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Efficient application of configuration and pricing technologies to industrial service products at Valmet Technologies Oy

Elena Sorokovaia

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Abstract

The developing technologies and the growing number of customer requirements have challenged companies to remain competitive while aiming at customizable production. In order to keep pace with others, companies need modern approaches to the long and complex sales processes that they manually lead. With possibilities to construct fast and precise quotes, a Configure, Price, Quote (CPQ) software has evolved from sales and product configuration systems to relieve that struggle.

At the time of the study, Valmet was in the process of integrating their products to a configurator in order to streamline their quotation process. The spotlight was on Valmet's Breast Roll Shaker (BRS) – one of the company's Paper Improvement Projects (PIP). A high demand for the product made it seem like a good fit for CPQ, and the company needed its configuration and pricing structures.

A BRS PIP delivery structure was proposed along with the pricing BOM for further implementation as a configurator. In addition, a general PIP delivery structure was deduced, which would serve as a basis for Valmet's future similar PIP CPQ development projects. The structures were partially modelled into the configuration software with the results presented to the company.

Based on the experience obtained from the study, guidelines for the company to follow smoother product configuration projects in the future were developed. In addition, the products' evaluation criteria were created so that Valmet would know whether a product would be a good fit for CPQ before even starting its implementation.

Finally, recommendations for further research were outlined. The possible obstacles were also revealed as precautions for the future.

Keywords (subjects)
CPQ, configurator, product configuration, configuration software, product pricing structure, project delivery structure, modularization, modular engineering, mass customization

Miscellaneous
Appendixes 1-13 are confidential, and they have been removed from the public thesis. Grounds for secrecy: Act on the Openness of Government Activities 621/1999, Section 21, 5: business or professional secret. Period of secrecy ends 31.12.2021.

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1 Introduction

1.1 Research motivation

The general problem of automatization is unquestionably demanding in modern business life. Nowadays, in the times of digitalization, manual work from the beginning to the end of any process is a relic of the past. All processes that companies lead require continuous improvement and streamlining due to a strong competition and trends' change. With the modern technologies developing rapidly, automatization is an absolute way for a company to be able to compete with others. Being the reason of the *problem* of automatization, the evolvement of technologies, however, has also brought a *solution*.

Configure, Price, Quote (hereafter referred to as CPQ) is the newest application in the field of sales and product configurators. Even though CPQ applications have existed for over 20 years, academic literature discussing their definion is scarce. (Dunne, Huittinen, Kumpulainen, Seppänen, & Sorri 2017, 4.) Dunne and others (2017, 4) describe CPQ as an enterprise software application that helps configure products of different complexity levels and receive pricing and quotations. Forza, Perin, and Trentin (2014, 694) define it as a knowledge-based software that supports a potential customer, or a sales specialist interacting with the customer, by precisely specifying a product solution within a company's product offer.

Automating and mass-customizing through configurators are becoming more and more widespread within companies (Haug, Hvam, & Shafiee 2019, 121). Current business challenges relate to the long times to quote, which are caused by manual efforts required to customize a product individually for each customer. Configurators bring to life a multitude of benefits, including: reduced time for generating quotes, eliminated errors, better supplier communication, smoother operations, and more (ibid.). Satisfying a customer is the main goal of many businesses, which is why special and careful attention must be paid. With a smooth and efficient sales process comes a happy customer, which then results in commitment, a strong business network and a higher profit.

Assimilation to new technologies for a company is a long and hard process that takes years. Full digitalization, more specifically, can take decades, considering that modern technologies are still not sufficiently impeccable. Therefore, the focus of this thesis work was on digitalizing the data of one particular company's product to reach a satisfactory level of automation. The research executed by the author can allow remodeling of a product's quotation process from manual work into as high a share of machine work as possible with the help of a configurator. Once completed, this framework can be applied to another product to analyze, a) how the cost elements of the first product can fit into the general PIP pricing structure, b) how the work done can help in the configuration of other PIPs, and c) how possible it would be to connect all PIPs into the same work-breakdown structure.

This thesis work is structured as follows. At first, subchapter 1.2 reveals the problem of the work, its objectives, and the questions that must be answered in order to conduct the research.

Chapter 2 refers to the theoretical base of the thesis, where:

- Subchapter 2.1 contains the explanations of the necessary abbreviations;
- Subchapter 2.2 is a generic-data background study that includes the processes that are essential to be understood;
- Subchapter 2.3 introduces a short familiarization with the case company and the case product.

Chapter 3 explains the methodology used for the research.

Chapter 4 represents the results acquired through the research and their analysis for Valmet's consideration.

Chapter 5 provides a conclusion in the form of clear answers to the stated research questions, discussion of the research value, and suggestions for future studies.

1.2 Research objectives and questions

The main aim of the research was to define configuration and pricing structures for the delivery project of a particular industrial service product of the case company. Therefore, this thesis aimed to reveal the criteria required for configuration. The idea was to understand whether CPQ tools would be capable of streamlining processes and making pricing and quoting of PIPs more efficient. Additionally, the author concludes in which cases CPQ use is suitable, and which PIPs should be primarily integrated and how.

As a result, the configuration and pricing logics of the product were defined and modelled in CPQ software as a pilot version to test its feasibility. Based on them, a general framework was created and applied to another PIP to understand if it could be introduced to more products.

In order to reach the objectives, the following questions had to be answered:

- What are the elements needed to enable configuration?
- What does a project delivery structure include?
- How to model a product into CPQ efficiently?
- To what extent can a framework of one PIP be applied to other products?

Taking all the points stated above into account, the goal of the research was not to just answer the questions, but to provide Valmet Corporation with a valuable outcome that they would be able to utilize in their global sales.

2 Theoretical base

This chapter represents the topic-related data that was collected by the author for a deeper understanding of the problem. The necessary processes and terms were described and understood, which helped distinguish the phenomenon of configuration. To be able to succeed in the research, not only the previously established generic data, but also the company-specific information needed to be revealed.

2.1 Explanation of abbreviations

BOM

A Bill Of Materials is a complete list of all the parts with their quantities and prices that are required for building a product. It is used for planning purchasing and sales processes, where the product parts' prices are accumulated. A BOM can also be helpful in describing a product and defining its manufacturing way. (BOM 2010.) A bill of materials has a hierarchical structure, where the final product is set on the highest level, and its components are presented in sublevels. The structure is most commonly presented as a table (e.g. in Microsoft Excel), but it may have various appearances, such as a block diagram.

ERP

Enterprise Resource Planning is used by companies to streamline processes and improve data visibility around finance, project management and manufacturing (What is ERP System? 2017). It is a shared database that allows employees from different departments of an organization to have access to the up-to-date information on such processes as inventory, order management, accounting, and others (Enterprise Resource Planning Systems Transform, Integrate and Scale Businesses n.d.).

PLM

As stated by Rouse (n.d.), Product Lifecycle Management is a process of managing the complex product data which constantly changes from the beginning to the end, from the product's development to its disposal. It streamlines collaboration between people, processes and data continuously, centralizing all the critical information that is relevant to the product, so that everyone using PLM is up-to-date (What is PLM software? 2019). A PLM software is used to handle products' lifecycles, automating the management of product-related data and integrating it with other business processes, such as ERP (Rouse n.d.). Furthermore, the software closely collaborates with BOM by managing it as well as visualizing and sharing it across the users (What is PLM software? 2019). Rouse (n.d.) argues that waste eradication and improving efficiency are considered to be the main goals of PLM.

CRM

Customer Relationship Management is a powerful tool for businesses because it lets them collect, store and analyze the data of their partners, suppliers, and current and potential customers. In other words, CRM helps control, plan, and analyze the work with clients. Its purpose is to create, develop and strengthen corporation's relationships with their customers, which helps the clients', the company's and the investors' profits increase. (Boruta 2017.) As well as ERP and PLM, CRM provides a cloud-based data storage with the latest updates available to all users.

PIP

Paper Improvement Project (previously known as IPP) is a term used in Valmet to describe a part of mill improvement projects offered for paper and boards machines. PIPs are equipment that ensure better paper quality production, higher capacity and efficiency, and raw materials and energy savings. (Kalapudas 2019.) They are meant to stabilize running processes in all phases of paper production without requiring major investments (How to improve quality? 2019).

PIP delivery is a name for the whole process of delivering such equipment. A single PIP delivery covers not only a complete product itself, but also every cost associated with it, such as travel expenses, logistics services, project management, spare parts, and much more.

HW – hardware

SW – software

LU – lubrication unit

PDM – product data management

2.2 Background research: generic data

2.2.1 Modular engineering

As stated by Mahoney, and Sanchez (1996, 63), modularization is a product development strategy that is based on a product architecture where different functions of a product are implemented as a nearly independent system of loosely coupled components. Modular structures consist of modules, which in engineering design approach are seen as standardized, combinable and changeable units. Each module has well-defined functions and pre-defined interfaces similar to the other modules in the product family, which lets them be combined into modular product architectures. (Bonev, Dengler, Denkena, Hvam, & Schürmeyer, n.d., 1.) The composition of a product is based on a specified set of such modules with pre-defined components inside (Jørgensen 2009, 4) (Figure 1). A modular product architecture allows to create a flexible product architecture due to a range of variations in components (Mahoney, & Sanchez 1996, 66).

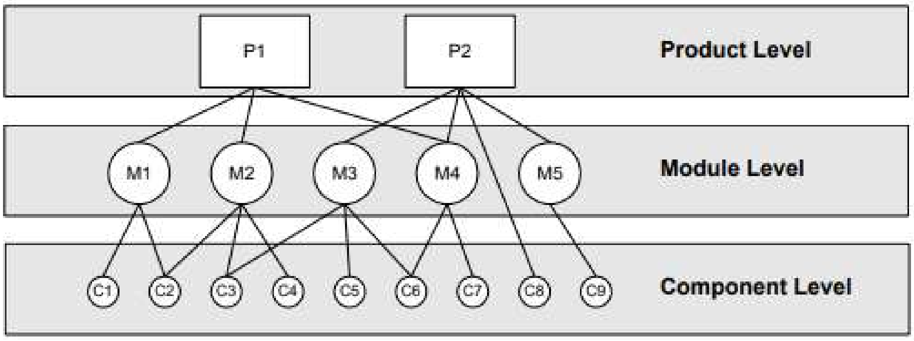

Figure 1. Model of a three-leveled structure (Jørgensen 2009, 9)

Golfman, and Lammers (2015, 58) argue that modular product architectures serve as a reliable approach and one of the critical facets of developing an integrated PLM strategy. Modular structures help push the process faster and simplify it without losing the accuracy of the delivered service. They make companies respond faster to changing trends by rapidly creating new product variations (Mahoney, & Sanchez 1996, 66). This, consequently, reduces lead times, which is quite a critical variable in case of product development. The reason for that is that a longer lead time results in losing the competitive advantage making a company not able to react as fast to the continuously changing customer requirements and market trends as other companies (Foss 2001, 5). In such case, it will be worth nothing for a corporation to be occluded by outstanding faster competitors.

The working principle and the fundamental meaning of modular architecture, as mentioned by Golfman, and Lammers (2015, 58), is to easily break down a product's structure into several standardized building blocks to allow their rearrangement, i.e. *configuration*. Hvam, Piroozfar, and Shafiee (2018, 2), specify two approaches for modularization: top-down and bottom-up.

As the name 'top-down' suggests, the modular product structure in this approach is made by dividing levels into sublevels. Such modularization starts with splitting a product into its main components, where each of them is then split into smaller parts, for as many levels as needed. This approach is commonly applied for complex products, where the details are not significant. A company with the top-down approach concentrates mainly on a full end-product in order to have a holistic overview of the re-usable solutions. (Hvam et al. 2018, 2.)

The bottom-up way of modularization, on the other hand, originates at the smallest components, which are combined in groups to form bigger parts, again and again, until a satisfactory ending is achieved. Consequently, the meaning of details here is more substantial. This approach allows a detailed analysis of less complex components in order to be fully able to automate the process, eliminating other parts that are not directly relevant. (ibid.)

The study of this thesis work was identified to use the top-down approach, as the case products' delivery structures were complex and mainly focused on the bigger, more valuable components. When it comes to global corporations such as Valmet, enormous flows of products force to look at the big picture disregarding the prices of bolts and screws.

2.2.2 Product configuration

Configuration is an aggregate of product's settings that are set by the user. It is also an activity of changing of those settings to meet the user's needs (Bagley, Felfernig, Hotz, & Tiihonen 2014). Product configuration, more specifically, customizes a product in accordance with the customer's requirements. Often it is done by means of a configurable BOM – CBOM – which differs from a usual BOM by offering customizable variations of the components that it consists of. With the help of CBOM companies are able to create dynamic end products that are personalized for a particular customer case.

In order to be configurable, it is almost necessary for a product to have a modular architecture (Männistö, Soininen, Sulonen, & Tiihonen 1998, 3). In addition, Männistö and colleagues (1998, 1) point out more properties that a configurable product must possess:

- a pre-design to meet customer requirements;
- each delivered product individual is adapted to customer's needs;
- each product individual is specified as an arrangement of pre-designed components;
- a pre-designed architecture;
- no creative or innovative design is needed as a part of the sales-delivery process.

From the manufacturer's point of view, a configurable product is a product family, from which an individual product can be selected through configuration. A generic model of a product family has a set of open specifications that are defined in the configuration process. Each configuration results in a configured product model, from which a physical product can be produced. (Jørgensen 2009, 4.)

However, while companies aim for customer-specific production, the competition demands a price decrease and shorter lead times (Haug, Hvam, & Mortensen 2012, 471). Paunu (2014, 1) states that it is especially challenging for engineer-to-order (ETO) companies to overcome this problem. The reason for this is that the products in the industry are mostly highly customized and uniquely built (ibid., 9). The recent manufacturing paradigm of satisfying personalized customer requirements while keeping the costs and the lead times on the level of mass production is called mass customization (Haug et al. 2012, 471). The paradigm went widespread in the 1990s when it became possible to satisfy large markets and to have high product variability. A key role in shifting from mass production to mass customization was played by the progresses in IT technologies and manufacturing principles. (Paunu 2014, 4.) As Figure 2 shows, the goal is that mass customization is balanced between one-of-a-kind production and mass production, taking benefits from both of them.

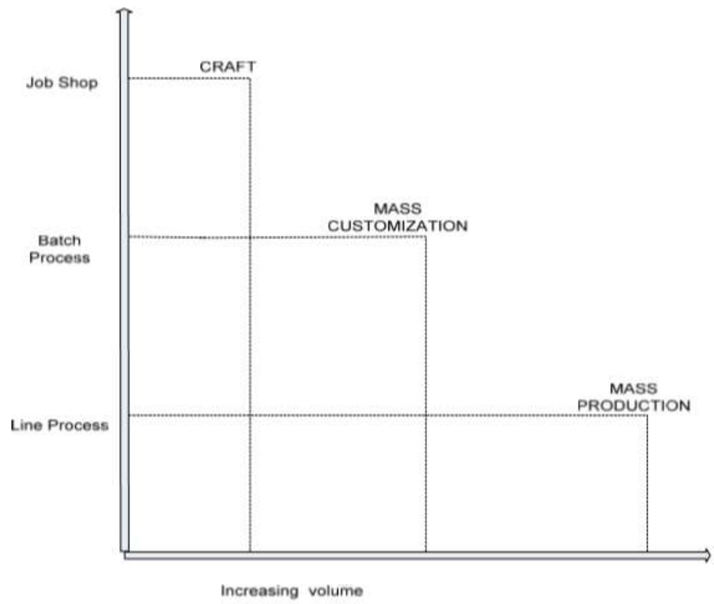

Figure 2. Three production forms positioned regarding customization level and production volume (Kundana 2007, 10)

Paunu (2014, 8) argues that reliability and efficiency of mass customization can be reached with, firstly, the ability of a company to modularize processes and products, which was explained in the previous chapter. Secondly, the workers involved must be familiarized with new and more ambiguous tasks, and thirdly, a company needs to employ solutions that enable flexible automation. (ibid.) Bagley and colleagues (2014) claim that the paradigm of mass customization itself calls for evolving configuration technologies to enable its effective implementation. The growth of the Internet has given companies an opportunity to close the gap between a customer and a manufacturer, letting orders be configured and placed online. To meet customer's needs and build a long-lasting relationship, it is crucial to assume how information is collected, documented and translated. (Kundana 2007, 12.)

As Bonev and others (n.d., 2) mention, the development of product configuration can be divided into seven steps (Figure 3). It starts with analyzing the specification tasks (phase 1). Then, the product range needs to be defined (phase 2). In phase 3, an object-oriented analysis (OOA) model is constructed and the product features are defined. After that, the right configuration system is chosen to adapt the OOA-model (phase 4). Phase 5 is dedicated to programming, and phase 6 to implementation and educating the users. In the last phase the system is maintained, and the performance of the new specification process is measured. (ibid., 3; Hvam 1999, 78.)

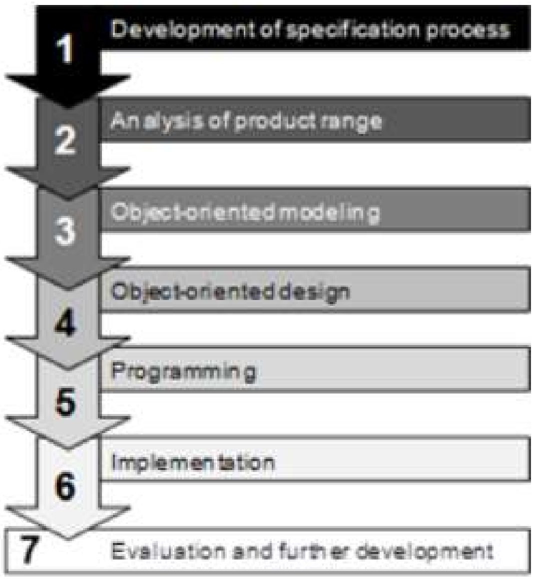

Figure 3. Development of product configuration (Bonev et al. n.d., 2)

2.2.3 CPQ: a knowledge-based configurator

New technologies are capable of maintaining product configuration and providing data richness of products and processes, and one of them is known now as a *configurator* (Kundana 2007, 12). As mentioned by Paunu (2014, 13), configurators can be assumed as mass customization toolkits. They help reduce the costs of mass customization's implementation significantly (Bagley et al. 2014). According to Bonev and colleagues (n.d., 2), a configuration system represents human knowledge and uses expert problem-solving methods. In general, a configurator software understands customer's needs and provides a choice navigation, so that the user is able to configure a product that best matches them (Paunu 2014, 13).

Dunne and others (2017, 8) argue that CPQ has evolved from the sales or product configuration systems, and now it is a software solution used in a quotation process. Companies use it as a tool that supports their sales personnel in serving their customers (ibid., 10). With the help of CPQ companies define the prices in a simpler and faster way, despite the growing amount of variables. In the software the variables are accumulated, which releases the possibilities to configure products or services in the most optimal way, price them, and quote customer the absolute best price possible. (What is Configure Price Quote (CPQ)? n.d.) Moreover, customers are allowed to interactively test the configured models and reconfigure them, which enhances customer retention (Paunu 2014, 8). Due to the centralized and real-time information the software provides, the sales representatives and partners work hand in hand (The ultimate guide to Configure Price Quote 2018, 5).

Customer's demands can be met in the configurator by following the process of product configuration (Härder, Kovse, & Ritter 2002, 2). The process produces configurations of a product by adapting product individuals to meet the given customer requirements (Lehtonen, Pulkkinen, Riitahuhta, Soininen, Sulonen, & Tiihonen 1998, 3). Härder and colleagues (2002, 2) claim that the product configuration process uses the knowledge of product's configuration potential and product structures, which are expressed as a configuration model. According to Lehtonen and others (1998, 1), the configuration models involve a set of predefined product components, the rules that help combine the components, and the rules related to meeting customer's needs (Figure 4).

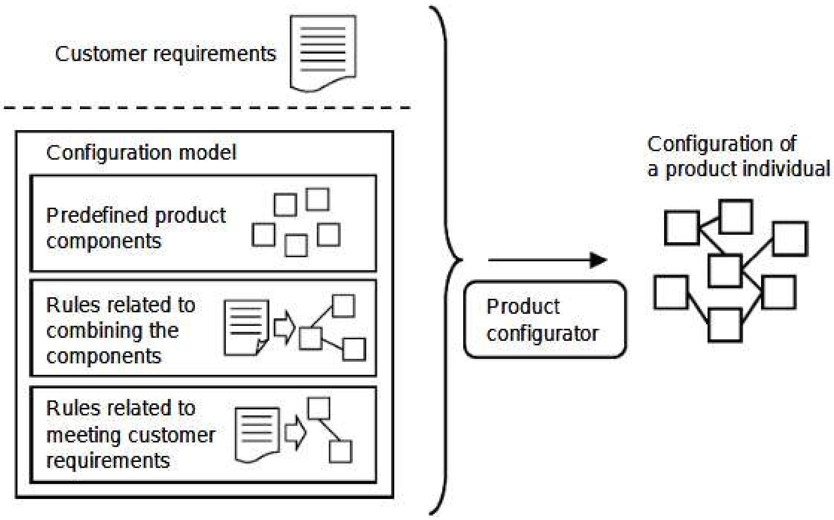

Figure 4. Product configuration process (Härder et al. 2002, 2)

Despite the fact that the configurators are designed to manage configurable products, Lehtonen and colleagues (1998, 5) emphasize that it is important to find the balance between the level of configuration and the ability to manage it. A model should use as few types and definitions as possible, enough to contain all necessary data and be understandable and manageable (ibid.). Männistö and others (1998, 3) mention that it is more cost-effective to design rare product variations case by case rather than extending the product's configuration possibilities.

Considering this thesis work, the configuration model's inputs are as follows. CPQ picks up where CRM leaves off – therefore, all the customer data needed is uploaded into the software from CRM. The product's initial BOM and pricing data also play a role of an input, as well as the quotation templates. (Figure 5.)

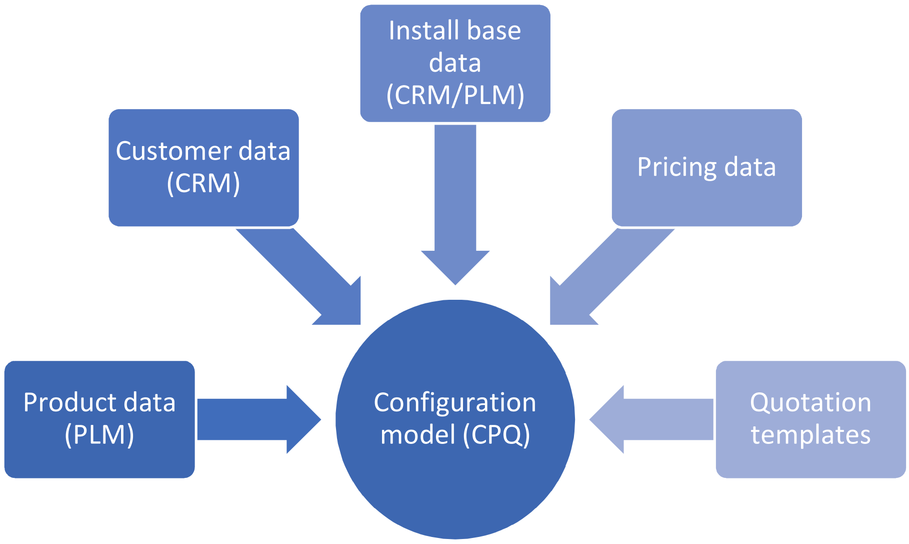

Figure 5. CPQ inputs (adapted from: Halmari 2018)

Knowing customer's requirements, a sales person configures a product by simply choosing the appropriate customization options, which can be, for example, different materials, sizes, colors. While configuring, there are different restrictions – constraints – applied to any component that the product to be sold consists of. The constraints specify the conditions that hold in a correct configuration (Lehtonen et al. 1998, 13). Those built-in rules do not let the user bale incompatible elements, and the built-in prices form a quotation offer and a sales BOM in the end. Additionally, a document of product's technical specifications is constructed.

The study of seven CPQ platforms conducted by Dunne and colleagues (2017, 9) in 2016 gives an idea of the possibilities CPQ should offer:

1. Configuration;
2. Guided selling;
3. Pricing and quoting;
4. Order management;
5. Reporting;
6. Promotion management;

7. Contracts;
8. Approval process;
9. E-commerce;
10. Machine learning.

The configurators all include a knowledge base about the product characteristics and structure, production processes, costs and prices (Haug et al. 2019, 121–122). However, only first six out of ten capabilities were noticed to be available in all studied CPQs. Nevertheless, though the sizes and revenues of the companies differed significantly, each of the CPQs could solve different configuration challenges. (Dunne et al. 2017, 8.)

Therefore, a broad number of companies gives preference to the configurators. Männistö and others (1998, 2) specify the most popular motives for manufacturing configurable products based on their study of Finnish companies. The reasons mentioned (in the descending frequency order) are:

- the ability to fulfil a wide range of customer requirements,
- the shorter lead times in the sales-delivery process,
- the increased control of production,
- the reduction in customer-specific design,
- the efficient way to offer a broad product line, and
- the improved quality (ibid.).

On the other hand, Jørgensen (2009, 8) mentions the motives of Danish companies, which are:

- establishing a link between the sales department and the production,
- securing fully specified orders,
- securing valid production documentation,

- the easiness in dealing with large number of variants,
- less maintenance of production documentation, and
- the proactive sales.

Jørgensen (2009, 8) notices that companies can have different reasons for product configuration depending on their actual problems. All motives listed above give an idea of the benefits a configurator system must offer.

Based on the study of four different companies, Haug, Hvam, Mortensen, and Thuesen (2013) have concluded the benefits obtained from using a product configurator. They argue that the configuration offers measurable and non-measurable improvements. The valuable measurable indicators – for instance, lead time, on-time delivery and resource usage – have improved significantly throughout the experiment of product configuration. The lead time has been reduced from weeks to days, from days to minutes. The on-time delivery has been improved up to 95-100%. The resources used for making the specifications have been reduced by 50-95%. The companies also claim that the quality of their quotations has fairly improved, leading to more accurate prices and fewer costs. (ibid., 336.)

Besides these, the study has exposed other benefits from applying the product configuration systems:

- increased sales;
- reduced total lead time;
- improved total on-time delivery;
- reduced costs;
- formalized engineering knowledge;
- reduced item number (ibid.).

These, however, might not have been directly affected by the configuration system. Even though it is hard to calculate the contribution of CPQ to the abovenamed benefits, it is clear it has somehow influenced them. (ibid., 333−334.)

Being the mass customization toolkits, configurators solve its key challenges. Bagley and others (2014) mention the five challenges and the configurators' benefits that address each of them (Table 1).

Table 1. Mass customization's challenges and benefits of configurators that solve them (Bagley et al. 2014)

Mass customization's challenges	**Benefits of configurators**
Avoiding erroneous and suboptimal offers	Less errors
	Shorter lead times
	Increased sales
	Lower personnel costs
	Stable effort estimation
	Higher-value products
	Stable schedules
Avoiding mass confusion	Customer self-service
	Pre-informed customers
	Corporate memory
Complexity handling of needs elicitation	Increased sales
	Preference knowledge
	Open innovation
Knowledge integration	Reliable demand prediction
	Decreased time to market
	Less errors
Efficient knowledge management	Efficient development
	Efficient maintenance

The tabled information answers the questions *why* the configuration technologies are needed in times of mass customization, and *how* they are beneficial in dealing with it. A faster and precise quoting remains the main point of CPQ, saving the customers and corporations money by saving their time. Its benefits all lead to *less time consumed* and *more accuracy* in comparison with the manual way of handling quotations. The configurators allow more efficient, more effective work with the tools that help sell more and faster. Nowadays, they are the right choice for businesses that operate complex products and numerous sales processes at a time, as they get an opportunity to manage even multi-channel strategies in a single system. (The ultimate guide to Configure Price Quote 2018, 5−17.) However, there may be also problems with using the configurators. The main one, as Männistö and colleagues (1998, 5) claim, is a long-term management of the product knowledge. In addition, they mention no general way of representing configuration model as another problem of using CPQ (ibid.).

As CPQ is connected to the evolving of digital technologies, Dunne and colleagues (2017, 4) claim that it is undergoing a transformation continuously. So CPQ, that nowadays can be described as an indicative of expanding process automation, could further extend to interoperating with order management, billing, renewals, incentives, e-commerce, and partner relationship management. These trends that CPQ is aiming at will make it a key asset in achieving a high value through collaborative network dynamics. The expanding support of processes, democratization of setup and administration, implementation of machine learning, enablement of diverse business models – they all move CPQ forward. (ibid., 4−12).

2.3 Background research: Valmet

2.3.1 Valmet as a company

As an industrial operator's, Valmet's history goes back over 250 years, to 1750s. It had started with a small shipyard in Viapori fortress near Helsinki, and the company was continuously expanding and altering to become the Valmet we know now. (Valmet has over 220 years of industrial history 2019.)

Nowadays, the company is a global leader in developments and supply of technologies, automation, and services for the pulp, paper, and energy industries. The range of technologies they offer is diverse: pulp mills, tissue, board and paper production lines, and power plants for bio-energy production. (Valmet in brief 2019.)

In order to satisfy their own expectations and customers' and suppliers' requests, Valmet keep expanding steadily. At this time, Valmet's offices occupy every continent and are set in more than 30 countries with the Head Office in Espoo, Finland and 12,500 employees all around the globe (Figure 6).

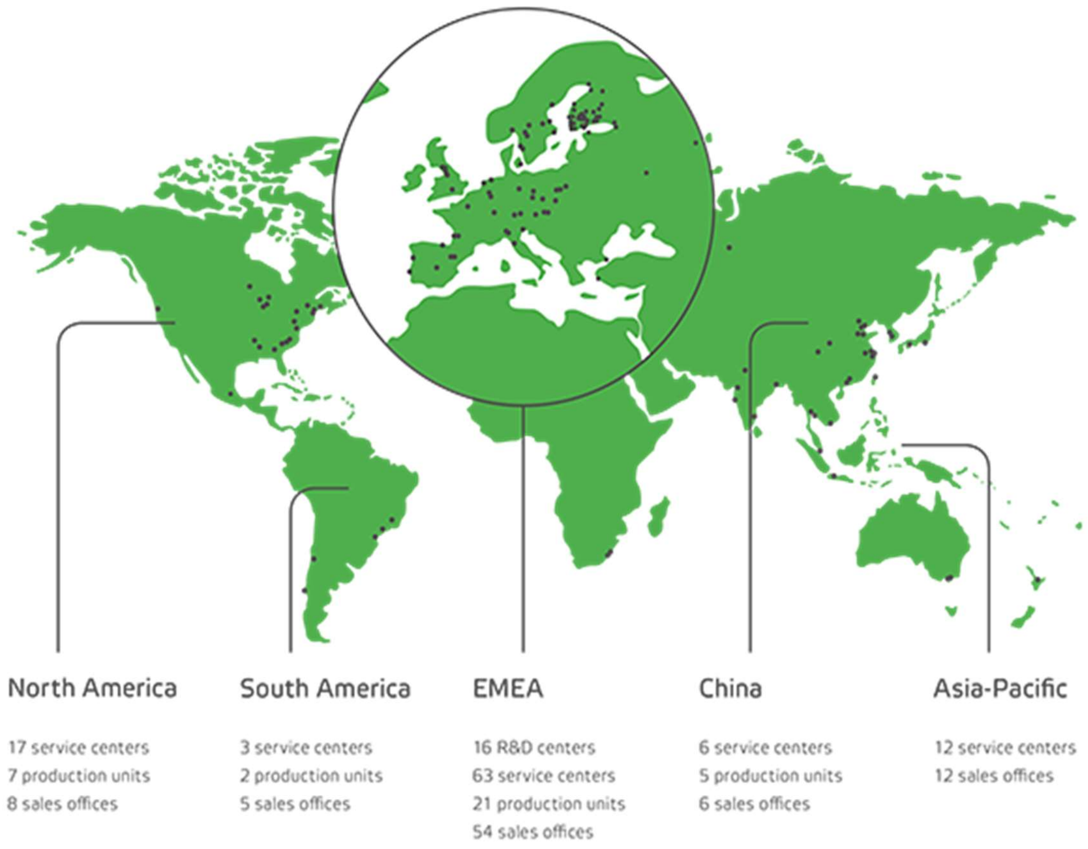

Figure 6. Valmet offices' locations (Our businesses 2019)

Besides the five geographical areas, the company is organized into four business lines, which are: Services, Pulp and Energy, Paper, and Automation (Table 2) (Our businesses 2019).

Table 2. Valmet business lines (Adapted from: Our businesses 2019)

Business line	**Description**
Services	providing customers with mill improvements, roll and workshop services, spare parts, fabrics, and life-cycle services
Pulp and Energy	providing technologies and solutions for pulp and energy production as well as for biomass conversion
Paper	delivering complete board, tissue and paper production lines and machine rebuilds
Automation	delivering automation solutions ranging from single measurements to mill wide process automation systems

This study was mainly focused on the first business line – services. Out of four business lines, this one shares over one third of all the orders received by the company (Figure 7) and plays a magnificent role in its daily operations. The services cover everything from maintenance outsourcing to mill and plant improvements and spare parts (Valmet in brief 2019).

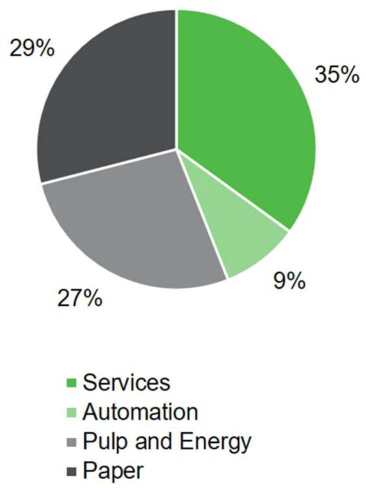

Figure 7. Orders received by business line (Key figures 2019)

Out of the approximately 3,800 pulp and paper mills operating in the world, over a half purchase services from Valmet annually. Services play a significant role in promoting reliability, cost-efficiency, capacity and quality of the buying companies' operations. (Services business line 2019.) To execute such a responsible work with the best outcome possible, the company needs a coherent and reliable action algorithm for every service sold.

Valmet's quotation process is rather manual and requires an engineering expertise to construct a quote due to the high share of ETQ (Engineer to Quote). However, the integration of CPQ would help enable a higher rate of CTQ (Configure to Quote) operating model in the company with a possibility to create quotes independently from technical experts. (Shared Journey Forward n.d.) Therefore, Valmet's quotation process needs to adapt for the new technologies (Appendix 1).

Price formation in the step of service and material pricing can slightly differ. The company uses three proposal types in their sales – indicative, budget and firm – which affects the sales price accuracy of an offered product. The indicative phase is used for the indicative quotations with approximate prices to engage a customer. At the budget proposal, the sales prices are still not exact, but the products' technical specifications and delivery limits are specified. The stage of firm proposal offers their customer the whole scope of supply along with a firm pricing. The proposal phases are described in Table 3. They need to be assumed while creating a configuration model, since different product components are priced in CPQ at different types of quotation. It is important to define when exactly they are priced, as the CPQ platform Valmet use assumes the proposal types while constructing a quote.

Table 3. The content and the objectives of different proposal phases (Adapted from: Hellberg 2018; Valmet Sales Process Handbook 2016, 11–12)

Proposal type	**Content**	**Objectives**
Indicative	*preliminary high-level scope* definition with delivery time and non-binding *indicative pricing*	➢ analyze if the business case is commercially solid ➢ analyze if Valmet has a technical solution for the customer's needs ➢ estimate the price and delivery time
Budget	*short scope of supply* including technical specifications and delivery limits with delivery time estimation, and non-binding *budget pricing* with a guiding principle of accuracy of 0-20%	➢ evaluate if Valmet's solution justifies the investment and differentiates them from the competitors ➢ perform risk evaluation ➢ identify the customer's financial frame, schedule, project organization ➢ define the scope of supply and delivery limits ➢ calculate the costs
Firm	*scope of supply* including technical specifications, documentation and delivery limits with delivery time, and binding *firm pricing*	➢ verify the costs and delivery times for critical components and products ➢ prepare a preliminary execution plan ➢ perform risk evaluation ➢ define the scope of supply, delivery limits, delivery times ➢ agree on the final firm price ➢ document the delivery ➢ build the commitment

It is essential to note that most of the sales projects do not pass through all three stages. For instance, when a buyer has a clear scope and an understanding of a solution and enough budget for it, the buyer and Valmet can move on straight to the firm proposal. However, it is still recommended to involve the parties into the budget proposal first, as to define the costs and to be sure the customer can bear them. (Liedes 2019.) Usually such cases happen when the customer is already familiar with Valmet and is loyal to them.

In case of the indicative proposal, on the other hand, the buyer is yet not committed and may not have enough budget. Nevertheless, the buyer wants to seize a new product or service and, therefore, asks for the information about the possibilities and receives a rough price. (ibid.) Such cases generally occur with the new customers, or when a committed customer is about to purchase a particular product for the first time.

2.3.2 Case product

The particular product this study was based on was a Breast Roll Shaker (hereafter referred to as BRS) (Figure 8). The BRS was considered as one of the so-called industrial service products. Industrial service products were the components sold by Valmet to paper and board mills all around the globe as either stand-alone deliveries or as parts of bigger mill improvement projects. The BRS had been recently upgraded before the study and, consequently, needed the new modern pricing and configuration approaches. The machine was sold with a high demand, which is why defining the new structures was crucial.

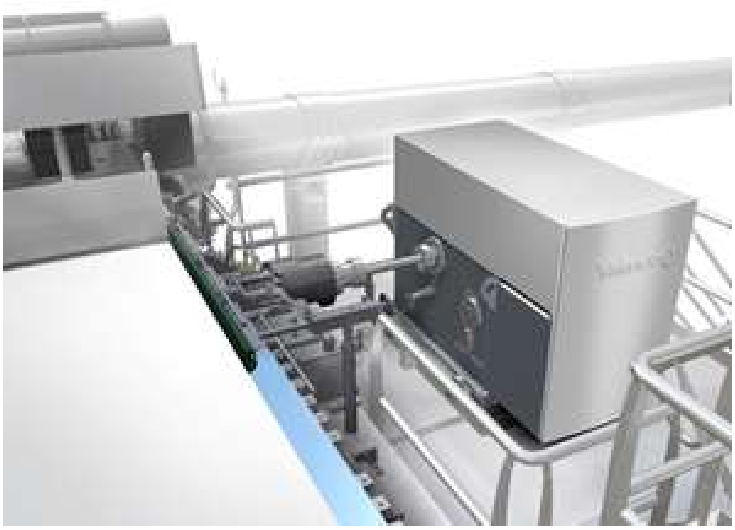

Figure 8. Set-up BRS (Valmet Breast Roll Shaker 120 improves sheet properties 2018)

The BRS was an additional equipment to a paper machine, and was used in paper production to provide a better quality of the final product. It was a relatively mobile machine with the approximate dimensions of 2m×1m×1.5m (L×W×H) of the shaking unit. The unit was connected to a breast roll, which was also supplied, with a connecting rod, a thrust bearing and a slide bearing (Figure 9).

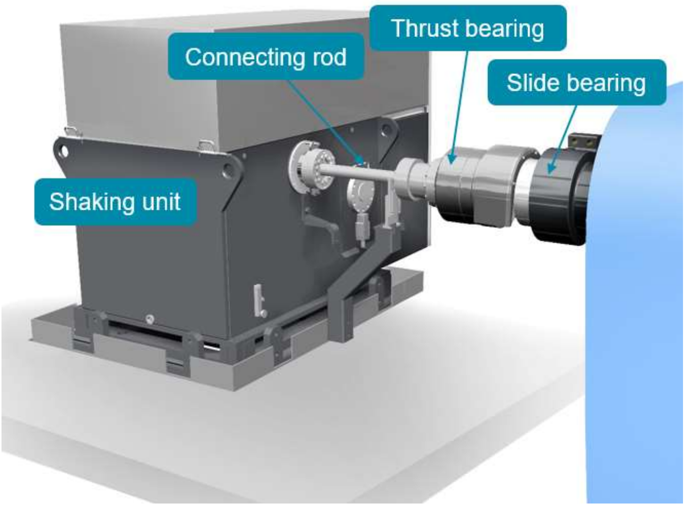

Figure 9. BRS's main visible components (Valmet Breast Roll Shaker 120 improves sheet properties 2018)

The operation of the BRS was based on a balanced shaking system. Basically, the machine shook the breast roll cross-directionally and broke up fiber flocs by creating shear forces in the web (Figure 10). (Valmet Breast Roll Shaker 2017.)

Figure 10. BRS's working principle (Valmet Breast Roll Shaker n.d.)

The shaking forces were generated by the rotating eccentric mass pairs (2) in the shaker unit (1) (Figure 11). (ibid.) These mass pairs were connected to the breast roll (5) by the connecting rod (3). Due to the rotation, the mass pairs moved back and forth on an oil film (4), lugging the connecting rod. Its reciprocation, in turn, generated the cross-directional shaking of the web. Adjustment of the main motor's revolutions allowed to control the shaking frequency, and the stroke length could be changed by regulating the phase angle between the mass pairs (ibid.). The smaller the phase angle was, the bigger stroke length could be achieved.

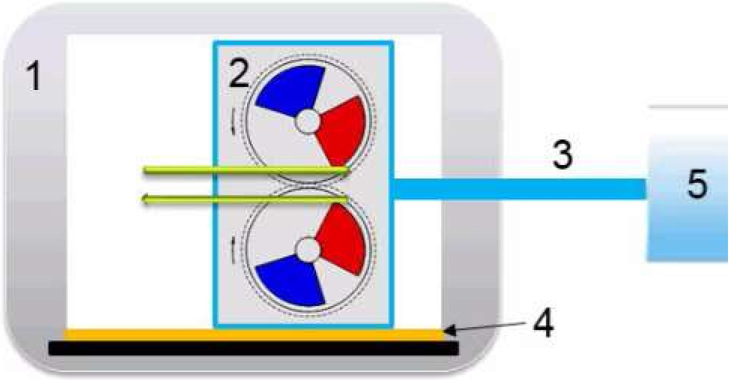

Figure 11. BRS's operating principle (Peltomäki 2019)

The system improved the sheet formation as well as the strength and visual properties (Valmet Breast Roll Shaker 120 improves sheet properties 2018). In the end, the produced product had a more even structure, a smoother surface and a better printability (Figure 12).

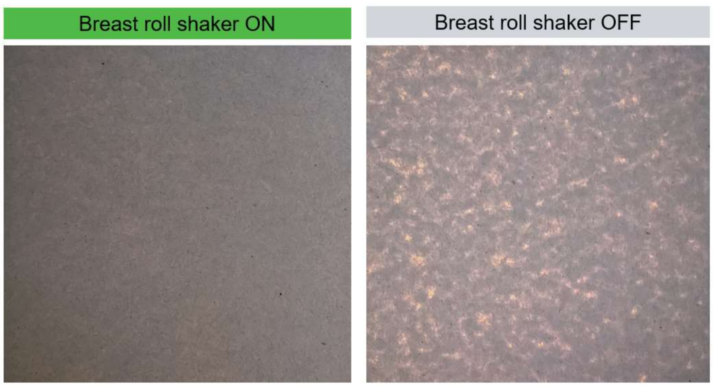

Figure 12. Product's structure with BRS ON and OFF (Valmet Breast Roll Shaker 120 improves sheet properties 2018)

However, the enhanced product's properties were not the only advantages of the BRS. Along with them, the machine provided raw material savings, less power consumption and an easy maintenance (Valmet Breast Roll Shaker 2017). Its design had also been improved – it had become more compact. It was one complete assembly with gears, torque cylinder, eccentric masses and shafts. With flexibility of its features, less space requirements and fewer parts, the machine could be installed in most sites. (Valmet Breast Roll Shaker 120 improves sheet properties 2018.)

3 Methodology

3.1 Research nature

The nature of this thesis work was chosen to be practical, as the study was focused on *developing* the pricing structure. A development project can usually be divided into two parts:

1. the product or event to be developed, and
2. a descriptive report of the process (The main part of the thesis — various approaches n.d.).

The outcome of such project work can, for example, be a new tool or another practical implementation (ibid.). The outputs of this particular thesis work's development project are the configuration and pricing models for the BRS. In addition, the PIP's common configurable model and the guidelines for new configuration development projects can be used in Valmet's sales process as a framework for conducting PIPs' quotations.

3.2 Research approach

In pursuance of the main objective, a pragmatic approach was chosen to support the development project. This type of approach includes both major research methods – qualitative and quantitative. The advantage of a pragmatic approach is that it allows to use the method which appears best suited to the research problem. Pragmatic researchers recognise that every method has its limitations and that the different approaches can be complementary. (The four main approaches 2009).

One of the features of mixed methods studies is triangulation. It is generally used by researchers to ensure that an account is robust and that adequate light is shed on a phenomenon. In this thesis work, triangulation can be seen through:

- the use of a variety of data sources (data triangulation),
- the use of multiple perspectives to interpret the results (theory triangulation),

- the use of multiple methods to study a research problem (methodological triangulation). (ibid.)

Moreover, it must be emphasized that, in such approach, qualitative and quantitative methods can be used in both ways: in a sequence and simultaneously (ibid.). Qualitative methods are generally used to uncover and understand thoughts and opinions, and thus, they provide a basis for further decision making (Shusterman n.d.). The qualitative approach gathers data that is free-form and non-numerical, such as open-type questions, interviews and observations (Qualitative vs. Quantitative n.d.). In McLeod's view (2017), qualitative research is exploratory and seeks to explain *how* and *why* a particular phenomenon operates. Such phenomena can be understood adequately only if they are seen in context. Therefore, a qualitative researcher engages in natural surroundings and gains an insider's view of the field. (ibid.)

Quantitative research, on the other hand, gathers data that can be presented in a numerical form with a possibility to remodel it into graphs and tables for easier analysis. Such information can be obtained through, for instance, experiments and closed questions. (Qualitative vs. Quantitative n.d.) The numerical form allows this research method to be objective. Objectivity is paramount here; researchers avoid affecting the results by their own presence, behavior or attitude. The conclusions are also examined for any possible bias. (The four main approaches 2009). According to McLeod (2017), statistics gained through quantitative research help turn the data into useful information for decision making. The method is used for measuring and predicting, which leads to a final course of action (Shusterman n.d.).

3.3 Data collection

In case of the qualitative method, the data was collected with the help of meetings with Valmet employees and by familiarizing with the information available on both the company's internal and external webpages. Mainly, the information retrieved included information about the working principles and the sales process.

Every meeting led to a discussion of one of the topics that needed to be covered so that the author could become familiar with the company's internal operations. In most cases, the meetings had one-on-one nature, where the author discussed the matters with expert employees of different fields. Before every meeting, a theme-specific list of open-type questions was prepared, and the answers provided by the employees were carefully documented. The information obtained from those meetings played a key role in proceeding with the research at the initial stage. Some of such information led to a quantitative data analysis, since the employees did not always have common points of view on the same matter. In such cases, the author was obliged to refer to already-existing materials (such as past quotations and delivery cases) in order to reveal the most resembling option and to understand the grounds on which an option can change.

Regarding the quantitative method, workshops, group meetings, and numerous pricing and quotation documents were useful. The costs data for the case was acquired from the company's existing documents. There was no need for the author to calculate anything, only to find the missing prices and to analyze them. Practical workshops and group meetings that were organized with the competent employees supported the author's understanding of the origin of the costs data and its implementation into the research. Afterwards, the pricing data was analyzed by using a quantitative data analysis. The prices were collected from different Valmet's sources, compared for mistakes and checked for relevance.

Continuous cooperation with Valmet employees appeared to be the most significant source for the data collection. Planning and attending the meetings regarding the company's various working processes that were essential to be understood in order to achieve the objectives helped the author form an insight into Valmet's business. Moreover, the quantitative data discussions assisted in application of that knowledge. It is also important to point out that as long as Valmet's internal website and meetings were the tools for accessing the company's private data, such as product developments, sales strategies and pricing, confidentiality issues should be taken into account.

3.4 Research steps

The practical research implemented in Valmet had a total duration of 4 months. Considering that it was the main focus of the thesis work, it was decided that a scheme would be made as a timeline to show all the research steps taken (Figure 13).

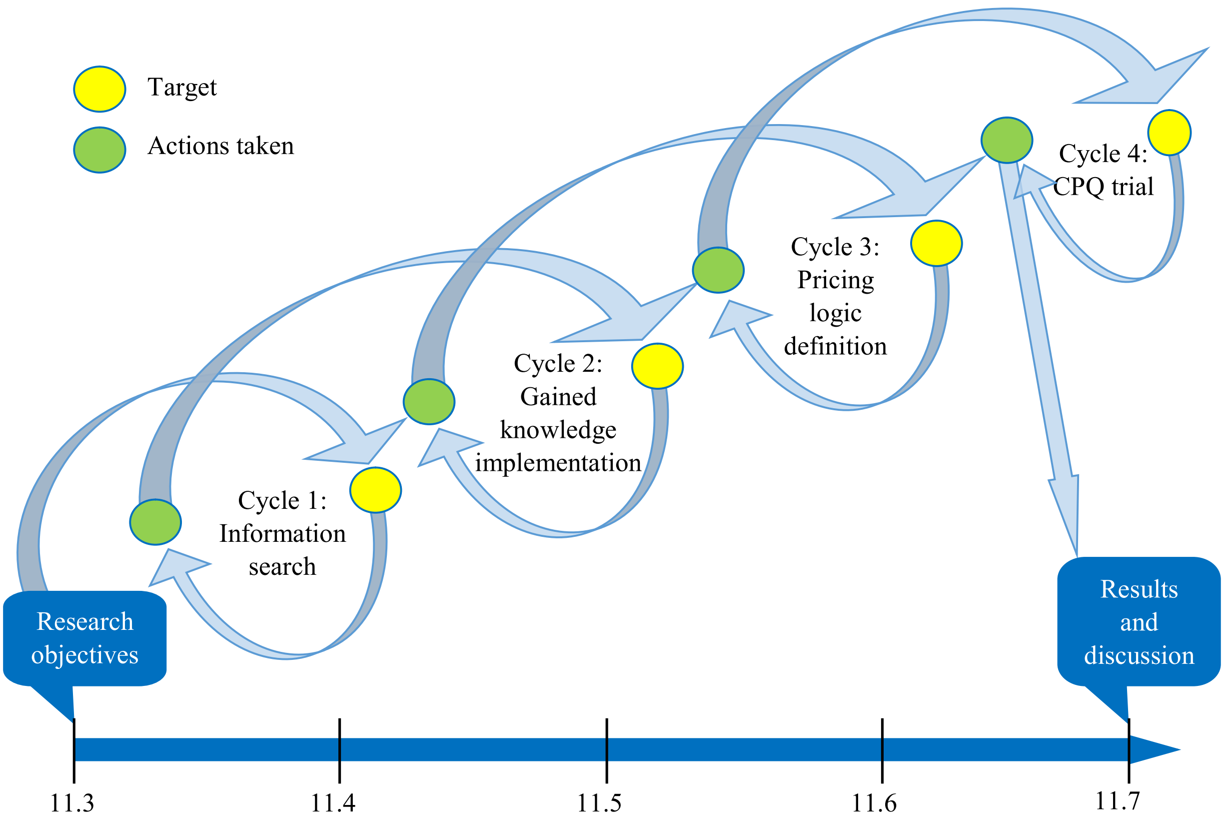

Figure 13. Research process timeline

Cycle 1: Information search

Dates: 11.3-24.3 (week 1-2)

Stakeholders involved: Application development engineer

Target: Understand the product and the processes related to configuration

Actions taken:

- Day 1 onboarding meeting: explanation of the objectives;
- Familiarization with the BRS, sales process, quotation process, PIP, CPQ through Valmet online database and the meetings with the competent workers.

Dates: 25.3-21.4 (week 3-6)

Stakeholders involved: Global product manager, Senior chief engineer, Automation manager, Senior product sales manager, Project manager, Application development engineer

Target: Define the BRS's product portfolio

Actions taken:

- Gathering the technical specifications, delivery limits, and other relevant PIP delivery elements through the meetings and workshops;
- Defining the constraints and conditions for choosing customization options of the collected BRS's elements through the meetings and workshops;
- Making the detailed initial BRS's structure diagrams based on the BOM and PIP delivery elements.

Cycle 2: Gained knowledge implementation

Dates: 22.4-19.5 (week 7-10)

Stakeholders involved: Global product manager, Senior chief engineer, Automation manager, Application development engineer

Target: Construct the BRS PIP delivery model for CPQ

Actions taken:

- Combining the product portfolio with the constraints and configuration logic to get a configurable BRS model for CPQ integration;
- Three revision meetings: modifications of the model.

Dates: 20.5-26.5 (week 11)

Stakeholders involved: Application development engineer

Target: The BRS CPQ pilot

Actions taken:

- A BRS CPQ workshop together with a CPQ product and application modelling specialist: integrating a part of the BRS model to CPQ to analyze if it works right and to reveal the possible mistakes. The screenshot results from the software are presented in Appendix 2.

Cycle 3: Pricing logic definition

Dates: 27.5-30.6 (week 12-16)

Stakeholders involved: Purchasing engineer, Senior product sales manager, Application engineer, Project manager, Project engineer, Application development engineer

Target: Define the BRS's pricing BOM

Actions taken:

- PDM database research to get familiar with the BRS BOM structure;
- Comparing the BRS BOM from PDM with the BRS's pricing tool's BOM through the meetings and individual work;
- Making the BRS's pricing BOM on the right for CPQ level.

Dates: 10.6-30.6 (week 14-16)

Stakeholders involved: Global product manager, Purchasing engineer, Application engineer, Global roll center manager, Project manager, Project engineer, Application development engineer

Target: Define all priceable components

Actions taken:

- Meetings discussing the pricing of the breast roll and documenting of its logic for further implementation in CPQ;

- Getting all the needed spare parts lists for the BRS;
- Gathering the missing prices through the meetings.

Cycle 4: CPQ trial

Dates: 1.7-11.7 (week 17-18)

Stakeholders involved: Application development engineer

Target: Integrate the BRS model to CPQ

Actions taken:

- Integrating the BRS's product portfolio, constraints, customization options and pricing data to CPQ;
- The BRS's configuration trial;
- Generation of the quotation offer and technical specifications based on the configuration.

4 Research results

4.1 Case product's project delivery structure

The first data that the author needed to be familiar with was all the data required for configuration. Therefore, information search was what the practical research started with. Its goal was to indicate all the relevant product data that would enable configuration. Based on the theoretical knowledge of CPQ, product configuration and the comparison of different BRS's delivery projects, the criteria needed for the configuration were defined. They included the technical specifications with the constraints and the customization options, the attributes of PIP delivery with prices, and the prices of the product's parts. The data was collected and reviewed with Valmet's relevant product experts, i.e. those who had expertise in sales, design, engineering and other related fields.

The product-related data collection had a bottom-up nature. At first, the BRS BOM was constructed based on the product's technical specifications. Some pricing data was specified here, but at this point of the research, the focus was on the technical structure. The complete pricing data was defined later, in the third cycle of the research (see Figure 13). At the same time with the technical BOM, the author defined the PIP delivery's BOM. In order to construct it, all the necessary PIP delivery elements and their prices were collected. Together, the BRS BOM and PIP BOM created a project delivery structure of the BRS, which combined all elements of the BRS delivery. In order to reach the last step – "Configurable model" – the author needed to define the constraints and variation options that could exist in the BRS delivery case. By integrating those to the delivery structure, the author obtained the BRS's configurable model that could be integrated to CPQ. (Figure 14.)

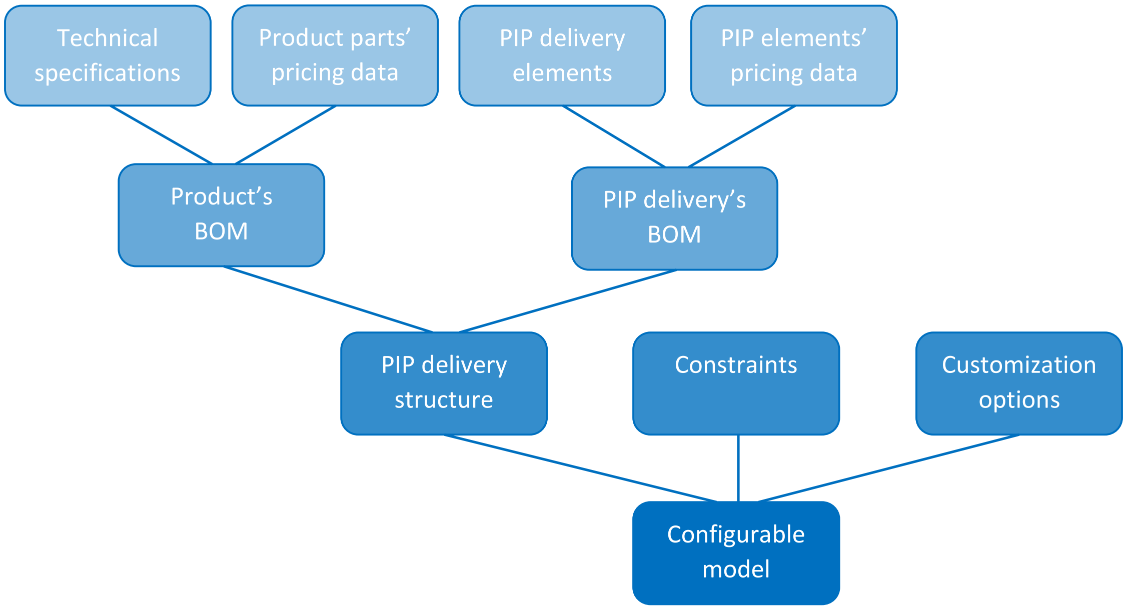

Figure 14. Attributes required for PIP's configuration

Special attention needed be paid to the PIP delivery structure in order to reveal what was included in there in addition to the BRS itself. The BOMs of the PIP delivery and BRS were not uncovered separately in detail, since in this case, the configuration required both to be combined. Hence, it was more important and clearer to look at the BRS's product portfolio in order to have an idea of the whole BRS delivery (Appendix 3).

The BRS's product portfolio was divided into two main processes: manufacturing (physical structure, i.e. the technical product portfolio) and sales (sales structure, i.e. the commercial product portfolio). The commercial product portfolio was visible for the clients and sales; it showed the level at which the BRS was sold. The highest level of the presented hierarchy was the BRS itself, which consisted of two main HW parts: the shaker unit and the breast roll. Each of them got configured in the software according to the order-delivery groups: mechanical, automation, spare parts, and services.

The technical product portfolio consisted of all the data from the technical point of view: materials, raw materials, processes, labor, etc. In other words, everything that referred to the expenses for offering the BRS. Each one of the defined order-delivery groups contained a technical and manufacturing structure made of levels. Appendix 3 shows only the main assembly / main process and subassembly / sub process structure to give the reader a better view and understanding of the BRS PIP delivery. Clear that each subassembly / sub process was divided into smaller components and subcomponents, until the satisfactory ending was achieved. The blocks marked with "*" were removable depending on the automation logic chosen for the BRS. The whole PIP delivery structure can be found in Appendix 4.

The last items crucial for configuration – the constraints and the customization options – were defined in Appendix 4. The document was made as a Microsoft Excel table for the BRS PIP delivery structure. It was meant to contain all kinds of information that had not been grouped and/or documented before. The file was believed to be of help to the people who would integrate the BRS to CPQ.

The first tab in the Excel document was called "BRS structure". It had a form of a table with six levels of hierarchy. The table was divided into sections according to the author's vision of the integrated into the software BRS CPQ model. The vision was gained through practical examples of configuring other products in the software that were showed to the author by Valmet employees during the workshop meetings. The first section "Configuration input" differed from the others. It was meant for the input of customer and their mill's information that was crucial for further configuration. This data served as the constraints for the customization of some product components.

The remaining part of the table was structured in the following way. On the left, there was a list of the BRS PIP delivery elements, that had been collected by the author throughout the information search. They were logically grouped according to the order delivery structure defined in the BRS's product portfolio. The next column "Constraint" defined the constraints for the column "Action", i.e. the restrictions for choosing one or another customization option. Hence, the configuration lied in the "Action" column, as long as it let the user choose the product variations according to the exact customer's requirements. In "Action", there were different types of actions defined for the end user:

1. *default*: the value/selection is necessary and/or is based on the previous selections and cannot be changed (except if there is "choose" after; in that case "default" means advisable);
2. *optional*: the item can be selected or not;
3. *choose*: the user must select one of the offered options;
4. *type*: the value should be typed in by the user;

5. *upload from CRM*: the value can be obtained from the CRM software;
6. *customer's scope*: the customer must take care of the item by oneself.

The column "Type of constraint" identified whether the constraint applied to the choice of the item was soft or hard. To clarify, the soft constraints allow to choose another customization option, apart from the default one set by the constraint. The hard constraints, on the opposite, do not allow so. The last column, "Proposal", indicated in which type of the quotation proposal to the customer – indicative, budget, or firm – the item should be first priced and mentioned.

The second tab of the Excel document was called "Delivery limits". It defined the engineering, material and assembly limits for Valmet (V) and their customers (Purch). The three tables were corresponding to the main delivery components of each: the mechanical equipment of the whole machine, the breast roll's lubrication system, and the shaker unit's automation system. The "V" mark identified that the item was delivered by Valmet; "Purch" stood for customer's scope; and "V/Purch" meant that the item could be delivered by either Valmet or the purchaser, which directly depended on the corresponding customization option chosen while configuring.

The last tab "Additional information" included the auxiliary data that could help define the prices for the on-site services, logistics, and mechanical engineering of the shaker unit. All other necessary pricing data that already existed was stored in internal company's documents and tools. Its collecting was done later on.

In addition to the whole BRS PIP delivery structure, the author made the configurable class diagrams for the product (Appendix 5, Appendix 6, Appendix 7). The diagrams with no specified confidential data are presented in Figure 15, Figure 16, and Figure 17. They were also valuable for Valmet, as they allowed to see clearly all customizable components of the BRS with their constraints. The diagrams represented only the configurable elements that were written in capital letters. Each element name was followed by the description of *what* could vary (written in lowercase letters) and *how* (written in braces {}). The dashed arrows were used to show the dependency relationships, i.e. the constraints, and which product components they affected. Mostly, the constraints came from the customer's information – so-called "Customer's constraints". They referred to the restrictions set by the customer's mill location, mill layout, paper machine's automation logic and design. However, the constraints could be also applied to one product component based on the previous choice of another –

so-called “Product-specific constraints”. For example, the size of a thrust bearing depended on the chosen size of the slide bearings. In this case, the customer’s data did not affect the choice of the thrust bearing’s size. The choice of the components with no specified dependency relationship was based on the customer requirements.

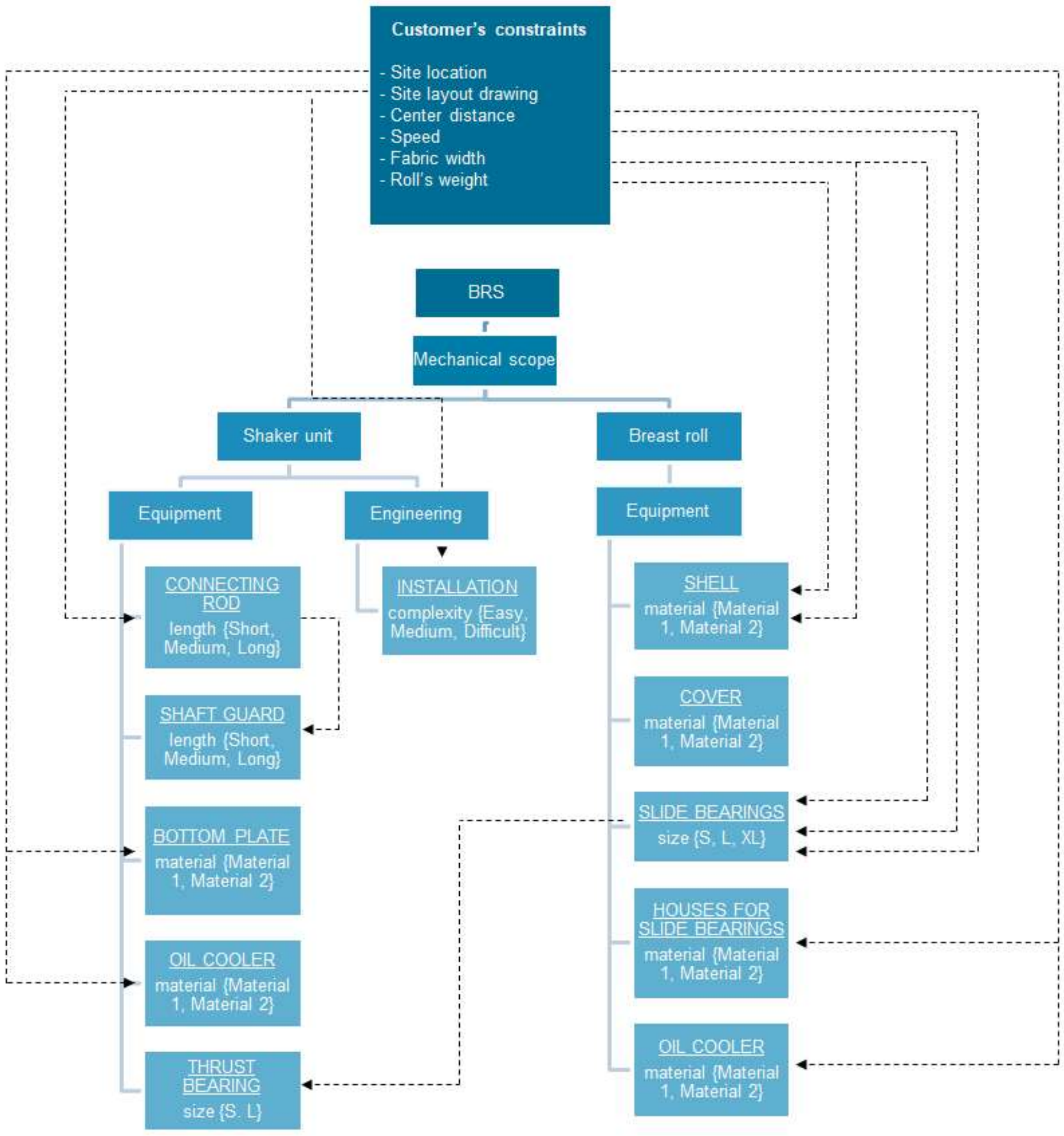

Figure 15. BRS's class diagram: configurable mechanical scope

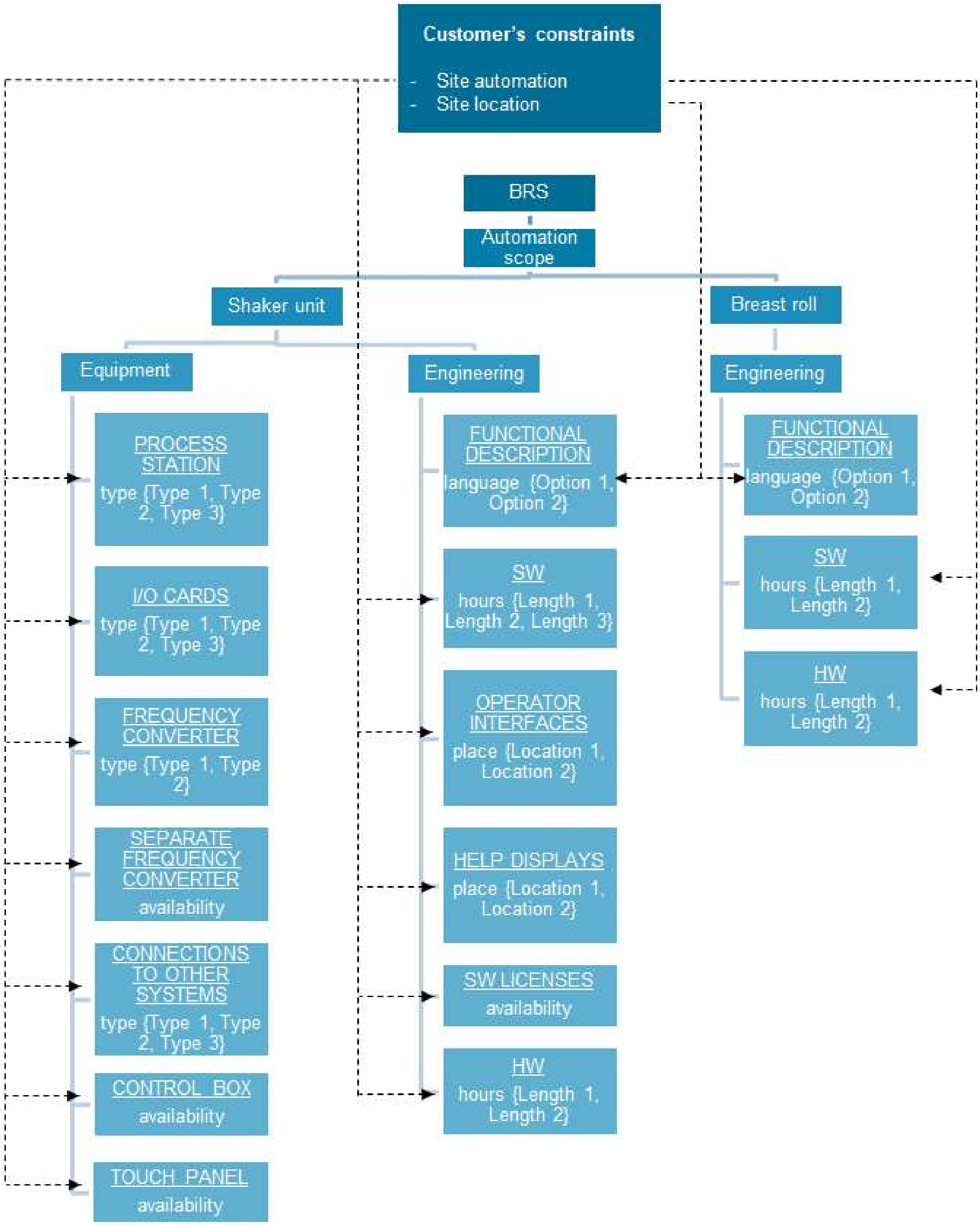

Figure 16. BRS's class diagram: configurable automation scope

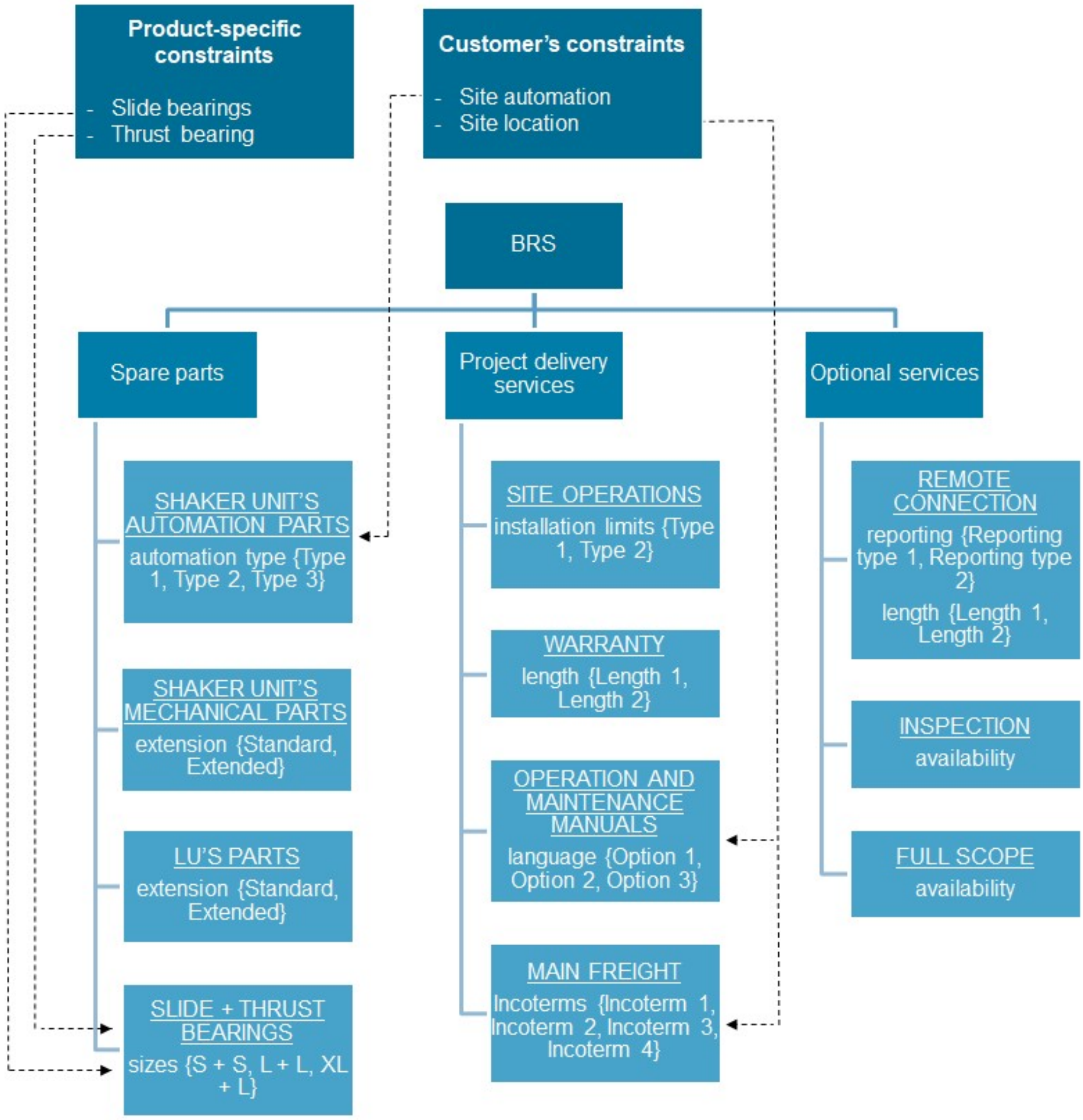

Figure 17. BRS's class diagram: configurable spare parts, project delivery services and optional services

When the author ensured that the project breakdown structure was correct, the definition of the pricing BOM started. It was essential to understand on which level it should be made, so in this case the PDM BOMs were taken into account to serve as a base for the constructed pricing BOM. The BOM was divided into sections – the main BRS's parts – according to which it could be priced. It contained all the common variations of the BRS's elements, including the add-on prices (e.g. a titanium cooler), and the different size (e.g. a short, medium, or long shaft guard) and material (e.g. a steel or composite shell) variations. As to the layout equipment, it was grouped by the author from separated components in PDM, since they did not vary significantly from case to case, so one price for the whole package was easier to maintain. There were examples of the item IDs listed, where relevant, for the components, that had been taken from the suitable PDM projects. The costs or the formulas for their calculations were also documented, as well as the standard and minimum profit margins, which were obligatory for the price calculations. The made by the author example of BRS's pricing BOM is presented in Appendix 8.

4.2 Analysis of the results

Due to the fact that the product's data was not yet standardized and gathered in one place, the author faced the biggest challenge. Collecting all the information regarding the BRS took weeks. All the data collected needed to be compared to ensure correctness and resemblance. This refers to, for example, the PDM BOMs and pricing tool's BOMs that were made on different levels. Else, the PDM BOMs of the past projects were found to be not completely standardized. Therefore, the author needed to define the right level of the BOM for the configurator. Considering that a lot of information was undocumented, an interaction with Valmet employees took place. Contacting the specialists from different departments appeared to ease and complicate things at the same time. On the one hand, they as experts could evaluate the accuracy of the data and, therefore, were one of the most reliable sources for the author. However, on the other hand, diverse opinions on one matter from different specialists brought a necessity to research and analyze the bases of their points of view in order to come to a single solution. This issue could be referred to, for instance, the product's technical specifications that were not matching each other in different workers' opinions.

Needs to be noted that these obstacles are most likely to appear in the beginning of CPQ product modelling. Therefore, once the software is used completely for the whole spectrum of the products and services, it will take times less time to quote, finally leading to the time and effort efficiency.

Nevertheless, a sales and product configurator such as CPQ is not an easy fit for any product. For companies, it is a long way from wishing to use it to actually using it that takes years and many efforts. The actual benefits of using CPQ for one or another product should be carefully evaluated. This work represents the main evaluation criteria in author's opinion.

First of all, a company needs to consider that CPQ is designed for configurable products, since the software makes it easier to handle customization. Here it is important to note that each company chooses the own number of scenarios they wish to obtain from configuring a product. If satisfying every single customer's demand is the company's policy, then they make it possible to customize as many product's elements as possible. This way, although, has a significant disadvantage: the configuration and pricing logics become too complex, the standardization level is too low, therefore, a product is harder to integrate to and maintain in CPQ. As a result, the price for such product gets higher and the quoting takes longer, which may make customer consider an alternative less configurable but cheaper and faster option. The other way, however, leaves company a choice of putting variations only to the product elements they consider the most common. For Valmet, the reason for choosing this way was to retain a competitive advantage. Their strategy was aimed at balancing varieties of the products with their prices to show the customers that Valmet were ready to meet their biggest requirements keeping the prices affordable. Therefore, one would say that a highly customizable product with complex constraints is not a priority for CPQ from the business' perspective.

The second point of the assessment to consider is that the products as well must be standardized to some extent, otherwise it will be not possible to make a common product breakdown structure that should be put inside CPQ. Although, the standardization cannot be complete, otherwise CPQ will be useless. Thirdly, the current sales volumes must be taken into account. It is essential to understand that the products to be configured in CPQ should be sold with a high enough level of regularity to ensure the bigger profits and, consequently, a faster return on investment (ROI). It is also of advantage if the product being analyzed is sold most frequently compared to other products. The more product is popular within customers, the more of its quotations are made. Consequently, if such a product is quoted through CPQ, a lot of time and effort get saved.

Furthermore, the business potential should be evaluated. That way a company is able to compare it with the current sales and examine, whether the use of CPQ can bring a substantial difference. From the perspective of this study, the current product sales and the business potential could not be rated and judged due to the fact that the CPQ investment costs had to be considered for that. However, Valmet was armed with that data, and for them it would be possible to calculate ROI for every development project needed. The percentage of the product sold compared to all PIP sold could be criticized by a competent person in Valmet. Therefore, its rating by the author could not be relevant, so it was left out. The rating scale for other guidelines for evaluating product fit for CPQ is from “unsatisfactory” to “exceptional”, where “unsatisfactory” means that the product should not be considered a priority for CPQ, and “exceptional”, on the contrary, denotes its high suitability and easiness of integration. The guidelines proposed by the author for evaluating PIP are shown in Table 4.

Table 4. Guidelines for evaluating product fit for CPQ

Guideline	**Form of evaluation**	**Way of evaluation**
Current product sales	Numerical	Yearly sales amount, €: $(P_{avg}) \times (QTY)$
Business potential	Numerical	Potential yearly sales amount, €: $(P_{avg}) \times (QTY_{max})$
Product sales share in all PIP sales	Numerical	$\frac{QTY}{QTY_{tot}} \times 100\%$; $\frac{S_{product}}{S_{tot\ PIP}} \times 100\%$
Product's complexity	Rating	Overall complexity of a product based on the amount of its components and product specialist's professional perception: Simple: *exceptional* Rather simple: *very good* Medium: *satisfactory* Rather complex: *marginal* Complex: *unsatisfactory*
Configuring complexity	Rating	Based on the amount of constraints: 1-5: *exceptional* 6-10: *very good* 11-15: *satisfactory* 16-20: *marginal* 21-25: *unsatisfactory*
Level of standardization	Rating	$\frac{N_{standardized}}{N_{tot}} \times 100\%$ 0-20%: *unsatisfactory* 21-50%: *satisfactory* 51-70%: *exceptional* 71-90%: *satisfactory* 91-100%: *unsatisfactory*

where P_{avg} – average product's sales price;

QTY – quantity of the product sold per year;

QTY_{max} – maximum quantity of the product that can be sold per year;

QTY_{tot} – quantity of all PIP sold per year;

$S_{product}$ – yearly sales of the product in euros;

$S_{tot\ PIP}$ – yearly sales of all PIP in euros;

$N_{standardized}$ – number of standardized product components;

N_{tot} – total number of product components.

The evaluation was rather simple and could be done by the competent employees who had the needed knowledge. According to the guidelines, the BRS was evaluated as to check whether the decision to start its development project was reasonable. In addition, the author studied another Valmet's PIP called Dryer Fabric Cleaner (hereafter referred to as DFC) to the extent enough for the configuration complexity assessment and attempted to evaluate it as well. The DFC's development project was a company's plan for the future and, therefore, the evaluation of its suitability for CPQ was necessary. The evaluation results could show the potential of the DFC's configuration to be made in CPQ. Since the BRS was approved to fit CPQ in an advantageous way, similarities in evaluation results between it and other PIPs could denote their potential for CPQ as well. The results of both PIPs' evaluation are presented in Appendix 11.

Nevertheless, the evaluation of a product fit into CPQ is not enough to start its integration. The integration takes a chain of sequential steps – the guidelines for collecting data that are outlined later. Since the data is diverse and decentralized before CPQ usage, contacting the main relevant specialists (i.e. stakeholders) is inevitable. Their knowledge combined brings value to the whole business and, consequently, to the case problem in particular. Although, too many stakeholders should not be involved – it may lead to the problem of diverse opinions, which the author faced to some extent. All up-to-date information must be exchanged between a project developer and the stakeholders to ensure the accuracy of the ongoing project. An application development engineer plays a big role in evaluating it, considering that this person is fully aware of all specifics of the software and has a clear vision of integrating the project into it. Although the CPQ integration is a hard and long process, it may get smoother once one knows whom to contact, at which stage, and for which information. Table 5 presents the list of the main contacts during the BRS configuration research, indicating their positions, their relevant for the research knowledge, and the input they provided for the research. The stages of the research at which every stakeholder was contacted are mentioned in chapter 3.4. In Appendix 12 a similar table with mentioning of the stakeholders' names and Valmet business units they belong to can be found.

Table 5. Key data providers for the BRS CPQ development project

Stakeholder	**Knowledge**	**Input**
Global product manager	PIP sales and structure	Technical specifications, mechanical variations and the conditions for their choice, constraints
Senior chief engineer	Mechanical engineering	Mechanical specifications, mechanical variations and the conditions for their choice, constraints
Automation manager	Automation engineering	Automation specifications, automation variations and the conditions for their choice, constraints
Purchasing engineer	Purchasing structure	Pricing BOM, prices of components
Senior product sales manager	PIP sales and structure	Technical specifications, BOM
Application engineer	Pricing	Pricing logic, pricing BOM
Global roll center manager	Breast roll pricing	Steel breast roll's pricing logic and priceable components
Project manager	Project management	PIP delivery services, pricing BOM
Project engineer	Spare parts	Commonly-used spare parts lists
Application development engineer	Configuration implementation	Product structure, product configuration, implementation into CPQ

Based on the knowledge acquired through the practical research, the author outlined the guidelines for integrating other PIPs to CPQ (Figure 18). They were made with the consideration of the steps the author took in the own development project. However, based on the experience that had been acquired throughout the practical research, the author made corrections to the steps taken to offer smoother and more logical development of future PIPs. The guidelines were believed to be of help for Valmet's future similar projects.

The first step was project scoping. At this point one needed to indicate whether the status of productization was feasible. The list of the stakeholders needed to be made, and with them a project scope was agreed on.

Data harmonization was the second and a crucial step, considering that at this stage the product-related data (the technical specifications, the pricing) was checked to be identical in different sources (PDM, the pricing models, IBM Notes) and to match the actual product description. Before making a project breakdown structure, the data had to be verified and standardized with the help of the relevant stakeholders. Afterwards, the elements of the project delivery were established and combined into a PIP delivery structure – a product portfolio was made.

At the third stage, "Configuration scoping", it had to be specified which project delivery elements could vary and how. The effect of configuring such elements needed to be defined, too. The customer's and product-specific dependency relationships – the constraints – needed to be documented here. The constraints and customization options were then merged with the product portfolio to get a configurable model.

The fourth step was aimed at defining the costs and pricing logics. At this point all the relevant to the project costs had to be collected and documented. It was important to make a pricing BOM for the product to identify on which level it should be priced. And, furthermore, all existing pricing logics had to be specified – then CPQ would be able to calculate a unique price for a configured product.

The fifth stage clarified the specifics of the sales process for the particular product. The proposal types had to be defined for each product component, so that CPQ was able to price the product at every type of quotation (see Table 2). Also, it was important to decide on the content of the generated by CPQ documents such as the technical specifications and quotation, since they were the valuable outputs of the configuration for the company and the purchaser.

Before the implementation of the development project in CPQ, all the data had to be verified another time, the possible missing data had to be defined. Then, the acquired knowledge was checked to be fully documented and centralized, and after that the modelling could start. The first configuration test needed to be carefully examined for mistakes and fulfilling all customer's requirements. If mistakes were found in the generated by CPQ quotation or technical specifications, the cause needed to be revealed and fixed, then the configuration could be done again.

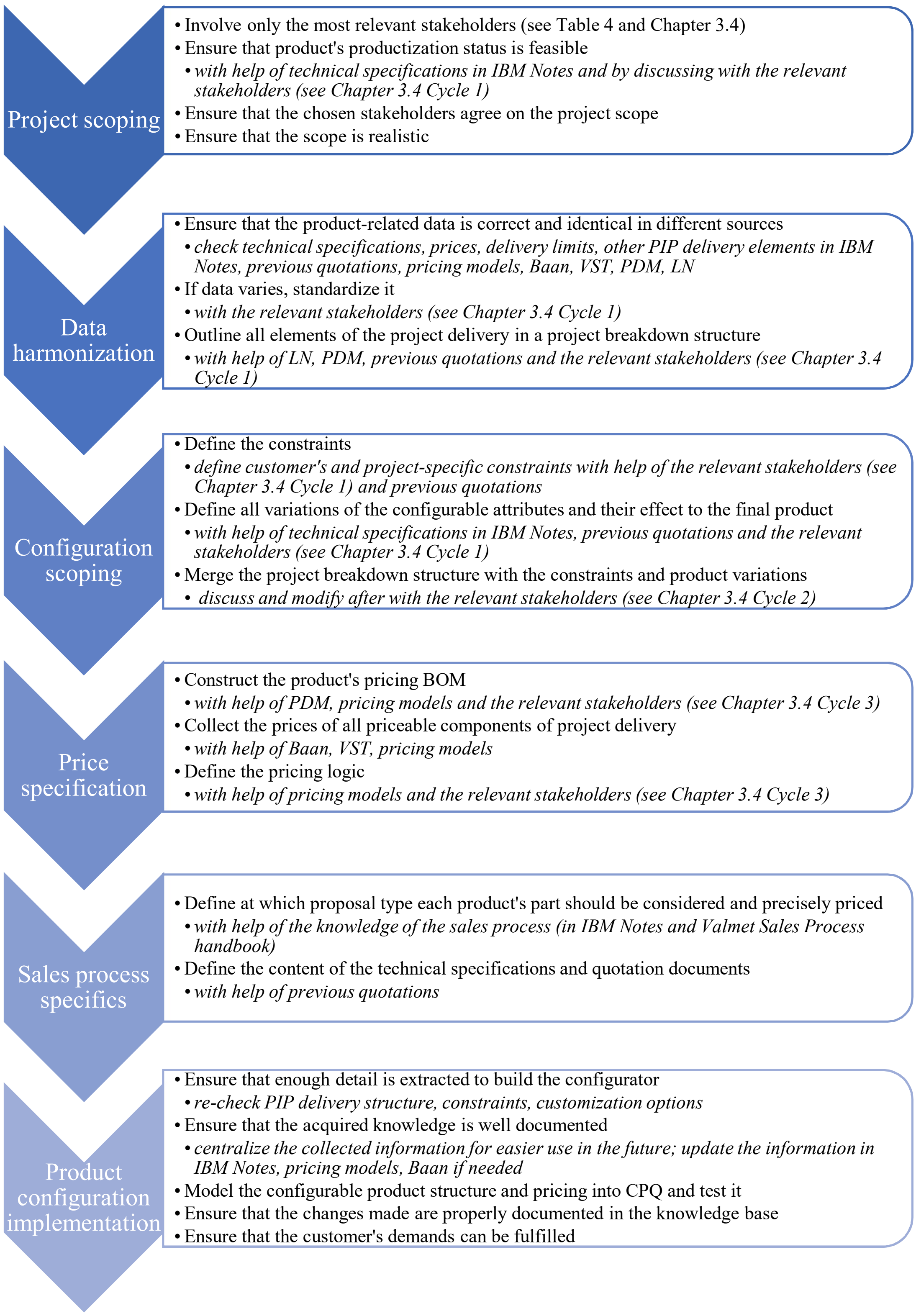

Figure 18. Guidelines for a new product configuration project

5 Conclusion

5.1 Answers to the research questions

The research questions that had to be answered throughout the research were stated to be the following:

- What are the elements needed to enable configuration?
- What does a project delivery structure include?
- How to model a product into CPQ efficiently?
- To what extent a framework of one PIP can be applied to other products?

In order to come to the definite conclusion, all the answers to the questions need to be presented clearly.

What are the elements needed to enable configuration?

The elements of the product's data that are essential for a sales and product configurator are structured in Figure 14. Those are: the product's technical specifications with pricing, the PIP delivery elements with pricing, the constraints, and the customization options. Moreover, to give the configuration a purpose, the customer's information and requirements must be known. The results were gained through the case study, but they are suitable for an overall concept of CPQ inputs.

What does a project delivery structure include?

The project delivery structure contains the main delivered parts of a product, in this case: mechanical parts, automation parts, spare parts, and project delivery and optional services. The BRS's product portfolio can be found in Appendix 3, where this order delivery structure was specified. The whole BRS PIP delivery is documented in Appendix 4.

How to model a product into CPQ efficiently?

The sequence of actions taken for every development project is important. The experience acquired through the practical research helped the author document the action chain from evaluating a product to implementing its development project. The points to consider were exposed and documented in Table 4 and Figure 18 with the necessary descriptions.

At first, the product needed to be evaluated to conclude whether it was a priority for CPQ. The assessment considered the product's sales, the product's complexity with the level of standardization, and the product's configuration complexity. Afterwards, if the product was agreed to be suitable for CPQ, the project developer was suggested to proceed with the development project following the suggested guidelines that covered the steps from the project scoping to the product configuration in CPQ. What was important to keep in mind was deciding which stakeholders to involve at each step to ensure the effective and efficient project development and to avoid the inconsistency of opinions (see Table 5 and chapter 3.4).

To what extent a framework of one PIP can be applied to other products?

Based on the knowledge acquired during the BRS study, the author drew a conclusion that the action steps made throughout the research were applicable for the development projects of other PIPs. The logical path "project scoping – data harmonization – configuration scoping – price specification – sales process specifics – product configuration implementation" (see Figure 18) defined the main points to consider and the main information to gather for an effective integration of product to CPQ. Since following them the author had done a successful development work of the BRS, the steps could be concluded to be efficient.

Furthermore, the special yet simple evaluation guidelines were outlined for the assessment of other PIPs (Table 4). The BRS was evaluated based on them, and the results confirmed that it had been the correct decision to integrate it to CPQ. The assessment of another PIP – DFC – was done based on the available data as a test to indicate the product's potential for CPQ.

Talking about the product's structure, needed to be noted that the whole framework could not be applied to other PIPs, since all of them varied in components. However, a common configurable class diagram could be pointed out (Figure 19, & Appendix 13). During a short study of the DFC, the author defined its product structure as well, and afterwards deduced the similarities between it and the BRS. With the help of discussions with the stakeholders, the author concluded which configurable components, their variations, and constraints are common for other PIPs.

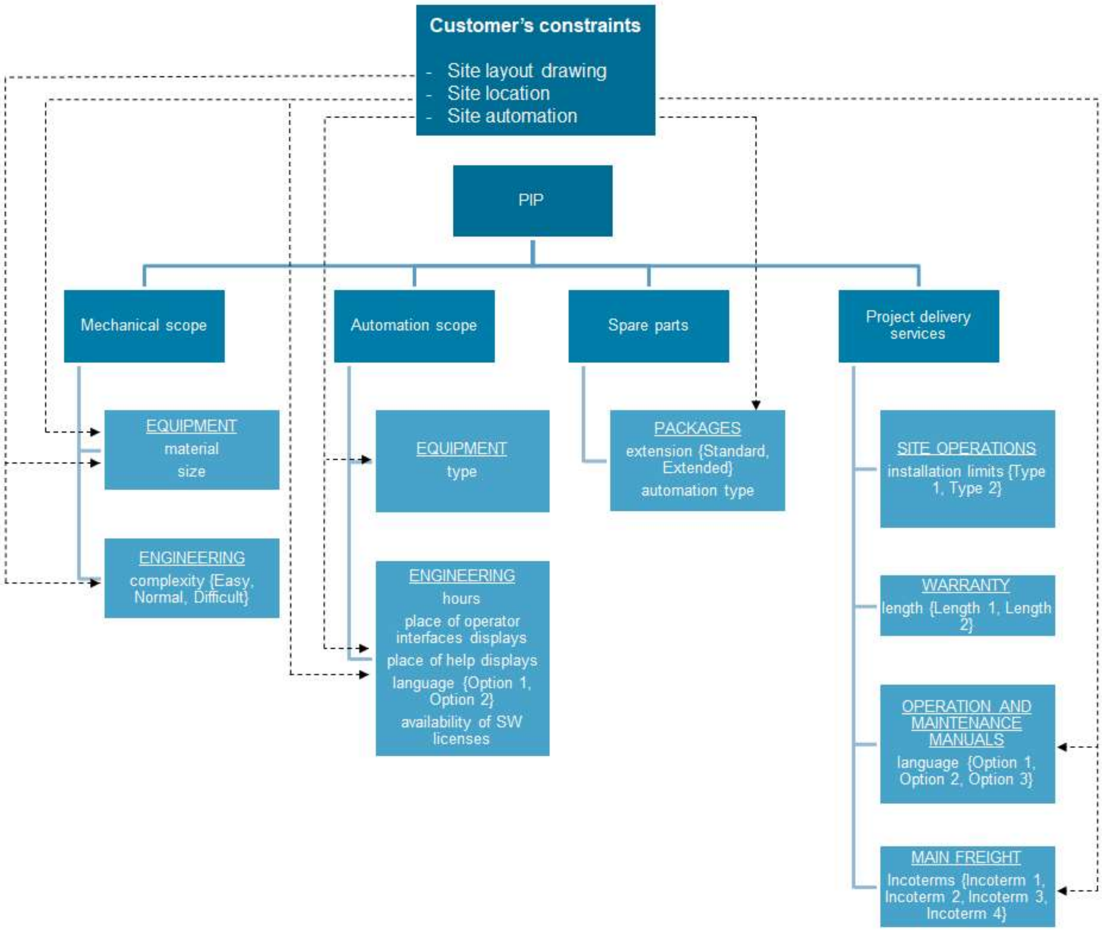

Figure 19. PIPs' common configurable class diagram

5.2 Research value

The current research was believed to bring value to the case company. Despite the fact that it was mainly based on one PIP, the analysis of the results showed that the similar actions could be applied to other PIPs. The criteria for evaluating the product's suitability for CPQ could be helpful for Valmet in decision-making regarding the products' integration to the software. And the documented steps to take during a new development project could ensure it went smoothly. The specified general PIP configurable class diagram was meant to show the extent to which all PIP structures were similarly configured.

Moreover, during the study the case product's data, as well as some DFC's data, was gathered in one place and structured for a better visualization and understanding of the next person using it. All complementary materials structured by the author were handed over to Valmet for further implementation. It was still for the company to develop the outcome, as it was only in their competence to adapt the information provided by this work for every-day working life. The purpose of the research was not to make the very final ready-to-use version, but to evolve and deliver a general idea that would work at the time of the study and would be of help with more products in the future.

One would not say that the sales would significantly increase with CPQ, since its implementation did not have a direct effect on customers. Instead, it would allow streamlining of Valmet’s processes, making them smoother, less time-consuming and more efficient. It was probable that the shorter times to quote and the clearly stated product variations would improve customer retention, increasing the sales.

As to the general use of CPQ, it is always a company’s decision whether it will be beneficial or not. They must consider all possible outcomes and beware of problems that can be faced.

All in all, CPQ is designed for companies that feel the lack of flexibility in the product customization, and that suffer from the mistakes in quotations and the long times to quote. Even if it does not work out, the attempt of CPQ integration will benefit a company either way. The main reason is that in order to implement it, all products’ data gets verified, collected and documented, and the customization options with constraints give a clear vision of the configurable products. Centralization brings such advantages as a high company’s data standardization level, shorter quoting time and effort efficiency.

5.3 Suggestions for future studies

Due to the fact that this work was mainly based only on one PIP, the presented results might happen to not completely suit all of them. Even though the gained results were comprehensive for the BRS alone, after its integration to CPQ Valmet would be in need of new development projects. The obtained generalized results presented in this thesis work could help integrate other PIPs, however, a broader investigation would be necessary. For future studies, it was suggested to consider several PIPs and to compare their structures completely in order to, considering their similarities and differences, come to the common project breakdown structure.

Deeper research of the financial part (e.g. the CPQ investment costs, the PIP sales for a bigger time period) would let calculate a precise ROI to make fairer conclusions about suitability of the product for CPQ. Moreover, investigating the reasons for integrating any product to CPQ would help define more guidelines for the product evaluation. The outcomes of such studies were believed to bring a positive effect to the new development projects, nevertheless, the time for their execution must be considered and should not be too long, since technologies and trends constantly change.

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Appendices

Appendix 1: The plan for Valmet's future quotation process (Adapted from: Kalapudas 2019)

Appendix 2: Pilot CPQ trial results

Appendix 3: BRS's product portfolio with main assembly / main process and subassembly / sub process levels of the physical structure

Appendix 4: BRS PIP delivery's configurable model

Appendix 5: BRS's class diagram. Configurable mechanical scope

Appendix 6: BRS's class diagram. Configurable automation scope

Appendix 7: BRS's class diagram. Configurable spare parts, project delivery services and optional services

Appendix 8: BRS's pricing BOM

Appendix 9: BRS's sales from 2016 to 2019

Appendix 10: BRS's sales share in all PIP sales from 2016 to 2019

Appendix 11: Evaluation of the BRS and the DFC for CPQ

Appendix 12: Key data providers for the BRS CPQ development project

Appendix 13: PIPs' common configurable class diagram