (Teufel, Christian & Mühlherr, 1995).

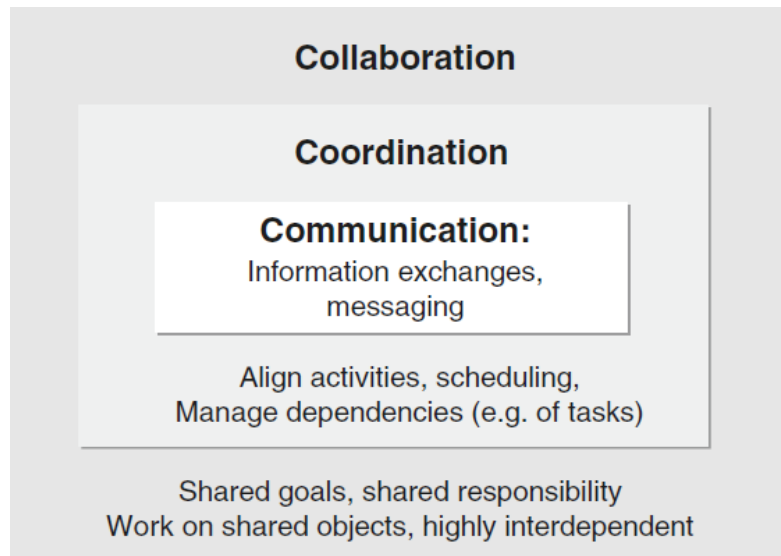


Figure 5. Forms of interaction in group work.

Insight from the picture above shows that communication is the key to any teamwork. It helps to facilitate information sharing and flow among group members (Wendel, 2013). Secondly, coordination makes it easy for parties involved in a communication to align their attitude whenever they need to share / access resources in real time or not, no matter what the content is (Back & Seufert, 2000: 5–22). Thirdly, collaboration enable team members to share goals, responsibilities and resources (Teufel et al., 1995).

2.3 SMEs inter-firm collaboration framework and factors influencing it

Understanding SMEs cooperation helps to apprehend how they operate and collaborate. Researches by Casal (2011:118–124), delve into the issue and came out with a unique model of three dimensions (strategic, management and social) involved in SMEs collaborations.

2.3.1 Factors influencing SMEs inter-firm collaboration

By combining the three factors mentioned above with internal and external factors that affect business collaboration, Casal was able to draw the SMEs cooperation Framework in **Figure 6**.

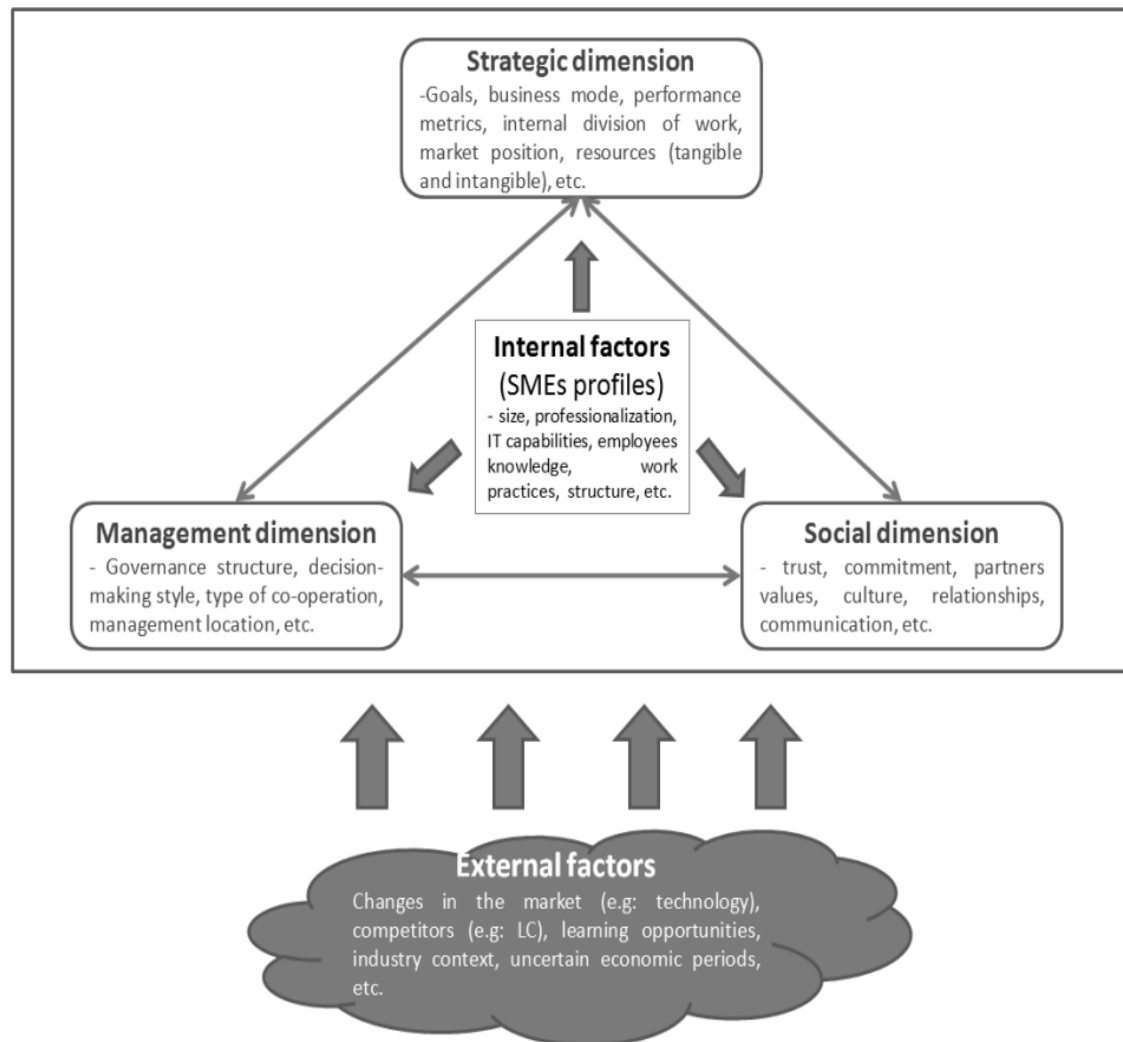


Figure 6. SME co-operation framework

An overview of the framework show the following:

- ***The strategic dimension:***

This explains the strategic approach an SME must develop and use if it desires to collaborate. It has to do with setting networking goals, having a clear business model and been able to take into account his partner' interest.

- ***The management dimension:***

This include having a clear view of the type of collaboration the firm is initiating. It also defines how its management is structured and how decisions are made.

- ***The social dimension:***

This is about how interaction and communication are performed between all stakeholders. It considers individual cultures and values. It helps to diminish any individual behavior and fear that may hinder the desire to collaborate. (Casals, 2011: 118–124.)

Complementing on the previous findings and prior to the spread of social networking heavily used in collaboration today, Johannsson's social network theory was developed (Johannisson, 1987: 3–23). According to this theory, human factors and personal relationships are essential ingredients in building collaborations. This theory pointed out among other things, trust, friendship, shared values between parties involved as key factors. Additionally, some other factors (internal and external) influence SME co-operation framework as seen in the Figure 6 (Casals, 2011: 118–124):

- ***Internal factors:***

They are variables concerning a potential SME trying to collaborate. Some of them are company size, sector or business activity, management and the employee's profile. These factors, which are internal to the firm, need not to be neglected, because they can have big impact on its collaboration process.

- ***External factors:***

These are factors external to the firm. It includes factors like the business environment, competition, local and international regulations.

2.3.2 Collaboration process framework

Like any business or partnership process, collaboration, been digital or not follow structured steps. It is a roadmap with different stages that leads to a desired result. In case of digital collaboration, various frameworks are suggested. For example, a group of researchers (Fachrunnisa & Mutamimah, 2012: 20–25) designed a digital collaboration network (DCN) framework for SMEs operating in industrial sectors as seen in **Figure 7**.

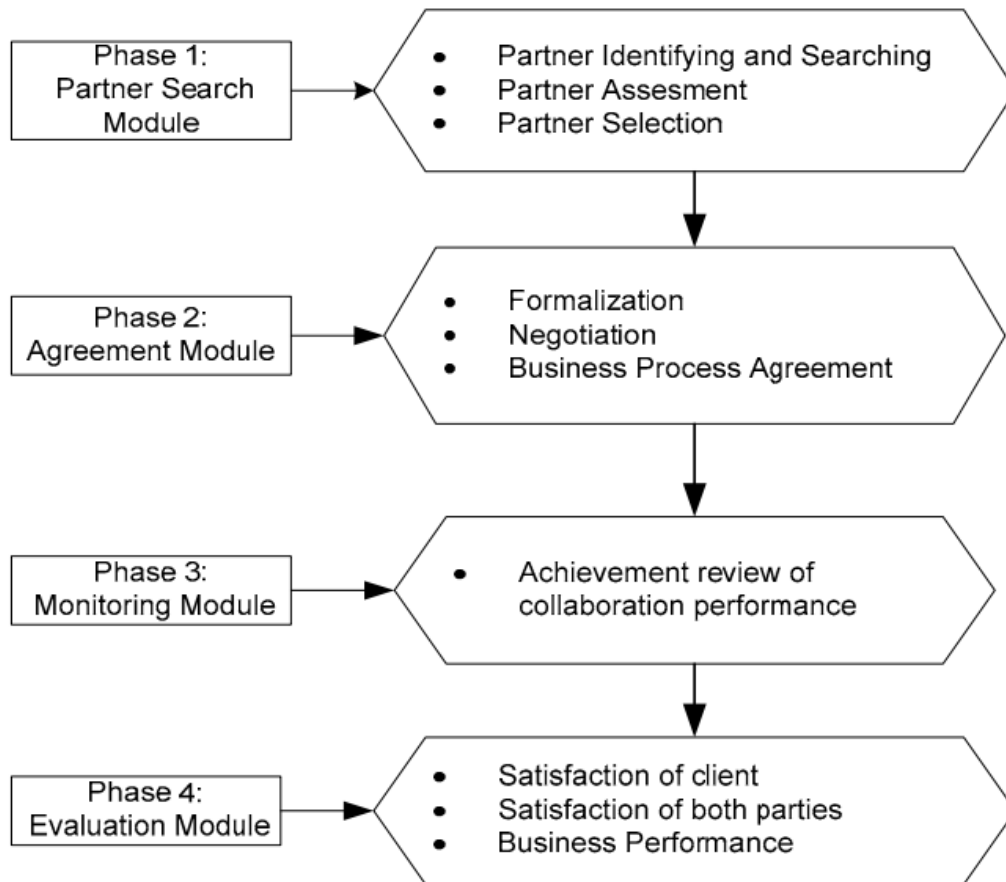


Figure 7. A framework of DCN for SMEs in an industry

The framework above highlights four steps, which are: “partner search and identification, achieving business agreement, monitoring and evaluation”. Although this was designed primarily for Batik industry in Indonesia, it could apply to other SMEs.

Bititci et al. (Bititci et al., 2006: 23–26) proposed a five steps collaboration process framework. The first phase is the attraction phase where companies try to identify what collaboration is all about and if there is a clear need for then to collaborate. The next stage is the Identification phase, which comprises of two elements such as internal analysis meant for the collaboration inside the company and external analysis meant for the collaboration for external partners. The third stage is the formation stage where groups and partners are formed based on common objectives. This is the phase where some legal and binding documents as to the roadmap and confidentiality are signed. This is followed by the implementation stage which involves the clarification of specific activities and tasks that

will be carried out in the collaboration. The last phase is the Evaluation phase. It consists of reviewing the whole collaboration process. Below is the flow diagram that depict all stages of the collaboration process (Bititci et al., 2006: 23–26).

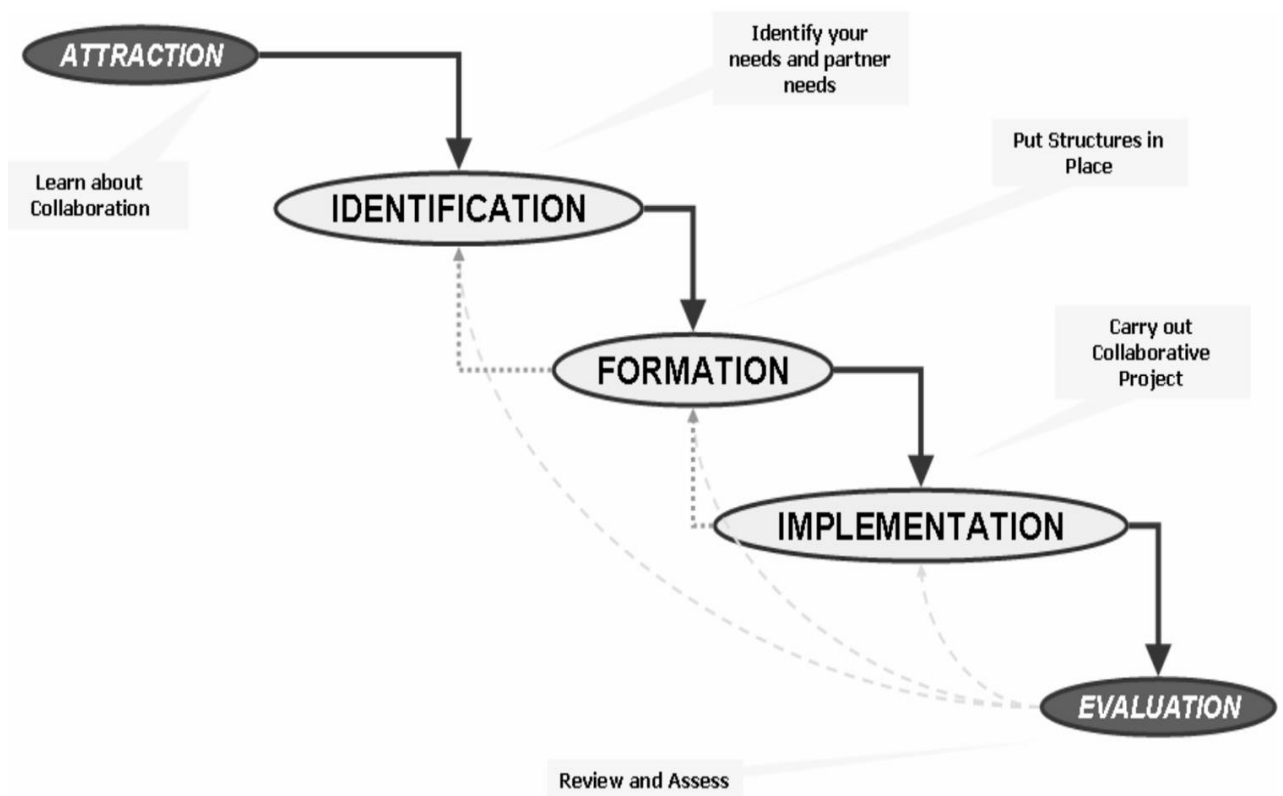


Figure 8. The collaboration process by SMEexcel team.

Hoffmann and Schlosser identify success factors for SMEs when it comes to building strategic alliances (Hoffmann & Schlosser, 2001: 357–381). They build a framework based on “transaction-cost theory, the resource-based and knowledge-based strategic theory as well as inter-organization theories”. Out of these three theoretical perspectives, they identified five phases of collaboration and alliance formation (Hoffmann et al., 2001: 357–381):

- *Phase 1: Strategic analysis and taking the decision to collaborate.*

It is recommended that the collaboration happen in a situation where there is a real need for proper strategy with a limited need to control. This phase is also about knowing the

strength of the firm that intend to start the collaboration and what it can contribute accordingly and complement with what others are bringing (Ahuja, 2000: 317–343). It is important to be aware of the time needed for the alliance development. Patience is important to organize multiple meetings and finally agree on major points before proceeding to the next step (Lorange, Roos & Brønn, 1992: 10–12).

- ***Phase 2: partner search and selection***

This phase is equally important. It is where trust-based relation is built. According to Dyer, trust in inter-organization relationship influence positively the formation of partnership and bring mutual benefit to parties involved (Dyer, 1996: 271–291). Another criterion to consider is to know the value, goal and company culture of the other partner. Sharing the same values make is easy to embark is a healthy relationship.

- ***Phase 3: Partnership design***

The duty and right of each partner need to be defined here. Hennart proposed *transaction-cost theory*, which stipulate that the success of any alliance depend on the minimization of “behavioral uncertainty and the resulting need for control” (Hennart, 1988: 361–374). Parties should contribute equally and the potential for joint value creation must be clarified. Aside from protecting key knowledge, trust need to prevail. Lack of trust will endanger the relationship durably. It can also jeopardize the whole project and protect against opportunistic behavior (Hoffmann et al., 2001: 357–381). The next step is to agree on clear and attainable objectives and set achievable milestones.

- ***Phase 4: Implementing and managing the collaboration.***

Hoffmann et al (2001: 357–381) suggest a systematic approach which consist of setting up information and coordination system. They stress the role the top management need to play by supporting it. Next, once agreement have been reached, the implementation phase can start. Then followed by a continual check-up for how the alliance is performing.

- ***Phase 5: Ending the collaboration***

This takes place upon approval from all parties. The termination process should be clearly stated in the conception phase. The collaboration may continue under other terms and condition if the parties agree to that.

The summary of factors influencing the success of SMEs alliance and collaboration is shown in the figure below.

	1. Strategic analysis and decision to co-operate	2. Search for a partner and partner selection	3. Designing the partnership	4. Implementation and management of the partnership	5. Termination of the partnership
C o n t e n t V a r i a b l e s	<p>Strategic rationale of the alliance</p> <ul style="list-style-type: none"> • Collaborating in situations with high need for strategic flexibility and limited need for control (TCE) • Contributing specific strengths and looking for complementary resources (RbV) 	<p>Looking for strategic and cultural fit</p> <ul style="list-style-type: none"> • Building on established trust-based relationships (TCE, Soc) • Partner is excellent in field of co-operation (RbV) • Complementary contributions (RbV) 	<p>Organisation of principles</p> <ul style="list-style-type: none"> • Precise definition of rights and duties (TCE) • Equal contributions from all partners (RbV) • Emphasising the potential for joint value creation (RbV) • Keeping and protecting core competencies (RbV, KbV) 	<p>Following through</p> <ul style="list-style-type: none"> • Establishing an information and co-ordination system (TCE) • Establishing required resources (RbV) • Avoiding unwanted transfer of knowledge (KbV) • Capacity to learn from partners (KbV) • Top Management Support (RbV, GMI) 	<p>Ex-ante rules</p> <ul style="list-style-type: none"> • Preparing for termination already in the design phase (TCE)
P r o c e s s V a r i a b l e s	<p>Systematic strategic analysis</p> <ul style="list-style-type: none"> • Deriving alliance objectives from business strategy (GMT) • Awareness of time requirements for alliance development (Soc) 	<p>Building a common understanding</p> <ul style="list-style-type: none"> • Agreement of fundamental values and convictions (Soc) 	<p>Leadership of negotiations</p> <ul style="list-style-type: none"> • Agreement on clear and realistic objectives (GMT) • Building trust by unilateral commitments and avoiding opportunistic behaviour (Soc) • Implementing plan with fixed milestones (GMT) 	<p>Putting it in action</p> <ul style="list-style-type: none"> • Speedy implementation of measures and fast results (GMT) • Continual review of alliance performance (GMT, Soc) 	<p>Keeping trust-based relationship</p> <ul style="list-style-type: none"> • Termination only upon approval by all partners (Soc)

TCE ... Transaction Cost Economics

RbV ... Resource-based View

KbV ... Knowledge-based View

Soc ... Sociological Theories (Interorganisation Theories)

GMT ... General Management and Leadership Theories

Figure 9. Success factors in the steps of alliance evolution (Hofmann & Schlosser, 2001: 357–381).

2.4 Problems and barriers to SME's collaboration

Issues hindering an effective inter-firm collaboration may come from within the firm (internal problems) or /and with external partners (external problems). Internal and external problems can discourage SMEs to begin the journey towards collaboration. Risikko (2017) looked into the major problems SMEs in Finland face when starting collaboration. The following table lists the result he got.

Table 1. Problems starting inter-firm networking and collaboration

Biggest problems faced by SMEs when starting collaboration
Internal Factors
Lack of time and resources
Management problems
External Factors
Difficulties in finding suitable partners
Building trust and a common goal
Lack of development

Further research (Casals, 2011: 118–124) group the barriers into these same two groups (internal and external). According to that study, the biggest internal barrier is the lack of human, financial and time resources. SMEs rather focuses on their daily activity with the limited resource they have and do not care much about finding appropriate partner or begin a journey of collaboration formation, nurturing and maintenance. Similarly, he mentioned poor result from previous attempt to collaborate (if there was any attempt in the pass) and lack of proper mechanism to assess collaboration as the biggest external factors. Based on these finding the next tables is drawn and list more internal and external problems and barriers to collaboration.

Table 2. Internal problems and barriers to SME's collaboration (adapted from Casals, 2011: 118–124)

Internal problems and barriers
<p>- <i>Searching for partners:</i> Not having enough time to search for partners. Having problem of finding the right one.</p> <p>- <i>Absence of clearly defined strategy</i> Due to lack of time, SME are not able develop a proper company culture towards collaboration formation. They also fail to investigate alternative businesses opportunities.</p> <p>- <i>Lack of resources</i> Most of the time SMEs have little to offer. Their resources are limited</p> <p>- <i>Poor collaboration planning</i> Most of the time, decisions are made by the owners, without a clear strategy. No idea about collaboration goals and objective.</p> <p>- <i>Individual factors and fear to share</i> SMEs are more reluctant to share their knowledge and expertise compared to bigger firm.</p> <p>- <i>Lack of eagerness to collaborate</i> No interest in collaborating because of having not heard about success stories.</p> <p>- <i>Unavailability of the skilled personnel to use</i> Unavailability of personnel with knowledge in IT, management or other field needed may discourage the implementation of collaborative approach.</p> <p>- <i>Lack of Investment</i> With limited financial resources, SMEs are not willing to invest in collaboration where there is no clear outcome in the horizon.</p>

Below are some external problems and barriers to collaboration.

Table 3. External problems and barriers to SME's collaboration (adapted from Casals, 2011: 118–124)

External problems and barriers
<ul style="list-style-type: none"> - <i>Inefficiency</i> Been afraid of the failure and poor efficiency of those who tried in the past. - <i>Inability to evaluate proper collaboration mechanism</i> Lack of efficient mechanisms to evaluate co-operation. No consensus as to how to assess the way the collaborative relationship is going. - <i>Competences of bigger firms</i> Unlike SMEs, bigger firms have more to offer when it comes to making alliance and building partnership. - <i>Organizational problems</i> Since building alliances is a complex process that demand resources, it is important to invest. Most of the time, that is a problem for SMEs - <i>Trust, dedication and willingness to compromise</i> No mechanism to fight the problem of trust, dedication and the willingness to compromise.

The internal and external problems to collaboration make the journey to alliance and partnership formation difficult. However, the next part shows that there is merit to collaboration.

2.5 Advantages of SME's collaboration leading to performance and productivity

Literatures widely covered the spectrum of SMEs collaborative approach. For instance, Franco stipulates that inter-organizational collaborations involve partnerships as well as relationships within stakeholders (Franco, 2008: 267–286). While collaboration contribute to the growth of firms, this becomes more relevant to SMEs because they need to increase their internal knowledge with external sources.

2.5.1 Impact of collaboration in the growth of SMEs

Studies show how collaboration has affected the growth of SMEs. According to Kanter (1994: 98–108), a competitive way to do so is to develop a collaborative relationship. Some authors emphasize the relationship between firm's ability to cooperate and innovate (Coombs, Coombs, Saviotti & Walsh, 1996). That is why an analysis of data collected from Belgian manufacturing firms concluded that there is a positive correlation between firms' ability to innovate and inter-firm collaboration (Faems, Van Looy & Debackere, 2005: 238–250.). Other advantages are the reduction of the time needed to perform a task, the increment in the aptness to find solution to complex problem and the generating of innovative alternatives (J. Alonso, 2010: 429–438).

Furthermore, firms that involve in collaborative relationship show their growth intention. Since this type of collaboration involve joint ventures, networks and alliances, participating in them can be helpful as it provides bigger base of resources as well as managerial skills and intellectual abilities (Dobbs & Hamilton, 2007: 296–322). In addition, collaborative relationship is as an important factor in a successful internationalization for SMEs since they have limited resources (Barringer & Jones, 2004: 73).

2.5.2 Internal and external reasons for SME's collaboration

Casal (2011: 118–124) suggested that two groups should be identified when it comes to SME's cooperation strategy. Identifying them make it easy to have deep knowledge about the reasons to collaborate. Thus, the author focuses on reasons for internal (the firms) collaboration and external (industry environment) collaboration. According to him, the first group is about reasons pertaining to the internal functions and operations of the SMEs. It also embodies their resources, goals and values. Secondly, the reasons for external collaboration includes but not limited to how the SME is positioned in the market and how it reacts to competition, customers, suppliers and external threats. An overview of both internal and external is depicted in the **Table 4** below. (Casals, 2011.)

Table 4. Reasons for SME collaboration adapted from Casals et al. (2011: 118–124) modified and simplified

<p>Internal reasons for SME collaboration</p>	<p>Learning and sharing experience Innovation Find complementarities Saving costs Increase sales Gain buying power External communication Improve investments Access to big projects and funding Lobbying power Increase product quality Increase flexibility Improve competitiveness Performance Keep business autonomy</p>
<p>External reasons for SME collaboration</p>	<p>Internationalization Overcome uncertain economic periods New businesses opportunities Reputation Better position Risk sharing</p>

Additionally, Umit et al. (2006) concede that internal collaboration allows employees in the same company to share documents, files and communicate effectively which in turn helps to build a good network and sharing spirit among colleagues. They argue that knowledge sharing and team spirit are also reinforced when an SME create environment and platform that bring employees together and allow them to express themselves and take advantage of company resources.

2.6 Theoretical framework

Literatures discussed above shed a light on how SMEs can collaborate both internally and externally. Furthermore, it became obvious that collaboration need to be planned and performed in various stages until the desired result is obtained. In this case, what is needed is a framework that brings together important ideas that will help SMEs to align themselves strategically with a digital collaboration platform. Failure to support the research with theoretical framework will lead to a limited usefulness in the final findings and conclusions (Sarter, 2006: 123). For that reason, the theoretical framework below is suggested.

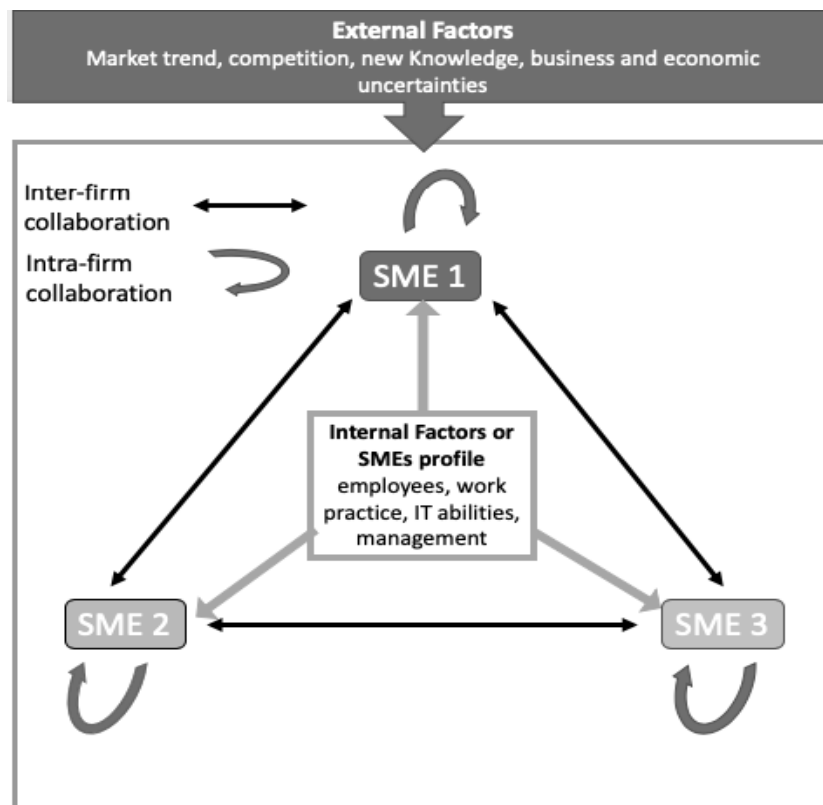


Figure 10. Theoretical framework for SMEs collaboration

This framework encompasses factors that affect SMEs in their journey towards collaboration. It also shows that collaboration starts from inside the company (intra-firm collaboration) before been extended to outside partners (inter-firm collaboration).

3 RESEARCH METHOD

This section presents the empirical part of the thesis, which was conducted in the form of a survey. The main objective of the survey was to find out how SMEs in Finland are involved in various form of collaboration. The questionnaire delved into their opinion as to how they collaborate among themselves directly or by means of collaboration platforms. It also asked about the needs and challenges they faced while collaborating.

3.1 Data collection

The Pisku project originally aimed at working with forty-eight SMEs. Each one of them were selected from four regions (Ostrobothnia, Lapland, Uusimaa, Southwest Finland) in Finland. However, by the time this thesis is written, only thirty-five responded to the survey. Each region focuses on a specific business or industry sector. For that reason, companies in the Ostrobothnia region are selected from the energy cluster, those in Lapland are into tourism, those in Uusimaa are taken from the welfare sector and those in Southwest Finland are in the metal industry. Nevertheless, the survey was open to any other company throughout Finland. The questionnaire was built around issue pertaining to the operation, the employee's management and business processes of SMEs involved. The theoretical part of the concept of collaboration platforms and intermediary organizations as well as the value chain theory was also taken into account. The questionnaire is structures in four main parts as follow:

- Part 1: Inter-firm collaboration among SMEs
- Part 2: The relation that exist between collaboration platforms and local intermediary organizations
- Part 3: Future of SMEs collaboration
- Part 4: Assessment of the economic and sales perspective of business cooperation.

The survey was implemented using Google Forms. Some of the questionnaires has been set using the Likert scale 1-7 and others are open-ended questions. Although the survey was conducted in Finnish and English, companies were allowed to answer in any language that issuitable to them. The data collection was carried out from summer to autumn

2017. Other researchers involved in the same Pisku project made the design of the survey and the data collection.

The graph below shows the number of different type of SMEs (Micro: 17, Small: 14, Medium-size: 4) that partook in the interview. They are grouped in three category depending on their size and turnover as see in the **Figure 11**.

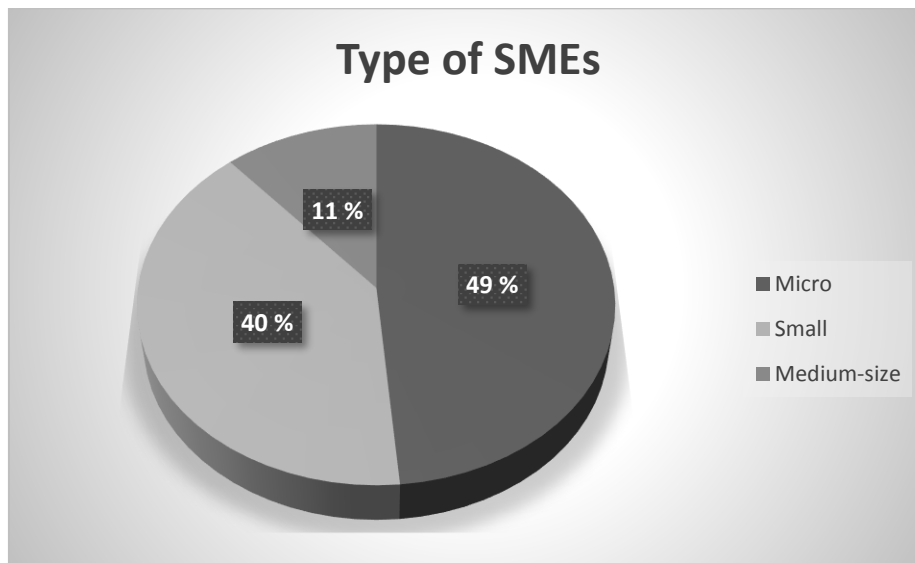


Figure 11. Distribution of the type of SMEs that took part in the interview

3.2 Methodology and data analysis

In the first part of this project, a study by Risikko (2017) used both qualitative and quantitative approach to analyze the data collected from the survey. Aside from these two methods, the main research approach used in this thesis was the Axiomatic system (AD) methodology. This theory uses matrix technics to analyze the transformation of customer's needs into functional requirements, design parameters, and process variables (Suh, 1998: 189–209).

3.3 Research reliability and validity

This part discusses the reliability and validity of the data collected and the whole study. Yin concedes that in a scientific research, the term reliability denotes the ability to duplicate and replicate the results (Yin, 1994).

In this study, one factor that is related to reliability is the sample population of SMEs chosen. Although the thirty-five respondents are taken from four regions representing four business sectors in Finland, they may not give the right picture of all SMEs in Finland. Another issue is about the personal factor that may also affect the result. In most of the cases, managing directors were the one who responded and they may not apprehend the questions from the employee's perspective. Few SMEs were too small and started business not long ago. For that reason, some questions were not relevant to them as their priorities are somewhere else. However, the questionnaires focused on issues and challenges faced by any SMEs not only in Finland but also in the whole world. It can therefore, be replicated.

The concept of "constructive validity" or the building up of correct operational measures is used here to verify the validity of this study (Yin, 1994). In this case, the replies from the interviewees were carefully analyzed and used to reflect key terminologies used in the research.

3.4 Axiomatic design

Axiomatic Design (AD) is a general design framework created and popularized by Professor Suh of the Massachusetts Institute of Technology (MIT) (Suh, 1990: 11–21; Suh & Do, 2000: 95–100). According to Suh (1998: 189–209), this approach can be used in system design and applicable to different kind of systems like machine design systems, software systems and to system combining hardware and software. He explains that since systems in general and software-based system in particular have many functional requirements (*FR*) and lines of computer codes, the complexity in their design is reduced by using AD theory.

3.4.1 Axiomatic design fundamentals and concepts of domains

Design is a process that aims at mapping what need to achieve and how it should be achieved (Suh 2003: 3).

The concept of AD is based on four different design domains (Suh, 2001: 11-21):

- ***Customer Domain with Customer Needs (CNs):***

This domain is characterized by the needs expressed by the customer as well as the attributes he is looking for. It strives to understand the basic expectations of the system been designed. These requirements have to be transformed into independent requirements.

- ***Functional Domain with Functional Requirements (FRs) and Constraints (Cs)***

In this domain, the needs of the customer are expressed in terms of Functional Requirements (*FRs*) and constraints (*Cs*). *FRs* are the actual target of the design whereas *Cs* are the limitations of the design. There are two types of *Cs*: ***Input constraints*** (constraints imposed as part of the design specifications) and ***System constraints*** (constraints imposed by the system in respect to the design solution).

- ***Physical Domain with Design Parameters (DPs)***

This is where the *FRs* are satisfied. *FRs* are mapped into *DPs*.

- ***Process Domain with Process Variables (PVs).***

The solution is provided if the design is achieved in the Process domain with the Process Variables according to specified *DPs*.

The four domains are well described in the picture below.

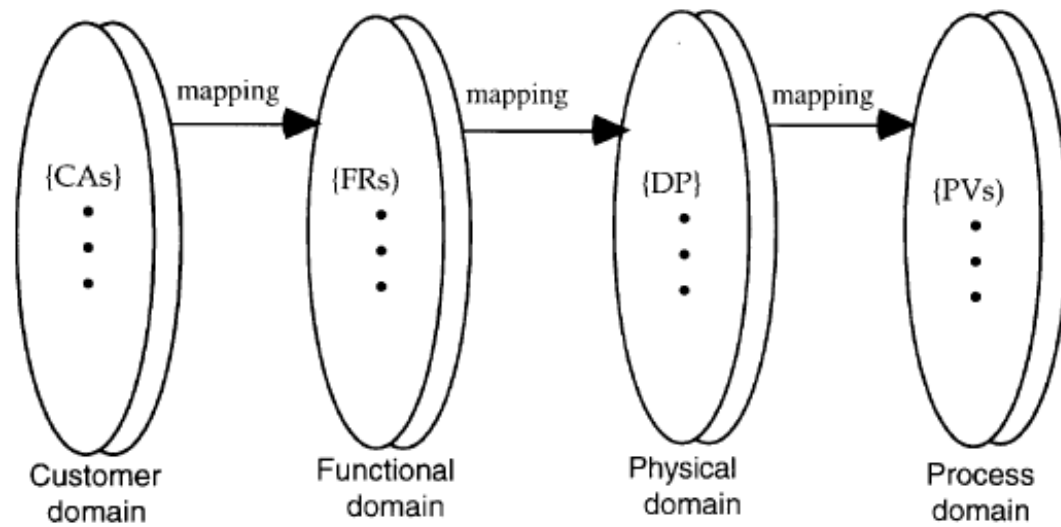


Figure 12. Domains of the design world. {x} represents vectors of each of the four domains (Suh, 1998: 189–209)

The idea behind these four domains is to know **What** we want to achieve, **How** to achieve it and **How** to produce it. For each pair of adjacent domains, **what** we want to achieve is seen from the domain on the left relative to the domain on the right, whereas the domain on the right represents the design solution for **how** to achieve it while satisfying the requirements specified in the left domain (Suh, 1998: 189–209).

The figure below illustrate the AD domains and how they are interrelated.

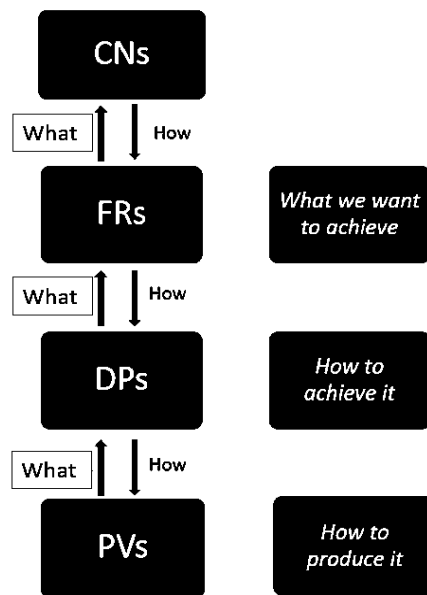


Figure 13. Design mapping and meaning of the different variables related to the domains

3.4.2 The Independence axiom and design equations

The *Independence axiom* is one the two axioms (*Axiom 1: independence Axiom* and *Axiom 2: information axiom*) that are used in mapping between domains (Suh, 2001: 11-21). It helps to maintain the independence of *FRs*. For a good and acceptable design, *DPs* and *FRs* are connected so that a specific *DP* can be set to satisfy its corresponding *FR* while at the same time not affecting other *FRs*.

To better illustrate this, *FRs* and *DPs* are represented mathematically as a vector (Suh, 2001: 11-21). These vectors are:

- *{FRs}*: functional requirement that define the specific design goal in the functional domain.
- *{DPs}*: Design parameters in the physical domain.

The relationship between the two vectors is written as:

$$\{FR\} = [A]\{DP\} \quad (1)$$

When expanded it gives:

$$\begin{Bmatrix} FR_1 \\ \vdots \\ FR_n \end{Bmatrix} = \begin{bmatrix} A_{11} & \dots & A_n \\ \vdots & A_{ij} & \vdots \\ A_{n1} & \dots & A_{nn} \end{bmatrix} \begin{Bmatrix} DP_1 \\ \vdots \\ DP_n \end{Bmatrix} \quad (2)$$

Where $[A_{ij}]$ is referred to as a design matrix representing the relationship between FR_i and DP_j .

The differential form of Equation (1) is written as:

$$\{dFR\} = [A]\{dDP\} \quad (3)$$

This is followed by the design matrix:

$$A_{ij} = \frac{\partial FR_i}{\partial DP_j} \quad (4)$$

Equation (3) becomes

$$FR_i = \sum_{j=1}^n A_{ij} DP_j \quad (5)$$

Where n = number of DPs

For linear design, A_{ij} are constants.

For a nonlinear design, A_{ij} are functions of the DPs .

Furthermore, Suh proposed two special acceptable designs cases when it comes to design matrixes (Suh N. , 2001):

- **Diagonal matrix:**

A diagonal design matrix (i.e. $A_{ij} = 0$ for all $i \neq j$) correspond to design where exactly one DP can satisfy each of the FRs independently. This type of design is called **uncoupled system design**.

- **Triangular matrix:**

A lower triangular matrix (i.e. $A_{ij} = 0$ for all $i < j$) where all matrix elements A_{ij} above the diagonal line including the diagonal line, are equal to zero. This is known as **Decoupled design**.

In case the design matrix is neither diagonal nor triangular, the design becomes a **Coupled design**.

The figure below shows the FR – DP relationship according to the design matrix (Park, 2007: 11-21).

	Design equation	Design process
Uncoupled design	$\begin{bmatrix} FR_1 \\ FR_2 \\ FR_3 \end{bmatrix} = \begin{bmatrix} A_{11} & 0 & 0 \\ 0 & A_{22} & 0 \\ 0 & 0 & A_{33} \end{bmatrix} \begin{bmatrix} DP_1 \\ DP_2 \\ DP_3 \end{bmatrix}$	$FR_1 = A_{11} \times DP_1$ $FR_2 = A_{22} \times DP_2$ $FR_3 = A_{33} \times DP_3$
Decoupled design	$\begin{bmatrix} FR_1 \\ FR_2 \\ FR_3 \end{bmatrix} = \begin{bmatrix} A_{11} & 0 & 0 \\ A_{21} & A_{22} & 0 \\ A_{31} & A_{32} & A_{33} \end{bmatrix} \begin{bmatrix} DP_1 \\ DP_2 \\ DP_3 \end{bmatrix}$	$FR_1 = A_{11} \times DP_1$ $FR_2 = A_{21} \times DP_1 + A_{22} \times DP_2$ $FR_3 = A_{31} \times DP_1 + A_{32} \times DP_2 + A_{33} \times DP_3$
Coupled design	$\begin{bmatrix} FR_1 \\ FR_2 \\ FR_3 \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} & A_{13} \\ A_{21} & A_{22} & A_{23} \\ A_{31} & A_{32} & A_{33} \end{bmatrix} \begin{bmatrix} DP_1 \\ DP_2 \\ DP_3 \end{bmatrix}$	$FR_1 = A_{11} \times DP_1 + A_{12} \times DP_2 + A_{13} \times DP_3$ $FR_2 = A_{21} \times DP_1 + A_{22} \times DP_2 + A_{23} \times DP_3$ $FR_3 = A_{31} \times DP_1 + A_{32} \times DP_2 + A_{33} \times DP_3$

Figure 14. FR – DP relationship according to the design matrix.

A good axiomatic design should always have a FR – DP design matrix that respect independence axiom. It must be either an uncoupled or a decoupled design. A coupled design matrix violates the independence axiom and must be avoided.

3.5 Decomposition, zigzagging and hierarchy

Suh (1998: 189–209) emphasized that in order to create hierarchy in the design, FR s and DP s need to be decomposed until they are implemented without further decomposition. However, this decomposition does not happen independently in each domain. It occurs

simultaneously and involve different domains. It starts from the top to the lowest level. This top-down decomposition and mapping process between two domains is called Zigzagging (Suh N. , 2001). In the top level or level 1, a *DP* is assigned to an *FR*. In the next level, *FR* has to be decomposed based on the previously chosen *DP*. The same process continues until the designer obtained the suitable *DPs*. The decomposition and zigzagging process between domains is shown in the figure below.

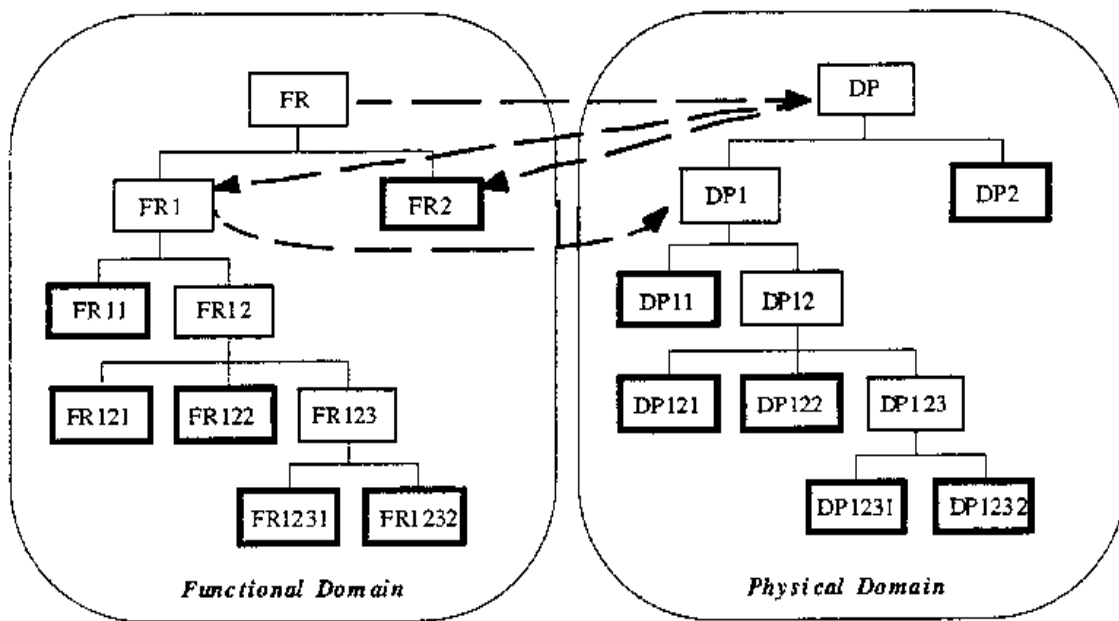


Figure 15. Decomposition and zigzagging process between domains (Suh N. , 2001, p. 30)

The figure above shows a zigzagging to decompose *FRs* and *DPs* and the hierarchy that exist among them. This concerns both functional and physical domains. The numbers 1 to 4 represent the zigzagging process. It could be seen that at each level, *DPs* are defined and mapped according to *FRs*. Then *FRs* of the lower level are defined based on the characteristics of *DPs* in the upper level. This process continues until the last level known as *leaf* or a level where there is no need for further decomposition. In Figure.15, an example of *leaf* is shown by the tick lines boxes.

3.6 The Information axiom

The purpose of the information axiom is to bring to the minimum level possible the design's information content. Therefore, the best design suitable to fulfil the *FRs* is the one having a minimum information content or the maximum probability of success (Suh N. , 2001). This is calculated according to the following equation:

$$I_i = \log_2 \left(\frac{1}{P_i} \right) \quad (6)$$

Where

$$P_i = \frac{CR}{SR} \quad (7)$$

For

- CR = Common Range (design range). It describes what the design achieves in terms of tolerance
- SR = What the system is capable of delivering.
- P_i = Probability of satisfying the given *FR_i*,

3.7 Using modules in axiomatic design

In striving towards good design using axiomatic design theory, the *FRs* and *DPs* must be decomposed until the level where no decomposition is needed. After that it is easy it to create hierarchies that gives a clear overview of the system. Another important concept to consider is the concept of modules. In this context, Suh (1998: 189–209) stresses that the concept of module needs to be defined carefully in order to avoid confusion. He pointed out that, most of the time, a module is a piece of hardware or in few cases a piece of software by coincidence. In axiomatic design, a module is described in terms of (*FR/DP*) or (*DP/ PV*) relationship “as the row of the design matrix that yields an *FR* when it is provided with the input of its corresponding *DP*” (Suh, 1998: 189–209). This explained in the following equation:

$$\begin{Bmatrix} FR_1 \\ FR_2 \end{Bmatrix} = \begin{bmatrix} a & 0 \\ b & b \end{bmatrix} \begin{Bmatrix} DP_1 \\ DP_2 \end{Bmatrix} \quad (8)$$

From equation (8) FR_1 and FR_2 are derived as follow

$$FR_1 = aDP_1 = M_1 * DP_1 \quad (9)$$

$$FR_2 = bDP_1 + cDP_2 = M_2 * DP_2 \quad (10)$$

Thus, M_1 and M_2 are calculated as follow

$$M_1 = \frac{FR_1}{aDP_1} \quad (11)$$

$$M_2 = b \frac{DP_1}{DP_2} + c \quad (12)$$

Where M_1 is equal to the Module that stands for the elements of the design matrix and its corresponding DPs that yield FR_1 when it is been multiplied by DP_1 . In the same way the value of FR_2 is calculated as FR_2/FR_3 if DP_2 is given as an input to the module.

Next the differentiation of equation (9) and (10) gives:

$$\Delta FR_1 = a\Delta DP_1 = M_1 * \Delta DP_1 \quad (13)$$

$$\Delta FR_2 = b\Delta DP_1 + c\Delta DP_2 = M_2 * \Delta DP_2 \quad (14)$$

Where:

- M_2 is given in equation (12)
- a is a partial derivative of FR_1 with respect to DP_1
- b and c are the partial derivatives of FR_2 with respect to DP_1 and DP_2 respectively.

4 TECHNICAL DESIGN

The aim of this thesis is to focus on the design of electronic or digital platform. The first part of this chapter answers the first research question, which is about identifying needs and challenges SMEs face when trying to collaborate. The second part focuses on using AD theory in designing the e-collaborative platform and thus answering the second research question.

4.1 Customer domain with customer needs (CNs)

A thorough analysis of interview data collected from SMEs that participated in the project reveals their needs. With respect to the first research question, the axiomatic design approach is used to distinguish these needs. For this project, the customer is associated with the participating SMEs. Below are the customer's needs:

- CN₁: Need for Financial support
- CN₂: Ability to work together and share company's resources internally in an effective way
- CN₃: Networking and developing partnership with other firms
- CN₄: Get knowledge and skills
- CN₅: Need to break business barriers
- CN₆: Employees work wellbeing

The identification of customer needs happens in the customer domain.

4.2 Mapping and decomposition using Axiomatic Design

A critical phase in this design and of the whole process is to determine the first level of Functional Requirement (*FR*) from the CNs. Below are the *FR* derived from the customer's needs:

- *FR*₁: Financial support
- *FR*₂: Internal collaboration

- *FR*₃: External collaboration
- *FR*₄: Knowledge and skills
- *FR*₅: Breaking business barriers
- *FR*₆: Increase work welfare

These *FR* are explained in detail below:

- ***FR*₁: Financial support:**

Although some SMEs interviewed were old (SMEs in energy sector) and have quite strong financial situation, most of them are new and are even categorized as micro SMEs. Their major needs were about getting financial support to run daily activities and survive. Some of them needed strategic-based financial planning and affordable sales channels. Solving product-pricing problem was also mentioned as an issue to be tackled.

- ***FR*₂: Internal collaboration:**

Collaboration and cooperation within the same company (internal collaboration) with colleagues and the management was seen as a key to growth. Employees needed to collaborate on tasks and projects by means of effective communication and resource sharing tools.

- ***FR*₃: External collaboration**

One of the key objectives of the interviewee was to be able to network and communicate with their partners and customers. They express their need as to how to build a better networking strategy and how to keep constantly in touch with those they have networked with already. Expanding the list of customers and been able to manage them was also an important need.

- ***FR*₄: Knowledge and skills**

It was clear that no matter how old or new, and how big or small these SMEs are, all of them acknowledge that they needed more skills in different areas ranging from managerial skills (for managers) to IT skills. Some agreed that their personnel needed more training in order to adapt to technological changes.

- ***FR5: Breaking business barriers***

Breaking barriers imposed by challenging business environment is seen as a tough situation. This needed to be handled so that it does not turn to be a hindrance to growth.

- ***FR6: Increase work welfare***

All agreed that knowing the employees' welfare is very important for better human resources management in the company. Most of them accept that welfare issues are not their priority. However, they express the need to improve it.

4.2.1 Constraints (Cs) related to the whole design

There are both ***Input constraints*** and ***System constraints*** associated to the design. Primarily, the platform is entirely an online platform. It needs to be simple and self-explanatory. Taking into account the SMEs involved in this project and similar SMEs that may have the same characteristics like them, the final design aimed at helping in networking and collaborating internally and externally.

Additionally, the platform was not built from scratch as an application. It is based on exiting small applications and IT tools. Furthermore, in order to avoid any licensing issues, only open-source applications were used.

While analyzing the wishes (CN) expressed by the SMEs, it came out that some of them needed financial support (like development loan and/or grant) or a wellbeing support from a specialist (physiotherapist or doctor). This collaboration platform is therefore not able to respond to such an aforementioned need. The constraints identified help to know the suitable *FRs* and *DPs*.

4.2.2 Top level *FRs* and *DPs* for the platform

The constraints cited above guide in mapping the top level *FRs* to their design parameters. There are six main *FRs*. They represent the top-level modules on which the whole design is based. Below is the first level decomposition (Step 1).

Table 5. Decomposition of top level *FRs* and *DPs*

<i>FRs</i>	<i>DPs</i>
<i>FR</i> ₁ Financial support	<i>DP</i> ₁ Get a loan or contact financial services for SMEs
<i>FR</i> ₂ Internal Collaboration	<i>DP</i> ₂ Develop collaboration strategy
<i>FR</i> ₃ External Collaboration	<i>DP</i> ₃ Build internal and external collaboration framework
<i>FR</i> ₄ Knowledge and skills	<i>DP</i> ₄ Get trained and be abreast with new technologies and changes
<i>FR</i> ₅ Breaking Business Barriers	<i>DP</i> ₅ Do not ignore business indicators and competitors
<i>FR</i> ₆ Increase work welfare	<i>DP</i> ₆ Data and research works about well-being at work

The relationships among the set of *FRs* and *DPs* in Table 3 are represented by the design matrix below.

Where:

- X is a nonzero element
- 0 is a zero element.

$$\begin{Bmatrix} FR_1 \\ FR_2 \\ FR_3 \\ FR_4 \\ FR_5 \\ FR_6 \end{Bmatrix} = \begin{bmatrix} X & 0 & 0 & 0 & 0 & 0 \\ 0 & X & 0 & 0 & 0 & 0 \\ 0 & X & X & 0 & 0 & 0 \\ 0 & 0 & 0 & X & 0 & 0 \\ 0 & 0 & 0 & 0 & X & 0 \\ 0 & 0 & 0 & 0 & 0 & X \end{bmatrix} \begin{Bmatrix} DP_1 \\ DP_2 \\ DP_3 \\ DP_4 \\ DP_5 \\ DP_6 \end{Bmatrix} \quad (15)$$

The design is an uncoupled design

However, the selected design solution cannot be completed at the highest level. Therefore, the *FRs* have to be decomposed further by zigzagging between the two domains.

4.2.3 Zigzagging and decomposition of *FRs* (Step 2)

Starting from *DP*₁, the next *FRs* level are determined as follows:

✓ *FR*₁: Financial support

Table 6. Decomposition of *FR*₁: Financial support

Index	<i>FR</i>
<i>FR</i> ₁₁	Acquire financial support
<i>FR</i> ₁₂	Acquire affordable sales channels
<i>FR</i> ₁₃	Improve cost effectiveness.
<i>FR</i> ₁₄	Obtain strategic-based financial planning
<i>FR</i> ₁₅	Develop wider sales channels.
<i>FR</i> ₁₆	Acquire financial support

✓ *FR*₂: Internal collaboration

Table 7. Decomposition of *FR*₂: Internal collaboration

Index	<i>FR</i>
<i>FR</i> ₂₁	Collaborate on tasks and project
<i>FR</i> ₂₂	Manage internal collaboration effectively.
<i>FR</i> ₂₃	Save and share documents for internal and external use
<i>FR</i> ₂₄	Communicate internally effectively

✓ *FR*₃: External collaboration

Table 8. Decomposition of *FR*₃: External collaboration

Index	<i>FR</i>
<i>FR</i> ₃₁	Expand list of partners and customers
<i>FR</i> ₃₂	Manage partners and customers
<i>FR</i> ₃₃	Utilize existing connections effectively
<i>FR</i> ₃₄	Develop cooperation with service providers
<i>FR</i> ₃₅	Collaborate with other firms

- ✓ *FR*₄: Acquire knowledge and skills

Table 9. Decomposition of *FR*₄: Acquire knowledge and skills

Index	<i>FR</i>
<i>FR</i> ₄₁	Increase contacts.
<i>FR</i> ₄₂	Acquire technical knowledge disbursement
<i>FR</i> ₄₃	Adapt technological changes
<i>FR</i> ₄₄	Acquire managerial skills
<i>FR</i> ₄₅	Train personnel
<i>FR</i> ₄₆	Obtain feedback from partners.

- ✓ *FR*₅: Breaking business barriers

Table 10. *FR*₅: Decomposition of breaking business barriers

Index	<i>FR</i>
<i>FR</i> ₅₁	Break business barriers.
<i>FR</i> ₅₂	Business contact list

- ✓ *FR*₆: Increase work welfare

Table 11. Decomposition of *FR*₆: Increase work welfare

Index	<i>FR</i>
<i>FR</i> ₆₁	Know the employees' welfare need
<i>FR</i> ₆₂	Improve employees' wellbeing

4.2.4 Mapping *FR*_{*ij*} to lower level *DP*_{*ij*} (step 3)

The second level *FR* are mapped into their respective *DP*. Their design matrices are also shown:

- For FR_1 : Financial support

Table 12. Mapping FR_{1x} to DP_{1x}

FR_{1x}	DP_{1x}
FR_{11} Acquire financial support	DP_{11} Create a platform to grant or a loan
FR_{12} Acquire affordable sales channels	DP_{12} Develop online sales and Value-Added Resellers (VARs)
FR_{13} Improve cost effectiveness.	DP_{13} Strategic cost management
FR_{14} Obtain strategic-based financial planning	DP_{14} Contact Finvera for financial services for SME's
FR_{15} Develop wider sales channels.	DP_{15} Develop export strategy
FR_{16} Determine better pricing	DP_{16} Develop a good pricing strategy

Design matrix (uncoupled design)

$$\begin{Bmatrix} FR_{11} \\ FR_{12} \\ FR_{13} \\ FR_{14} \\ FR_{15} \\ FR_{16} \end{Bmatrix} = \begin{bmatrix} X & 0 & 0 & X & 0 & 0 \\ 0 & X & 0 & 0 & 0 & 0 \\ 0 & 0 & X & 0 & 0 & 0 \\ X & 0 & 0 & X & 0 & 0 \\ 0 & X & 0 & 0 & X & 0 \\ 0 & 0 & 0 & 0 & 0 & X \end{bmatrix} \begin{Bmatrix} DP_{11} \\ DP_{12} \\ DP_{13} \\ DP_{14} \\ DP_{15} \\ DP_{16} \end{Bmatrix} \quad (16)$$

- For FR_2 : Internal collaboration

Table 13. Mapping FR_{2x} to DP_{2x}

FR_{2x}	DP_{2x}
FR_{21} Collaborate on tasks and Project	DP_{21} Build clear task and project management strategy
FR_{22} Manage internal collaboration effectively.	DP_{22} Increases and measures internal collaboration effectively
FR_{23} Communicate internally effectively	DP_{23} Develop a communication tools
FR_{24} Save and share documents for internal and external use	DP_{24} Setup a Document management system

Design matrix (uncoupled design)

$$\begin{pmatrix} FR_{21} \\ FR_{22} \\ FR_{23} \\ FR_{24} \end{pmatrix} = \begin{bmatrix} X & 0 & 0 & 0 \\ 0 & X & 0 & 0 \\ 0 & 0 & X & 0 \\ 0 & 0 & 0 & X \end{bmatrix} \begin{pmatrix} DP_{21} \\ DP_{22} \\ DP_{23} \\ DP_{24} \end{pmatrix} \quad (17)$$

- For FR_3 : external collaboration

Table 14. Mapping FR_{3x} to DP_{3x}

FR_{3x}	DP_{3x}
FR_{31} Expand list of partners and customers	DP_{31} Increase your customer and customers base
FR_{32} Manage partners and customers	DP_{32} Setup a customer and customers management tool
FR_{33} Utilize existing connections effectively	DP_{33} Build system to coordinate and manage existing customers
FR_{34} Develop cooperation with service providers	DP_{34} Build cooperation framework with external service providers
FR_{35} Collaborate with other firms	DP_{35} Develop external collaboration framework

Design matrix (decoupled design)

$$\begin{pmatrix} FR_{31} \\ FR_{32} \\ FR_{33} \\ FR_{34} \\ FR_{35} \end{pmatrix} = \begin{bmatrix} X & 0 & 0 & 0 & 0 \\ X & X & 0 & 0 & 0 \\ X & X & X & 0 & 0 \\ X & X & X & X & 0 \\ X & X & X & X & X \end{bmatrix} \begin{pmatrix} DP_{31} \\ DP_{32} \\ DP_{33} \\ DP_{34} \\ DP_{35} \end{pmatrix} \quad (18)$$

This design is decoupled.

DP_{35} : *Develop external collaboration framework* is a solution to all the FR s in this design. This means that developing a good external collaboration framework is necessary to *expand the list of partners and customers, to manage partners and customers, to utilize existing connections effectively and collaborate with other firms.*

- For FR_4 : Acquire knowledge and skills needed

Table 15. Mapping FR_{4x} to DP_{4x}

FR_{4x}	DP_{4x}
FR_{41} Increase contacts.	DP_{41} Find easy ways to engage those that matter and engage people in business conversations
FR_{42} Acquire technical knowledge disbursement	DP_{42} Subscribe to technical magazine and embrace a variety of software.
FR_{43} Adapt technological changes	DP_{43} Be open minded and use new technologies
FR_{44} Acquire managerial skills	DP_{44} Take more courses.
FR_{45} Train personnel	DP_{45} Implement Skill-based Metrics.
FR_{46} Obtain feedback from partners.	DP_{46} Create a feedback loop system.

Design matrix (uncoupled design)

$$\begin{Bmatrix} FR_{41} \\ FR_{42} \\ FR_{43} \\ FR_{44} \\ FR_{45} \\ FR_{46} \end{Bmatrix} = \begin{bmatrix} X & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & X & 0 & 0 \\ 0 & 0 & X & 0 & 0 & 0 \\ 0 & 0 & 0 & X & 0 & 0 \\ 0 & 0 & 0 & X & X & 0 \\ 0 & 0 & 0 & 0 & 0 & X \end{bmatrix} \begin{Bmatrix} DP_{41} \\ DP_{42} \\ DP_{43} \\ DP_{44} \\ DP_{45} \\ DP_{46} \end{Bmatrix} \quad (19)$$

- For FR_5 : Been able to break business barriers

Table 16. Mapping FR_{5x} to DP_{5x}

FR_{5x}	DP_{5x}
FR_{51} Break business barriers.	DP_{51} Set up effective information system
FR_{52} Business contact list	DP_{52} Build a contact list

Design matrix (decoupled design)

$$\begin{Bmatrix} FR_{51} \\ FR_{52} \end{Bmatrix} = \begin{bmatrix} X & 0 \\ X & X \end{bmatrix} \begin{Bmatrix} DP_{51} \\ DP_{52} \end{Bmatrix} \quad (20)$$

- For FR_6 : Increase work welfare

Table 17. Mapping FR_{6x} to DP_{6x}

FR_{6x}	DP_{6x}
FR_{61} Identify employee welfare needs	DP_{61} Create a feedback form to collect employee's needs.
FR_{62} Improve personnel's well-being	DP_{62} Create a page for data and re-search works about well-being at work

Design matrix (uncoupled design)

$$\begin{Bmatrix} FR_{61} \\ FR_{62} \end{Bmatrix} = \begin{matrix} X & 0 \\ 0 & X \end{matrix} \begin{Bmatrix} DP_{61} \\ DP_{62} \end{Bmatrix} \quad (21)$$

At this level of decomposition, only FR_{2j} and FR_{3j} need to be decomposed again.

4.2.5 Zigzagging and decomposing of FR_{2j} and FR_{3j} (Third level)

➤ **For FR_{2j}**

- FR_{21} : Collaborate on tasks and project

The DPs obtained here are satisfactory. There is no need to decompose them any further.

- FR_{22} : Manage internal collaboration effectively.

Table 18. Mapping FR_{22x} to DP_{22x}

FR_{22x}	DP_{22x}
FR_{221} Collaborate on project and task effectively	DP_{221} Build project and task management system
FR_{222} Organize assets like images, video and documents	DP_{222} Build digital asset management (DAM) system
FR_{223} Share files securely	DP_{223} Develop secure cloud system
FR_{224} Live communication	DP_{224} Setup chat and video conferencing system

Design matrix (uncoupled design)

$$\begin{pmatrix} FR_{221} \\ FR_{222} \\ FR_{223} \\ FR_{224} \end{pmatrix} = \begin{pmatrix} X & 0 & 0 & 0 \\ 0 & X & 0 & 0 \\ 0 & 0 & X & 0 \\ 0 & 0 & 0 & X \end{pmatrix} \begin{pmatrix} DP_{221} \\ DP_{222} \\ DP_{223} \\ DP_{224} \end{pmatrix} \quad (22)$$

- FR_{23} : Communicate internally effectively

Table 19. Mapping FR_{23x} to DP_{23x}

FR_{23x}	DP_{23x}
FR_{231} Send and receive Emails easily	DP_{231} Setup Inbound/outbound emails from CRM
FR_{232} Make free call and send text message for free	DP_{232} Setup Inbound/outbound calls and messaging from CRM
FR_{233} Have group discussion	DP_{233} Setup social media platform

Design matrix (uncoupled design)

$$\begin{pmatrix} FR_{231} \\ FR_{232} \\ FR_{233} \end{pmatrix} = \begin{pmatrix} X & 0 & 0 \\ 0 & X & 0 \\ 0 & 0 & X \end{pmatrix} \begin{pmatrix} DP_{231} \\ DP_{232} \\ DP_{233} \end{pmatrix} \quad (23)$$

- FR_{24} : Save and share documents for internal and external use

Table 20. Mapping FR_{24x} to DP_{24x}

FR_{24x}	DP_{24x}
FR_{241} Save document both online and on local machine	DP_{241} Setup online storage or drive
FR_{243} Edit documents online	DP_{243} Embed online office editing tools
FR_{244} Protect files and documents	DP_{244} Setup document lock system

Design matrix (Decoupled design)

$$\begin{pmatrix} FR_{241} \\ FR_{245} \\ FR_{243} \end{pmatrix} = \begin{pmatrix} X & 0 & 0 \\ X & X & 0 \\ X & X & X \end{pmatrix} \begin{pmatrix} DP_{241} \\ DP_{242} \\ DP_{243} \end{pmatrix} \quad (24)$$

➤ FR_{3j}

- FR_{31} : Expand list of partners and customers

Table 21. Mapping FR_{31x} to DP_{31x}

FR_{31x}	DP_{31x}
FR_{311} Run Email campaign	DP_{31x} Set newsletter features
FR_{312} Use company website to get new customers	DP_{312a} Setup CMS system and keep website contents up to date
FR_{313} Get new customers from social media	DP_{313} Promote your business on social media networks

Design matrix (uncoupled design)

$$\begin{cases} FR_{311} \\ FR_{312} \\ FR_{313} \end{cases} = \begin{matrix} X & 0 & 0 \\ 0 & X & 0 \\ 0 & 0 & X \end{matrix} \begin{cases} DP_{311} \\ DP_{312} \\ DP_{313} \end{cases} \quad (25)$$

- FR_{32} : Manage partners and customers

Table 22. Mapping FR_{32x} to DP_{32x}

FR_{32x}	DP_{32x}
FR_{321} have a centralized system to manage customers and partners	DP_{321} Develop a CRM system
FR_{322} Reduce technology barriers	DP_{322} Design a user friendly and simple to use system

Design matrix (decoupled design)

$$\begin{cases} FR_{321} \\ FR_{322} \end{cases} = \begin{matrix} X & 0 \\ X & X \end{matrix} \begin{cases} DP_{321} \\ DP_{322} \end{cases} \quad (26)$$

- FR_{33} : Utilize existing connections effectively.

Table 23. Mapping FR_{33x} to DP_{33x}

FR_{33x}	DP_{33x}
FR_{331} Expand list of partners	DP_{331} Integrate social media systems and newsletter features
FR_{331} Change leads into prospects then to customers	DP_{332} setup lead and prospect conversion features

Design matrix (uncoupled design)

$$\begin{Bmatrix} FR_{331} \\ FR_{332} \end{Bmatrix} = \begin{matrix} X & 0 \\ 0 & X \end{matrix} \begin{Bmatrix} DP_{331} \\ DP_{332} \end{Bmatrix} \quad (27)$$

- FR_{34} : Develop cooperation with service providers

Table 24. Mapping FR_{34x} to DP_{34x}

FR_{34x}	DP_{34x}
FR_{341} Work with service providers via a common interface	DP_{341} Setup a common technical interface or dashboard
FR_{342} Have a good Communication channel	DP_{342} Setup easy-to-use communication tools such as Emails, phone call, social media.

Design matrix (uncoupled design)

$$\begin{Bmatrix} FR_{341} \\ FR_{342} \end{Bmatrix} = \begin{matrix} X & 0 \\ 0 & X \end{matrix} \begin{Bmatrix} DP_{341} \\ DP_{342} \end{Bmatrix} \quad (28)$$

- FR_{35} : Collaborate with other SMEs

Table 25. Mapping FR_{35x} to DP_{35x}

FR_{35}	DP_{35}
FR_{351} Get the right partner or company to collaborate with	DP_{351} Look for a common interest while keeping your values in mind
FR_{352} Work together	DP_{352} Create portal for webinar, cross-promotion and special events together

Design matrix (uncoupled design)

$$\begin{Bmatrix} FR_{351} \\ FR_{352} \end{Bmatrix} = \begin{matrix} X & 0 \\ 0 & X \end{matrix} \begin{Bmatrix} DP_{351} \\ DP_{352} \end{Bmatrix} \quad (29)$$

4.2.6 Platform architecture

The architecture of this design is presented in the *FR / DP* hierarchy with the associated design equation and matrices. It shows a broad overview of how the whole design is structured and looks like. The design architecture presents the roadmap for the final implementation. The figures 16 and 17 show the *FR* and *DP* hierarchies and the decompositions that took place in the functional and physical domain. The leaf is shown by the boxes with blue color.

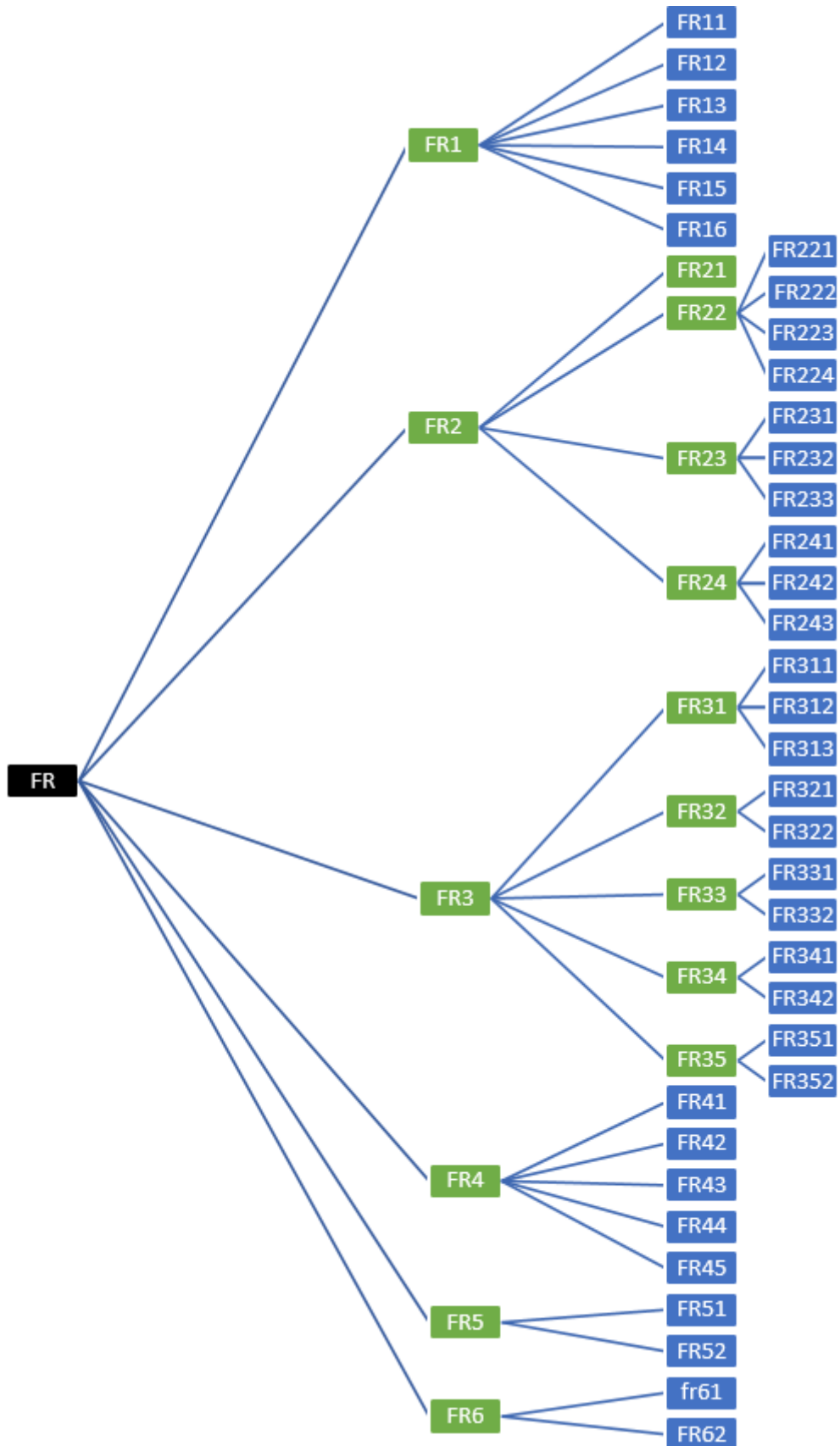


Figure 16. *FR* hierarchies in the functional domain

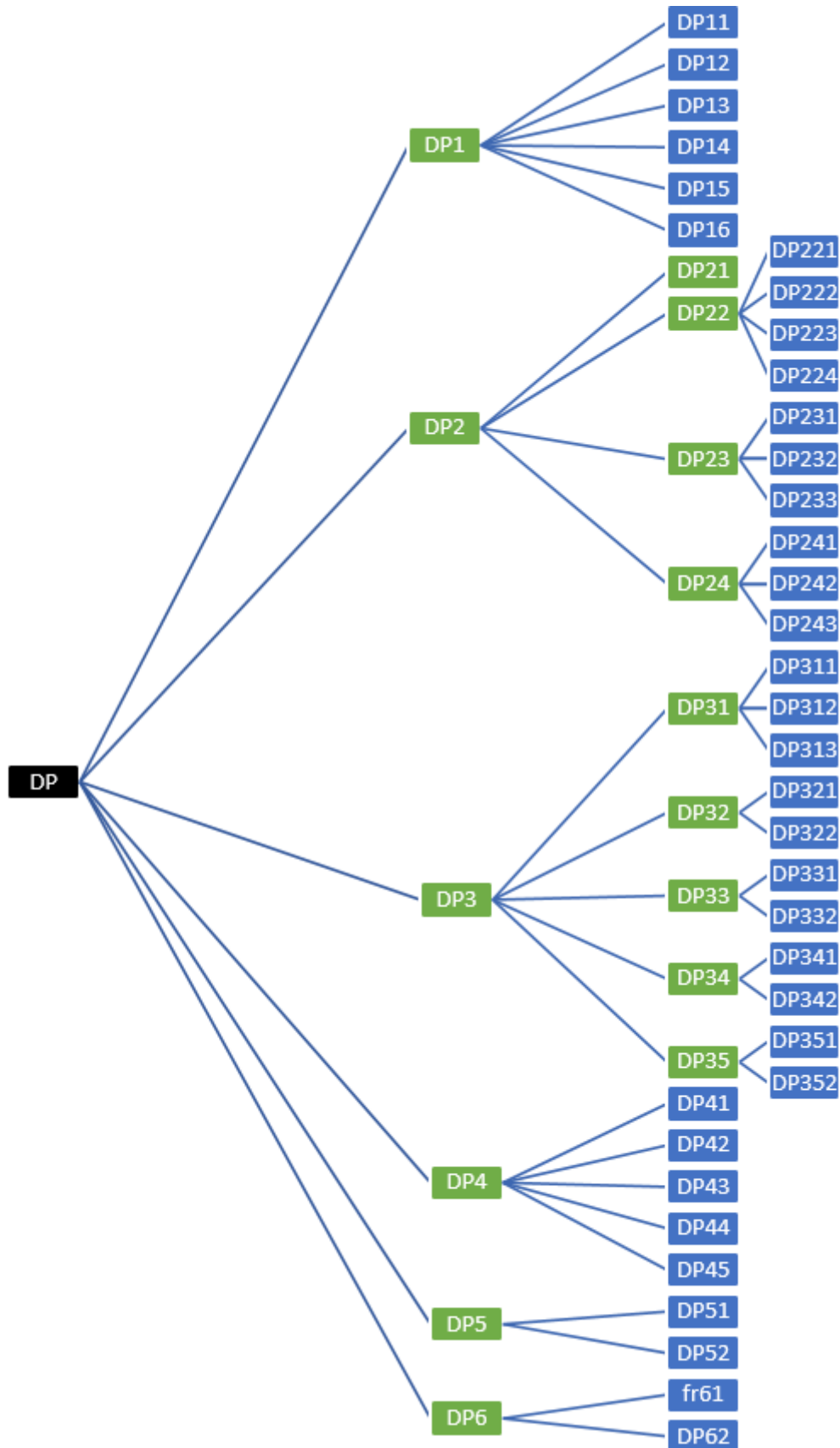


Figure 17. *DP* hierarchies in the physical domain

4.3 Platform main modules and functionalities

Design parameters derived from the *FR* in the previous helped to design the final product. Based on the concept of modules defined earlier, six top-level modules identified were used to design the six main parts of the platform. These modules and the functions they performed are seen in the next part. However, it must be acknowledged that there are some features that are still missing in the final design at the time this thesis is written. The main concept behind the modules is shown in the **Figure 18** below where all the modules and the combined *FRs* and *DPs* associated to them are shown.

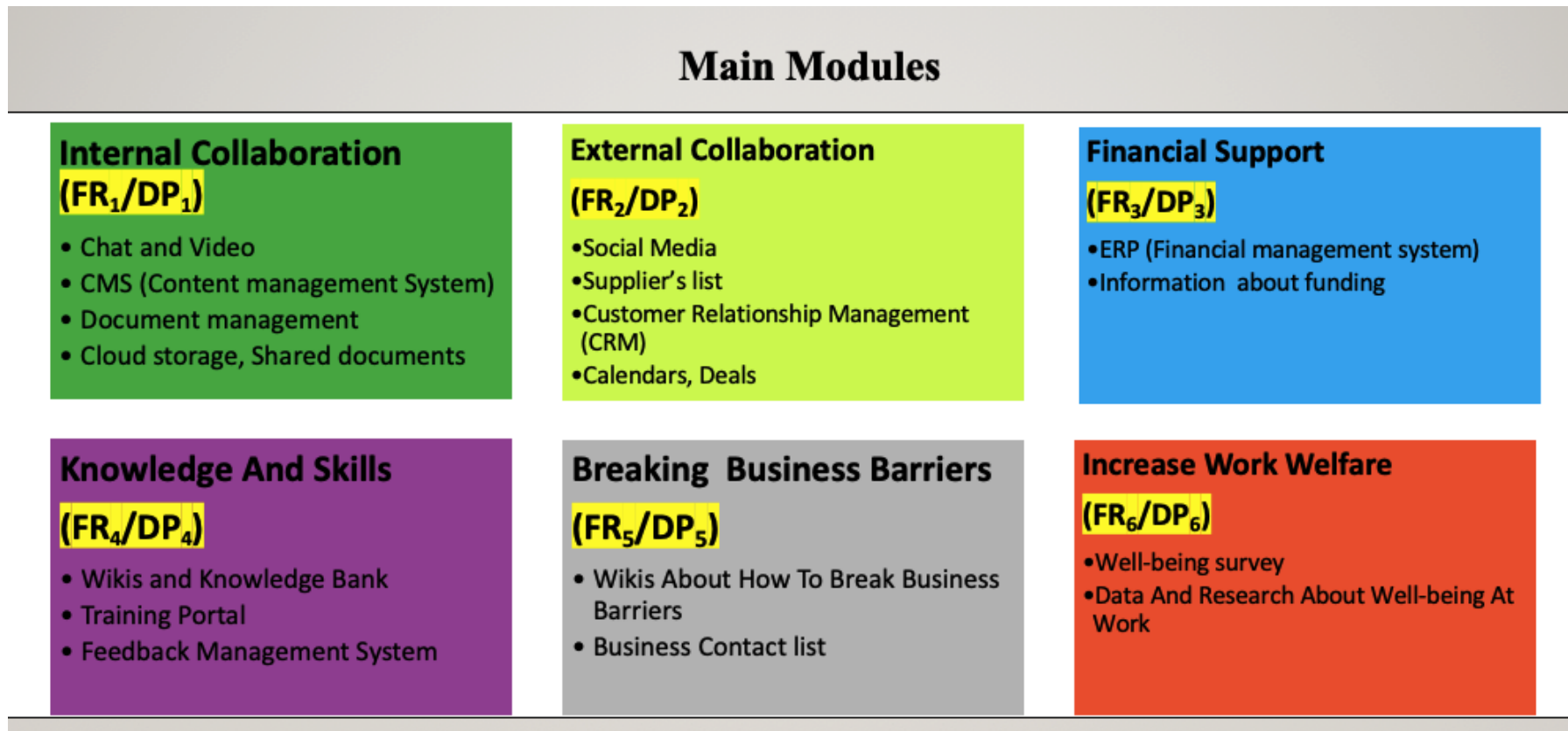


Figure 18. Main modules and their associated *FRs/DPs*

The first three modules are managed from the back office by some IT tools or plugins whereas the last three are basic website pages.

The next part talked about the functions and features of each module.

4.3.1 Internal collaboration

Issues related to any collaboration performed inside the firm (SME) is handled here. It contains tools used to manage personal calendar and schedule. Employees can use them to collaborate on tasks, projects and different activities. They can also collaborate on the same documents or files by sharing it among themselves. These files in turn are saved securely on the company's server for future use.

4.3.2 External collaboration

This is where activities pertaining to collaboration with customers, clients, and other business partners are handled. The SME can use this module to build a database of future prospects or customers. This serves as a customer's and partner's management portal where interaction and communication take place.

4.3.3 Financial support

As stated in the constraints, this portal cannot offer grant or loan to any company. However, the *financial support* module plays two roles. First, it gives useful information about where to get financial support as well as some local institution that support SMEs in Finland. It also provides some financial and accounting tools that SMEs in general and micro SMEs in particular can use for their bookkeeping or other financial and accounting activities.

4.3.4 Knowledge and skills

This is an education and training module. It looks like a Wiki that lists information and links to website that employees and managers can use. It displays the links to some online

training portal such as MOOC, Coursera and EDX. It also lists some open-source software in various field such as: ERP, Finance, Risk Management, free file manager, Office suite.

4.3.5 Breaking business barriers

Here is where tips are given as to how to break business barriers. Some articles and video are collected from trusted and respected website such as Forbes and TED. It highlighted articles like *Breaking Down Barriers: 3 Steps to a successful content strategy* (by John Hall Contributor, Forbes), *Eight ways to break down barriers in traditional workplace culture* (by TJ McCue Contributor, Forbes) and *The Scandinavian way - breaking down barriers between entrepreneurs and financiers* (by Trevor Clawson Contributor, Forbes).

4.3.6 Increasing work welfare

This part focuses on wellbeing at work. It features advices from some official website that deal with that issue in Finland. It also shows some video from professionals as seen on TED show. Issues discussed here are for example about how to take care of his back at work and how to work in a positive way. Another important feature of this module is a work wellbeing survey (the survey was not ready at the time this thesis was written).

4.4 Platform system design Controllability, validity and Stability

Like any software or computer application, the platform design at hand need to be checked for quality and reliability. This is often done by rigorous and sophisticated metrics. Asthana and Olivieri suggest a checklist approach as one of the current states of art method to software readiness assessment (Asthana & Olivieri, 2009: 1–6). In this context where AD theory is used, the aim purpose is to see if the final deliverable is valid, stable and controllable.

4.4.1 Platform system design controllability and validity

A good AD design satisfies the Independence Axiom. Its design axioms satisfy an uncoupled or decoupled design in opposition to coupled designs. This can also be shown in the scalability of the designed system into a new system without much trial- and-error when these axioms are used. Furthermore, a design that has the lowest information content is preferable than the designs with higher information contents (1998: 189–209).

According to Suh, controllability means that the “*FRs* can be satisfied within the specified tolerances” (Suh et al., 2000: 95–100). In the case of the design of the platform, this is done by firstly choosing the suitable *DPs* and then by changing them to satisfy the *FRs*. Decomposition of *FRs* and *DPs* are made till the optimum stage is reached. At that stage, any foreseeable biases and variances are removed. The independence and information axioms are thus satisfied. By so doing, the desired operating points are reached in the design and the *FRs* that were specified are satisfied in the desired range of the design space.

In this design, the top-level *FR* were decomposed into the lowest possible level. Few of them were even decomposed up to the third level. There was no coupled design matrix found in all the *FR* to *DP* mapping. The independence and information axioms were respected making therefore the design controllable and valid.

4.4.2 Platform system design stability

Suh defines an AD system Stability as a design that “performs consistently and reliably even when subjected to external disturbances and noise” (Suh et al., 2000: 95–100). This is made possible by” selecting a set of $\{DPs\}$ that can be used to change $\{FRs\}$ over the range specified in a stable manner” (Suh et al., 2000: 95–100). Furthermore, a design that satisfies the independence axiom is inherently stable. Otherwise, it violates the independence axiom and thus becomes unstable. Uncoupled and decoupled design respect the independence axiom whereas coupled design violates it. It is observed from the design matrices of this platform that all design axioms were either uncoupled (majority of them) and decoupled. That makes the design stable.

4.5 Key technologies and the process variables

The design of this platform is similar to a design of a system using axiomatic design. Aside AD which is used as a main design methodology, there are some additional technologies that were considered. For simplicity, quickness and licensing issues, only open-source software (OSS) or applications were used.

The implementation happens in the process domain of axiomatic design process. According to Suh (2001: 10–11), a process characterized by process variable (PV) in the process domain is used to produce the product specified in the DPs.

4.5.1 Open-source applications (OSS) as key technology

One limitation of this design is that it is not supposed to be designed from scratches. It is based entirely on open-sources applications. According to Laurent, open-source software (OSS) is a kind of software or computer application which “source code is released under a license in which the copyright holder grants users the rights to study, change, and distribute the software to anyone and for any purpose” (Laurent, 2004). For easy and fast design of the platform, the main technology adopted is *WordPress*, which is a content management system (CMS) platform. In 2012, *WordPress* is used by more than sixty million websites (Coalo, 2012: 11–21). This type of CMS makes it easy for any user with little IT background to manage and add contents to the portal. Secondly, because *WordPress* include plugin architecture and template system, it was instrumental in using already made plunging that addresses the needs of the platform.

4.5.2 Open-source application licensing

A contributor to an open-source project does so under a clearly defined license. An example of such a license is the Apache Contributor License Agreement. This license is used for *Apache.org* project (Apache Software Foundation, 2019). This type of license and any free-software license grants the user an extensive right to modify and redistribute that software. It applies to the source code as well as the binary object-code form of the software because the copyright law recognizes both forms (Terry, 2019). Basing the

design on this type of technology made it possible for any SME to use it without paying any license fee. The only cost they may incur is the setup fee.

5 DESIGN CONCEPT OF THE PLATFORM

This chapter focuses on the design concept of the whole design. It shows various steps taken from collecting the customer need to the implementation of the final product. It also shows what happens in the various AD domains

5.1 Design problem

Dorst define design problem as “underdetermined problems” (Dorst, 2003: 135–147). The goal was to identify and clarify the problems the customer (SMEs) was facing in order to know how to address them. The journey, therefore, started by collecting data from the SMEs by means of interviews. Upon analyzing them, it was possible to identify their needs and challenges. This process takes place in the customer domain. The major problems are decomposed into sub-problems in order to better understand them.

5.2 Platform Development process

The main methodology used to develop the platform was the Axiomatic design theory. It was coupled with a qualitative research method. By means of AD design approach, the needs of the SMEs were clearly and concisely established. They were later transformed into functional requirements (*FR*) in the functional domain. However, there were some constraints associated with the whole design. These constraints guided in mapping the *FRs* into design parameters (*DP*) in the physical domain. The top level *FRs* constituted the top-level module that determined the main modules of the platform design. It was not possible though to have the desired parameters for the final design from the top-level *FRs*. For that reason, a decomposition and zigzagging method was used to decompose further the *FRs* and *DPs*. The final design for this system needed to be good and respect the axiom rule of AD. These rules are set by the independence and information axioms. A close look at the design matrices showed that all the design functions were either decoupled or uncoupled. The information content was also limited and straightforward. The independence and information axioms were therefore, not violated. Subsequently, the inter-firm e-collaboration platform design was controllable, valid and stable.

From the above development process, the following design concept is proposed.

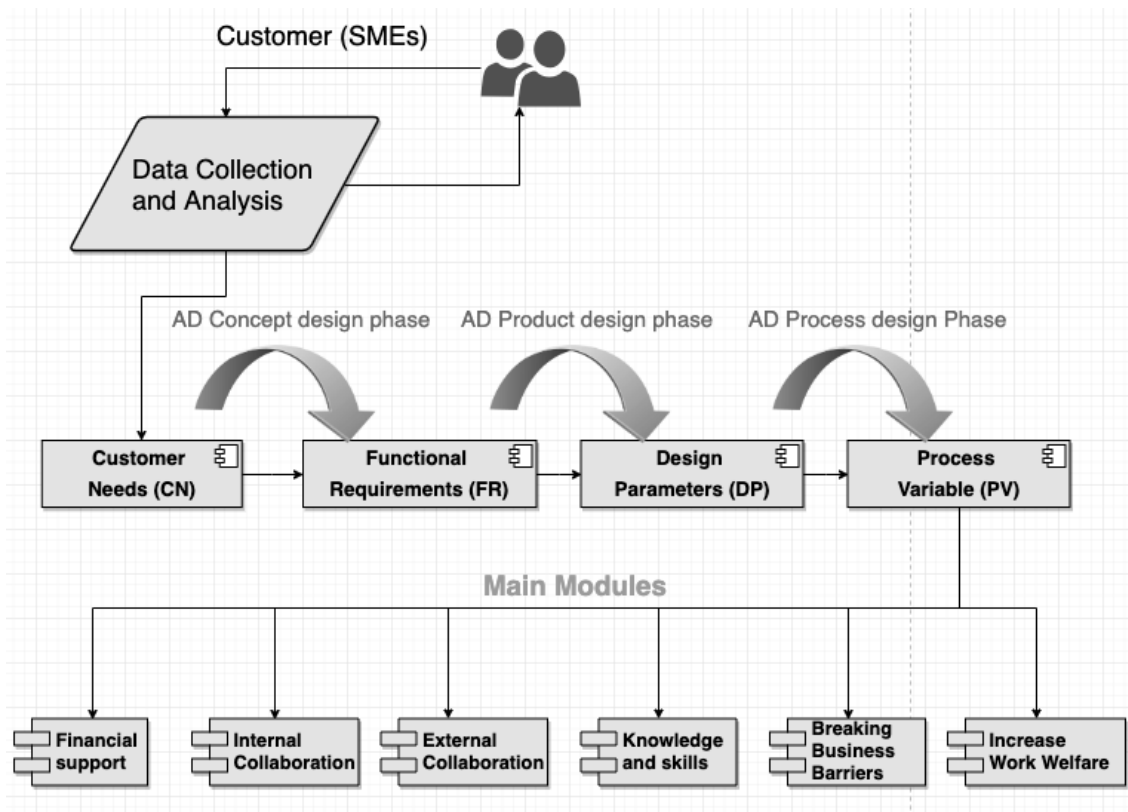


Figure 19. Concept design for the e-collaboration platform

This concept gives a clear overview of the AD domains and the main modules of the platform.

5.3 Platform design steps

Different designs were made and proposed to the project team for assessment and improvement. The **Figure 20** shows the mock-up design.

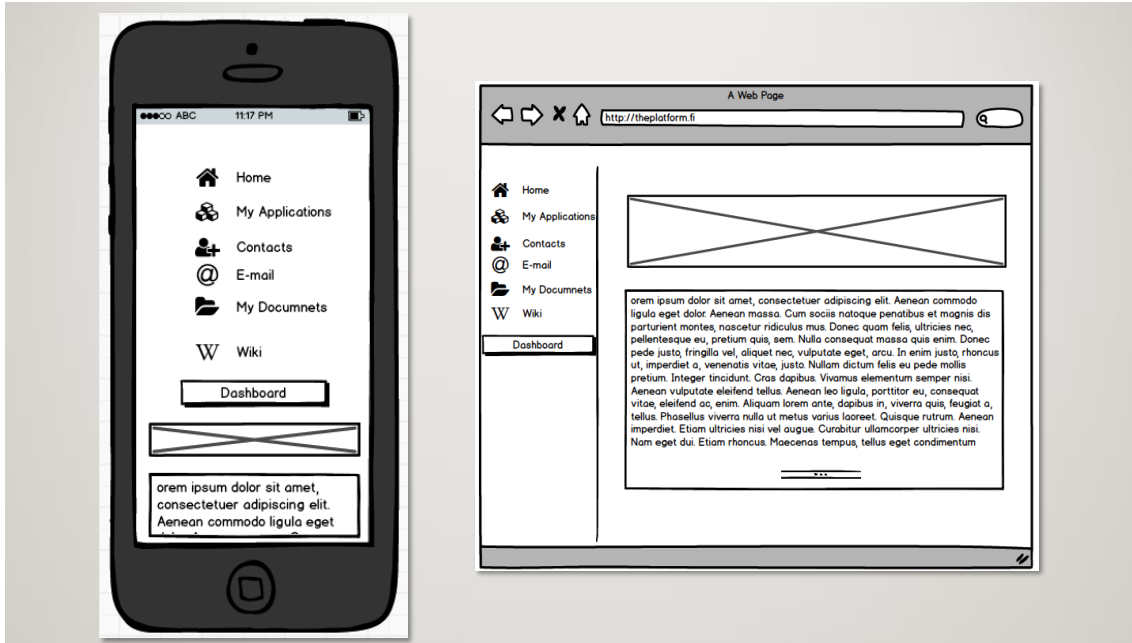



Figure 20. Mock-up for the e-collaboration platform

Based on that mock-up, the first design is made as seen in the figure 21 below. Upon receiving feedback and analyzing carefully the design parameters, the first design was modified to the final design seen in the **Figure 22**.

PISKU PLATFORM

Welcome to our Collaboration platform

Dashboard
ERP Subscription
↓



- Login
- Chat
- Webmail
- Calendar

- ✓ **Financial Support**
- Accounting
- Financial Links


- ✓ **collaboration and interaction**
- Chat
- Video
- Document
- Project management
- Cloud

- ✓ **Connection and Network**
- Social Media
- CRM
- Calendar

- ✓ **Communication**
- Chat
- CRM
- Email

ACTIVITY STREAM

This a Collaboration platform ...



Project Progress

50%

Sales indicator

87%

- ✓ **Knowledge and skills**
- Wikis and knowledge bank
- Training Portal
- Feedback

- ✓ **Breaking Business Barriers**
- Business Wikis
- Business Contact list

- ✓ **Work welfare**
- Welfare Wikis
- News

This is an Alert ×

Alert description.

▶ **My Task**

▶ **To do List**

News ×

Alert description.

Figure 21. First design of the e-collaboration platform

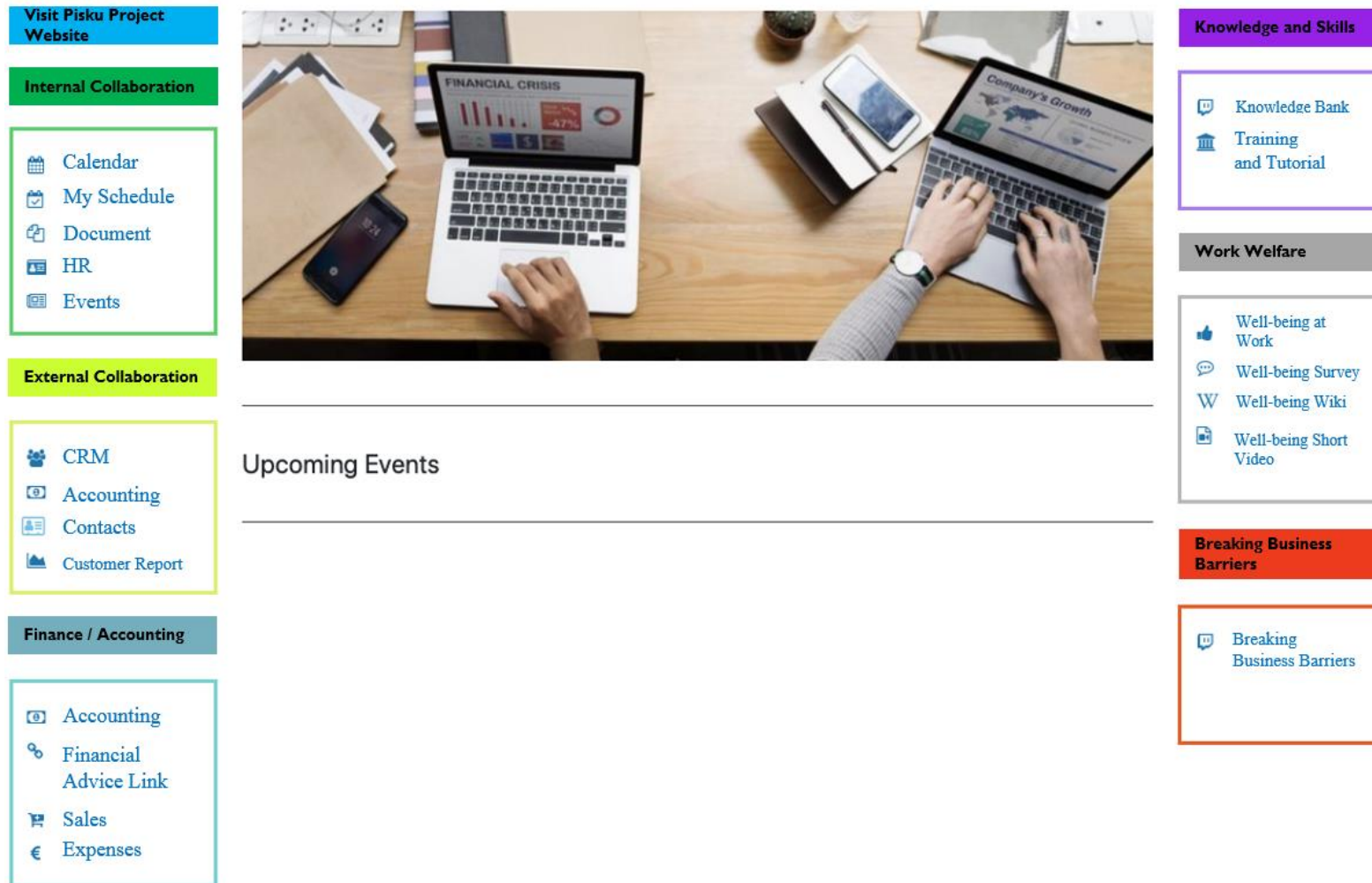


Figure 22. Front office dashboard of inter-firm e-collaboration platform (desktop view) - final design

The platform was designed using the Responsive Web Design (RWB) approach. According to w3schools official website, a responsive web design is about using computer language to automatically “resize, hide, shrink, or enlarge, a website, to make it appear good” on desktops and mobile devices (tablets, and phones) (w3schools, 2019). Aside the desktop view (**Figure 22**), the tablet and mobile view are also shown below:

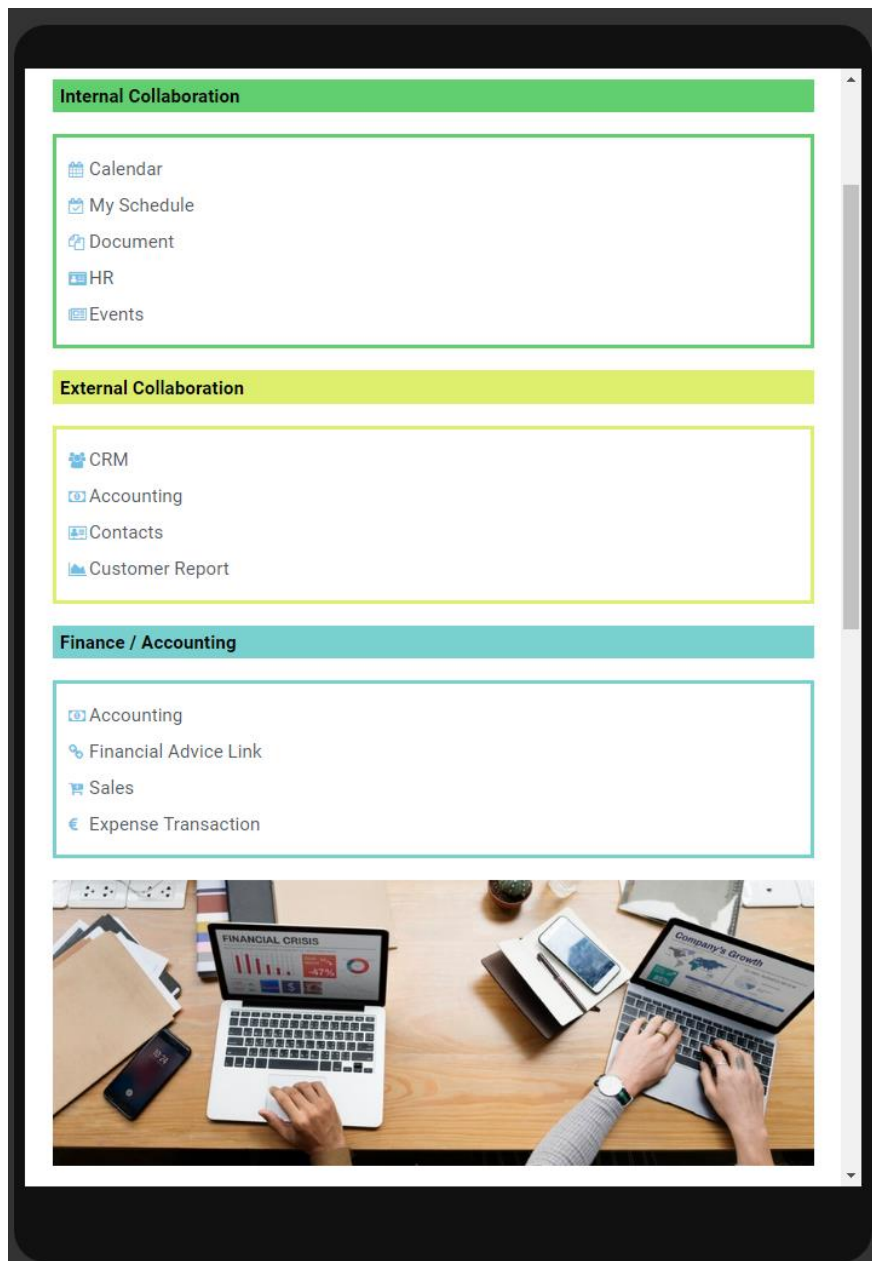


Figure 23. Front office dashboard of inter-firm e-collaboration platform (tablet view)

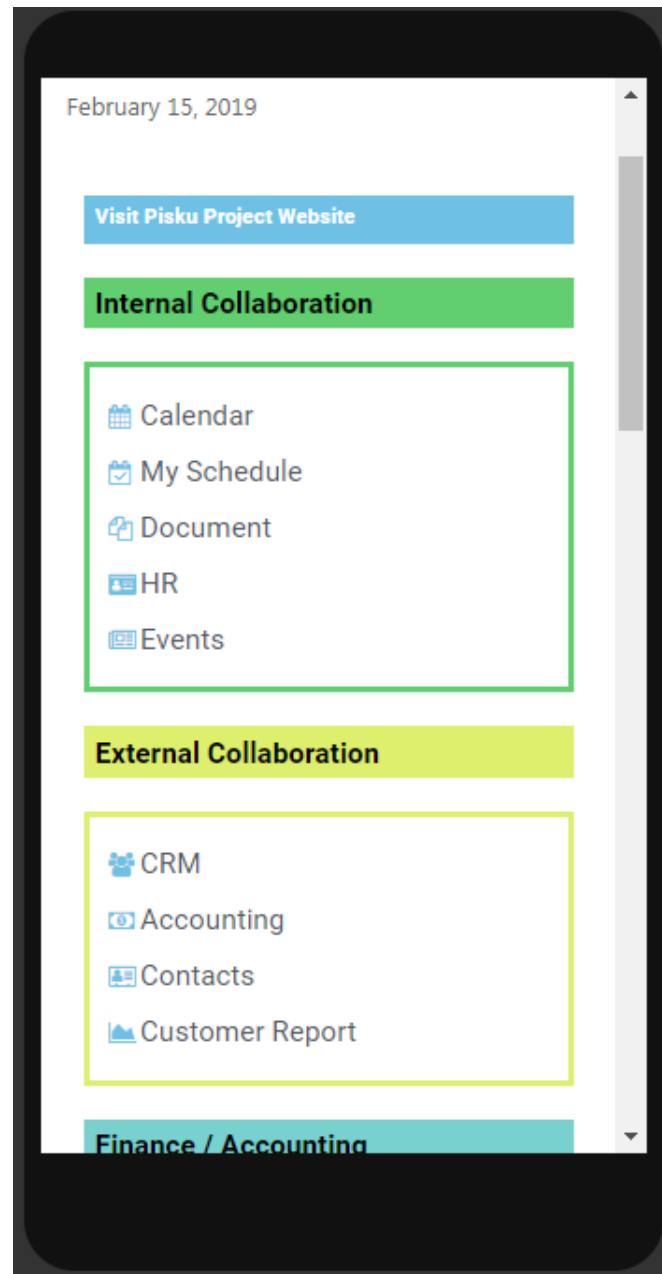


Figure 24. Front office dashboard of inter-firm e-collaboration platform (mobile view)

The idea behind the whole design is to have a portal that is easy to use and not crowded with so many information. Its interface need to clear and clean. The six modules representing the major needs should be clearly identifiable. For that reason, the final design looks simple and easy to use. Six different colors are used to represent each module.

5.4 Unified modelling language (UML) diagram for the Project

A Unified modelling language (UML) diagram for the Pisku project is drawn to show all stakeholders of this project and the final deliverables. The four Universities and the SMEs they have collaborated with throughout the project are seen on the diagram. Once again, the six Modules of the platform are also listed to better understand the whole process from the beginning up to the end.

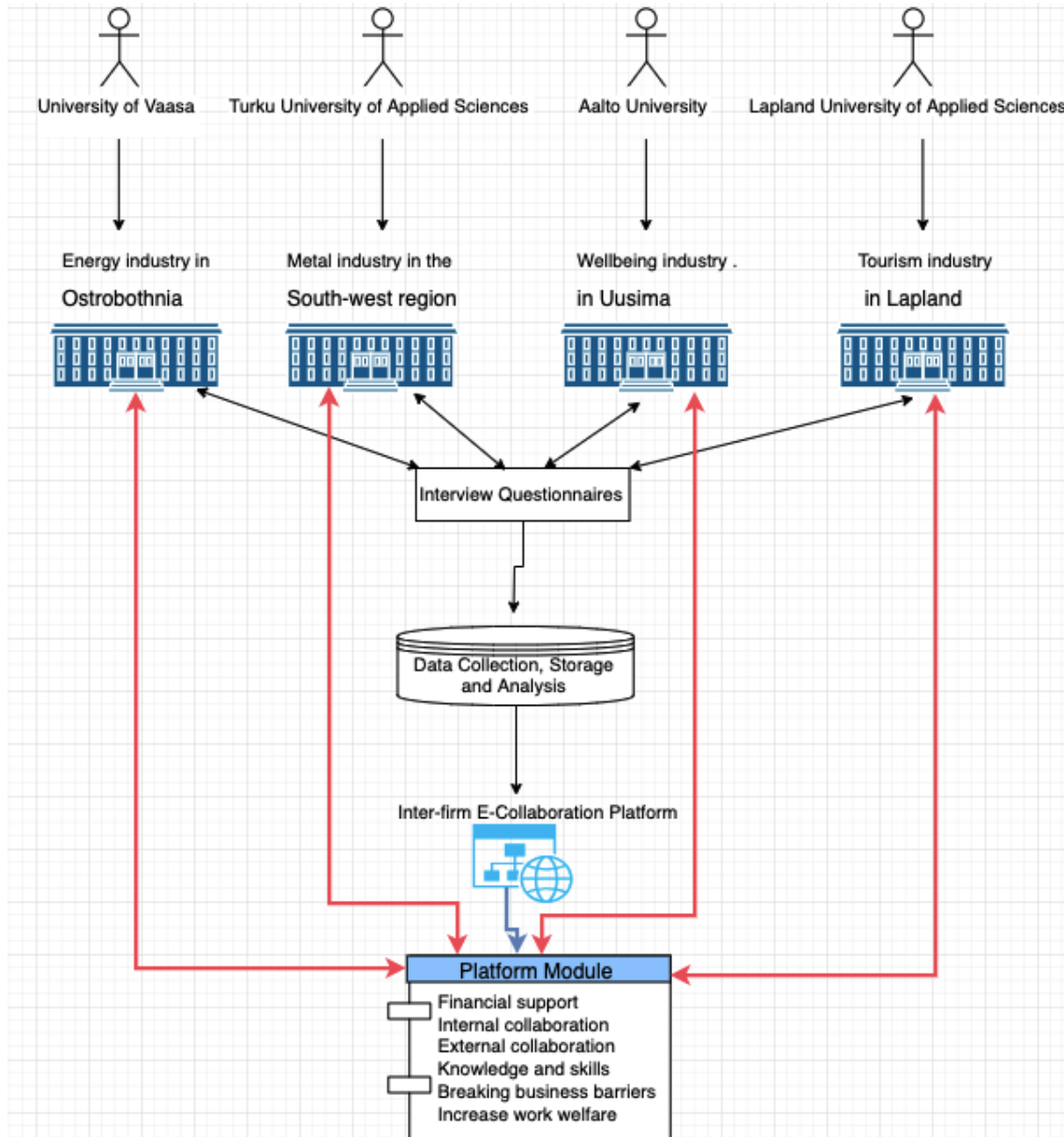


Figure 25. UML diagram for the Pisku project and the e-collaboration Platform

6 DISCUSSION AND CONCLUSION

This last part of thesis summarizes the whole thesis. It discusses the findings, draw conclusions and make recommendation for future researches.

6.1 Summary

The theoretical part of this research shed light on how SMEs are key players in the EU economy. The effect of globalization coupled with digitalization create a challenging yet interesting business environment for firms including SMEs. In order to survive they need to adapt and adopt new Information and Communication Technology (ICT) tools available. The literature review part made it clear that a competitive approach to sustain growth and remain competitive is to engage resources in inter-firm collaboration. However, a successful collaboration with external partners carry more weight if it starts from within the firm itself, thus the intra-firm collaboration. Although there are so many collaboration platforms, this thesis focuses only on the electronic or digital inter-firm collaboration platform, which can fit well into the industry 4.0 and Enterprise 3.0 era. An AD design theory was used to identify the needs of the SMEs and to build a platform that addresses them.

6.2 Discussion and limitations

There are limited literatures on axiomatic design. However, Suh argue that AD theory is applicable to different kind of systems (Suh N.-P. , 1998). According to him, one goal of AD is to reduce the complexity of systems been designed by making the appropriate and good decision at all levels. The design of an online collaboration platform is close to the design of a software system. That is why the AD theory related to a software system designed was used for this project.

Another aspect that needs further consideration is the type and size of SMEs involved in the project. The EU commission categorizes SMEs in 3 groups (**Figure. 1**) such as medium-sized (staff headcount < 250 and turnover \leq €50m), small (staff headcount < 50 and turnover \leq € 10m) and micro (staff headcount < 250 and turnover \leq € 2m)

(European Commission, 2019). The needs for these different type of SMEs may vary according to their size and financial status. For that reason, the main needs derived from the analysis of the interview question may not represent each of them accurately. The big picture drawn from this research may forgo and ignore specific issues. Additionally, these firms come from four different sectors and regions in Finland. The organizational and networking need for an SME in the energy sector may be different from the one in Hotel businesses.

A *User Evaluation survey* (see Appendices 1 and 2) was designed. Its purposed was to get the user experience from the SMEs and any other user in order to improve the platform. Although the questions for the survey were available in Finnish and English, it was not possible to get replies from SMEs at the time this thesis was written.

6.3 Key Recommendations for further research

In view of issues discussed above, there are some recommendation for future re-searches. First and foremost, there should be a cross case analysis of the SMEs regarding a collaboration platform. This should be based on two criteria:

- *Industry or business sector*
- *Size of the SME*

Secondly, a user evaluation survey needs to be made so that the SMEs been interviewed can express their opinions and views as to the usefulness of the platform. It will also be important to evaluate the user journey and user experience of those who will test and use the platform.

Thirdly, it will be interesting to study how this type of e-collaboration platform could be used by intermediary organizations and traditional non-electronic collaboration platform to serve their clients better.

6.4 Conclusion

Collaboration in general and inter-firm e-collaboration platform in particular is a complex and broad topic to study. It is obvious that the digitalization of business processes though challenging can be a push to shift from the old and traditional way to collaborate and

network to a more innovative way. If it is true that collaboration benefit firms and organizations, it is vital for SMEs because it gives them tools and opportunities to overcome challenges when competing in unpredictable and difficult business jungle.

Though there are limited literature about digital inter-firm collaboration when it comes to SMEs, this study strived to shed more light on this issue and gives broad understanding on how SMEs can collaborate.

The empirical part of the study by means of a questionnaire has helped to map out the challenges and needs SMEs have in general, especially when they want to embark in the journey of collaboration.

Using the Axiomatic design theory in identifying the needs of the customer (SMEs), and developing functional requirements and finally mapping this requirement into design parameter was rewarding. It helped to simplify a complex system design into an easily understandable system.

However, collaboration between companies will still require more research in the future. It will also be good to make SMEs cross analysis study regarding their size in one hand and their field of business in the other hand.

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APPENDIX 1. User Evaluation for the Pisku inter-firm collaboration platform in English

Thank you for participating in the Pisku Inter-firm Collaboration Platform / Website for Small and Medium Size Enterprises User Evaluation survey.

The objective of this online Collaboration platform is to respond to NEEDS expressed by 35 Small and Medium size Enterprises in Finland. Some of these needs are: Financial support, Internal collaboration, External collaboration, acquiring knowledge and skills, been able to break business barriers, Increasing work welfare. The Platform is a collaboration and communication tools. It serves as a work-space to manage projects, documents and activities. Customer Management, accounting and human resources management activities can also be handled from this platform.

This survey asks you about your opinion as a user to how easy it is to browse, read and find information on the website. You are also asked to check if the contents of the website are reliable and load quickly.

We will like to hear your feedback so we can keep improving our website. Please fill this quick survey and let us know your thoughts (your answers will be anonymous).

Website Details

Website: <http://piskuplatform.voguebiz.com/>

Username: demo

Password: Pisku1,2

1. Occupation *

Mark only one oval.

- Employer
- Student
- Other: _____

2. 1. Overall, how well does our website meet your needs?

Mark only one oval.

	1	2	3	4	5	
Not very	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very much

3. 2. Specify to what extent is the Web site's content legible (readable) for you?

Mark only one oval.

	1	2	3	4	5	
Not very	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very much

4. 3. Specify the degree to which you find the Web site's navigation simple and comprehensible?

Mark only one oval.

1	2	3	4	5	
Not very	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very much

5. 4. Did it take you more or less time than you expected to find what you were looking for on our website?

Mark only one oval.

1	2	3	4	5	
A lot less time	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	A lot more time

6. 5. How visually appealing is our website?

Mark only one oval.

1	2	3	4	5	
Not at all	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Extremely Appealing

7. 6. Evaluate the speed by which the Web site's elements are loaded

Mark only one oval.

1	2	3	4	5	
Not at all quickly	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Extremely quickly

8. 7. How easy is it to understand the information on our website?

Mark only one oval.

1	2	3	4	5	
Not at all easy	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Extremely easy

9. 8. How much do you trust the information on Website?

Mark only one oval.

1	2	3	4	5	
Not at all	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Very much

10. 9. How likely is it that you would recommend our website to a friend or colleague?

Mark only one oval.

1	2	3	4	5	6	7	8	9	10	
Not at all likely	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Extremely Likely

11. 10. Do you have any other comments about how we can improve our website?

12. 11. Any overall feedback for the Website?

13. Name (optional)

APPENDIX 2. User Evaluation for the Pisku Inter-firm Collaboration Platform in English

Kiitos, että osallistut Pisku Inter-firm Collaboration Platform in / verkkosivustoon pienten ja keskisuurten yritysten käyttäjäkyselyyn.

Tämän online-yhteistyön alustan tavoitteena on vastata 35 pienen ja keskisuuren yrityksen esittämiin tarpeisiin. Jotkin näistä tarpeista ovat: Taloudellinen tuki, Sisäinen yhteistyö, Ulkoinen yhteistyö, Tietämyksen ja taitojen hankkiminen, Kykenevä rikkomaan liiketoiminnan esteet, Työn hyvinvoinnin lisääminen. Järjestelmä on yhteistyö- ja viestintävälineitä. Se toimii työtilana hankkeiden, asiakirjojen ja toimintojen hallintaan. Asiakasjohtamista, kirjanpitoa ja henkilöstöhallintoa voidaan hoitaa myös tästä alustasta. Haluamme kuulla palautteesi, jotta voimme jatkaa verkkosivustomme parantamista. Täytä tämä nopea kysely ja kerro meille ajatuksesi (vastauksesi ovat nimettömiä).

* Required

5. Kestääkö sinä enemmän tai vähemmän aikaa kuin odotit, mitä löysit sivuillamme?
Mark only one oval.

	1	2	3	4	5	
Paljon vähemmän aikaa	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Paljon enemmän aikaa

6. Miten visuaalisesti houkutteleva on sivustomme?
Mark only one oval.

	1	2	3	4	5	
Ei lainkaan	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Erittäin houkutteleva

7. Arvioi nopeus, jolla Web-sivuston elementit ladataan
Mark only one oval.

	1	2	3	4	5	
Ei lainkaan nopeasti	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Erittäin nopeasti

8. Kuinka helppoa on ymmärtää verkkosivuillamme olevat tiedot?
Mark only one oval.

	1	2	3	4	5	
Ei lainkaan helppoa	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Erittäin helppo

9. Kuinka paljon luotat verkkosivuston tietoihin?
Mark only one oval.

	1	2	3	4	5	
Ei lainkaan	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Erittäin houkutteleva

10. Kuinka todennäköistä on, että suosittelisitte verkkosivustomme ystävälle tai kollegalle?
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Ei lainkaan todennäköistä	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Erittäin todennäköistä

11. Onko sinulla muita kommentteja siitä, miten voimme parantaa verkkosivustoa?

12. Kaikki sivuston palautteet?

13. Nimi (valinnainen)

Powered by
 Google Forms

APPENDIX 3. Back end view of the platform's Dashboard

Hey, I noticed you created a contact form with WPForms - that's awesome! Could you please do me a BIG favor and give it a 5-star rating on WordPress to help us spread the word and boost our motivation?

~ Syed Balkhi
Co-Founder of WPForms

[Ok, you deserve it](#)
[Nope, maybe later](#)
[I already did](#)

TranslatePress data update - We need to update your translations database to the latest version.

[Run the updater](#)

Overview

Latest Announcement

View All

Team meeting

HR

Visit Dashboard

1 Employees	7 Departments	2 Designations
View Employees	View Departments	View Designations

CRM

Visit Dashboard

500 Contacts	0 Companies
Customers: 500	Customers: 0
Leads: 0	Leads: 0
Opportunities: 0	Opportunities: 0
Subscribers: 0	Subscribers: 0
View all Contacts	View all Companies

Accounting

Visit Dashboard

Cash & Bank Balance	
Petty Cash	€0.00
Savings Account	€0.00
Total	€0.00
Revenues	
Income	€0.00
Expense	€0.00
Revenues	€0.00

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