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Development of Cable Distribution Cabinets by utilizing digital technology and connected devices

Investigation of future opportunities and implementation of IoT in the low voltage power grid

Master's thesis in Master Programme Product Development

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Gothenburg, Sweden 2017

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Abstract

ABB has been established as one of the drivers of digitalization in power and automation for many years. ABB continue to advance digital industry through their concept of the Internet of Things, Services and People (IoTSP). ABB's business unit in Alingsås, Sweden, (ABB - Kabeldon) develop and manufacture electrical distribution products for the low voltage power grid. To push for advancements in the area of IoTPS, the aim of of the thesis project is to conduct an exploratory investigation about the future opportunities for ABB - Kabeldon's Cable Distribution Cabinet (CDC) by implementing digital technology and connected devices, to either increase value for current customers, or open up for new markets.

This thesis project is the first initiative for ABB - Kabeldon towards advancements in the area of IoTSP, which creates significant challenges due to a high degree of uncertainty and non existing in-house knowledge or information regarding the subject. The process used to handle this high level of fuzziness is divided into three main phases, where methods and tools for each phase is almost entirely conducted in a qualitative manner.

Product and market study - is used to gain knowledge and understanding of the current product, its' market and IoT related technologies and trends. Resulting hypothesis: The geographical placement of the CDCs' in relation to the population and access to electricity makes the CDC ideal as a station for observing and communicating information with the surrounding people and devices.
Opportunity identification - Generation and screening is conducted mainly through workshops with internal and external stakeholders. The most important finding from this phase is that there is no justifiable need for direct implementation of IoT related functionality into the CDC. But there is a substantial need for a foundation/system/product to facilitate the expansion of the IoT ecosystem in urban environments. The CDC can act as an enabler of such due to its geographical placement, constant access to electricity and commonly fibre internet connectivity.
Product service system (PSS) solution identification - is used for further problem breakdown to facilitate for both how to understand the physical product and its services. The results from this phase indicates a high level of complexity and uncertainty, both of the PSS-layout and technology implementation. But, the complexity level and identified risks can be significantly reduced by sequential development.

The final product recommended is a, so called, Data Distribution Cabinet (DDC), that can act as a platform/foundation in the predicted IoT ecosystem of the future. The DDC should be developed in sequential manner, where the first two steps (A,B) considers the explicit needs of today, whilst the third and fourth concepts (C,D) considers the predicted future needs. By structuring the development in this manner, knowledge could be gained by observing how the customers use the DDC, and use that as input for the next step in development, this to decrease the uncertainty of the future.

Keywords: ABB, Low Voltage Power grid, Cable Distribution Cabinet, DDC, IoT, IoTPS, Digitalization, Infrastructure, Connected devices, CDC, Data Distribution Cabinet.

Acknowledgements

When ABB in early January asked us why we should get the position as thesis workers, we thought, why so serious? And answered, "That's right, we know nothing about IoT or connected devices, but we are eager to learn and take on the problem!", which was an offer they could not refuse.

This learning, and the thesis as a whole has been dependant on the knowledge and input from several persons and organizations, and we would like to give them a sincere thanks for sharing their expertise.

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List of abbreviations

CDC - Cable Distribution Cabinet
IVL - The Swedish Environmental Institute
MVP - Minimum Viable Product
GFRP - Glass Fibre Reinforced Plastics
ABB - Asea Brown Boveri
IoT - Internet of Things
IIoT - Industrial Internet of Things
SDC - Special Distribution Cabinet
DFA - Design For Assembly
DFM - Design For Manufacturing
PIC - Product Innovation Charter
DDC - Data Distribution Cabinet
API - Application Programming Interface

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Introduction

1.1 Background

ABB is a Swedish-Swiss multinational corporation with its core business in power and automation technologies. With a revenue of US$33.828 billion it is ranked as the 286th largest company in the Fortune Global 500 list (2016). ABB employs approximately 132.000 people in around 100 different countries (December 2016). ABB's operations is organized in four global divisions:

Power Grids - Technology offerings within transformation, distribution and automation for the high voltage power grid.

Electrification Products - Technology offering across the full electrical value chain from substation to the point of consumption (low- and medium voltage electrical products).

Robotics and Motion - Provides products and services for industrial production (electric motors, generators, drives, power electronics and industrial robots).

Industrial Automation - Offers technology and service solutions for instrumentation, automation and optimization of industrial processes.

Each global division is made up of specific business units focused on particular industries and product categories. This thesis project is set off by one of these specific units, namely ABB - Kabeldon situated in Alingsås, Sweden. The name Kabeldon comes from the acquisition of Kabeldon AB in 1995. The official name for the site in Alingsås do not include Kabeldon, but due to the fact that Kabeldon is still a well known brand on the market ABB in Alingsås is still known as ABB - Kabeldon. In this thesis report ABB refers to ABB Group and ABB - Kabeldon to ABB in Alingsås. The tree-diagram in figure 1.1 shows ABB - Kabeldon's place in ABB's organization. ABB - Kabeldon are developing and manufacturing enclosures, busbars and fuse-gear for low voltage distribution boards and Cable Distribution Cabinets (CDC, see section 4.2.2). ('About ABB', 2017)

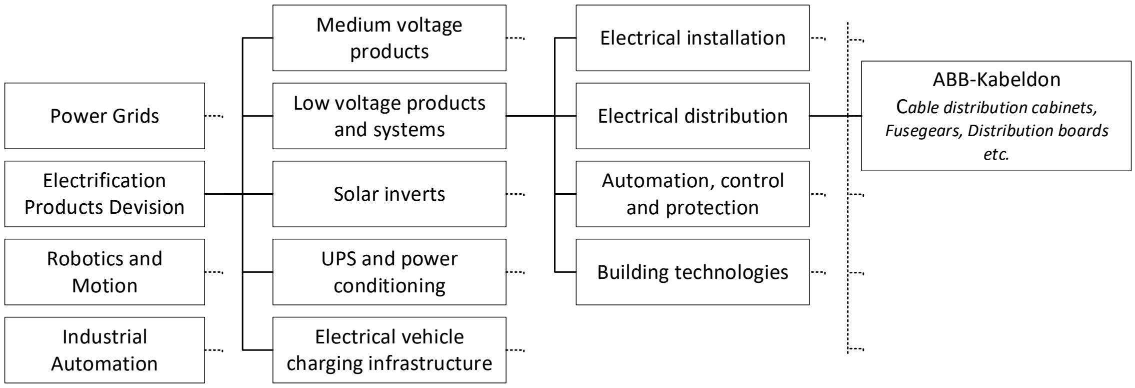

Figure 1.1: ABB - Kabeldon's place in ABB's organization.

ABB has been established as one of the drivers of digitalization in power and automation for many years. ABB continue to advance digital industry through their concept of the Internet of Things, Services and People (IoTSP). Exchanging data by utilizing the Internet as an open platform paves the way for a wide range of applications that optimize and improve the flexibility and productivity of industrial and power processes ('Internet of Things, Services and People at ABB', 2017).

The Internet of Things (IoT) is the internetworking of physical/virtual sensors and devices (things) embedded with digital technology, software and network connectivity enabling communication between such (collect and exchange data) (Vermesan & Friess, 2013). IoT-GSI, Global Standards Initiative on Internet of Things defined it as: "the global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies" (Union, 2014). ABB extends the IoT concept with services and people. IoT enables new service models on system level related to e.g. high resolution data (big data) analytics, preemptive diagnostics and predictive maintenance. The people aspect is based on the fact that people will always be a crucial part of the big picture, they will remain decision makers and be the ones programming and controlling processes and activities performed by things ('Internet of Things, Services and People at ABB', 2017).

To push for advancements in the area of IoTPS ABB's global strategy involves exhortations to the specific business units to invest R&D resources in IoTSP projects. Proven R&D efforts towards digitalization can lead to positive effects in terms of increased R&D budget.

ABB - Kabeldon has, as of today, no product offerings related to IoTSP. This thesis project is the first step related to ABB's global IoTSP strategy. The thesis group are set of to investigate how their Cable distribution cabinet (CDC) can be used in the future and possibilities of digital technology integration and IoTSP.

1.2 Purpose and research questions

The purpose of this project is to investigate the future opportunities for the CDCs', both their current customers and possible new customers and markets. Digital technology and connected devices are to be utilized to either improve current functions, or create opportunities for new ones, this to stay in line with ABBs' strategy related to IoTSP.

Research question;

How can an implementation of digital technology and connected devices in the CDC increase value for current or potential new customers?

1.3 Aim

The aim is to identify if the current cabinets can utilize digital technology and connected devices to increase customer value for current customers or facilitate functionality for expansion to new customers.

1.3.1 Deliverables

The deliverables from this thesis is this report, that proposes a future development strategy together with an illustration in the form of a Minimum Viable Product.

1.3.2 Clarification of the scope

Today ABB - Kabeldon's CDCs' are only connected via the electrical power grid. For the past fifty years the development of the CDC have mainly been focused on safety, usability and manufacturability aspects, functionality wise there is not that much of a change. Their function is to house fuses, receive electrical energy from one or more supplies and distribute through one or more cables to other equipment. See section 4.2.2 for more information about the functionality of the CDC. ABB - Kabeldon wants to investigate what the future holds for these cabinets, both regarding function, integration of digital technology and IoTSP, based on their customers current needs and potential future needs.

1.4 Delimitations

The following list will clarify the delimitations for the thesis and the work conducted;

- The thesis will focus on ABB - Kabeldon's CDC
- Market information will only be gathered from the Nordic countries
- Interviews and workshops will be conducted in close proximity to Gothenburg
- Deadline of the project for ABB - Kabeldon is 20170616

- Most market data will be gathered from larger cities to enhance time-efficiency during data collection
- New functionality must be related to digital technology and connected devices
- Technology will not be assessed in depth, only in general for chosen applications

1.5 Disposition

Since the thesis is an exploratory research, the structure of the report is some what different compared to a regular research thesis. This is due to the uncertainty of the findings along the way, that leads to change in focus and areas of exploration, see table 1.1 for the structure of the report.

Table 1.1: Disposition of the report

Chapter	Content
2 **Theoretical Framework**	The underlying theory regarding both technology and methodology is presented to give a soild base for further reading.Technology theory is presented in general terms to emphesis understanding regarding IoT. Concept specific technology theory is presented in the identification chapters.
3 **Method**	Presents how theories and methodologies is combined and used to provide a exploratory reserach and development framework adapted for this thesis.
4 **Product and Market Study**	The current CDC and its' surrounding systems (low voltage power grid) are described and investigated, in parallel to a technology analysis and forecast about IoT and its' future. These investigations are then analyzed for synergies and combined into a hypothesis to act as a base in the next chapter, about opportunity identification.
5 **Opportunity Identification**	The hypothesis from the previous chapter are combined with the ABBs' strategy, goals and guidelines to act as a framework for generation of opportunities. Opportunities are generated (internally at ABB - Kabeldon and externally) and screened through results from workshops and literature studies. The chosen opportunity are presented as a Minimum Viable Product (MVP) and possible stakeholders are identified and analyzed. Findings are compiled in a mission statement.
6 **PSS Solution Identification**	The mission statement from previous chapter is used as input for further generation of alternatives regarding how to structure the opportunity. The opportunity is divided into smaller "chunks" with the aid of Product Service System, to better understand and map possible stakeholders, as well as understanding the ingoing technology and development efforts required. Cost assessments and other necessary assessments is conducted to act as a base for understanding and evaluation of concepts.
7 **Result**	The result of the exploratory research, e.i concepts and learnings about the CDC, IoT, combination of such and PSS are summarized and presented as a Minmial Viable Product.
8 **Test and Validation**	To assess how ABB would utilize the findings from this thesis, they where tested against personnel from ABB - Kabeldon to start a discussion about how to take the findings further, and what problems that could occur in doing so.
9 **Discussion**	The fulfillment of purpose and research question is discussed in combination with critical reflections regarding methodology and results.
10 **Conclusion and recommendations**	The proposed concept's development plan are presented together with possible organizational problems that might occur when traditional manufacturers are moving to a more customer focused approach.

2
Theoretical framework

Theory of a number methods and technologies are introduced below.

2.1 SWOT

SWOT is a method for assessing a product/service Strengths, Weaknesses, Opportunities and Threats. Results from such analysis could give a hint on where focus should be later in the development process and what challenges and possibilities lay ahead. A good preparatory method for understanding and mapping the current status for a product or service (Maylor, 2010).

2.2 PESTEL

PESTEL-analysis is a method used for assessing the interaction between a product/service and its' surroundings. It is conducted by analyzing; Political, Economical, Socio-cultural, Technological, Environmental and Legal aspects. The tool facilitates understanding and decision making with regards to the different aspect. It could also, just like the SWOT-analysis (see 2.1) give hints about threats and opportunities that lay ahead, hence giving a base for prioritizing development and decision making (Maylor, 2010).

2.3 Competitor Benchmarking

This method is a tool to gain an understanding of competitive products, their market and how products compare to each other in different aspects. The method is in this project mainly used for the reason of understanding as well as future opportunities (Maylor, 2010).

2.4 Opportunity identification process

In the concept of product development an opportunity can take many shapes. In general it can be thought of as a hypothesis about how value might be created. Based on the teams' current state of knowledge about the need and solution related to the opportunity Ulrich and Eppinger (Eppinger & Ulrich, 2015) presents a way to categorize the opportunity, see figure 2.1.

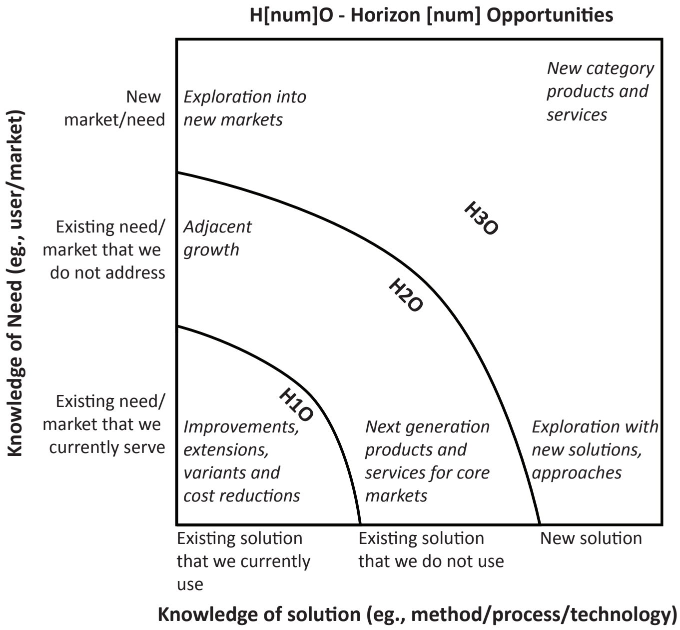

Figure 2.1: Illustration of categorization depending on level of uncertainty of need and solution following (Eppinger & Ulrich, 2015).

The *"Opportunity identification process"*(Eppinger & Ulrich, 2015) presents a structured way of generating and screening opportunities.
The six-step structure of the opportunity identification process:

1. Establish a charter
2. Generate and sense many opportunities.
3. Screen opportunities.
4. Develop promising opportunities.
5. Select exceptional opportunities.
6. Reflect on the results and the process.

In the first step a Product Innovation Charter (PIC) is created. PIC is a method for how to plan development work with regards to several critical aspects. This to ensure that resources are adequate and to avoid "scope-creep" (Maylor, 2010). The typical PIC contains; **Background**, **Focus**, **Goals & Objectives** and **Guidelines**.

Background - The background often contains different types of analyses to assess the environment of the product and organization, this to answer the question what the business is about, and the reasons behind the strategy.

Focus - The focus includes a map of the organizations competences and resources, and how to spend these to derive maximum value of the development effort. The focus is set out to answer questions about core competence, market advantage and customer needs.

Goals & Objectives - Should include both the short and long term targets with the development efforts, preferably in measurable terms.

Guidelines - Should clarify how the target should be achieved, and should be useful for both the persons conducting the work and the senior managers. Basically a map for the coming development efforts.

2.5 Product development process

The opportunity identification and product development are much alike, they both consists of development steps and selection steps. But the overarching goals of the processes are quite different. In the opportunity identification process the goal is to generate a large number of opportunities, evaluate opportunities, kill inferior opportunities and formulate the final opportunity as a mission statement. The product development starts of with the mission statement and hypothesis generated by the opportunity identification process with the goal to assure that the product/service becomes the best it can be (Eppinger & Ulrich, 2015). See figure 2.2 for description of the opportunity identification process followed by what is used in the thesis from the conventional PD-process.

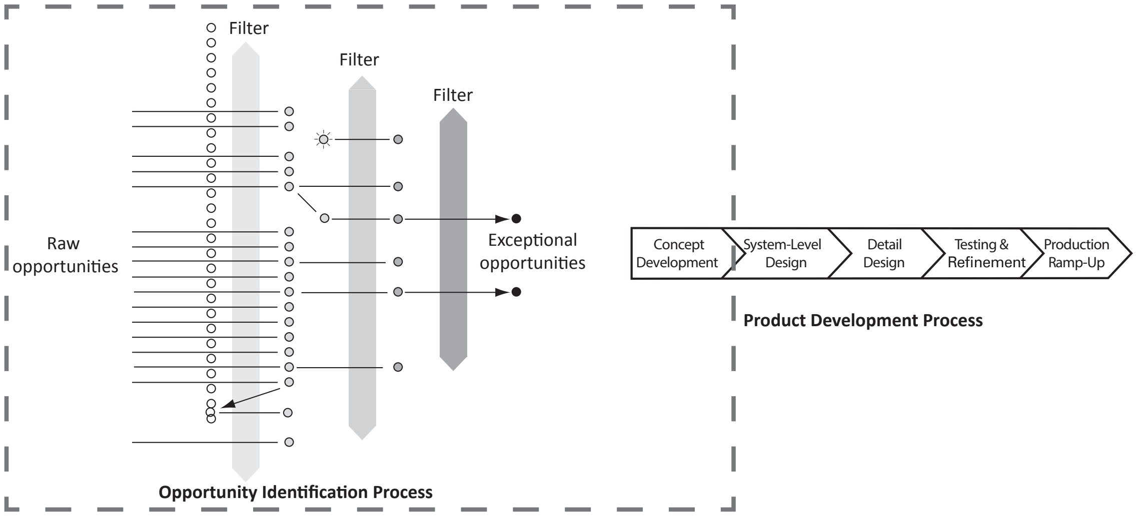

Figure 2.2: Illustration of categorization depending on knowledge of need and solution following (Eppinger & Ulrich, 2015).

The product development process in its' essence consists of five basic steps from concept to production.

The thesis uses the opportunity identification process to formulate a mission statement, to then be used in the first step of the product development process, namely concept generation. The reason for not using the whole product development process is due to the aim of the thesis, to investigate the future possibilities for the CDC in combinations with the trends in IoT. Therefore only the first step in the PD-process is used. This to act as a base for the strategy and future development by ABB - Kabeldon. But all steps in the conventional PD-process are described to facilitate understanding about the process, and how the thesis differs.

Concept development, is the phase where the target is defined and concepts are generated with these targets as guidelines. The concept should describe the function, form and features. Often the concept has some specifications to clarify possible performance to facilitate comparisons to other concepts.

System-level design, is the phase where architecture and links to other systems are defined. How things should work together in combination with the system boundaries. This stage often results in technical specifications (more detailed than in concept development phase), relations among sub-systems and geometrical descriptions of the product.

Detail design, is where the the specifications of all sub-systems, geometry, materials and production related information is included. This enables the planning for production and sourcing proactively. The phase has three critical dimensions which needs to be evaluated; material selection, robust design and production cost.

Testing and refinement, is where physical/virtual prototypes are made and tested. For example, one way of evaluating a video-game is beta-testing, an early version is handed to a selected few (often "early adapters"), that uses the product in their own environment and gives feedback on possible problems/improvements.

Production ramp-up, is where the production is tuned and adjusted to ensure production of the right quality. This often means a great degree of inspection and adjustments to ensure improvements and decrease defects on the products. At the same time, the project are evaluated from a commercial and technical perspective. By doing so, lessons can be learned and facilitate for improvements in the next project.

2.6 Fuzzy front end

The front end of innovation is the introduction of a project, in general it contains opportunity identification and all product development phases before system-level design. Innovation is about the unknown and the opportunity to do something new without knowing if it's going to pay-off in the future. Information tends to be limited in the front end phases, high level of uncertainty and several questions without answers makes the front end "fuzzy" (Gaubinger, Rabl, Swan & Werani, 2015). Success in the front end phases is dependent on innovation value. Although a structured front end processes might seem desirable, there has to be room for creativity to ensure the best possible outcome of the front end phases (Herstatt & Verworn, 2004). Too much structure kills innovation and unstructured work makes it hard to keep track of the teams performance in the front end phases.

One way of handling this trade-off and create a sense of performance measuring is Knowledge Value Stream Mapping. Innovation in the context of product development is about creating something new. The degree of newness can be translated to a knowledge gap that need to be managed in order to realize an opportunity. *"The development process can be viewed in one way as the filling of a gap in knowledge between what is known today and what is a desired future state of knowledge"* (Cedergren, 2011). By defining and document knowledge gaps the team get a good understanding of what they do not know. Closing gaps shows progress in the fuzzy front end even though a promising opportunity or product idea is not yet found.

2.7 Product Service System - PSS

Traditionally, manufacturers provided products, service was something that could be found in a restaurant. The trends of today are that traditional manufacturing companies includes services into their offers to customers. Examples of this change are SKF, whom was and still are producers of bearings. But the difference today compared to a couple of years ago are that they now try to deliver a solution to a problem, more than just sell bearings. Their main product is still the bearing, but they offer their knowledge and other products (such as lubrication etc.) to enhance the performance of the bearings, and increase value for their customers (SKF, 2017). This means that they are involved with the customer from the phase development, implementation, maintenance, updating and sometime changing or recycling the solution. So they now have a more customer-centric rather than product-centric strategy to facilitate all this customer collaboration (Nordin, Brozovic, Kowalkowski & Vilgon, 2015) (Foote, Galbraith, Hope & Miller, 2001).
So the customers view has changed over the years, from ownership to availability. This presents new problems regarding coordination of different development aspects (product and service). Some phases may still require a traditional product development approach, but needs to be complemented by adding more aspects of the systems life cycle to obtain a more holistic view.

To tackle problems with how to structure development and delegate responsibilities a framework presented by (Isaksson, Larsson & Johansson, 2011) will be used.
Four topics needs to be considered:

1. A clear link to the environment the product/service are set to act in.
2. The design of a solution.
3. Integration of development-processes for product and service development.
4. Understanding of the Product Service System.

When defining the system, three aspects needs to be considered, the *User*, the *Provider* and the *Enabler*. The reason for dividing the system is because they often have a different perception of the system, and therefore different needs and capabilities.

- User - Consumer of the PSS
- Provider - The organization responsible for offering the integrated PSS
- Enabler - all the capabilities needed for the realization of the offer

The customer has a need, that need can be satisfied with a solution, and the solution consists of capabilities (hardware, software and service)..

To ease the mapping and planning of the PSS a six-step life-cycle model can be used. See figure 2.1 below for schematic view.

Table 2.1: Six step life-cycle for PSS

Need Phase	Solution Seeking	Solution Development	Solution Realization	Solution Support	Solution Closure

Need phase - Is either where an explicit need is identified, or a technology (that is not yet wide-spread) is used as a solution to identify (predict) a future need.
Input: Often a strategic decision to offer improved functionality to the market.
Output: Identified needs, or an area of opportunity. The output needs to be clearly enough defined so that solution seeking can be facilitated.

Solution seeking - Solution seeking can take many shapes, existing, alternative and sub-solutions that could be beneficial to use. If compared to a “classic” PD approach, this phase would be concept development for example.
Input: Needs from previous phase.
Output: Conceptual solution, including both hardware, software and service.

Solution development - Coordinating development efforts of the PSS components. This phase may include more traditional product development methods to facilitate both the development of hardware and software. Even tough traditional methods are used, it’s of great importance to develop the service in close collaboration with the other efforts.
Input: Conceptual solution from previous phase.
Output: Complete solution (including: hardware, software and service) are offered to customers.

Solution realization - In traditional PD, the realization phase are where the physical manufacturing takes place. But in this case, it’s the actual use phase of the product, where the service and product are both used by the customer.
Input: Offer to customer from previous step.
Output: The actual use of PSS by the customer.

Solution support - This phase is defined by change, either by updates, services and/or new offers, to keep the customer satisfied by maintaining or improving performance in according to their current needs.
Input: The customer using the PSS.
Output: The maintained/changed state/performance of the PSS.

Solution closure - This phase handles the end use like disposal/recycling.
Input: The changed PSS and leanings from the previous phase.
Output: The closed PSS system.

By combining the six-step life-cycle with the three aspects of consideration (User, Provider and Enabler) a more detailed framework is gained. In all phases of the life-cycle, all three aspects needs to be considered, to assess their responsibility and capability in each phase. The market/sales are not included in the basic map, but should be placed in one or more phases, where it's dependant on what area of business the PSS operates in. See table 2.2 for the combined framework (Isaksson et al., 2011).

For this thesis, only the first three phases are used to really understand the developments. The latter phases are for manufacturing and how to keep the system running and dispose of such. The latter three phases will only be touched upon, to "highlight" important aspect of these to have in mind for future development and use of the system.

Table 2.2: Life-cycle combined with the three aspecs of concideration (Isaksson, Larsson & Johansson, 2011)

Need Phase	**Solution Seeking**	**Solution Development**	**Solution Realization**	**Solution Support**	**Solution Closure**
User View	User View	User View	User View	User View	User View
Providers View	Providers View	Providers View	Providers View	Providers View	Providers View
Enablers View	Enablers View	Enablers View	Enablers View	Enablers View	Enablers View

⟵ Marketing/Sales ⟶

2.8 Workshop

A workshop is an interactive meeting between people where all participants gets fully involved in discussions, activities and exercises to create room for creativity to generate and/or evaluate ideas. A topic for discussion is presented and questions are handled as they arise. The method rely on independent judgments of the participants. Typically the group comprises members from the organization, project stakeholders, customers or others with relevant expertise. (Eppinger & Ulrich, 2015)

The advantages of workshops in this thesis is the "openess", since the participants is chosen due to their expertise/knowledge in the area discussed, they are given the chance to steer what is to be discussed, what they think are important from the given topic.

The disadvantage of this approach is the dependency on meetings, since it's time-consuming, both for the research group to find the right persons, prepare the workshop, conduct the workshop and analyze the results. Another disadvantage is bias, this is something that needs to be considered at all times during the workshop, but also after, when the results are analyzed.

2.9 Brainstorming & Brain writing

Brainstorming is a group creativity technique where the goal is to gather a list of spontaneous ideas for a specific problem. The technique originates from the advertisement business where Alex F. Osborn began developing methods for creative problem-solving in 1939. He discovered significant improvements when hosting group-thinking sessions compared with individual employees' creative development (Lehrer, 2012).

Osborn's Brainstorming method have evolved into multiple variations but they still share Osborn's following principles and rules:

- Quantity is key - large number of ideas generates more radical, creative and effective solutions.
- Withhold criticism - focus should be on extending and develop ideas, by suspending judgment and save criticism to a later stage participants will feel more free to present innovative and unusual ideas.
- Encourage wild ideas - to be able to generate a large amount of idea, wild and even "unfeasible" ideas are welcome, this generates "out of the box" thinking and might lead to better solutions.
- Combine and improve ideas - generate additional and better ideas by association and combine parts of different ideas or an entire idea with another. (Osborn, 1963)

Brain writing or "The nominal group technique" is a method to gather and screen ideas anonymously before a brainstorming session. Interactive "group thinking" is not suitable for everyone. Time to think and process given information and problem by oneself prior to the brainstorming session increase the possibilities that everyones' opinion is taken into account. (Delbecq & Van de Ven, 1971)

2.10 Minimum viable product (MVP)

In the product development context, an MVP is an early prototype or an illustration of the product's/service's functionality, used to provide feedback for future development. It is mainly used as a tool to facilitate communication with stakeholders and other persons of interest, both externally (potential customers, suppliers etc.) and internally (project team members, managers etc.). The process of creating an MVP and illustrate the idea in an early stage forces the creator to think and reflect upon the idea. The development of an MVP facilitates an efficient learning process and reduces risk of incorrect assumptions (Reis, 2011).

2.11 Kesselring matrix

The Kesselring matrix is a tool for evaluating (for example) how different concepts compare to each other and stated aspects of performance. Each aspect needs to be weighted, to give the aspect a relative importance compared to other aspects. Later, all the concepts are evaluated from the given aspects. These "scores" are then multiplied by the weighed, and the product from these are then summarized to give a total score for each concept. The concepts could later be compared by their total score, which gives a good understanding about how they stand in comparison to both each other and to the stated aspects of performance. It's a useful tool for both understanding and evaluating concepts, and the level of accuracy is completely dependant on the input data, such as weight, aspects and scoring.

2.12 Internet of Things

The Internet of Things (IoT) is the internetworking of physical/virtual sensors and devices (things) embedded with digital technology, software and network connectivity enabling communication between such (collect and exchange data) (Vermesan & Friess, 2013). IoT-GSI, Global Standards Initiative on Internet of Things defined it as: "the global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies" (Union, 2014).

Things that receives information and then act on that information is something that almost everyone is familiar with today e.g. the TV receives a signal from the TV-remote and the TV interpret the signal and increases the volume, or a document is sent to a printer and the printer prints the document. There are three different categories of things, things like the ones from the example above (receives information and then act on it), things that collect information and then send it (e.g. sensors for temperature, light, air quality, vibration, motion etc.) and things that can do both (e.g. a lamp switch that receives a signal to switch off and then sends a confirmation back to the sender). (Vermesan & Friess, 2013) It is when these things start to communicating with each other on a system level it gets a bit more interesting and the concept of IoT arise.

A system of connected things in a "smart home" is given as an example to illustrate how value can be gained from IoT in a normal life situation. Everything that move can be equipped with an actuator (e.g. window blinds), what can be measured can be equipped with a sensor (e.g. sunlight), everything that is connected can be controlled and/or exchange information. A connected car shares its location with the home automation system which in turns prepares your home for your arrival, opens the garage door, turn on the lights, identifies that your kids is not in the car even though the slot "pick up kids at daycare" is in your calendar and then sends a notification to your phone: "you forgot the kids, by the way your fridge is empty" etc.

3

Method

3.1 Development strategy

Due to the combination of time limit and a high level of fuzziness, methods and tools described in the theoretical framework section, chapter 2, is combined in a structured project process. Figure 3.1 illustrates these methods and tools put together in a project process. The process is divided into three main phases. The first phase is Product and market study focused on gaining knowledge about current product, market and technology. Key points are summarized in a product innovation charter (PIC) which will act as input for the second phase, opportunity identification. The second phase results in a mission statement which will act as input for the last phase, PSS solution identification. The output contains a plan for further development. The three main phases' sub-activities is not strictly chronological but each main phase output (PIC, mission statement and development plan) acts as gates. Once the gate phase is defined and approved previous main phase is considered done and next phase can start.

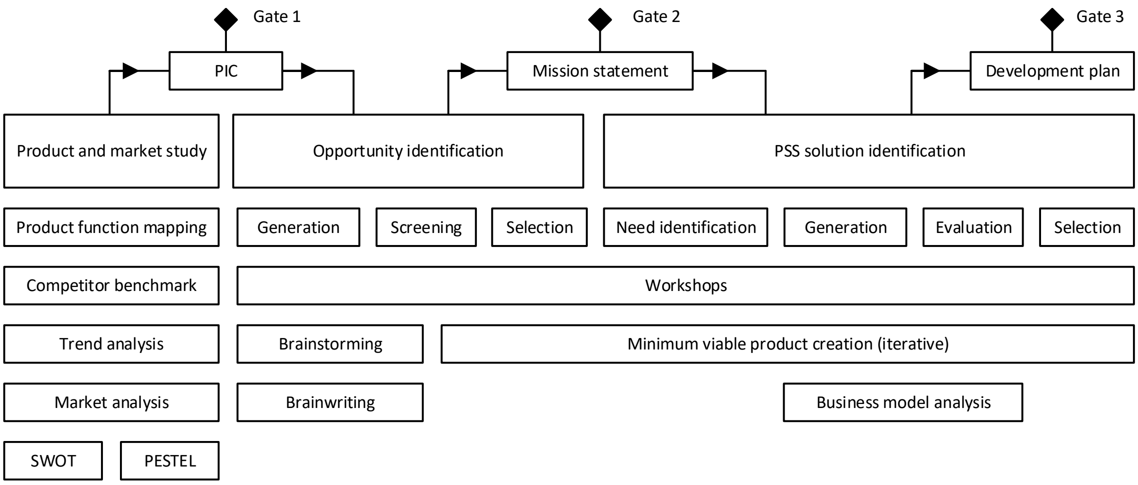

Figure 3.1: Illustration of process used in this project

The method used in all main phases of the project process is similar to knowledge value stream mapping described in section 2.6. It is mainly used to structure these fuzzy phases and facilitate the understanding of the unknown by keeping track on the flow of information and the learning progress. See figure 3.2 for an illustration of the knowledge gathering process. The first input in the Product and market phase is the research question from section 1.2, which is used in the first iteration of the knowledge gathering process to define the desired future state of knowledge (DFSK). An evaluation of what is known today in combination with a break down of the DFSK identifies knowledge gaps and the filling of the gaps starts with the information gathering.

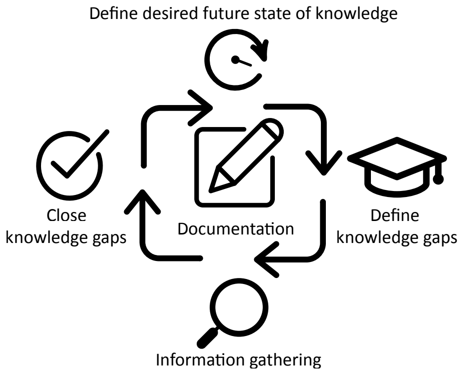

Figure 3.2: Illustration of knowledge gathering process

Even though the main DFSK won't change (since there won't be any change to the research question) the DFSK will be broken down into parts and new parts might be added. When previous knowledge gaps are closed, new ones arise and previous assumptions might be proven to be wrong, hence the DFSK need to be updated.

3.1.1 Workshops, exploratory tool

Due to high level of uncertainty, workshops where chosen as exploratory tool in combination with unstructured interviews. This to avoid unnecessary preparatory work based on incorrect assumptions. Prior to the workshops, a hypothesis is defined. Topics for discussion are then formulated based on this hypothesis in combination with current knowledge gaps. This to keep the process agile and facilitate changes based on new findings. After each workshop or interview the hypothesis is reviewed and refined depending on the outcome. This is an iterative process, and the main advantage of doing the exploration in this manner is the flexibility and openness towards new ideas and utilizing stakeholder input for the continuation of the process. The possible negative aspect is that the method can be time-consuming and ineffective if new findings do not correlate with previous ones, consequently, constant change of hypothesis.

3.1.2 Product and market study

The main reason of the product and market study is to gain knowledge and understanding of the current product and its market. This in combination with knowledge gathering of project related technologies, such as communication networks and protocols, sensors, gateways and other IoT-devices. Sources of information are mainly online articles, news papers, internal documentation (at ABB, and ABB - Kabeldon) and personal communication.

3.1.3 Opportunity identification

The opportunity identification phase is conducted in a qualitative manner. This to facilitate a high level of flexibility in terms of exploration and being able to change and get the "right" stakeholder opinion depending on the opportunity discussed. To make sure that ABB - Kabeldon is in on the process and that the focus of the thesis stays correct, ABB - Kabeldon receives weekly reconciliation. The drawback with this reconciliation might be that ABB - Kabeldon "hinders" the innovation and radical ideas by a lack of knowledge in the area of IoT. Since this is the reason for the thesis in the first place, to investigate opportunities in this field. To counter this problem, the thesis group needs to be clear in communication about ideas, and make sure to have the data to justify decisions about concepts and customer needs.

The advantages by using a qualitative approach when conducting the opportunity identification is therefore flexibility, which in this project is of most importance due to the limited time and level of fuzziness. Drawbacks by using a qualitative approach in comparison to a quantitative would be the "measurability" of feasibility, traceability and the risk of bias and other inherent errors (McQuarrie, 2015).

3.1.4 PSS solution identification

PSS is chosen for the problem breakdown, this to facilitate for both how to understand the physical product and the services. The reason for needing both aspects in the development is the high level of uncertainty, since the service aspect can consider collaboration with customers to reach a high level of needs fulfillment, e.i. result oriented services (Tukker & Tischner, 2006). The framework that is used for the breakdown is presented by Isaksson et al., 2011 and considers both the ingoing technologies and services, from the perspectives of the user, provider and enabler.

First step is to analyze the market and technology, to map the technology and need simultaneously in a qualitative manner. To understand the need and the solution to solve that need, since this process often has parts of both, it will be an iterative process. Going from the need to the solution and back again, until a good enough base is created for further analysis.

The second step is to identify possible stakeholders. This is done by creating a hypothesis about how the stakeholder could be structured, and then confirm/dismiss this by more research and/or workshops. By analyzing the stakeholder structure before confirming/dismissing, understanding is obtained to ease the process of structuring and screening the stakeholders. When stakeholders are identified, the next step is to identify what drives the value for each of them. This is done in the same manner as before, by defining a hypothesis, and later confirm/dismiss that. In an ideal case, the value drivers should be quantifiable to act as a base for a requirements specification. But in this case, for the thesis, it will act as a base for understanding stakeholders and their needs.

The previous steps are compiled, together with all conclusions and results to form a proposal for a PSS-structure for continued development.

4

Product and Market Study

4.1 Power grid

The power grid is divided into the high voltage section (see figure 4.1, and the low voltage section (see figure 4.2). The high voltage is often referred to as transmission network, and the low voltage often as distribution network. Since the transmission is not going directly to users, whilst the distribution is (Wikipedia, 2017c) (Bondesson, 2017).

Starting at the power station (power plant of some sort), the first step is a step-up transformer, to increase the voltage. The reason for increasing the voltage is to lower the energy losses during transmission. When reaching a point of distribution, the power is transformed down by a step-down transformer. This transformer is the part that divides the grids. The transmission could be conducted both by over-head lines, or by lines below the ground. The latter is the most expensive to build, but also the cheapest to maintain, since it's better protected from the elements (Wikipedia, 2017c) (Bondesson, 2017).

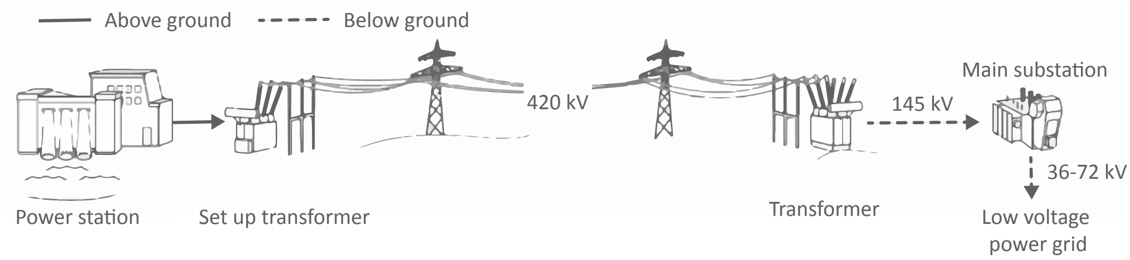

Figure 4.1: Illustration of the high voltage power grid

The low voltage grid (distribution network) starts at the step-down transformer (main substation in figure 4.1). Where the transmission to end user starts, depending on the users' needs, it could be right after the main substation if it's heavy industries, but often it's after another transformation at the Compact Secondary System (CSS). After the CSS, the voltage is down to 400V. How it later reaches the end user is depending on how the system is structured (detailed description of alternatives in sections 4.2.1.1-4.2.1.3). The figure 4.2 illustrates how the low voltage power grid would be structured using CDCs', where the power is transmitted and distributed through the CDCs' until reaching the end user (Wikipedia, 2017c) (Bondesson, 2017).

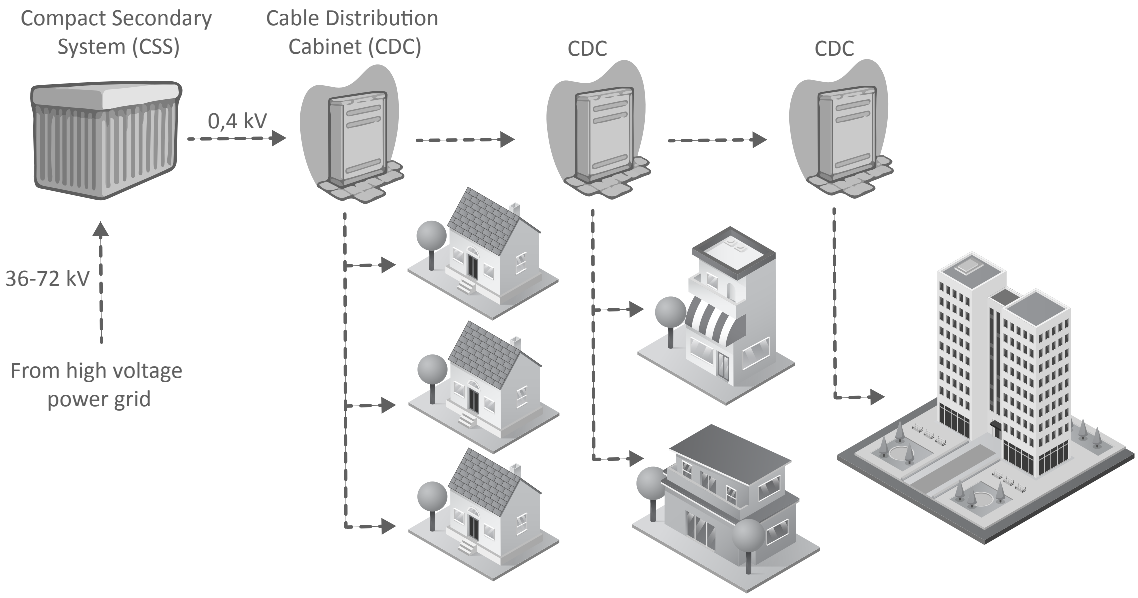

Figure 4.2: Illustration of the low voltage power grid

4.2 Current system description

The following systems described are all below ground, to get a fair comparison of such system. There are still parts of the world where cables are above ground in the low voltage power grid, but due to reliability issues, personal safety and issues with theft, such systems are a thing of the past and should be avoided.

4.2.1 Low voltage power grid

There are several ways of structuring the low voltage power grid, and it differs depending on what country concerned. The power grid market are often regulated by law and previous knowledge. If a country has been building in a specific way for a number of years, they will not change their way of building in an easy way. This even if another way could be proven more feasible due to economic or safety reasons, the power grid markets are relatively slow moving and unperceptive towards change (Bondesson, 2017).

4.2.1.1 T-joints

The T-joint system is structured below ground, and each new consumer is connected directly to the main cable in the ground. This operation requires digging and are therefore relatively complicated and costly. But when the system is up and running, there are few complications and drawbacks. The problems and costs occur when faults occur and/or new consumers needs to be connected to the grid, this due to the hard accessibility and often costly operations (Bondesson, 2017).

- Low fault frequency (+)

- No maintenance (+)
- No outside damage (vehicles etc.) (+)
- Difficult to get in contact with electrified parts (safety) (+)
- Energy theft is difficult (+)
- Very costly to install new consumers (-)
- Hazardous work for personnel conducting installation/maintenance (-)
- Power must be cut during work with cables in the ground (-)
- Failures in cables leads to large blackouts for consumers (-)
- Unreliable due to lack of fuses in connecting points (-)

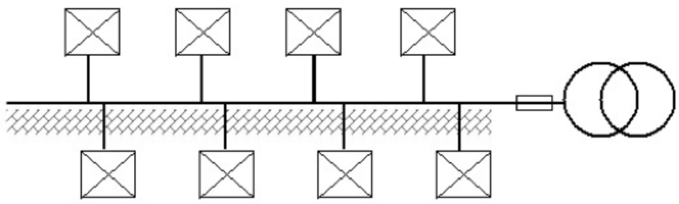

Figure 4.3: Schematic of power grid using T-joints.

4.2.1.2 Directly to consumer from CSS

This could be seen as the natural step after T-joint system, since the consumers are less affected by other faults at other consumers. The system are more robust than the T-joint, and are less costly to maintain when faults occur (Bondesson, 2017).

- Every consumer is isolated from each other (fuses), high reliability (+)
- Easy to connect/disconnect consumers (+)
- Could lead to long cables and costly digging work/cables depending on distance from customer to CSS. (-)

Figure 4.4: Schematic of power grid directly connecting consumer to secondary substation.

4.2.1.3 CDC

The difference between the direct from CSS are the easier access and increased reliability of the system. Since the CDCs' acts as fuses as well, the consumers are more independent and are less likely to be affected by errors in other parts of the system. It's the most expensive system when first implemented, but is often the least costly system over time. This due to the reliability and easy access to maintenance

(Bondesson, 2017).

- Easy connection/disconnection for consumers (+)
- Possibility for service cables to increase reliability of system (+)
- High reliability due to fuses at critical points (+)
- Right cable at right place (+)
- Less digging work for new consumers (+)
- Safe for maintenance personnel (+)
- Possibility to temporarily connect consumers (+)
- Easy to identify and eliminate consumers not paying (+)
- Relatively high initial cost of installation of system (-)

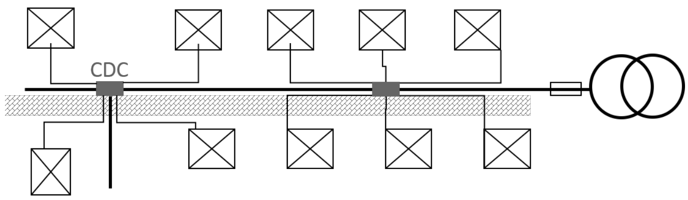

Figure 4.5: Schematic of power grid using CDCs'.

4.2.2 Cable distribution cabinets - CDC

The function of the CDC is to act as a point of distribution to the surrounding end consumers. By providing easy access, a more reliable power grid and easy scalability for the future. The drawbacks of using the CDCs' are the increased cost when first building the power grid, but that increased cost is often small in comparison to the increased cost when later expanding or connecting new end users to the system later on. The system also becomes more reliable since the CDC contains fuses and can protect the power grid from overloads and short cuts. By also providing this easy access, the digging jobs when putting down cables could also be minimized, since the end user only has to dig to the CDC, instead of digging to the main cable and then do a physical fusing to such.

The function of the CDC in a power grid could therefore be described by the functionality of having a branch connector behind the TV, for all the electric products, such as amplifier, video game, lighting, computer etc. Instead of putting down cables all over the home to the main outlet (often in the hallway), a branch connector is used. It's a cheap and easy way of eliminating the need for expensive and long cables through the home. Just like the branch connector functions in the home, the CDC functions in the power grid, see figure 4.6 for examples of CDCs'.

Figure 4.6: Varying size Cable Distibution Cabinets in Kabeldons product portfolio.

4.2.3 Geographical placement of CDCs'

ABB - Kabeldon has a large share of the Swedish market, and some cities only uses their products. Since the 70's, ABB - Kabeldon has sold cabinets in the millions, and there are only a few of them not in use as of today. An interesting aspect of the CDC's is their geographical placement. Due to the function as distribution "centrals" for electricity, they are a part of the infrastructure. As for almost all infrastructures, the more people, the more infrastructure. So there are a correlation between how the cabinets are placed and how many people live/act in that geographical area. This means that where there are people, there are almost guaranteed to be CDCs' manufactured by ABB - Kabeldon, also regarding new expansion of society, since electricity is one of the first things considered when building new sites.

To get a more precise assessment over the number of CDCs' in a Swedish society, a deeper analysis where undertaken. Three cities where chosen as representatives for different sizes, namely, Gothenburg, Borås and Alingsås. By analyzing how the cabinets are placed in combination with other societal factors, a perception of the spread in comparison to the population could be identified and analyzed.

Table 4.1: Comparison of public power grids CDC placement in three different sized counties.

	Gothenburg (Wikipedia, 2017d)	**Borås** (Wikipedia, 2017b)	**Alingsås** (Wikipedia, 2017a)
CDCs' (total in county, public grid)	17500	4500	2000
Area (county) [km^2]	448	32	14
Level of urbanization [%]	90	99	78
Population county [$persons$]	998000	110000	40000
Population urban [$persons$]	556000	64000	24000
Population density (county) [$persons/km^2$]	1243	120	85
CDC density [CDC/km^2]	39	141	143
Persons per CDC (county) [$persons/CDC$]	57	24	20

Table 4.1 gives an understanding about how the CDCs' are placed in an urban environment. The conclusions that could be drawn from this are that there are less CDCs' per persons and also per km^2 owned by the power grid in larger cities. The reason for this is most likely the number of apartment blocks in closer populated areas, where the CDCs' are owned by the owner of the building. Another conclusion are that the CDC/km^2 have an almost linear correlation with population, this applies for persons/CDC (county) as well. Concludingly, the placement of the CDCs' are strongly correlated to population, even tough the number of CDC increases with the level of population, the increase rate drops per person after a while. Therefore, if other applications could be found for the CDCs', it would not only favour large cities, but small and medium sizes as well. An example of using the electrical grid for expansion of other functions of society in Sweden are the building of the fibre-network. When building the fibre network, it was done in close proximity to the CDCs', and often in the same manner (using distribution cabinets for fibre). And when expanding society, the fibre and electricity are put in the ground simultaneously.

4.3 Market Analysis

In this section, the market analysis will be presented in the form of different methods to assess the market (Nordic with focus on Sweden) and the CDCs' position in comparison to the competitors.

4.3.1 SWOT-Analysis

The SWOT was conducted to assess the current cabinets, to understand and identify areas of improvement and other important aspects of a possible development.

Strengths - The strength of ABB - Kabeldons current products are their market position and their good customer relations. Durability and robustness is a key strength, since many of their returning customers stresses that. Safety, for the personnel working with the cabinets are also a key strength, and ABB - Kabeldon has been one of the drivers of that development in the low voltage power grid.

Weaknesses - One weakness is the lack of digitalization in the low voltage power grid compared to the digitalization of the high voltage power grid. This is something that ABB - Kabeldon has identified earlier, and are the reason for this thesis.

Another weakness is the difference within ABB - Kabeldon, that the digitalization development are separated from the manufacturing of CDCs'.

Opportunities - The combination of ABB - Kabeldon's current market position and customer relations gives them a good start for setting a new standard regarding changes in the low voltage power grid. Since ABB - Kabeldon are the one that competitors are benchmarking themselves against, they have the possibility to strengthen their position even more by being first with the digitalization. Another reason that ABB - Kabeldon are suited to investigate the digitalization aspect of the CDCs' are the competence in that area within ABB. Since they are one of the drivers of digitalization, they both have the market's expectations driving development as well as the possibility, both with monetary means and knowledge. That would possibly give the opportunity for new markets and increased sales.

Threats - The main threats are the lack of opportunities identified regarding digitalization, there could be other vendors on the market that implements new functionality before ABB - Kabeldon, which could affect their revenue and market position. The lack of technology is mainly dependant on the knowledge that many parts of society are moving towards digitalization, but the low voltage power grid, are relatively offline. That could lead to the conclusion that the low voltage power grid will probably move in that direction as well, and it's important to consider how such development would look.

Table 4.2: SWOT-analysis

Strengths	**Weaknesses**
Current market position Robust design Safety	Not been adapted to new trends (IoT) Gap between digitalization development and manufacturing of CDCs' within ABB
Opportunities	**Threats**
Set new standard Increased sales Potential for new markets Deep technological knowledge within ABB ABBs' strategy regarding digitization	Innovative competitors Lack of technology

4.3.2 PESTEL-Analysis

To assess ABB - Kabeldons' CDC in comparison to its' working environment a PESTEL-analysis was conducted.

Political - ABBs' strategy is to be one of the leaders in the development of digitalization, and to implement digital technology to increase customer value throughout their product portfolio (ABB, 2016). This is of importance for the development of the CDC, since this development needs to be anchored at a high level in the organization. This anchoring is given by that strategy.
Economic - The CDC of today are of remarkable quality, and there are examples of cabinets being outside for over fifty years and still in good condition. But the price

for buying one is one of the highest within the segment compared to new players on the market. Since the lifetime of the competitors can't be measured in comparison to ABB - Kabeldons', the only conclusion that could be drawn are that ABB - Kabeldons' cabinets are a bit more expensive, but will perform as promised.

Social - ABB - Kabeldon is one of the leaders regarding safety within the high and low voltage market segment. Since the 1970s' the number of lethal accidents has decreased from about 20 per year during the 70's to none in 2013. In the aspect of facilitating easy access to electrical energy for the surrounding population the CDC fulfills its' purpose. A regular connection could be made in a couple of minutes provided that there are room on the busbars in the cabinet. Hence, the responsibility for making sure that there are enough room for new connections are the owner of the cabinet, not the manufacturer in this case.

Technological - The inside of the cabinet are updated continuously, the fuses and busbars are regularly changed to improve the safety for the electricians conducting work inside the cabinet, but also the reliability and efficiency of the low voltage power grid.

Environmental - The effect the cabinet has on the environment is relatively low, except the manufacturing of the material (metal) and the energy from the production itself. But since the function is to effectively distribute the electricity to the end user, that phase is the important one. Thus, the CDC is a function that enables and makes the distribution more efficient than the distribution would be without CDCs (see more about the possible layouts of a low voltage power grid in section 4.2).

Legal - There are several laws that regulates how access is made to the cabinets, and depending on what is inside (voltage-vise) different education gives different access. There are also several laws on how electricity should be measured, and how that system should be set up. This can cause troubles with adding functionality if the electrical utility is not the owner to the specific system. This can and is solved today by adding a cabinet beside the regular CDC with a different lock, then customers and/or regular persons with the key can access the inside without the "proper" electrical education.

4.3.3 Competitor benchmarking

Table 4.3: Qualitative competitor benchmarking for actors on the Swedish market in the CDC segment. The companies are ranked from best (1-6), low total score means high performance.

Brand/Aspects	Adaptability	Delivery time	Reliability	Safety (Internal)	Material	Result:
Kabeldon	2	1	1	IP20	Galvanized steel (2mm)	4
CEWE	3	1	1	IP20	Galvanized steel (2mm)	5
Garo	1	3	2	IP20	Magnelis (1.5mm)	6
GEVEA	6	4	2	IP20	GFRP	12
ENSTO	5	2	3	IP20	Galvanized steel (2mm)	10
STITEC	4	5	5	IP20	Galvanized steel (2mm)	14

The competitor benchmarking was conducted as a qualitative approximation with information gathered from several persons that has good market insight.

A common aspect of all the actors are the material the cabinet are built of, galvanized steel. This to facilitate for harsh outdoor weather in combination with standards of resistance against impacts. Manufacturing wise, the process are mainly the same for all cabinets made of steel, with the difference that some companies use welds to strengthen some parts of the cabinet. Garo uses coated Magnelis steel in their slightly thinner cabinets (1.5 mm compared to 2mm) have shown problems regarding the standards of impact since the cabinets cannot withstand impacts in the same manner as the cabinets of 2mm. GEVEA uses glass fibre reinforced plastics in their cabinets, the main advantage of using this is the weight aspect, since a lower weight means an easier installation both when placing them in the ground and also when mounting them without ground contact.

Concludingly, the important aspects of future development for the physical development of the CDC will probably focus on aspects such as manufacturability and minimizing/optimizing material use. Together with technology development in other fields such as 3D-printing gives opportunities to use optimization methods such as Topology-analysis to optimize for example structural rigidity while considering material use. Therefore it's important for companies that manufactures steel in a traditional way to stay perceptive towards new and possibly more efficient methods of manufacturing and material choice.

ABB - Kabeldon are market leaders in the segment of CDC, both in terms of quality and market share, which gives an advantage regarding channels of sale and geographical spread of their products. This gives an edge when trying to implement new technology, for either current or new markets. But it also means that there can be large impacts on their sales if they are not perceptive for new technology and development trends.

4.4 Technology forecast

Since this project aims to combine the CDC and digital technology to increase value for either current markets or new ones, both aspects will be studied. To be able to assess the future for the combined system, the parts needs to be assessed apart, since the combination has not been done before, there are no information found regarding that combination.

4.4.1 CDC

The CDC has had the same function for the past 50 years, to house and protect electrical components and to act as a point of distribution for the power grid. The appearance has changed slightly (to enhance manufacturability) and the material has decreased in thickness but remained the same (galvanized steel). The electrical components inside are the ones that has changed the most, whilst the outer cabinets has remained almost the same.

The future predictions for the cabinet itself are therefore that they will probably not change in any radical way. As previously mentioned in the competitor benchmarking in section 4.3.3. Some competitors are trying new materials to improve manufacturability and/or sustainability aspects, but the customers of ABB - Kabeldon are very satisfied with the current design and material, and that's part of the reason for their continuous use of ABB - Kabeldon's cabinets, which means unchanged/slightly increased sales in the future, but small risk/chance for large decrease/increase in the future.
The market and sales of the CDC are dependant on the current situation of the construction sector. If the investments in that area rises, then the production and sales of cabinets will automatically follow that trend. Rules governing the power grid will also affect sales of the cabinets, since laws regulates how old the power grid could be before it has to be rebuilt/updated, currently that law states 40 years. So if the power grid in an arbitrary location is older than 40 years, it has to be changed. This law also contributes to the relative stability of the sales of cabinets on the Swedish market (Weidenmark, 2017) (Nordling, 2016).

4.4.2 Internet of Things - IoT

In this section, the Internet of Things will be given a short background, a description about today's use and how it can be seen/used in daily life and a technology forecast linked to how society needs to change to facilitate for all this technology. All the following topics will only be described in the most basic way.

4.4.2.1 Background

In 1982 one of the first concepts of an IoT device was a Coke-machine at the Carnegie Mellon University. The machine could communicate information about its stock and the temperature of the drinks inside.

The next major step forward was in 1991 when Mark Weiser released his paper "The Computer of the 21st Century" and different academic projects started to take shape and unite around the future vision for IoT.

Between 1993-1996 a number of IoT solutions was developed, examples of these are; Microsoft's at Work and Novell's NEST. There where however a slight "delay" in the market, and the market didn't really move until the rise in 1999. The rise in the market was mainly due to the Auto-ID at MIT and publications about the future potential for IoT (Wikipedia, 2017e).

4.4.2.2 Applications

The applications for IoT are still under development, but under the following sections (4.4.2.2 - 4.4.2.2) some applications will be explained further.

Environmental monitoring - Sensors can be used to monitor factors such as; air pollution levels, water quality, noise pollution, temperature, activity level, soil conditions etc. This data could be used for prioritizing cleaning of city streets, warnings about air quality (polluted cities), give a go/nogo regarding the drinking water or even give tsunami/earthquake warnings (Wikipedia, 2017e).

Infrastructure management - IoT could be used to monitor structures such as bridges, buildings, railways and roads. Instead of having inspections, data could be used to analyze the state of the infrastructure. By also having it real-time, prioritations and pro-activity could be enhanced (Wikipedia, 2017e).

Manufacturing - By being able to control and monitor products and processes enables large advantages in manufacturing. Being able to assess and counter critical situations means less down-time and faster response to a more diverse and global market. This could also lead to benefits regarding sustainability, hence having a faster response and a more adaptable manufacturing will result in less energy and material use. This will be beneficial from both an environmental and economical point of view (Wikipedia, 2017e).

Energy management - The most likely scenario is that different types of energy management systems will be integrated in all devices that either consumes or delivering electric energy, all from switches to televisions. And they should all be able to communicate with each other and the origin of energy supply, to balance the power grid and energy usage. This functionality would also give the user the ability to remote control, to be able to turn everything that's not being used off by a single button, or even automatically by scheduling activities (Wikipedia, 2017e).

Medical and health care - IoT devices can be used to monitor health and control the emergency system of society. By for example having wearable devices that can measure blood pressure, oxygenation, heart-rate and other vital functions.

These devices can then be worn by people in the risk zone of various afflictions and communicate real-time health information about the user to the right authorities. Such systems could possibly change the health care to the better, by collecting and analyzing information, proactive measures could be taken to improve quality of life whilst reducing cost (Wikipedia, 2017e).

Transportation - By integrating IoT technology, communication between vehicles, infrastructure and user, efficiency and safety could be increased by dynamically controlling e.i traffic lights, speed-limits, toll-systems, logistics and road safety (Wikipedia, 2017e).

Metropolitan scale deployments - Santander in Spain is an example of this application. The city has been equipped with 10000 sensors to monitor everything from parking spaces to environmental factors such as air quality etc. The sensors are connected to an app that almost 10% of the population in the city are using. This setup gives the inhabitants real time data about the surrounding areas, all to give them the tools to have a higher quality of life (Wikipedia, 2017e).

Consumer application - A large portion of the IoT devices are today developed and used by end customers for their own personal needs, such as; health monitoring, connected cars, smart homes and entertainment (Wikipedia, 2017e).

4.4.2.3 Technology forecast

There are several forecasts for the number of IoT devices in the year of 2020, and they ranges from approximately 20-200 billion depending on source. (Intel, 2017) (Gartner, 2015) (ABI, 2013)

Intel's projections suggest that the number of devices in IoT will be 200 billion in the year of 2020. That compared with 15 billion in 2015 (and 2 billion in 2006) means that an expansion of a whole new way of building societies will take place(Intel, 2017). Infrastructure therefore needs to prepare and be adaptable to be able to keep up with the coming development in the area of IoT and connected devices (Intel, 2017).

4.4.2.4 Conclusions

If the forecasts are correct, of even slightly correct, the world is in the beginning or in the midst of a big data boom (Intel, 2017). This also means that the CDCs' could act as base in terms of connectivity and security. Because somewhere in the network there might be a need of stations that never go offline and are a reliable distributor of data within the IoT. This is where the CDC come in to play, since the geographical placement in relation to population and access to electricity also are important factors for the future of the IoT. This in combination with ABBs' strategy to implement IoT and connected devices into their products, means that there are too many synergies to ignore. And further investigation needs to be conducted.

4.5 Hypothesis

The geographical placement of the CDCs' in relation to the population and access to electricity makes the CDC ideal as a station for observing and communicating information with the surrounding people and devices.

5
Opportunity identification

5.1 Innovation Charter

The purpose of the innovation charter is to map and structure what is to be done, why and how.

5.1.1 Background

The hypothesis from section 4.5 will act as a foundation for the coming identification of opportunities. The hypothesis is formulated with respect to both current market conditions and technology trends, the result from analyses in 4 and ABBs' strategy about digitalization (ABB, 2016).
ABB has good knowledge, and are one of the drivers of digital technology from a global perspective. This means that the knowledge required for developing and implementing such technology in the CDC already exist within the global organization. Even though the knowledge required exists within the company, it doesn't mean that the development will start automatically. Identified obstacles for such development are the size and the separated divisions within ABB. An example of this is that division A doesn't even know that division B exists, and therefore it's hard to synthesise the divisions knowledge. In this thesis, division A could be described as ABB - Kabeldon and division B could be ABB - Robotics. Where Kabeldon has the knowledge about the CDC system, and ABB - Robotics has the knowledge about the cutting edge digital technology. But since they are barley aware about each others existence it's impossible to obtain the synergistic affects of their combined knowledge required to implement digital technology in the CDC without explicit managerial orders.

5.1.2 Focus

As described in the previous section, a sense of urgency must come forward to facilitate the synergistic effects needed to develop an IoT system. This urgency can be created by communicating the idea, and get the concerned division to understand for themselves that it's a real opportunity, and that they later will communicate this on a higher level in the hierarchy to obtain resources for development. Or to go the other way around, to start at the higher level, and let them sense the urgency and later communicate (in explicit orders) what is to be done.

ABB - Kabeldon has an advantage compared to others in developing/implementing digital technology in the CDCs', due to their knowledge within the company. Since ABB are both drivers and developers of the needed technology, and also has good market relations to the suggested providers. Since ABB has good knowledge about their customers and good customer relations in the power grid market and IoT. They have a clear advantage compared to competitors, which may have one or the other, but seldomly the combination of both.

5.1.3 Goals

ABBs' strategy regarding digitalization of their products and services, the reached level differs depending on what part of the organization is assessed. But generally, their products that are connected to the manufacturing industry, such as robotics, have come very far in that process, and ABB is one of the market leaders in digitalization of manufacturing automation equipment. On the other hand, some of ABBs' products have not reached the same level of digitalization, and one of those products are the CDC. As previously stated, their function is to house electronics and protect them from the surrounding environment. Since there has been not explicit customer need about digitalizing of the cabinets, no real effort has been done to counter this. Therefore, the goal with the innovation effort is to create synergies between different parts of ABBs' organization, since for example, the division of corporate research is currently developing gateway technology, and has released several gateways for the Industrial IoT (IIoT) market. But that division has not much communication with the division that manufactures the cabinets. So the goal is to utilize and synergize the competences and products already existing within ABB, to create a system that could be a part of the infrastructure of the future.

Short term, the goal is to coordinate competences within ABB, to facilitate for development efforts for implementation of digital technology in the CDC. The goal is to hand ABB a strategy, that could provide the outlines for both the strategy and where to aim with respect to physical products.

Long term, the goal for ABB is to be one of the leaders in digitaliztion, and in combination with the trends in IoT and the probable changes in infrastructure presents great opportunities for such a company. Since ABB is already a supplier of other infrastructure parts, they have a great opportunity to make sure that they could be the supplier of new types of infrastructure in the future.

5.1.4 Guidelines

Opportunities need to be related to the CDC and IoT. Proposed development strategy need to be aligned with ABBs' IoTSP advancements, this to be able to obtain resources for future development. Other guidelines is not defined due to risk of constraining the development too much.

5.2 Opportunity generation

The opportunity generation section is a summary of the generations that has been conducted throughout the project, both internally and externally from ABB - Kabeldons' point of view.

5.2.1 Early internal generation

The first internal idea generation was conducted in an early stage of the project to utilize the boundary free conditions, before knowledge would constrain such process too much.

The list below is the generated ideas and a short description of each.

- **Measurement for electricity loss** - Used to better control and supervise system, to facilitate improvements.
- **Self-repairing system** - By trying to add this functionality, the system becomes more robust.
- **Online-connection with ability to control electricity (on/off)** - To be able to control access for end user, example; if a customer hasn't payed the electricity bill, the power could easily be cut off from a central control system.
- **Gathering electricity meters for end users into one place, only using one network connection to measure several meters** - Save the use of connectivity, and have a more central location for manually reading and servicing meters.
- **Mobile base station** - Use the spread and placement of the CDCs' to place extra mobile base stations in specific locations.
- **WiFi-hotspot** - Enhance WiFi Internet connectivity for chosen areas by adding this function to the CDCs.
- **Charging station for electric vehicles** - Rebuilding or adding functionality that enables fast charging for electrical cars.
- **Weather station** - Rebuilding or adding functionality that enables weather readings.
- **Postal central, add-on cabinet for pickup/sending of larger gods** - Make use of the spread and placement relative to the population by adding cabinets for postal services.
- **Data communication station** - Utilizing the placement in urban areas, and give the cabinet the function of environment supervision and communication with nearby devices.

The opportunities listed above where screened in a qualitative manner in collaboration with a product specialist at ABB - Kabeldon. This early screening was conducted to get an understanding of ABB - Kabeldons' expectations and their openness to ideas related to, for ABB - Kabeldon, unknown markets. The most interesting ideas where the *"Data communication station"* and *"Charging station for electric vehicles"*, with the justification that they where the most radical (from an ABB perspective), and according to the product specialist, would suit the trends of the future.

Data communication station - The main advantage of using the CDCs' as data communication centrals is the quantity and placement in relation to the population. So the higher the population in a specified area are, the more CDCs' are there as well. This could be a large opportunity when it comes to autonomous driving and active safety. There are potential future problems with autonomous driving as of today, and general problems include accuracy of GPS-technology and data transfer limitations. By utilizing the existing CDCs and integrate them with data communication centrals, with the possibility to monitor the close surroundings and deliver/receive data to cars in close proximity. The winnings could possibly be large in terms of location accuracy, warn the vehicle about the conditions at the location of the CDC and enhance communication with the larger network (to act as a hub for information). By acting as a hub for information, and possibly speed up the connection for the car, the car not only relies on the cellular network, which can be beneficial for safety aspects. The CDCs' placement and geographic location in comparison to urban environment is beneficial from this perspective, since the closer population in an area, the more CDCs' exist. Just like a car driving, the more urban location, the more information is needed to safely move forward.

Charging of electric vehicles was the other opportunity. Just like the other opportunity the placement of the CDCs' in comparison to urban population was seen as a huge advantage. The electricity in the CDC agrees well with the one needed to super-charge (fast charging) an electric vehicle, and it would probably be relatively easy to rebuild/use add-ons to create a dual purpose CDC, both as distribution central and charging station. To be assess the feasibility of the idea, data regarding the placement of the CDCs' are needed. First the total number and where they are placed, then how many of these that are in close proximity to a location which either are, or could easily be transformed into a parking space. Then a market research would be conducted to see which of these sites would be feasible to turn into charging stations.

For both of these ideas, it's critical to find external information regarding the technology and market, since the information about none of these are ABB - Kabeldons' main areas of operation. It's also important to structure how such ideas would be handled in terms of owning, both the physical parking station, the charging station and the electricity provided.

From this early opportunity generation the conclusion can be made that opportunities might be related to technologies and markets that is unknown for ABB - Kabeldon as of toady. The desired future state of knowledge needed to be able to evaluate these opportunities is a big uncertainty by itself, *"we do not know what we do not know, therefore, we do not know what we need to know"* e.i. Is there a need? Who is the customer? Would a product related to these opportunities be feaseble? etc. etc. There is a big knowledge gap that needs to be filled in order to evaluate these opportunities properly. But ABB - Kabeldon are willing to accept this level of uncertainty for this project which sets the level for further opportunity generations and indicates openness to radical ideas.

5.2.2 Workshop A (internal)

Workshop A was conducted with participants from different functions within ABB - Kabeldon in Alingsås. The target was to generate, discuss and come up with a continuation plan for interesting ideas.

The ideal case when conducting the internal idea generation would be to use the AIM-method, it's a structured, partially silent method for problem solving that can be used for generating and structuring ideas (Alänge, 2009). But the method uses a relatively long time for inexperienced participants ($\approx 3 - 4h$), which in this case is nearly impossible to occupy from the participants regular schedule at ABB - Kabeldon. Instead, parts of the method will be used, especially the parts with visually presentation, categorization and uniting/creating of understanding about the ideas for all the participants.

To reach the target with the workshop, some preparations had to be made. To get a good structure and rules regarding feedback and gathering of information. One important aspect was to let the participants understand the task before the workshop itself, to start their thinking-process well before the meeting. This was solved by giving them a description about the problem, and the ability to fill in an online document before the meeting, so they could share and build from each others ideas. See appendix A for the full agenda for the workshop.

The participants of the workshop was of a mixture of different functions within the ABB - Kabeldon organization to facilitate decision making and evaluation with multiple aspects considered. Represented functions: marketing/sales, R&D, technical support and product specialist.

To ease the idea generation for the participants categories to elaborate around was created. The generated ideas are presented in the list below.

- Welfare/Social benefit
    - Use cabinets for communicate information (maps, commercials etc.) Commercials based on person walking by, traffic information
    - Alarm, SOS communication line, surveillance (fire), personal safety zones
    - Help for visually impaired
    - Defibrillator station
    - Charging of mobility scooters
    - Electricity service, pay with an app to use electricity.
- Power grid measurement/communication
    - Gather electricity meters
    - Ability to control switches / fuses remotely (self repairing)
    - Shortage / overload tracking

  - Load redistribution
  - Quality metering (electricity)
- Third party measurement/communication
  - Big Data, autonomous vehicle communication
  - Wi-Fi hotspot
  - Environmental / surrounding supervision measurement
  - Communication module, let third part buy space and connection for sensors.
- Miscellaneous
  - Vehicle charging
  - Postal central (heating, cooling, etc. might be add-on functionality)
  - Interface for grid balancing for solar producers
  - Function to control climate inside cabinet

Many of the ideas are possible to combine, and are more or less the same, or utilizes the same technology but are used for different purposes. This means that one solution could solve several possible needs if combined and refined.

The workshop was ended with a vote, where the participants voted on the ideas that they thought was the most interesting and had the most potential. The voting result did not show a clear "best" or "worst", but it gave an overview of what the participants thought should be the focus in the future. The focus according to the participants and the voting should be *Welfare/Social benefit* and *Third party measurement/communication.*

One of the most important findings was the discussion about quality measurements in the CDC, and the general idea about hooking the CDCs' up to a network or enable them to communicate information about the electricity distribution. During the brainstorming and several times before, the thesis group got information about the need for measuring electricity quality was important, and therefore, a method for measuring this should be developed to be housed in each CDC. After some discussion with the persons during the meeting, the united verdict was that this was not justified from a market perspective. Since the customers of today has almost no interest, apart from industries that have very sensitive electric equipment. And even if they where interested in buying such a product, it wouldn't be housed in the CDC, it would either be housed in the large sub-station or in the industry's own incoming distribution station, not in a CDC. This discussion was of importance since that "need" was proven not to be true, and could therefore be rejected.

The meeting also concluded that the scope of the project should be kept broad, to facilitate for ideas that wouldn't normally come from the functions itself. This not to interfere with ABB - Kabeldons' daily activities, and try to get a more innovative approach to the implementations with digital technology, and focus on other markets than the existing electrical distribution companies.

5.2.3 Workshop B (external)

When assessing the potential regarding digitalization of the cabinets, external sources was seen to be critical. This to be able to broaden the idea generation, whilst involving potential customers. Some literature studies gave hints about environmental readings, which lead the thesis group to contact IVL and the Municipal of Gothenburg to set up a workshop with the purpose of generating and assessing ideas together with a potential future customer.

The second workshop was in collaboration with IVL (Swedish Environmental Research Institute) and the city of Gothenburgs environmental department. The idea was to present the ideas for the participants and let them elaborate around feasibility and see if there are any need for such functions in their projects and work. Today, measurements regarding air pollution, water quality and noise pollution are part of their daily work. The data is gathered with different methods, air pollution uses stationary meters at the top of high and public buildings and noise is measured by using a decibel meter. Data from the noise are later used to build models of the noise pollution with regards to the acoustics of the area. Their current ways of measuring have some problems, because they don't have a large number of measuring-spots, the equipment used must have a high accuracy, therefore it's often quite costly. Access to electricity is often a problem when placing these meters, especially air pollution meters. Their conclusions was that in their daily work, solutions for getting easier access to electricity and placement of their sensors would have a positive effect on their data gathering. By also having the possibility to use more spots to gather data, the accuracy of the measuring equipment could be lowered hence a cost reduction of that specific equipment. This also means that the data could be gathered directly instead of using models, which also has inherent errors and are costly to produce and slow to use.

The conclusions from Workshop B are that the involved parties have an interest in the idea of using the CDCs' as a part of a network to gather data of the surrounding areas. But by just having them involved as customers would probably mean an almost impossible business case, due to the limited funding projects that measures air and noise quality possesses. This means that this idea needs needs more customers that could use the same information to have a chance of being feasible from an economical standpoint.

5.3 Opportunity Screening

To be able to screen among the many opportunities, screening and workshops was conducted.

5.3.1 Stakeholder mapping

To be able to gather insight regarding both the technology and the market, a list with possible stakeholders was compiled by the thesis group. The stakeholders was also ranked with respect to their assumed interest and input-value to the thesis.

Table 5.1: Ranking and description of stakeholders identified in mid project

Rank	Stakeholders	Description
1	ABB - Kabeldon	Are the manufacturer of the cabinets and also the main stakeholder of the project itself
2	GöteborgsEnergi	Are responsible for the power grid in Gothenburg
3	ABB - Corporate research	Are the cutting edge technology research division within ABB, also have the "best" projection of the future within the company's research strategies
4	Rise	Are a joint research venture funded by the Swedish government and facilitate collaboration in research between large Swedish companies, such as, Volvo cars, Volvo GTT, Scania and Ericsson
5	AlingsåsEnergi	Are responsible for the power grid in Alingsås
6	BoråsElnät	Are responsible for the power grid in Borås
7	Volvo Cars	Have ongoing projects regarding autonomous driving, might have use of data communication system in urban area
8	IVL - Swedish Environmental Institute	Are involved in projects regarding measurement of the environments in urban areas, and also projects regarding IoT
9	Environment administration in Gothenburg	Are involved in projects regarding measurement of the environments in urban areas, and also projects regarding IoT
10	Trafikverket	Might have an interest in measuring activity levels regarding traffic, to be able to control and check traffic flow
11	Business owners association in Gothenburg	Might have an interest in monitoring activity in an urban environment

5.3.2 Workshop Elfördel

Elfördel AB is a small Swedish company that specializes in custom made electric centrals, they have a close collaboration with ABB - Kabeldon and are frequent users of their products ('Elfördel AB website', 2017). Since Elfördel is working with customizing products for customers, they could be seen to be in the forefront regarding technology and market knowledge. If a customer has a problem that has no standard solution, they often turn to Elfördel. Therefore Elfördel could offer valuable input to this thesis.

During the meeting, Elfördel presented their organization and their area of expertise. When the meeting touched the topic digitalization, the CEO Stefan (Johansson, 2017) concluded that digitalization is the way to go, and that many of their custom projects involve digitalized communication devices, but that are often left to the customer to install and maintain. The centrals they deliver have a space marked for the customers devices, and cables for electricity, but it's the customer that hooks it up together with electricity meter and other devices. The reason for not offering that system directly to customers are the vast spread in standards and what the customers use, and how they use it. An example of this where a distribution cabinet for controlling city lighting for a municipal in the region of Stockholm, where everything was installed, but the IoT-device for controlling was still for the customer to sort out. The reason for not delivering this was due to the specific protocol that the customer used for communication and that the customer only could use that protocol because they started with that a couple of years ago. Since Elfördel is a relatively small company, they have a limited possibility to take in extra personel to tailor-make communication systems for each customers specific needs, so today they are not able to deliver a complete system with communication.

5.4 Result of Opportunity Identification

The result from the opportunity identification are a need, based on both current markets for the CDCs' as well as a trend analysis, to make sure that the PSS not only satisfies the current customers, but is scalable and can open up for new markets in the future.

5.4.1 Conclusions

As described in the application section (4.4.2.2) and the results from the idea generation section (5.2.2), the applications of digital technology and connected devices are almost endless. Both the internal and external idea generation gave numerous ideas about how to create customer value by adding functionality in a large scale in combination with the placement of the CDCs'. This is a great finding, and it could be said with great certainty that there could be use of such both today and in the future. The problem with all these ideas is that not all of them can be implemented today, since all ideas need different systems and communication infrastructures, so it's the lack of infrastructure that is the problem.

5.4.1.1 Mission Statement

The most feasible approach for the continuation of the theses is to move the focus. From trying to implement direct functionality in the CDCs', to facilitate for the future development of such. Hence, the focus should instead be to develop a foundation/system/product to facilitate for the expansion/development of the direct functionality, e.i infrastructure for IoT.

6

PSS Solution Identification

6.1 Solution concept generation

This section describes how the generation is conducted, by first formulating the need, later to be followed by the breakdown of the stakeholders expectations and needs when structured as a PSS.

6.1.1 Need Phase (PSS)

The method of PSS (see 2.7) is chosen due to the fuzziness and level of complexity of both the identified needs and technology that can be applicable. So in comparison to the theory presented in "*Towards a Framework for developing Product/Service Systems*" (Isaksson et al., 2011), where the process either starts with a need, or a technology, this thesis has both. Since the combination between explicit needs and technology trends will be combined into a prediction about the future needs, the complexity increases. Therefore the PSS structure is of great use, especially in the early phases, to generate many alternatives of the PSS by combining alternatives regarding the User, Provider and Enabler, and also to be used for trying to map the needs for each stakeholder. Due to the large number of stakeholders and possible combinations, this will be conducted by doing a quick assessment of each, and then use that as an hypothesis for the continuation of the development.

The need is based on the voice of current markets for the CDCs' as well as a trend analysis (see section 4.3 & chapter 5), to make sure that the PSS not only satisfies the current customers, but are adaptable and can open up for new markets in the future.

6.1.1.1 Current needs

The electric utility company in Gothenburg (GöteborgsEnergi) is in the front-end regarding technology in their electrical grid, compared to other Swedish electric utility companies. As a result they are in the process of developing and implementing a system for gathering data from their electricity consumption meters by using a mesh network system based on the ZigBee protocol. The gateways for the mesh network system are placed in an add-on cabinet (CDC-A) attached to the side of a CDC. As of today, they have implemented $\approx$ 7000 units spread over the city centre and the nearby areas such as Partille. The system, as of today, has no Internet connection, due to the fact that the meter data is classified as protected information and direct connectivity to Internet could lead to increased security risks. The point to point communication is the main reason for the sheer number of gateways, which could be significantly reduced if gateways had Internet connectivity. Concludingly, gateways with Internet connectivity could lower the number of connected units, and make the data transmission simpler. But this will only be an opportunity if the internet connectivity could be proven to have a high level of security.

The current system has shown promising results compared to previously used technologies and the reliability is higher than expected. GöteborgEnergi is planning for an expansion of the network to cover data gathering from other systems and services, such as the long-distance heating system (district heating). They are also investigating possibilities for increased monitoring functionality in their electricity meters, e.g. quality monitoring. This kind of added functionality would increase the amount of communicated data. Which wouldn't be possible with the current system due to bandwidth limitations.

IVL also has an explicit need about the placement of their environmental sensors placed around Gothenburg. As of today they have several problems when placing these, but the main one are the access to electricity and space for housing the communication units (Bäck, 2017) (Hallgren, 2017).

6.1.1.2 IoT Infrastructure

As stated in section 5.4.1 there is a need for a IoT infrastructure/platform to facilitate future deployment of smart city IoT applications. A "system of systems" that can manage the connection, optimization and integration of multiple complex sets of IoT related sensors, devices and services. This section concludes findings from literature studies related to potential needs on a IoT infrastructure in a smart city environment.

Connectivity trade-off - There are multiple wireless connectivity options for sensors and devices in an IoT environment (cellular, satellite, WiFi, Bluetooth, ZigBee, NFC, LPWAN etc.) and each option have a number of different providers. Choosing connectivity option is is a matter of the devices needs regarding communication range, power consumption and bandwidth. An "all purpose optimal solution" with long communication range, low power consumption and high bandwidth do not exist (Hamilton, 2016). Longer range typically means increased power consumption and cost, this is a problem for small sensors/devices with limited battery life and it could counteracts possibilities for solar powered devices.

Security - Based on a survey conducted by McKinsey in collaboration with the Global Semiconductor Alliance, the security aspect topped the list of the participants greatest concerns about the IoT (Harald Bauer & Knochenhauer, 2017). There are two aspects to consider regarding IoT security. The first aspect is mentioned in section 6.1.1.1 where GöteborgEnergi emphasis the security aspect with regards to the fact that their meter data is classified as protected information. Therefore, security is of high importance due to risk of data "leakage". The other aspect is not related to the communicated information or the device owners at all. Hackers are not interested in information but to use IoT devices' processing power for DDoS (Distributed Denial of Service) attacks. Recently, 21 October 2016, a DDoS attack, largest of its kind in history, disrupted the internet in Europe and the US. The attackers where using the so called Mirai botnet that uses IoT devices for the attack. The attack was roughly twice as powerful as any similar attack on record because over 100.000 unprotected IoT devices where used.(Woolf, 2016) Devices act as "malicious endpoints" for such attacks and the device owner often remains unaware of the security breaches (Harald Bauer & Knochenhauer, 2017). This leads to the conclusion that users that put up their devices where "information lekage" is not considered a problem/risk the owners/users are not aware, or do not care that these devices can be used in attacks. But from a societal point of view, this is of greater importance, since these attacks can target core functions of society, such as health-care and emergency systems.

Varying protocols - IoT is as a gathering term for things that are connected, but it can differ on how they are connected. Since all things connected has different needs depending on range, power consumption and bandwidth, there are different ways of communicating data in terms of different protocols (see table 6.17) (STMicroelectronics, 2016). This could pose as a problem, that different functionality have different ways of communicating, since device A cannot communicate with device B since they are using different protocols. This problem has been tackled in some areas by installing multi-protocol gateways that gathers information from several protocols, and then trans-coding the data to distribute the information over another protocol. So instead of only being able to communicate over one protocol, these gateways can link the protocols together and also facilitate for fast internet access to distribute the information further (DELL, 2017).

Open up for horizontal business models - As providers of IoT products and services finds their niche on the IoT market they choose their technology (protocols, gateways etc.) based on their specific needs. Consequently, integration with other IoT systems will be difficult. Once the customer choose a provider for their IoT system their future system development will be limited to that providers offerings. These vertical business models complicates the system management for the end user since risk of ending up with different providers of IoT systems with no integration in between is high (Quinnell, 2013). Most of the first IoT offerings follow the vertical models due to the fact that there is no infrastructure in place that can support the horizontal models in a smart city ecosystem. In home automation the horizontal models are as of today quite common. There are numerous multi-protocol gateways that support third party automation software on the home automation market. But the IoT-ecosystem in a automated home is significantly smaller compared to the smart city ecosystem. The motivation for the horizontal models in a smart city is to facilitate system integration and innovation by allowing different providers to work on a common framework.

Edge computing - Bandwidth is a matter of cost and with increasing numbers of connected sensors and devices bandwidth might be the limitation itself. Sensors and devices for monitoring and measuring collects data which normally is sent forward to a datacenter where the refinement (filtering, computing etc.) of the data take place. In many cases it is just a small fraction of the data generated by sensors/devices that is valuable. As an example, a surveillance camera do not need to transfer video data of an empty street. By utilizing edge computing the data refinement, analytics or knowledge generation can be optimized by performing the computing/processing at the edge of the network (in close proximity to the sensors/devices). This reduces the communication bandwidth, processing and storage requirements. (Skala, Davidovic, Afgan, Sovic & Sojat, 2015)

Mesh-network - When several devices are communicating and distributing information among each other, they add up to a mesh-network/grid. Since IoT is often characterized by having short range to be able to transfer data efficiently, it is beneficial to let each device communicate with the next when transferring data. Instead of letting all devices communicate to the gateway, they can pass data along to the gateway. This is best illustrated by smart-cities, where sensors and devices that monitors/controls the cities functions are interconnected. By structuring the system in this manner instead of letting all devices having separate internet connections, the system will be less costly and more efficient. A mesh grid is also characterized by getting more reliable when adding new devices into the system, almost the opposite of how it would be to adding devices to a single internet connection. (Zanella, Bui, Castellani, Vangelista & Zorzi, 2014)

6.1.1.3 Trend analysis

The trend analysis gives hints about what the future holds for IoT and connected devices, and they are all pointing in the same direction, the increase in both the level and sheer amount of technology. Therefore, the developed world are in for, or are in the midst of a change in digital technology. Forecasts and technology analysis made in section 4.4.2.3 gives leads to that conclusion. There are several problems with the use of IoT today, such as; security, spread in communication method (communication frequencies, protocols), access to power and good connectivity. When having a lot of technology depending on a mesh-grid with previously mentioned problems, a solution could give a large opportunity. Some sort of platform/station to act as a solid base, with enough processing power to facilitate protection (in the shape of hardware based firewalls etc.) with secure access to power and internet. By having such system, the devices used to monitor/control the surroundings would be more power efficeint (see section 4.4.2.2 for examples), cheaper and easier to install, hence a more efficient network of IoT. There are also discussions about what kind of data people/companies/cities want, and there are no clear answer to this, only the future holds the answer. But one thing is certain, the importance of data will only increase as technology and society develops. Therefore, the future will have a need for data gathering, but exactly what cannot be specified, hence, it's important for the PSS to "take height" for that uncertainty by facilitating space and connectivity for many devices and instruments.

6.1.1.4 Needs Output

The need is a combination between explicit needs of today, and the projected future, driven by trends in the area of IoT and new infrastructure connected to IoT.

1. Easy accessible space for placing sensors and devices in urban environments
2. Easy access to electricity
3. Internet connectivity
4. Ability to communicate over several protocols
5. Facilitate for hardware security e.g. firewall
6. Ability to process data prior to long range communication
7. IoT infrastructure platform solution (software)

6.1.2 Stakeholder expectations/needs and combinations/-decision

The solution is defined by dividing the product, service and possible stakeholder relations. Since the technology of IoT and connected devices is complex and spread over several different protocols and technical platforms, special competence needs to be included in the development. Hence the stakeholders varies depending on product function. Another aspect are the differences in infrastructure and possible ways of implementing the product, and who will be the userof the the product and for what will they use it for, also adds complexity in structuring users, providers and enablers.

The approach to all this complexity and uncertainty the PSS-system will be divided into more manageable chunks, a structure which divides the need, solution and enablers, see table 6.1. The level of the table is basic, since the exact enablers is an uncertainty, also dependant on future development and needs, as identified in the trend analysis (see 6.1.1.3).

Table 6.1: Basic structure of PSS-system to visualize function and enablers.

Need
IoT infrastructure platform (physical/virtual)

Solution
Scalable Gateway from low range to internet

Hardware	**Software**	**Service**
Add-on cabinet	API	Installation
Transceiver	Security system	Maintenance
Receiver		Updates
Processor		Placement-planning
Connections for sensors		Customer value creation
Internet connection		Sensor choise
Electricity connection		

The previous table gives a good structure on need and how the solution could work, but are lacking an important aspect, ownership. How the ownership and responsibilities should be divided are a large and difficult aspect to analyze, since a great amount of different technology are supposed to be synergized and also combined with services. That problem will be approached by combining the model presented by (Isaksson et al., 2011) and the possibility to combine all these stakeholders. The problem when considering both the framework and the combination-possibilities are the amount of solutions. There will be to many possible combinations to analyze separately within the given time-frame for the thesis. Therefore the PSS-structure considers the system as a fully developed system, with all ingoing functionality. A suggestion of how to tackle the dilemma regarding future development of the system and level of technology will be described later in the report. When mapping the system as a complete system, the advantage is the understanding of its complexity and the stakeholder expectations/needs.

The evaluation of the Need structure, Solution and Enablers, problems arise. The level of accuracy on the hardware is a problem, because it's too complex and time-consuming for the thesis to evaluate and add needs for each aspect of the hardware. Since the market offers some communication systems as of today, and it's only a part of the PSS. So instead of creating a custom made system, current systems (e.i gateways) on the market will be analyzed and assessed. See table 6.2 for the updated "simplified" structure.

Table 6.2: Updated structure of the Need, Solution and Enablers.

Need
IoT infrastructure platform (physical/virtual)

Solution
Gateway from low range to internet

Hardware	**Software**	**Service**
Add-on cabinet	API	Installation
Gateway	Security system	Maintenance
Sensors		Updates
Servers		Placement-planning
		Sensor choise

By using this structure instead, more focus will be on the PSS as a whole without spending too much time on the details of the ingoing technology (e.i gateway). Instead, current gateways on the market is analyzed and assessed regarding performance of range and computing power.

6.1.3 Combinations of the PSS-layout

Since the PSS is relatively unknown, there are several ways of combining the User, Provider and Enabler to get almost the same system. By using the structure seen in table 6.3 as a base for stakeholder combination, understanding about the stakeholders, their expectations and needs are obtained.

Table 6.3: Illustration of stakeholders to enable a PSS

User	$\longleftrightarrow$	**Provider**	$\longleftrightarrow$	**Enabler**

User - Is defined as the consumer of the PSS, and in this case it could be several companies or persons. The persons/companies that need access to the IoT infrastructure and/or the information in the system.

Table 6.4: Description of possible users and how they would consume the PSS.

User	Description
Google	Might be interested in data regarding peoples habits and activities
Automotive industry	Can make use of mesh network for vehicle to vehicle communication, especially for autonomous driving, since mesh networks could decrease latency. It could also provide the car with data about the environment in a specific location, e.i "slippery spot"
Big data traders	Could use data to analyze and trade with, example is how data is traded regarding peoples internet habits for online shopping.
Citizens	By getting data about their environment, such as traffic, parking spaces, air quality, activity, transportation, noise etc. The person can "tailor" make their experience and habits in a more efficient way.
Cities (Municipal)	By having information about how the city is working at any given time, proactive and real-time measures can be taken to increase security, safety and well being for the citizens. Traffic can be redirected, public transport can be adapted, energy consumption could be optimized, it could be used for location of elderly or incapable persons and personal safety (alarm etc). They also have a spoken need for wanting to measure environment (Bäck, 2017).
Communication companies	Can use gateway to place communication devices to enhance their performance towards their customers. For example, placing a WiFi-hotspot that their customers have access to, or as a part of larger low-range network for their existing customers.
Application developers	Developers could have an interest of the data gathered. An example of such development would be an Asthma-App, that uses data about the current air-quality in specific locations, and then uses that data to ease the life of asthmatic individuals by giving them an indication about where they should go/not go to feel their best.
Electric utility company	Has a spoken need of wanting to have an easier way of using their current ZigBee system, and are now in a phase of expansion.

Provider - Is defined as the company that offer the PSS to the customer, and have the main responsibility of making sure that the product and services come along during the products life cycle. Due to the uncertainties regarding both the technology and the economical aspect in this stage, several companies/organizations/joint-ventures could act as provider. The reason for having many providers as joint-ventures are the level of technology, size and complexity of the PSS. Since both the software and hardware are assessed to be relatively advanced, instead of buying the services from them, alternatives are put out to involve these companies instead. This to reduce the risk for one company, increase commitment and increase the competence necessary for delivering a solution that satisfies the need.

Table 6.5: Description of possible companies to act as providers of the PSS.

Provider	Description
ABB	ABB could offer the complete PSS
ABB + other(s)	ABB could offer parts of the PSS, while letting other organization(s) in for their expertise in some area
Infrastructure provider (Municipal)	The municipal could start a company that is driven the same way as the existing local power grid, that focuses only on the IoT infrastructure, providing the whole PSS
Telecommunication companies	Could buy the complete enabler package, and be in charge of providing the offer
Big data traders	If the traders are interested in the data collection, and trading of the data that could be gained in a gateway system, there is a possibility that it is more profitable for them to collect it themselves than to buy it as a customer.
New organizations, start-ups	When offering a new technology or solution, there are cases where the already established companies don't want to take the risk of offering the complete solution directly to the customer. The established companies know that their technology will be bought and included in the larger offer, so they decline the possibility of doing it themselves. In this scenario, there might be a possibility for a new organization to take the risk and offer a complete solution to the customers.
Electrical utility companies	Electrical utility companies might have an interest in adding new functionality to their existing grid, with the prerequisites that it's a feasible business and can be of advantage for society.

After evaluating the different provider proposals, the most beneficial provider is assessed to be the electrical utility company, since they already have good knowledge and access to the electrical grid and the CDCs'. Some are also, as of today using low range protocols to communicate information about the current status of the grid. Interviews with both GöteborgEnergi and AlingsåsEnergi confirms this, that they probably would be the best suited for the role of provider. According to Mathias Larsson (Larsson, 2017) one of the most important aspects are the access to the power grid from third parties, since all this is regulated in the Swedish law, it would be problematic for third parties to gain access due to security and safety reasons. Another important aspect is the fact that the the local grids are (in many cases) owned by the municipalities, meaning, if the gateway system could be proven to have societal benefits, the business case could be of greater acceptance for higher uncertainty levels compared to what investors might demand. This combined with the local electrical utility companies knowledge and access to the system therefore makes them the main provider of a IoT-infrastructure system, and will therefore be used for further analysis.

Enabler - Is defined as the parts that finally adds up to the PSS, often divided into hardware, software and services. In this thesis the main enablers are therefore companies with knowledge in data communication and manufacturers of processing units and communication devices. Service has the highest uncertainty, since it's dependant on how the system is structured, implemented, used, and what other enablers are involved.

Table 6.6: Description of possible companies to provide enablers of the PSS.

Provider	Description
ABB	ABB has a lot of experience in the IoT field, especially in IIoT, since they are one of the global leaders in both digitalization and connectivity. Therefore they are suited to deliver all or almost all technology needed. Problems for a large organization such as ABB are the inherent inertia existing in the company. That the development and cross-functionality needed to produce a gateway system might make the company to slow.
Electrical utility companies	Electrical utility companies are important enablers in all aspects, since they are the owner of the majority of all the CDCs' placed around the cities. They need to be involved for the gateway to be successful, since they decide weather it's ok to add functionality to their existing CDCs' and use the power from the power grid.
Intel	Since Intel is the one of the worlds largest manufacturer of computing power, they will act as a representative for such companies. Since they are the owners of their technology, it's a matter of puzzling their technology together (hardware and software) to produce the gateway. Therefore they don't need as large investments as other possible enablers, with the prerequisite that the ingoing technology is the main cost bearer in the gateway.
Innovation labs	Could have the possibility to unite expertise in areas required, and from there create the solution.
Cities (Municipal)	To be able to expand the gateway system, the power grid and its' CDCs' needs to be utilized. And often the municipal are in charge of the local power grid, hence, the municipal needs to be involved, or at least approve (understand the need) for the expansion of such.
Telecommunication companies	Since this type of company has good insight into the market of communication and connected devices, because that's what they are specializing in today. Therefore they have a close customer contact, and also good technical knowledge, especially about the current system (4G, 3G, broad-band etc.). This would probably make them good as a coordinator for putting the PSS together in terms of technology, how to sell, what the customer needs are, get feedback and how to structure the service/updates throughout its' life-cycle,

6.1.4 Assessed stakeholder expectations and needs

By mapping the stakeholders of the gateway PSS-system, stakeholder expectations and also stakeholder needs could be assessed. This is done by identifying a stakeholder, and identify possible stakeholders expectations, later to "translate" these into needs, see table 6.7 for illustration. These needs can then be used to assist in the eliciting of design parameters, e.g. Value drivers.

Table 6.7: Illustration of mapping stakeholder expectations and needs.

Stakeholder

↓

Stakeholder expectations

↓

Stakeholder needs

↓

(Value Drivers)

The owner/owners of the solution has several expectations on the PSS (table 6.8), especially the reliability of the system, since downtime directly impacts the value of the PSS for the customer, that is seen as a need. It's also important that the system is easy to access and have the possibility to adapt to the customer needs. An example of this is when a person/company needs to install a sensor, the system must be able to accept the sensor, and the protocol that the sensor uses, and still provide the security for that sensor and the rest of the system. By making sure that the right guides/walk-through/customer service are there to assist the customer in need.

Table 6.8: The user expectations and needs

The User

↓

Easy to establish connection	Easy to interact with	Adaptability	Get data when needed	Integrity protection
↓	↓	↓	↓	↓
Simple user interface	Simple user interface	Support for several protocols	Reliable connectivity and high up-time	System security level (hardware/software)
Open source	Open API	Easy to add/remove functions/sensors	Easy to orientate in the system	
	Visualized mesh network map			

The Owners most important expectations is to get a return on investment, if translating that into needs (6.9), it's to have a low investment and low maintenance in relation to return. For the PSS to be feasible over a period of time, especially in the high-tech market, the PSS also needs to facilitate changes and updates to enhance the performance of the system.

Table 6.9: The Owner

The Owner

↓

Affordable to aquire	Work in landscape (appearance)	Available when needed	Low running cost	Easy to implement
↓	↓	↓	↓	↓
Low cost of manufacturing, (DFA/DFM/ standard parts)	Aesthetically pleasing/invisible	Secure connection and reliable technology	Simple maintenance and updating of the system.	Interface with current CDCs'

The one manufacturing and maintaining the PSS have almost the same expectations, and therefore these aspects are put together in one table, see 6.10. The needs therefore are Design For Assembly (DFA), Design For Manufacturing (DFM), easy to access, designed for operating conditions, modular and good documentation about system and design.

Table 6.10: The one maintaining/manufacturing

		The one maintaining/ manufacturing		
		↓		
Easy to produce	Possible to adjust to market needs	Low cost of parts	Predictable technology	Easy error diagnostic
↓	↓	↓	↓	↓
Standardized	Modular	Use of standard parts	Optimized for operating conditions	Documentation about system/previous errors and research
DFA	Scalable	DFM		User adapted error diagnostic tools

The suppliers of the hardware/software is most interested in knowing what they should deliver, in terms of performance and how to integrate that into the PSS. Therefore the needs are good knowledge about the system to aid integration, and well structured specification list, and ability to collaborate with other stakeholders. See table 6.11 for more details about expectations and needs.

Table 6.11: The suppliers

	The Suppliers	
	↓	
Known interface	Clear expected deliverables	Cost of parts
↓	↓	↓
Access to drawings, functional descriptions (software)	Specification lists	Standardized
Cross-functional work with other stakeholders		Adapted manufacturing for specific part

The environment/societies expectations of the PSS are that it should not be of danger to the public, which means that it should fulfill laws/regulations regarding wireless communication and work with electricity. And to be able to implement the system, the appearance of the box should not impair the cityscape from a aesthetic point of view.

Table 6.12: The environment/society

	The surrounding society/environment	
	↓	
No interference with other equipment	Not harmful/dangerous	Not impair cityscape
↓	↓	↓
Fulfill laws and regulations regarding wireless communication	Fulfill laws and regulations regarding work with electricity and material use	Appearance/aesthetically pleasing

The application developers are in essence a user of the system, but since they need a bit collaboration with the system, they are separated from the other users. To be able to develop ideas/systems with the gateway system as a base, they need access to data, documentation of the current state of the system in a specific geographical location of the system (sensors already there etc) and integration possibility, see table 6.13. An example of a product/service created by such application developers are the AsthmaWatch in Stockholm, where open-source data regarding the current weather conditions are used by a third-party developer to create a tool for helping asthmatic persons in an Stockholm (SmartSthlm, 2016).

Table 6.13: The developers

	Application developers	
	↓	
Innovation possibilites	Knowledge about system	Ease of implementing changes
↓	↓	↓
Customer/user contact/interaction	Documentation about system/ previous errors and research	Standardized API and online updatability
Access to data		Information/standards/manuals regarding implementation of new application

6.1.5 Conclusions

The needs should preferably be developed into quantifiable design parameters (Value Drivers), to be used in a requirement specification. By doing so, the end result will have good traceability, meaning that every design parameter can be justified by a stakeholder. So if troubles/doubts or trade-offs occur when designing, the possibility of tracing the parameters origin can be done relatively simple.

In this case, the expectations and needs are assessed by the thesis group internally. So the needs do not have good enough accuracy to be able to take it to the next step, e.i. Value Drivers. And since the thesis is exploratory, it's not targeted either. The result from this should only facilitate understanding for both the complexity of the system, number of stakeholders and possible stakeholder expectations/needs.

6.2 Concept Generation

The generated concepts all have the same purpose, according to the needs output, see section 6.1.1.4. The difference between the concepts are on what level they fulfill the purpose. The complexity of the system increases by the level fulfillment due to the amount and complexity of the ingoing technology. Since Concept A is basically just a galvanized steel enclosure with an electricity connection, whilst Concept D has a communication module, edge computing and software included in the solution.

6.2.1 Concept A

Concept A is the most simple concept, it's basically a cabinet for holding the ingoing technology together with a connection for electricity (power supply). The only difference from this cabinet and ABB - Kabeldons existing add-on cabinets are the adaption for ingoing technology, where this has a device-rack add-on. This concept do not contain any digital equipment made or developed by ABB, it only facilitates for the future implementation of such by either the provider or user of the system. This concept are has the lowest investment, but also the lowest return. ABB - Kabeldon can realize this concept as of today with their own in-house competence.

6.2.2 Concept B

Compared to Concept A, this concept should also facilitate for internet connection in the cabinet. So instead of having the customers solving this themselves, the concept should facilitate for fibre connectivity. ABB - Kabeldon can realize this concept with their in-house competance.

6.2.3 Concept C

Compared to concept B, this concept also has the add-on of a communication module (multiple protocol handling), to facilitate for easy implementation of functionality by the user (sensors etc.). This function requires two different "parts" both the physical communication module, and also a software that facilitates for accessibility for the user, while providing data security. ABB - Kabeldon cannot realize this concept without "anchoring" it higher up in the ABB organization.

6.2.4 Concept D

This concept are the most complex one, with all the functionality from the previous concepts, but with the addition of the following functionality, mesh-network scalability, IoT facilitation, edge computing and some sort of platform to facilitate for horizontal business models. By having all this functionality, the cabinet must house the following hardware; processors, firewall, communication module, sensors and data-storage. ABB - Kabeldon cannot realize this concept without "anchoring" it higher up in the ABB organization.

Concept D is the most advanced concept, where edge processing is included together with free rack space for customers own devices. A communication module is also included with the ability to communicate over the most used protocols at the time of implementation.

All this together gives the customers the ability to very easy set up their own, or use existing sensors in close proximity to the cabinets. It also gives them the possibility to process data at site, so instead of transceiving/receiving data to/from a cloud for processing. This could reduce latency and reliability for the data processing, which could be of interest to e.g the automotive industry and especially autonomous driving.

6.2.5 Comparison between concepts

To understand how the concepts differ in the level of technology and functionality see table 6.14.

Table 6.14: Comparison of functionality and level of ingoing technology of concept A-D.

	A	B	C	D
Power supply	X	X	X	X
Device rack	X	X	X	X
Communication module compatibility	X	X	X	X
Internet connectivity (fibre)		X	X	X
Communication module included (Multiple protocol handling)			X	X
Mesh networking				X
Edge processing				X
Online platform / open API				X

6.3 Solution Concept Evaluation

To get an understanding about how the different concepts perform with regards to different aspects, an evaluation was needed, and the chosen method was a Kesselring matrix.

6.3.1 Kesselring

The evaluation is conducted by comparing the concepts against one and other, and score accordingly. Since it's relatively simple to say which of the concepts is the most complex and which is the simplest, they are scored in a relative fashion. The aspects chosen are the following ones;

Customer Needs fulfillment - This aspect both considers the explicit needs and the predicted needs of the future. Scoring high in this aspect means a good needs fulfillment with regards to both current and future ones (see section 6.1.1.4 for list of customer needs).

Societal Benefit - This aspect considers the level of possibilities the system have for the end user, i.e how easy it is to add-on or adapt for miscellaneous functionality, such functionality mentioned in the idea generation (section 5.2.2). According to Larsson, 2017 this aspect is of high importance to be able to implement the system in a society, beacuse if the societal benefits are high, then the implementation will be easier and the certainty of the business-case could be less solid.

Cost - The cost assessment is a rough assessment on the ingoing technology and cost of the system. Since the scoring is conducted in a relative fashion, the simplest concept (A) will be the highest scoring, and the most complex concept (D) will score the lowest (see appendix C for a more detailed view of what effects the cost).

Complexity - This is the aspect that considers both the complexity of developing and synthesis the ingoing technology, and also the complexity of the PSS. This aspect also, implicitly considers the competence required for the development of the concepts. So a high score (> 6) means that ABB - Kabeldon can make the development themselves, in-house without any large organizational changes. But a low score (< 6) means that ABB - Kabeldon do not have the required competence in-house for the development, and are therefore required to reach out to ABB as a whole, or start a separate division for the development. However the decision, a low score requires high managerial support from within ABB to continue the development (Weidenmark, 2017).

Guidelines accordance - This aspect considers the accordance to the previously stated guidelines with regards to ABBs' strategy (ABB, 2016). This is of importance for the future development, since without accordance to their ABBs' strategy, the future development wont receive any funding (Axelsson, 2017).

Risk - The risk includes the uncertainties of the future, therefore the more advanced and costly a concept is, the less it scores at this aspect. This aspect was chosen to get a clarification of the difference between the concepts and the findings from this thesis, since the longer in the future the concepts rely on the findings from this thesis, the higher the level of uncertainty.

Table 6.15: Kesselring matrix with Cost as an important aspect (weight=10).

		Concept A		Concept B		Concept C		Concept D	
Aspect	Weight (1-10)	Magnitude	Value	Magnitude	Value	Magnitude	Value	Magnitude	Value
Customer needs fulfillment	**10**	4	40	6	60	8	80	10	100
Societal Benefit	**7**	2	14	4	28	8	56	10	70
Cost	**10**	10	100	8	80	4	40	2	20
Complexity	**8**	10	80	8	64	4	32	2	16
Guideline accordance	**8**	2	16	4	32	8	64	10	80
Risk	**5**	10	50	8	40	4	20	2	10
Total score			**300**		**304**		**292**		**296**

Table 6.16: Kesselring matrix with Cost as an unimportant aspect (weight=1).

		Concept A		Concept B		Concept C		Concept D	
Aspect	Weight (1-10)	Magnitude	Value	Magnitude	Value	Magnitude	Value	Magnitude	Value
Customer needs fulfillment	**10**	4	40	6	60	8	80	10	100
Societal Benefit	**7**	2	14	4	28	8	56	10	70
Cost	**1**	10	10	8	8	4	4	2	2
Complexity	**8**	10	80	8	64	4	32	2	16
Guideline accordance	**8**	2	16	4	32	8	64	10	80
Risk	**5**	10	50	8	40	4	20	2	10
Total score			**210**		**232**		**256**		**278**

6.3.2 Kesselring conclusions

Due to the complex layout of the PSS, the Kesselring will give different results depending on the aspects considered (see comparison between table 6.15 and 6.16). And since the aspects are set by the enabler, provider and user, and that the thesis aim is to provide understanding and proposals for these, the result must be critically assessed. An example of how the results of the kesselring will change due to minor changes are the comparison between table 6.15 & 6.16, where the weight of the aspect "Cost" has been changed from being very important (10) to not being important (1). This minor change, changes the whole result, from Concept B being the "winner" to Concept D. To handle this uncertainty, the result will be further analyzed.

When evaluating each concept separately, it could be said that concept A & B are the simplest ones, both in terms of development cost/complexity and also regarding how to structure the business model and PSS. While C & D are more complex, and require more technical development, more knowledge about the market and more work with the PSS to facilitate for a feasible business and customer satisfaction in the future. The conclusions that can be drawn from this is that ABB - Kabeldon can only manage development of concept A & B on their own, whilst concept C & D requires anchoring higher up in the ABB organization, to obtain the required monetary assets and competence for development. Since ABB - Kabeldon are a traditional manufacturing industry, this could lead to consequences, described and elaborated around deeper in section 10.3.1. The problems are mainly about moving from a transaction-based, to a relationship-based approach, towards the customer and development (Roy et al., 2009).

When adding up all the previous findings together with the conflicting results from the Kesselring matrix, a possible plan can be interpreted. Since information about critical areas are lacking the more complex the concept becomes, it would be most feasible to start at concept A & B, and consider the following concepts (C-D) to be future development. So the concepts should not be considered as unique, but more like a four-step rocket from basic to advanced. By structuring the development in such manner, continuous information from the customers and market could be gained, to keep development focus correct by facilitating for changes in area of technology and market.

So the proposal being that concept A & B should be first up for development, which is basically one of Kabeldons existing products (CDC-A) with the some minor add-ons to facilitate for electricity/fibre connectivity and a rack for processing/communication devices. When this is implemented and marketed within ABB, critical knowledge could be gained from the current users, how they use it, what problems they face etc. Since the explicit needs of today are mainly about space for devices and electricity and fibre connectivity, these needs will be fulfilled But it also gives a great starting point for the continued development (concept C-D). If the continued development is proven to be unfeasible, it could be "killed" to minimize losses, compared to if concept C-D would be the first step in development.

6.4 Solution development

Firstly, a appropriate name is produced by the thesis group. ABB - Kabeldons current product have abbreviations of three letters describing the function, such as CDC (Cable Distribution Cabinet) and SDC (Special Distribution Cabinet). So the function is the IoT infrastructure system is to distribute data, and it's housed in a cabinet, so the name falls naturally: Data Distribution Cabinet (DDC).

To be able to develop a solution of any kind, more information about the technology and costs are needed. And especially the relation between these, therefore a model for assessing how to place the DDCs' are developed, and a model for assessing the costs for each DDC is also developed. These are created both for the thesis, to create a foundation for understanding the relation and costs connected to the different concepts (A-D) and also for communicating this information to ABB.

6.4.1 Technology investigation

When deciding on how the DDC should function, an investigation on the current technologies is conducted. Since the DDC should be able to communicate over several different protocols, some understanding about these, and common application is critical, see table 6.17 . Hence, that information is needed to be able to chose the right type of gateway with/without applications, and also be able to approximate the cost of the ingoing technology in the PSS.

Table 6.17: Description of current IoT communication types and their common applications (STMicroelectronics, 2016)

Technology	Standard	Band	Range	Power	Data Rate	IoT Applications
Bluetooth	Bluetooth 4.x specification	2.4 GHz	Medium 50 - 150 m (Smart)	Medium Low (BLE)	Medium 1 Mbps	Wearable devices Sensors Nodes IoT application
Wi-Fi	802.11b/g/n/ac	2.4 / 5 GHz	Medium 50 m	High	High 500 Mbps to 1 Gbps	IP Camera Gate way devices
NFC	ISO/IEC 18000-3	13.56 MHz	Low 10 cm	Low	Low 100 – 420 kbps	Access Management BT/Wi-Fi pairing e-Tickets Payment
Sub GHz	802.15.4 6LoWPAN	868 MHz / 915 MHz	High	Low	Low 500 kbps	Smart Street light Energy meters Smart Building
ZigBee	802.15.04	2.4 GHz	10 - 100 m	Low	Low 250 kbps	Smart street light Smart Building
Z-Wave	ITU-T G.9959	900 MHz	30 m	Low	9.6/40/100 kbit/s	Home automation
Thread	802.15.4 and 6LoWPAN	2.4 GHz	N/A	Low	250 kbps	Home automation

As the table describes, communication over the network of IoT is done on many different frequencies with various properties. The main aspect when choosing a protocol is the data transfer speed, and that impacts the power and range properties. Therefore it's tough to get "everything" right when choosing a protocol, an example might be a surveillance-camera, which requires high speed of data transfer, and according to the table 6.17 the only suitable protocol would be Wi-Fi or giving the camera a separate internet connection (often how it's done today). By having a separate internet connection, cost increase, in comparison to using WiFi. If a gateway would be used, the camera could be placed in proximity and use the WiFi supplied from the gateway. This is generic for all applications, that trade-offs could be cut by using the DDC and the surrounding IoT connections for ensuring stability of communication, increase security while lowering costs (per application added).

6.4.2 Cost assessment

To obtain a better overview of the system, enabler, provider and user, the cost assessment is divided into three steps. When conducting the cost assessment, the uncertainty is relatively high, since the components needed are not developed in a fashion that the communication part could be bought separately with the functionality the system needs as of today. The cost of the physical DDC is later multiplied by an arbitrary margin (in this case 25%) to illustrate how that would impact the pricing for the customer, as well as pay-back for the enabler and provider (see appendix C for an assessment with full functionality, e.i. Concept D).

The second part of the cost assessment is the provider part, because the provider would probably be the owner of the electrical grid, and for them to implement such a system in a larger scale, there needs to be both profit and societal benefits. A trade-off between these two could also be identified, since large societal benefits could justify less earnings and the other way around. Since the owner of the electrical grid also would be the owner of the system, the connection cost could be avoided, since the electrical grid owner also is the user (van Rooij, 2017). It's also beneficial since the electrical utility company has the best knowledge and system to maintain their current system, the service aspect would be more like adding slightly more work, but as a whole, it probably wouldn't affect their daily activities (Larsson, 2017).

The life-span of the hardware in the gateway have an assessed life-time of three years, since technology develops rapidly, the hardware also have to be changed relatively often to facilitate functionality in relation to computing power development. This together means that the system would have a higher cost per year during the first three years, and after three years, the cost/year would drop significantly.

The most uncertain assessment is the end user cost for this PSS, since the system is relatively complex and large. And since there are no approximation about the users willingness to pay for using the gateway system, no critical mass can be identified. The only conclusions that could be drawn are that the more users that wants access to the gateway system, the less each one have to pay.

An important aspect of the system is the software, since the system should enable for third party developers, and information sharing, to lower the cost for each user of the data. Such systems are currently developed by Siemens under the label of Mindsphere. ABB has no software with this functionality, so either use Mindsphere or develop a new software at ABB. This is also an approximation of uncertainty, how much such software would cost, with the correct adaptions etc.

The cost assessment are done in a ground-up fashion, where each vendor has their own margin until the end user. But the pricing for a system like this to the end user/customer should be conducted in a top-down. If only using ground-up pricing to the end customer, the use of the system will have a set price depending on how many and how they use it, but the risk with only using that approach is to miss out on possibilities to set a higher price and increase profits. If both ways are combined, using the ground-up to assess the cost of the system, and then using top-down to decide the price for the end customer, the gap in-between are the profit. And by setting a price depending on value for the customer, the gap could be maximized (Maylor, 2010).

Exactly how the customers should get access and pay for the system, and how much usage would cost are still to be determined, but more thorough investigation about the customer needs are necessary to decide this, and also needed to be able to use the top-down pricing for the end customer. But what could be said is that that current trends are pointing more and more to tailor made solutions for each customer. An example of this is the business model of mobile phones or car-sharing, where customers pay for the function depending on their specific needs.

Concludingly, the cost assessment are conducted in a ground-up fashion, which have inherent errors when it comes to maximizing profit depending on value for the users. Therefore the top-down way are the best, but it also requires detailed market information, such as how much the end customer are willing to pay for using the gateway system and/or how many that wants to use a system. By having one of them, the unknown could be assessed and stress-tested, to give a hint of the feasibility of the system. By having both, the stress-test could be more comprehensive and also more accurate. So the suggestion for the future are more extensive market research about the users would interact with the system, and the value the system could bring them, and then use that information and apply the top-down method to set the price for the end user.

6.4.3 Placement of DDC

When assessing how to structure the IoT infrastructure using DDCs', two alternatives has been developed. One considering the mesh grid possibilities from a more theoretical aspect, whilst the other, is based on the combination of geographical and technological properties.

6.4.3.1 Only considering mesh grid structure

When deciding on how to place the Gateways, there are several ways of placing the DDCs' (nodes). Since a mesh grid automatically can decide on how to transceive/receive data, it chooses the most efficient (shortest) route. But if a node goes offline, there must be an alternative route. The critical information when deciding on how to place the gateways are therefore the range, and in this business case, the range for the calculations are set to 200m as an arbitrary range. That's the distance that the Gateways can be separated but still communicate without problems/too much interference from other wireless communication devices.

Placing the grid as a square mesh-grid, where each node has $200m$ to the next, in either the horizontal or vertical direction. Then each node has 4 surrounding connection nodes ($360/90 = 4$), which in turn has four connection nodes etc.

If this method is used, there needs to be 25 nodes in a km^2 to completely fill the space. But if this are done in a larger scale, in a city, the calculated amount per km^2 is instead 16, since the outer nodes will intersect if 25 is used. If this method would be used to cover the county of Gothenburg, 7200 cabinets have to be used, see equation 6.1.

$$16 \times 204 = 3264 \tag{6.1}$$

When placing the gateways as triangles instead, where the length always are 200m with the angle of 60 deg the node always has six possible nodes to connect to ($360/60 = 6$), and anyone of those six has got six more to connect to and so on.

If this method would be used to cover Gothenburg, each km^2 would need to have ≈ 19 gateways. So the total number of gateways would increase to 8592 (see equation 6.2), but so would also the reliability of the system.

$$19 \times 204 = 3876 \tag{6.2}$$

The total number of gateways would therefore increase by $\approx 16\%$ by using the latter method instead of the former, but the reliability would be increased. This is an important trade-off to consider when building the system. Exactly how to place the gateways is something that needs to be considered from case to case depending on the specific demands and cost limits for that system, if the system could be less robust and funding is limited the first placing is an option. But if the system should be more robust, and be able to handle data faster and in a more efficient way, the second alternative is more appropriate. Another problem with this approximation is the realisticness, since the goal is to make use of the existing placement of CDCs' when placing the DDCs', this placement method would not be feasible, since it demands very specific distances between the CDCs'.

6.4.3.2 Considering a combination of geographical and technological properties

When placing the gateways in a city, the most important aspect is the preferred range of the gateway, hence that decides the resolution of gateways placed. To be able to assess the resolution some simplifications and assumptions has to be made. The range the different protocols have a large impact on this, and since they vary a lot, an average range needs to be assessed to facilitate further calculations.

When doing this assessment of the solution, three cases could assessed using the data from table 6.17.

1. The gateways are placed with the most conservative range average from table 6.17, which is calculated to 35m (r_1).

2. First each range is interpolated between min-max, and then the average is calculated among the four ranges (58,75m = r_2), see table 6.17.

3. The third assessment is the most optimistic assessment, using all the protocols maximum ranges from table 6.17, which results in a range of: 82,5m = r_3.

When deciding on how to place the gateways, the third one is the most realistic one. Since the gateways main function is to act as a hub and enable sensors in the nearby area, the senors has to be placed with the range restriction in mind. So instead of enabling a whole area for all protocols, some areas will be suited for some protocols. And if devices with low range protocols expands like the predictions tells, the devices will be able to communicate with each other to enhance range, which will remove the range-problem all together.

Another issue that needs to be assessed is how much of a city that needs to be covered by the gateway, in this thesis, Gothenburg is used as an example. By using existing maps of the city centre, different geographic properties could be interpreted, such as water and uninhibited areas. In this case, only areas which are populated will be used to assess the number of gateways that needs to be placed. In the case of Gothenburg, only 18.6% of the city centre are feasible for placing gateways, see figure 6.1, which means 5,6 km^2, see 6.3.

Figure 6.1: Over-view of Gothenburg, used as base for gateway resolution approximations. (Blurred due to non-disclosure agreement)

$$0,186 \times 30,3 \approx 5,6km^2 \tag{6.3}$$

This gives three possible ways of how to place the gateways depending on the range, see equation 6.4. N = Number of gateways to fill the area, r_x = Range of the gateway and A = Area that needs to be covered.

$$N = \frac{A}{r_x^2 \times \pi} \tag{6.4}$$

This gives three different resolutions.

1. $N_1 \approx 1455$, r_1
2. $N_2 \approx 516$, r_2
3. $N_3 \approx 262$, r_3

To get an assessment of the cost of these alternative resolution could be combined with the business case. See appendix C for a combination of the different resolutions together with concept D.

6.4.3.3 Conclusions from geographical placement alternatives

The placement when only considering mesh grid structure is seen to be unrealistic since it requires very specific locations for the DDCs' to work. Since one of the prerequisites for the thesis it to make use of the existing CDCs' and their location, it's therefore unfeasible to use that method when structuring the system.

The alternative where a combination of the technological and geographical properties gives a more realistic placement structure, since it's considering both the technology and where the DDCs' should be placed to be in relation to the population, much like the current CDC-system. Therefore, that is the preferred way when structuring the system.

6.5 Solution realization

The exact model for the business is uncertain, and the cost assessment is an example where assumptions has been made to get a some what realistic assessment of the costs. There are alternative ways of structuring the business for the enabler of the system, such as selling the gateway to a discount, not making profits by selling the system, but instead having a deal that gives the enabler an arbitrary percentage of the total earnings from the system. By structuring the system in this way, the risk for the enabler increases, but the risk for the provider decreases, so the risk within the system are more evenly spread throughout the different stakeholders of the system. But in what way the business model should be structured is in need of more investigation, both regarding the ingoing technology and also in terms of mapping the possible usages and how to set pricing for the customer. The cost for a gateway is taken from a model provided by DELL, since the thesis group could not gather good-enough data about ABBs' own products in that segment regarding price and performance.

The installation of the system should be done by the provider, which the electrical utility company would be best suited for. By having the technology housed in a add-on cabinet, the installation would be relatively simple using few fastening elements to attach the add-on cabinet to the CDC, and one cable for electricity and one for fibre connection. By having the electrical utility company as a provider, they have the easiest access to their own cabinets regarding personnel safety for their electricians who would conduct the work. They also have the possibility to decide how the electricity is used by the gateway. Since the regulations tells that every user on the power grid should be responsible for their own cost and energy usage, if that user is the power grid itself, then they have the freedom to walk past that law. In that case the installation cost of 22100 SEK (Larsson, 2017) used in the cost assessment would be eliminated for every unit placed, since that cost is the cost of an electricity meter and installation of such.

6.6 Solution support

Since the gateway should both be updatable to facilitate enough computing performance for the current circumstances, and also be modified to facilitate solutions for specific customer needs. For example, customers need to gather data about current weather conditions and no sensors are applicable in that specific area. Then the new sensors needs to be placed, if there are only one customer of this data, the most likely scenario is that the cost for the customer will increase. But if there are several customers with the same need, and they could "share" sensors and data gathering methods, the cost for each customer will be less. And the cost for the customers could instead be based on how they use the functionality of the system. This phenomenon are seen more and more today. An example of this are Sunfleet car sharing, where the customers have a subscription, and the subscription is based upon the usage of the car. This means that the more the customer uses the car, the cost per kilometer decreases, but the monthly subscription cost increases. Each customer can tailor make their most feasible solution and the company have already secured their earnings by offering a thought-out solutions to the customers.

By offering this type of solution in the gateway system, the provider needs to be active in their maintenance and perceptive towards customer needs. Not only should the system be up and running, it should also be developed continuously in accordance to the current market situation. In the cost assessment, the life length of the ingoing technology is set to three years, this means that every third year the ingoing components needs to be changed by the provider. The technology is also divided into three chunks; firewall, communication and processing power, this to ease maintenance and technology updates. If, after a year the processing power needs to be increased, but the other parts are good-enough, only the processor should be changed to keep costs down. Since the uncertainty is high regarding the ingoing technology and the future for such, there modularity is seen to be necessary to take height for that uncertainty.

6.7 Solution closure

When a DDC and its ingoing components are used, meaning that the functionality is impaired beyond feasible repair/updates. The components should be changed to a new and improved ones, the old cabinet should be possible to re-use and house new technology. If the cabinet should be damaged, it should be recycled in accordance to current laws/regulations in the most sustainable way. If the inside technology is regarded as used and changed, it should also be recycled in accordance with current laws/regulations.

7
Result

7.1 Summarized Results

In the beginning the the thesis, the idea was to implement direct functionality, and a lot of ideas where generated. But when these ideas where investigated, the most important finding of the thesis was made; that it would not be possible to implement such functionality in an efficient way. This led to a change of focus, from trying to implement direct functionality, to facilitate implementation of such. The reason for this change came from both the technology and market analysis. GöteborgsEnergi and IVL are two examples of this, since they are both in the midst of implementing functionality for their needs (measuring electricity consumption and environmental data) they have to not only implement the sensors in this case, they have to structure the whole system, from placing the sensors to handle the data. This has been been a costly and time-consuming task, since it requires high investments in both technology and special competence. Since they have no collaboration or common platform, they build their own separate system. This lead to the finding of the need for a platform or common ground to give users the ability to build from, instead of having to build it all. From there, the DDC was developed.

The result are somewhat conflicting, since the only difference between the concepts are what level they solve the technology trends, since all of them solves the explicit needs of today. Attempts where made regarding a decision about what concept to take on further (see Kesselring matrix in section 6.3). Since the concepts are compared to each other, a realistic scoring could be verified. But the problem comes when assessing the weight of each aspect, since that will change the end result. The conclusions from that analysis was that a choice is not needed at this stage in development. Since all concepts have the same foundation, with the difference in complexity and future possibilities. Where each concept gets more complex, but also have larger future possibilities from A to D.

Therefore, instead of a specific concept, the thesis group proposes a way of developing the system simultaneously as it is in use. By doing so, continuous data about the market could be "fed" in to the development, hence increasing the accuracy of the efforts, while minimizing the risk of failure. By structuring the development efforts in such manner, the development always have an "escape-hatch" if proven to be unfeasible somewhere along the way. Market information could be gained, simultaneously as development and market establishment are continued/increased.

7.2 PSS - structure

As described in the previous chapters, the PSS are relatively complex, and a finding from the break-down of the system was that the combinations of User, Provider and Enabler are almost infinite. Since the thesis have a tight time-frame, the choice of the most feasible combination was made with the most basic assumptions. The User, could be both an organization or a person, and the functionality they desire could be anything in the future, but as of today, their needs are; sensor-housing, electricity and fibre connectivity.

The choice of provider was based partially on how the laws regulate access to the power grid, and partially the knowledge level about daily operations such as maintenance and installation. This was later confirmed by meetings with both GöteborgsEnergi and AlingsåsEnergi (van Rooij, 2017) (Larsson, 2017). And a finding during one of the meetings was that they would not only be the best suited from the previously mentioned aspects, they would also be the best Provider with regards to cost and also implementation of a system that could have societal benefits. If the system could be proven to bring societal benefits, the business case could be less solid and still be proven a feasible investment for the municipal.

As Enabler, ABB was chosen, since they are one of the thesis most important stakeholders. But also because they are one of the drivers in digital technology on the global market, especially in the IIoT area. Because they have the knowledge, monetary means and have good relations in the considered market.

Concludingly, the thesis proposes a structure for the Product Service System for the Swedish market, with regards to the current legislation. Other combinations of provider, enabler and user might also prove feasible, so this should not be considered a waterproof proposal, but more as foundation for further investigation.

7.3 Guidelines and tools for future development

The assessments about cost and placement of the DDCs' can be used by the vendor continuing the work, but not without knowing the limits of them. They should be considered as models for increased understanding and give a hint on where to move next, not as a universal correct answer. The geographical placement are dependant on the range of the ingoing protocols, robustness of the system and the geographical properties of the area it's set to work in. By having a map (geographical properties) and the information about the protocols (range), it's relatively easy to approximate the number of DDCs' that should be placed to get the different levels of robustness.

The cost assessment (see appendix C) should be considered the same way as the geographical placement guide. To provide understanding about how ingoing parts and services effect the end PSS, and to stress-test them to see the end cost per user. And by doing so, also be able to interpret if there are the required amount of users in a specific area to justify the investment. The assessment are structured to facilitate for all the concepts, where concept A will have many blanks (since there are no ingoing technology), while concept D will be completely filled in.

8

Test and validation

8.1 ABB - Kabeldon internal workshop for validation

Since the work of the thesis should act as a foundation for future opportunities for ABB, the models used should be verified to prove their feasibility/level and if they are realistic. Therefore a workshop was conducted in collaboration with personnel from ABB - Kabeldon.

The method for how to structure the geographical placement is a way developed by the thesis group, to give the enabler/provider a perception about how parameters as range and robustness of the system determines the amount and density of the system when it should be implemented. To assess the feasibility of the model, and also get feedback on its' functionality, it was described and tested together with personnel from ABB - Kabeldon.

The cost assessment is also developed by the thesis group, to be able to assess cost of the different concepts and also identify where in the system the largest costs occur, and whom that will impact. The profit mark-up used are just an arbitrary percentage used to get a sense how different mark-ups impacts the step from enabler to provider, and from the provider to the end customer. So the mark-up should therefore not be considered a realistic mark-up, but more as a way of understanding of how the system is interconnected. By having a simple model for cost assessments, that are easily adaptable for the different concepts (where concept A has few costs, and concept D are completely filled), it's easy to change and adapt the model to fit each concept scenario. According to representatives from ABB - Kabeldon, this could aid both communication and understanding about the concepts.

The topic of how to structure the business model was also touched upon, where the participants agreed with the thesis group that the final system should be offered to the customer with pricing depending on usage. Much like a cell-phone or car-sharing subscription, where the customer can the most beneficial solution depending on their usage.

Concludingly, ABB is satisfied with the findings from the thesis, can act upon and make use of them for further investigation/development. The next step for ABB is to start development and marketing of the concept A & B, by establishing contacts with some of the vendors that has explicit needs today. This to learn more about how they develop their own IoT system, and what their specific technical needs are. So in essence to start some sort of dialogue with the customers for the forthcoming development.

9
Discussion

9.1 Fulfillment of purpose and research question

The purpose of the project as described in section 1.2:
"The purpose of this project is to investigate the future opportunities for the CDCs', both their current customers and possible new customer and markets. Digital technology and connected devices are to be utilized to either improve current functions, or create opportunities for new ones, this to stay in line with ABBs' strategy of digitalization."

Research question posed in the beginning of the thesis;

How can an implementation of digital technology and connected devices in the CDC increase value for current or potential new customers?

The research questions can be answered fairly easy, by just looking at the generated ideas and the trend analysis. This can also be confirmed by observing current users of the CDCs', such as GöteborgsEnergi, which are implementing a ZigBee system for gathering information about their power grid. Already today they have 7000 units placed in the CDCs' in Gothenburg and Partille. So digital technology can and is definitely compatible with the CDC, both for the customers of today as previously described, but also for potential future needs (from trend analysis). The cabinets could also be used by other users than today, an example of such is IVL, which has an explicit need of monitoring the urban environment in terms of noise pollution, air quality and local weather. In IVLs' case, they need locations in an urban environment to place and have access to electricity for their data gathering equipment, and for that, the DDCs' are ideal.

Concludingly, the network of CDCs' are both well placed in relation to population, and there are several current needs that could be solved by adding for example a DDC-system. Combining this knowledge with the future trend analysis regarding the market for IoT and connected devices, it could with good certainty be said that the old CDCs' combined with the new DDC could be a contender to act as a cornerstone in the infrastructure of the future.

9.1.1 Connected devices and IoT

Since Internet of Things is a term that describes connected devices and communication between things, it's a wide term, and something that is really fashionable at the moment and has been for the past years. This means that a great amount of research and publicity is focused on the subject, which have lead to difficulties regarding the finding the adequate information. The thesis group discovered that there are so much information and predictions about the future for IoT, that only reading the summaries on Wikipedia would use the whole time-frame for the thesis. Since the subject is a focal point for publicity and research and that the buzz-word IoT is a wide term, a lot of the information could be seen to be bias, and therefore the projections of the future has a large variation, which could impair the results of this thesis.

Technology trends regarding machine learning, deep learning and artificial intelligence is something that is widely discussed in relation to IoT and it will certainly serve a roll in the IoT ecosystem in the future. Due to these technologies low maturity level and high complexity level they where chosen to be left out, but for further development it should be investigated.

To be able to handle the time-frame and the level of the exploratory research, the research has been conducted in a "wide and shallow" manner. This not to get stuck in deep technical problems related to IoT.

9.1.2 Implementation of new functionality in CDC

Since the free space in the current CDCs' vary a lot, it would not be feasible to implement the gateway system directly in the current ones. Therefore the system will be housed in an add-on cabinet, that could be attached to the existing CDC. By structuring the solution in this way, it will also be easier to work with the gateway, since it is separated from the "electrical" part, less qualified personnel could be used without increasing the risk of personal injury. This could have advantages regarding cost and maintenance of the system.

9.1.3 Company usability

ABB is a large organization, and one of the leaders in digitalizing products, especially in the IIoT market. They are already in possession of the technology needed for industrial use, to connect different protocols and devices to be able to gather all kinds of data for making production more efficient.

Their technology could be utilized in the DDC (concept C-D), but minor changes might be needed, and a new software might be in order to facilitate for more "openness" compared to their current IIoT technology.

Since ABBs' strategy is about creating sustainable value for their customers, and they see that that an enabler for this is digital technology. The DDC system not only suits ABB as an organization, it also benefits society to increase efficiency, and thereby sustainability. So the DDC system would be a good project to undertake and continue development on.

9.1.4 Result novelty

The DDC itself is not a finding in any way, the technology exists and are used today. The important part in this thesis, is the finding regarding placement of these to facilitate for a IoT infrastructure. Previously, there has been other ways of thinking when placing the ingoing technology and devices in a IoT-network, often proposals contain lamp-posts, since their placement has a good correlation to population, and also the need for such structure. There are however some problems with lamp-post, mainly the access to electricity, since lamp-post often are controlled as a mass, from a specific point, the electricity is not constant, which a gateway requires. The DDCs' however, has room for more technology and also has constant access to electricity and often fibre connectivity.

The idea about using CDCs' for placing IoT-technology is not novel either, an example of this is in Kista, where Intel Innovation Labs built approximately twenty new cabinets and dug new electricity and fibre communication to facilitate the digital technology.

The novelty in the idea lies in the proposal of using the existing CDCs' and their geographical position in relation to population to facilitate for a DDC system, together with the "openness" of the system, that would allow users to adapt the system for their own needs, as well as sharing information and develop new functionality.

9.2 Research method

To facilitate for the development under uncertainties, the thesis group used flexibility throughout the project. This meaning that the method used, varied with respect to purpose. So instead of only using one development method and all its methodology, the methods and theories where changed and adapted depending on the findings and current state of the thesis. There are several negative aspects of using a set-up like this. Mainly the traceability of errors and the uncertainty of the future success of the tasks conducted. The traceability could act as an issue if something goes wrong during the conducted work, then there could be more difficult to trace the error compared to using a standardized process from beginning to end. The uncertainty of the outcome is difficult to tackle since the continuation of the process is depending on the outcome from previous tasks conducted. Since a standard process is not used, there could be issues with how to use (or even know) that the outcome from one task will be suited as input for the next. So this aspect must be considered in detail before structuring a process of this kind.

9.2.1 Overall process

To hedge for the previously mentioned difficulties, the combination of methodology and tools needed to be structured. This to create clear targets during the thesis continuation, to be able to identify knowledge gaps and keep track on findings. Since the thesis has been dependant on interviews and workshops, this was seen as important. Following are a discussion about the method used, and aspects discussed are marked grey in the figure 9.1.

An important part of this process is the use of gates, these gates where used to find and later eliminate knowledge gaps. At every gate, the thesis group assessed if the results from the previous steps was enough to continue the work into the next step. So at the start of the work after the gate, the group could feel confident when continuing.

A problem with the process was the dependency on input from external sources in the form of workshops and personal contacts. This meant that the group had to make assumptions on the outcome from one workshop, and continue the work in forehand, and then hope that the result from the workshop would be close to the projection. One of these was the decision about who would be best suited as provider of the PSS, where the thesis group had to make a decision before having all the data to continue the work. The group concluded that the best suited would be the electrical utility company, and used that as a hypothesis for the continuing tasks. That was later confirmed during a workshop, but if it would have been dismissed, that would have resulted in a major setback of the schedule.

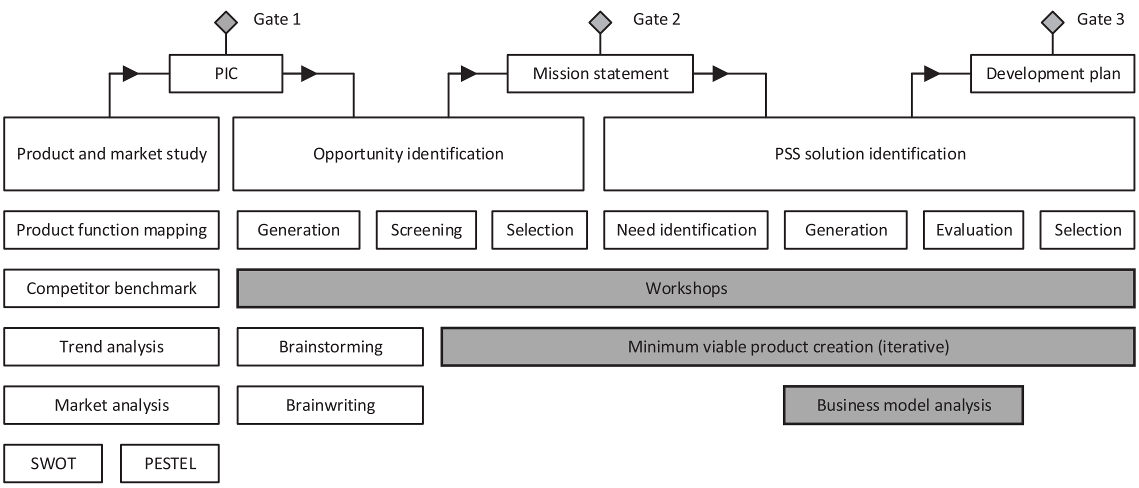

Figure 9.1: Illustration of process used in this project

9.2.2 Selection of stakeholders involved

One of the largest dilemmas during the thesis has been to get hold of stakeholders, and get the time to interview and make them reflect upon their reality. This was identified in the earliest phases of the project, so the delimitations reflected this.

The delimitations clarified that the main market research would be conducted in Sweden, but focus where kept on Gothenburg and the surrounding cities.

Therefore the stakeholders chosen, was in close proximity to Gothenburg to facilitate for interviews and personal meetings. Stakeholders within ABB was also chosen with their location in relation to Gothenburg if meetings was assessed to be necessary, otherwise, if email or phone was sufficient, the geographic location was of less importance.

The business model has not been evaluated as planned, this due to the high level of uncertainty. Models has been discussed and proposals has been made, but channels of sales, partnerships and cost/prices has not been analyzed further. This decision was made in agreement with ABB - Kabeldon.

The use of Minimum Viable Products has been of great use throughout the thesis, to communicate and discuss ideas with different stakeholders, both internally at ABB - Kabeldon and externally. By using simple descriptions and illustrations, that could be emailed in advance to the meeting, the stakeholder/interviewee is already prepared, which eases the discussions during the meeting, see appendix D.

9.2.3 Selection of concept

The ideas in the beginning of the thesis was to focus on finding or solving a specific problem, example is the focus on measuring air quality, noise pollution and general weather. But as the thesis came along, and trend analysis regarding IoT was conducted, the focus shifted. The reason for the change in focus was due to the uncertainty in combination with the unlimited possibilities. Since IoT and connected devices will most likely rocket in quantity (Intel, 2017), for many different applications. So instead of only focusing on a specific need, such as the IVLs' explicit need for measuring surrounding environmental factors, the focus changed to utilizing the quantity and geographical placement of the CDCs' to take care of the expansion of IoT itself, not the specific applications, since the possibilities are wast and only in its' early stages.

So instead of making a choice among the large number ideas and applications for IoT and how to integrate them into the CDC network. The decision was to create a system for enabling IoT connections, and then leave the applications itself to others/anyone.

9.2.4 Analysis method

Since the DDC system as identified, has a large number of stakeholders, especially since the plan is to use the PSS-layout, where yet more complexity is added through the service part. The analysis/evaluation of the system was done in collaboration with a few chosen stakeholders to act as representatives for a greater mass, namely;

ABB, GöteborgsEnergi and AlingsåsEnergi. By evaluating the system with these stakeholders, different perceptions could be gained, both from the enabler (ABB) and the most probable providers (the electrical utility companies).

9.2.5 Competitor analysis on communication infrastructure

Due to the change in focus from implementation of direct functionality to facilitation of such, in combination with the time-frame. The thesis lacks competitor analysis in the area of IoT infrastructure for smart cities, which is critical for the future of the concepts and development plans. To really assess the market, competitors and legislation regarding wireless communication and data-handling.

9.3 Sustainability aspect

"..in order to keep attracting people and ideas; the fast pace of innovation in the ICT industry calls for a continuous and deep restructuring and rethinking of the communication infrastructure, to prevent European cities from losing ground to global competitors." (Caragliu, Del Bo & Nijkamp, 2011) (ICT = Information and Communication Technologies). The thesis falls nicely together with that quote from the conclusions of Caragliu et al., 2011, where the future for Smart Cities in Europe is treated.

One of the customers with explicit needs are IVL, they have the need of placing sensors around the city to monitor its' function, and be able to take real-time measures against problems with e.g air/noise pollution. All this to make the city safer and more efficient for the inhabitants. This is the general trend with the implementation of IoT-technology, to make things more efficient by enabling learning from data, in real-time. With this data comes the possibility to develop better understanding and predictions of the surroundings, examples of this is the AsthmaWatch, which uses weather-sensors around the city of Stockholm to give the persons with asthma real time updates on where they might have problems (SmartSthlm, 2016). This is a functionality developed by a third party, using existing availible data about the current weather conditions in the city together with knowledge about asthma. This leads us into another aspect of sustainability, transparency regarding data. By sharing data, innovation and development are aided.

By having a system for communication, that enables sensors and data transfer in an urban environment, the possibilities are endless. So this section about sustainability feels much like an *open goal*. By knowing what happens, when, how and where in a city, predictive actions can be taken to make the city work more efficient, in several aspects, such as: transportation, health-care, safety, comfort and security for the inhabitants (see section 4.4.2.2 for possible applications). Much like predictive maintenance and optimization services in the industrial market (Wortmann & Flüchter, 2015).

9.4 Action plan for future development

Since one of the main stakeholders in this thesis is ABB - Kabeldon, they have been the main stakeholder when developing the strategy for future development of the DDC. With that said, the action plan is bias, and considers their capabilities for the future development, meaning that they do not possess the competence in-house for development of concept C & D. Which is why the thesis group proposes the development of A & B first, to be able to anchor it in the large ABB organization for possible future development. This means that there might be vendors out there, having the competence, resources and low organizational inertia and a strong customer focus that could start development of concept C & D faster. Which could be seen as either a threat or an opportunity, depending on who you are. The point being that the plan is bias, and developed for one specific organization, ABB - Kabeldon.

10
Conclusions and recommendations

10.1 Concluding remarks

The thesis should be considered a document for learning and aiding the future development and implementation of digital technology in the information infrastructure of tomorrow. The market and trend analysis are conducted in a general manner, where the conclusions are based on the synthesis between current and projected needs/trends.

10.2 Future research

One of the most important aspects for the future research/development of the DDC system is the capabilities within ABB. Since ABB is one of the global leaders in digitalization, and are in the front end regarding IIoT, they would be suited to take on the future development. But to be able to do so, their capabilities must be assessed closer. One result of this may be that all the needed technology to enable the DDC already exists, so the only thing left is to synthesis these. Another result may be that the technology do not exist, which would result in a tough dilemma weather to take the DDC system further, or if it should be killed. No matter the result from this assessment, it's critical that it is conducted, and should be the first issue to tackle.

The software to enable the DDC system has not been considered, this has been an explicit rule to follow according to ABB (Lindholm, 2017). The thesis has aimed for a wide scope, to get a general perception of the system. Therefore, one of the uncertainties are the software to enable such a system, and how that software should/would be structured. As of today, there are softwares that enable for third party development and horizontal business-models, the main one are developed by Siemens, called Mindsphere (Siemens, 2017). Such platform would probably suit the DDC system, and should definitely be considered a solution. And in general terms speaking, such platforms would probably be the way to structure data in the future, to enhance innovation and collaboration between different companies/users. Therefore, even without the DDC in mind, the development of such systems should be of ABBs' interest.

How the business should be structured are also something that needs to be researched further. Insights regarding how sharing economy is expanding and that customers are more interested in being offered a solution rather than just a product justifies this (Nordin et al., 2015). Since the DDC system has several stakeholders, and several combinations of how to structure these, this needs more research, to find the most feasible combination depending on the offer.

Areas of application should also be investigated further, since the thesis has focused on Sweden, and the infrastructures of cities, where the explicit needs was identified. But there might be other interesting areas, and according to Fagerström, 2017, ABB are encapsulating communication-modules for outdoor use in the off-shore industry, which shows that there might more applications for the concepts A-D, and also a place for identifying synergistic effects regarding ingoing technology.

Since the geographical delimitation for the thesis was set to Sweden, and that the proposal for provider was the electrical utility company due to the regulations and structure of the market in Sweden. It could be proven to be more feasible with other layouts in other markets. The aspect of how the PSS should be structured is therefore dependant on the country considered.

10.3 Action plan for future development at ABB - Kabeldon

One of the most important findings in the thesis was the shift in focus, from focusing on specific function implementation to the facilitation of such. By creating a foundation for future development of the direct functionality in collaboration with the customer, in a result-oriented way (Tukker & Tischner, 2006). The initial plan was to implement specific functions, that could bring value to specific users or society, but the research concluded that it would be unfeasible to do so. Since the infrastructure to facilitate such functionality was either poor or not existing. To handle all the uncertainties that comes with the development of the new infrastructure, the thesis group has previously presented a brief development strategy (see section 6.2, and appendix E for illustration). Since the concepts all have the same purpose, but differs in the degree of how much it solves, it could be considered the same solution, with the difference in the level of ingoing functionality. Where Concept A is an add-on cabinet with electricity connectivity, and Concept D is the same cabinet, but with processing-power, communication over several protocols, firewall and fibre/electricity connectivity. So the proposal for future development falls relatively naturally, since the explicit needs of today could be solved by concept A, and the technology trends will probably require a solution like Concept D, ABB - Kabeldon should start by developing/remodel their existing cabinet "CDC-A". By adding a server-rack, improving IP classification to be able to handle the more delicate ingoing electronics and start the marketing and sourcing of competence/establishment of collaboration to the right division simultaneously as the development of Concept A. This to be able to get the product out to customers, and gather data for the following development of concept B-D. By structuring the development in this manner, the learnings from the current system could be fed directly into the development of the next (Tukker & Tischner, 2006). By structuring the development in this manner, ABB - Kabeldon will have several advantages, first being the possible market advantage by establishing a system early, secondly being the development itself. Instead of going directly to Concept D, which will be both heavy in resources and time, they should start simple and fast with Concept A. Since each step in development is based on the current market conditions, ABB has the possibility to adapt/kill the development if it's proven to be unfeasible, hence reducing the risk of the development efforts. The structure of this development could be depicted like having both *braces and belt*.

Proposal for how the continuation of the DDC development could be structured.

1. Start development/investigation of Concept A (Started 20170509).
2. Establish relations with customers (current ones and vendors that has explicit needs such as IVL and GöteborgsEnergi)
3. Market Concept A internally, to obtain competences and resources needed for future development (Started 20170509).
4. Development business model
5. Release to market - Start development of next Concept (B-D)
6. Learn from current customers/Conduct analysis of technology trends in detail
7. Reflect → Decision about future development GO/NO-GO -> Iterate/Kill

10.3.1 Organizational challenges

Since ABB - Kabeldon is a traditional manufacturer within the ABB conglomerate, there might occur problems with the future development of the DDC (Oliva & Kallenberg, 2003). Since the solutions are supposed to be tailor made for the customers specific needs, which can vary from customer to customer depending on usage. In the latter concepts (C-D) this will phenomena will emerge more clearly due to the complexity of the ingoing technology and the number of involved stakeholders (Roy et al., 2009).

ABB - Kabeldon therefore needs to change their way of interacting with their customers, from a product-centric to a customer-centric interaction (Foote et al., 2001). This change can also be described as moving from a transaction-based to relationship-based relation. So instead of ensuring their products functioning towards the customers, they should focus on pursuing increased efficiency of the customers specific usage (Roy et al., 2009). There are several ways of getting to terms with this need for change, one being changing the whole organization, and another being to separate the service organization from the rest of the operations (such as R&D, marketing and sales etc.) to avoid collision of interests (Roy et al., 2009). But to be able to conduct any change at all, it's important that Kabeldon assesses their capabilities, to understand what they possess, and what capabilities are in need of development (Roy et al., 2009). This also has to be combined in collaboration with ABB as a whole, to map what the capabilities are within ABB, and how they could be used to continue the development of the DDCs'. When the capabilities for future development are assessed within both ABB and ABB - Kabeldon , the decision about how to structure the organizational change for Kabeldon can be made. ABB as a large global company has experience in the field of changing the organization from a product to a more customer focused organization (Oliva & Kallenberg, 2003), and therefore their internal knowledge about this should be utilized.

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A

Agenda for Workshop A

1. Invite and coordinate appointment time with participants. Together with topics of brainstorming, to let participants prepare ideas.
2. Cloud-based writing service to enable participants to drop ideas, and get inspiration from others
3. Categorize ideas before meeting and prepare presentation
4. Meeting plan
   (a) Declare boundaries, no negative feedback to any idea, the ranking and feasibility discussions are at the end of the session.
   (b) Initiated by summing up all the ideas from the participants, put down a couple of minutes per idea, to make every participant understand.
   (c) Use categories to further develop, evolve and mate ideas.
   (d) Categorize all the ideas again, if changes.
   (e) Screen and score ideas by conducting silent voting with participants.
   (f) End meeting, thank participants and give a short recap
5. Analyze/investigate the ideas and use them as springboard for further research, development and customer/expert contact.
6. Send progress information about the ideas and thank all participants.

B

Needs specification, compiled assessed customer needs

Table B.1: Compiled assessed customer needs

Stakeholder	Aspect	Value Driver
Owner	Affordable to aquire	Low cost of manufacturing, (DFA/DFM/standard parts)
	Work in landscape (appearance)	Aesthetically pleasing/invisible
	Available when needed	Secure connection and reliable technology
	Low running cost	Simple maintenance and updating of the system.
	Easy to implement	Interface with current CDCs'
The User	Easy to establish connection	Simple user interface
		Open source
	Easy to interact with	Simple user interface
		Open source
		Visualized mesh network map
	Adaptability	Support for several protocols
		Easy to add/remove functions/sensors
	Get data when needed	Reliable connectivity and high up-time
		Easy to orientate in the system
	Integrity protection	System security level (hardware/software)
The one maintaining/ manufacturing	Easy to produce	Standardized
		DFA
	Possible to adjust to market needs	Modular
		Scalable
	Low cost of parts	Use of standard parts
		DFM
	Predictable technology	Optimized for operating conditions
	Easy error diagnostic	Documentation about system/previous errors and research
		User adapted error diagnostics tools
The suppliers	Known interface	Access to drawings, functional descriptions (software)
		Cross-functional work with manufacturer
	Clear expected deliverables	Specification lists
	Cost of parts	Standardized
		Adapted manufacturing for specific part
The surrounding society/environment	No interference with other equipment	Fulfill laws and regulations regarding wireless communication
	Not harmful/dangerous	Fulfill laws and regulations regarding work with electricity and material use
	Not impair cityscape	Appearance/aesthetically pleasing
Application developers	Innovation possibilities	Customer/user contact/interaction
		Access to data
	Knowledge about system	Documentation about system/previous errors and research
	Ease of implementing changes	Standardized API and online updatability
		Open source and information/ standards/manuals regarding implementation of new application

C

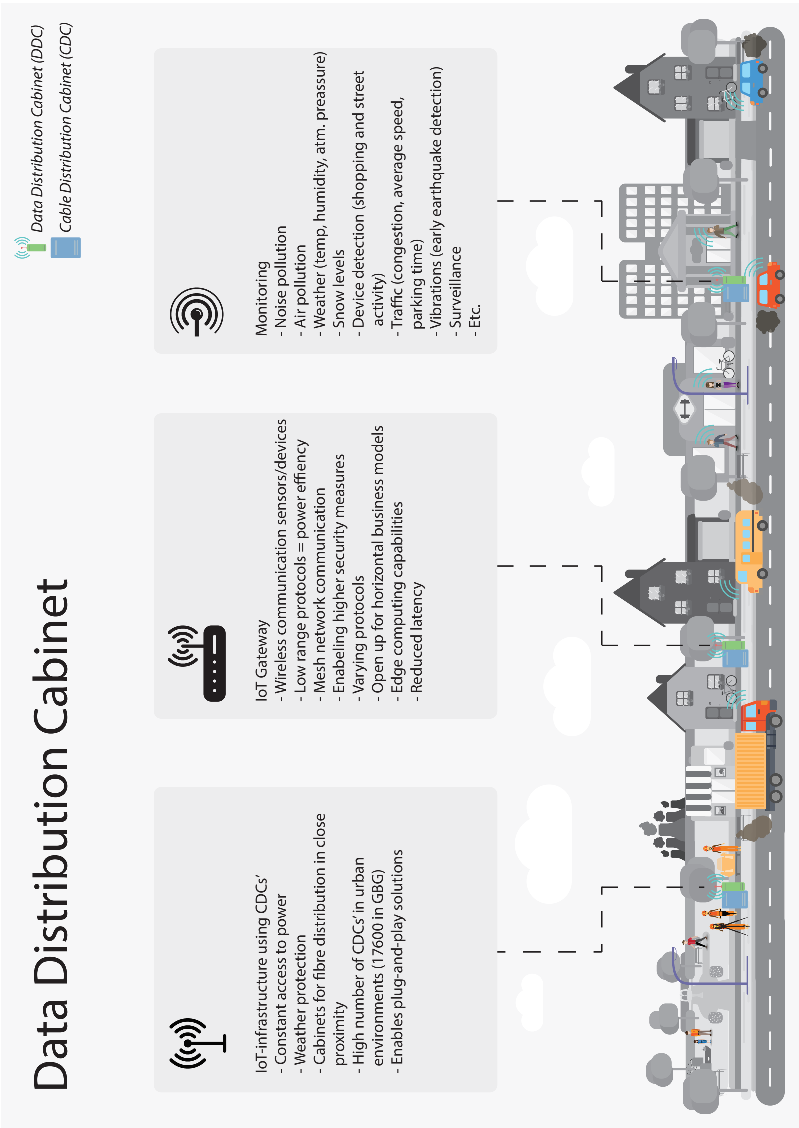
Cost Assessment

Table C.1: Cost assessment for Enabler, Provider and User.

Cost bearer	**Assessed cost**	**Cost type**	**Cost bearer**		
Cabinet (Kabeldon) CDC-A	2000	one time	Enabler		
Gateway	13000	one time	Enabler		
Power supply	1000	one time	Enabler		
Processing power	5000	one time	Enabler		
Communcation	2000	one time	Enabler		
Firewall	5000	one time	Enabler		
Software	Included in gateway		Enabler		
Security system	Included in firewall		Enabler		
One time	15000	Profit margin	25%	Sales price	**18750**
Electricity installation cost	22100	one time	Provider		
Installation	2000	one time	Provider		
Maintenance/Hardware upgrades	4000	After three years	Provider		
Fibre broadband connection	3600	yearly	Provider		
Price per unit (from enabler)	18750	one time	Provider		
One time	50450	one time	Provider		
Running/year (first three)	17883	yearly	Provider		
Running after three years	7600	yearly	Provider		
	First three years	Proft margin	25%	Sales price	**22354**
	After three years	Proft margin	25%	Sales price	**9500**
Cloud (amazon)	User dependant	N/A	User		
API	User dependant	N/A	User		
			First three years	After three years	
10	(Users/customer)/year	Yearly cost	2235	950	
100	(Users/customer)/year	Yearly cost	224	95	
1000	(Users/customer)/year	Yearly cost	22	10	
	Case 1 (N1 r1)	Case 2 (N1 r1)	Case 3 (N1 r1)		
Amount of gateways	1455	516	262		
Total investment cost (Enabler)	21825000	7740000	3930000		
Return (Enabler)	5456250	1935000	982500		
Total investment cost (Provider)	73404750	26032200	13217900		
Return (Provider)	18351188	6508050	3304475		
Investment/year (3yrs)	24468250	8677400	4405967		
	Case 1	**Case 2**	**Case 3**		
10	14550	5160	2620		
100	145500	51600	26200		
1000	1455000	516000	262000		
Area	30				
Density	1243				
Population in area	37663				
Percentage users	50%				
Users	18831				
CAPACITY	**Case 1**	**Case 2**	**Case 3**		
10	Feasible	Feasible	Feasible		
100	Unfeasible	Unfeasible	Unfeasible		
1000	Unfeasible	Unfeasible	Unfeasible		

D

MVP



Data Distribution Cabinet
Data Distribution Cabinet (DDC)
Cable Distribution Cabinet (CDC)
IoT-infrastructure using CDCs'
- Constant access to power
- Weather protection
- Cabinets for fibre distribution in close proximity
- High number of CDCs' in urban environments (17600 in GBG)
- Enables plug-and-play solutions
IoT Gateway
- Wireless communication sensors/devices
- Low range protocols = power effiency
- Mesh network communication
- Enabeling higher security measures
- Varying protocols
- Open up for horizontal business models
- Edge computing capabilities
- Reduced latency
Monitoring
- Noise pollution
- Air pollution
- Weather (temp, humidity, atm. preassure)
- Snow levels
- Device detection (shopping and street activity)
- Traffic (congestion, average speed, parking time)
- Vibrations (early earthquake detection)
- Surveillance
- Etc.

E

DDC Development Illustration