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PRICING VARIABLES SPECIFICATION AND EFFECT ON THE TOTAL PRICE CONTRIBUTION IN SUBCONTRACTING

Pricing and procurement development

Master of Science Thesis
Faculty of Engineering and Natural Sciences
Examiners: Dr. Timo Lehtonen & Prof. Tero Juuti
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ABSTRACT

Mikko Ristimäki: Pricing variables specification and effect on the total price contribution in subcontracting
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Making cost-effective pricing and purchasing decisions in a fast-paced manufacturing environment and fitting them into tight project schedules is a challenge that bothers global companies around the industrial world. Therefore, actions to develop pricing accuracy in procurement are essential for companies to maintain the cutting edge in the industry. Procurement processes under review include partnerships and their desired effects on co-operating business between involved parties. Such desired effects are for example general cost level decrease without hurting margins.

This thesis was assigned by a large-scale Finnish global operator and the task was to research, develop and examine previous pricing and purchasing transactions in a form of a case study. The thesis starts by reviewing the theory behind pricing, procurement and prefabrication. Afterwards, the theoretical study continues to research methods, which were pointed out to be important in this kind of study that doesn't have many relevant publications produced from the same field of study available. Along with research found in the literature, several internal and external interviews were used to evaluate the topics and results. After assessing research methods, the actual active research process starts by introducing research data and digging deeper into its findings and analyses. The results are presented by visualizing the used methods and presenting graphs to clearly determine the consistency of the linear spread of multiple variables and their numeric values.

The study was successful and answered the desired questions that had emerged in the assignment company. Based on the results, further recommendations regarding operating with key partners and how the pricing is developed more accurate and documented in a more comparable way are considered in the assignment company.

TIIVISTELMÄ

Mikko Ristimäki: Hinnoittelumuuttujien määrittely ja vaikutus kokonaishinnan muodostumiseen alihankinnassa
Diplomityö
Tampereen yliopisto
Konetekniikan diplomi-insinöörin tutkinto-ohjelma
Syyskuu 2022

Kustannustehokkaiden hinnoittelu- ja hankintapäätösten tekeminen nopeatempoisessa tuotantoympäristössä ja niiden sovittaminen tiukkoihin projektiaikatauluihin on haaste, joka vaivaa globaaleja yrityksiä ympäri teollisuusmaailmaa. Siksi hinnoittelutarkkuuden kehittämiseen tähtäävät toimet hankinnoissa ovat olennaisen tärkeitä, jotta yritykset voivat säilyttää etumatkaansa teollisuudessa. Tarkasteltaviin hankintaprosesseihin kuuluvat kumppanuudet ja niiden toivotut vaikutukset osapuolten väliseen yhteistyöhön. Tällaisia toivottuja vaikutuksia ovat esimerkiksi yleinen kustannustason aleneminen katteita vahingoittamatta.

Tämän opinnäytetyön toimeksiantajana oli suuri suomalainen globaali toimija, ja tehtävänä oli tutkia, kehittää ja tarkastella aiempia hinnoittelu- ja hankintatapahtumia tapaustutkimuksen muodossa. Opinnäytetyön alussa käydään läpi hinnoittelun, hankinnan ja esivalmistuksen teoriaa. Tämän jälkeen teoriatutkimus jatkuu tutkimusmenetelmiin, jotka tuotiin esille tärkeinä tämänkaltaisessa tutkimuksessa, josta ei ole saatavilla paljon samalta tutkimusalalta tuotettuja relevantteja julkaisuja. Kirjallisuudesta löytyvän tutkimuksen lisäksi aiheiden ja tulosten arvioinnissa käytettiin useita sisäisiä ja ulkoisia haastatteluja. Tutkimusmenetelmien arvioinnin jälkeen varsinainen aktiivinen tutkimusprosessi alkaa esittelemällä tutkimusaineistoa ja syventymällä sen havaintoihin ja analyyseihin. Tulokset havainnollistetaan visualisoimalla käytettyjä menetelmiä ja esittämällä kaavioita, joiden avulla voidaan selkeästi määrittää useiden muuttujien lineaarisen leviämisen ja niiden numeeristen arvojen johdonmukaisuus.

Tutkimus oli onnistunut ja vastasi toimeksiantoyrityksessä esiin tulleisiin haluttuihin kysymyksiin. Tulosten perusteella toimeksiantajayrityksessä harkitaan lisäsuosituksia, jotka koskevat toimintaa keskeisten yhteistyökumppaneiden kanssa ja sitä, miten hinnoittelua kehitetään tarkemmin ja dokumentoidaan vertailukelpoisemmalla tavalla.

PREFACE

Working with this study for the past several months has been an intense and challenging yet tremendously educational and interesting experience. Even though the study had its ups and downs, I'm proud to say I have now finished my journey with my master's thesis.

I'm extremely grateful for all the support I received during my research. I would like to especially thank my supervisor Jaakko and colleague Ari from the assignment company, who has been actively supporting me by giving insights and help during this process. Also, my deepest gratitude goes to all my co-workers here in the assignment company. I've been lucky to have such a network around me during this period. I would also like to thank my university examiners Dr Timo Lehtonen, who has helped me thru this process by giving support, instructions, and guidance, and tenure track professor Tero Juuti.

Along with my compliments on the work environment, I would like to thank my beloved girlfriend, family, and friends for supporting and encouraging me at all times. After quite a few years of studying, it's time to move student life aside and focus on the upcoming. I'm curious about the future, and I hope I can benefit from my knowledge in procurement and pricing sometime later on in my upcoming career.

Tampere, 29 September 2022

Mikko Ristimäki

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LIST OF SYMBOLS AND ABBREVIATIONS

SRM	Supplier relation management
WTP	Willingness to pay
WBS	Work breakdown structure
CBS	Cost breakdown structure
SG&A	Operating expenses or selling, general and administrative expenses
Muda	Wasted work
ANOVA	Analysis of variance
MANOVA	Multivariate analysis of variance
H_0	Null hypothesis
H_a	Alternative hypothesis
cov	Covariance
S	Standard deviation
W	Range
r	Correlation coefficient
GJ	Gigajoule
kWh	Kilowatt-hour
df	Degree of freedom
SS	Sum of the squares
MS	Mean square
F	F-statistic
Significance F	P-value of F
D	Diameter
s	Wall thickness
NDT	Nondestructive testing

1. INTRODUCTION

In constantly changing global situations and markets combined with complex, unique designs of deliverables, maintaining the competitive edge is crucial for global and large-scale companies. Competence among global companies operating in the same field is increasing annually at a fast pace. A diverse field of operations benefits from subcontracting and prefabricating basic elements of large delivery products while the company's internal manufacturing and design are focusing on its core competencies. Pricing and procurement are in a key role when companies are striving for maintaining and enhancing effective competence and maximise profitable cooperation with key partners. Pricing of prefabricated sub-products in assignment companies is currently done strongly based on previous experience. Due to increased material prices, inflation, and an uncertain environment in a global industry, savings in procurement are crucial when companies are trying to improve the efficiency and economy of their operations in the manufacturing industry.

The thesis is made as an assignment of a global, large-scale industry company in Finland. As the projects and manufactured entities are complex and very large-scale structures, prefabrication is in a central role in the manufacturing process. The thesis aims to reveal key factors of pricing. These factors will be for example what the final prefabrication price consists of and finding a successfully working method to divide and categorize elements of prefabricated products, such as physical specifications and materials, and finding a common factor in how they are priced. Data of orders in several different projects provided from the years 2017 to 2021 by one key partner company (Case A company) is used as research material. This data includes stacked pricing material of separated sub-assemblies. The companies have signed an agreement to reduce the pricing level by 10% during the period under review. A major challenge in this data is inconsistency, partial unreliability, and differences in the documentation. In the thesis, several research methods are considered to find the most suitable approach to delve into the data and find the key factors. These research methods are qualitative, similar to strategy as the pricing is following now, and quantitative, meaning the research is mainly focusing on numbers and trends.

1.1 Motivation and scope

Prefabrication is a key aspect of large-scale manufacturing, especially when final products are designed and constructed around the globe. Due to every project's complexity and unique designs, the pricing is still unpredictable and non-constant. Based on the data given by the company's partners in prefabrication, there are questions to be solved in the matter of pricing and points to improve in future pricing. The assignment company is keen on improving the pricing accuracy and level for better to ensure efficient and more precise pricing for future projects. Due to complicated prefabricated designs, in most cases, the actual design is not completed yet when the order for prefabrication is done. This means the paid price is always too high or rarely too low for the actual amount of prefabrication – so the purchase for prefabrication of elements is currently made by feeling and estimations. To improve this current way of working, the motivation for this thesis is to find a way by researching the data to consistently price the orders for prefabrication in future projects.

The research questions of this thesis are:

1. How has pricing changed over the case study period?
2. How do comparable pricing variables affect each other?
3. What are the causes of pricing variations?

As Case A company under review is operating in a different country, a comparison of the order and prefabrication countries is mandatory to understand the general total cost levels of working in each country. By comparing cost levels, conclusions of possible margin optimization can be made, whether the claimed profit margin by Case A company is a valid argument and has been followed. The summary of pricing general factors can be seen below in Figure 1. Pricing summary. Consistency of pricing in the case study is solved by numeric values of price-affecting elements that can be determined and modelled into equations and graphs to examine pricing consistency.

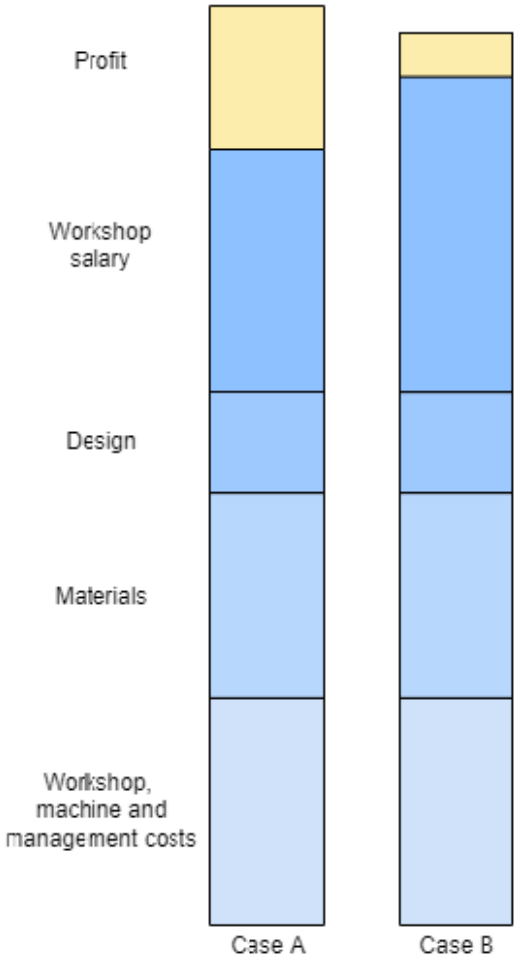

Figure 1. Pricing summary

The Figure 1. Pricing summary shows an assumption of the magnitude of general pricing elements. This study also digs deeper into pricing elements and what is causing the final price amongst these aspects and what causes the possible variations between the cases. From bottom to top, the elements are workshop, machine, and management costs, which are quite similar in Case A and Case B companies located in different countries. The second block is materials, which are also pretty much the same. The third is design, which may or may not be included in pricing depending on the contract. The price of design is also more or less equal depending on the subject and amount of order. What is the greatest difference is the fourth block, which is workshop salary. In Case A and Case, B country is visible a difference in workshop salaries, meaning Case B country has a higher average salary for workshop employees. Therefore, this block is larger in Case B country. This is why the final block is the profit the company receives from the order is larger in Case A country. By the first assumption, the profit should be smaller if the workshop salaries are smaller. Interestingly, Case B company has a lower overall

price in this review, which should be the other way around since workshop salaries are higher. The thesis treats prefabrication and subcontracting as similar terms because of the lack of information on prefabrication in available literature in this field of manufacturing. In literature prefabrication often relates to construction, which is why subcontracting as a term is closer to describing purchasing and cooperative actions in this thesis, however, subcontracting commonly refers to more universal actions. Both terms are related to purchasing goods or work from an external company, so they are both seen in use in this thesis.

This thesis aims to review the general pricing of procurement in assignment company and solve the odd pricing of previous projects in Case A. Due to geographical facts regarding labour cost prices, generally lower price levels and contracts, where the company has stated they have a roughly 5% profit level out of all orders, raises doubts in the assignment company about pricing inconsistencies. A qualitative starting-point assumption is Case A company may have higher profits than they state, and therefore the pricing agreement of a 10% reduction in pricing level is under review.

1.2 Thesis structure

The thesis is structured into six divided sections: Introduction, Research methods, Prefabrication in the manufacturing industry, Theoretical background, Analysis, and finally Results and discussion. The structure is presented below in Figure 2. Thesis structure.

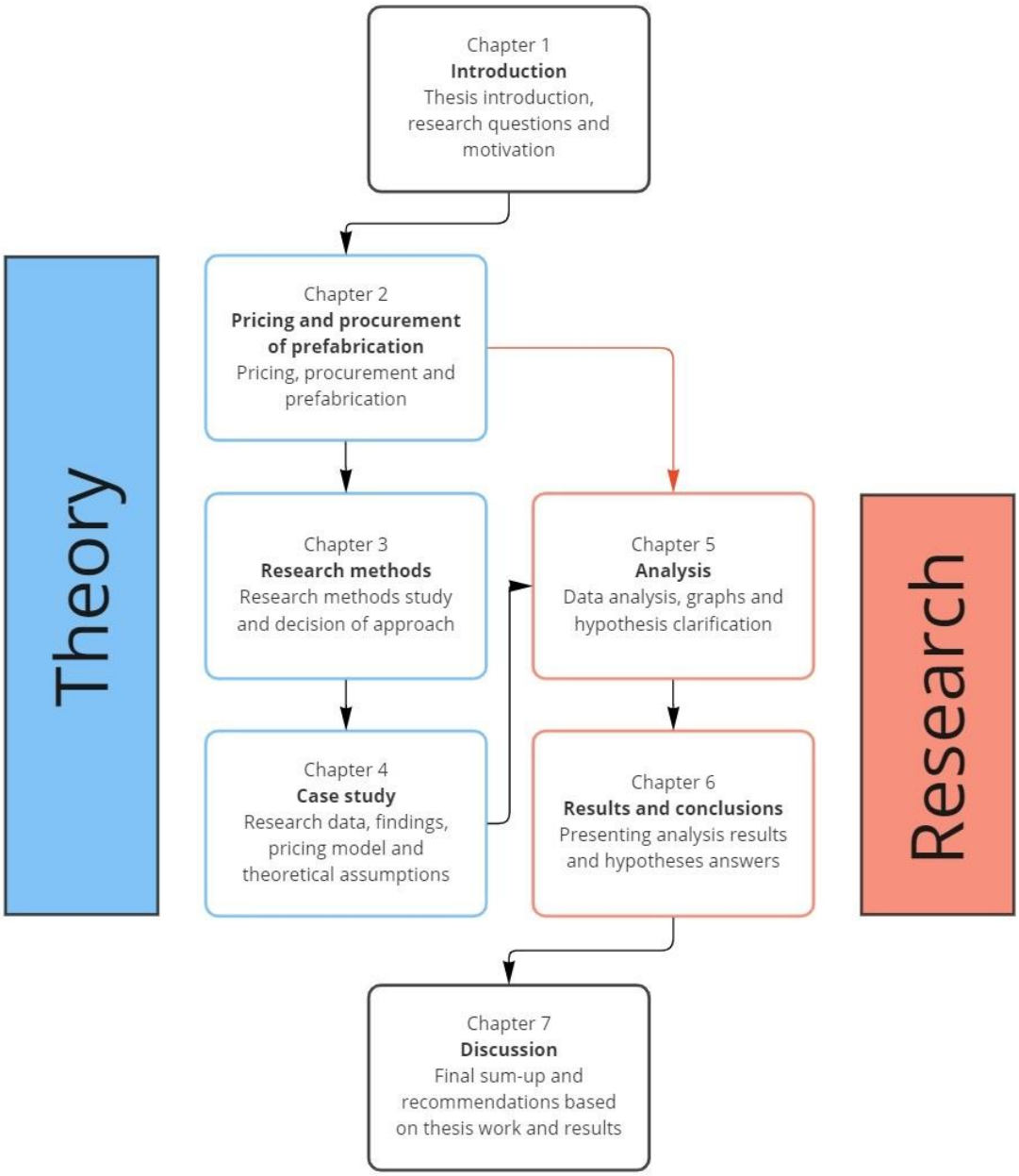

Figure 2. Thesis structure

Chapter 1 is the introduction of the thesis. In this chapter the thesis subject, research questions, and motivation are presented. It also determines the scope and limits of the study.

Chapter 2 introduces the reader to procurement and pricing in the prefabrication and subcontracting industry. The theory includes a walkthrough of what is prefabrication, why prefabrication is a key factor in certain fields, how and why it is used, and how prefabrication is used in the assignment company's projects.

Chapter 3 is focusing on the research methods for this study. In this chapter quantitative and qualitative research methods amongst a few others are considered, studied, and compared to this work. The chapter also introduces the current pricing methods of the assignment company. The core work of the thesis focuses on quantitative and qualitative research methods. The validation of the chosen methods is found in this chapter.

Chapter 4 is the theoretical background and introduces the research data, its findings, the pricing model and its factors. Until this, the thesis has been focusing on the theory around the subjects of the matter. Also, the formed hypotheses of the study outcome are created.

Chapter 5 starts the actual active research section of the thesis. This chapter presents a complete analysis of the research data with chosen research methodology, visual graphs, and findings.

Chapter 6 contains the results and conclusions of the results presented in the previous chapter and a summary of the thesis.

Finally, *Chapter 7* discusses how the results were obtained and what has affected the outcome. This chapter also includes suggestions for further processes on how pricing and its documentation could be improved in the company.

2. PRICING AND PROCUREMENT OF PREFABRICATION

The thesis will be carried out for the procurement department in the assignment company. As the pricing and its hidden aspects within the research data is the subject to be solved, procurement is treated as a point of development with the results we get from the pricing study. In the case study, pricing is proceeded by Case A company and the assignment company represents the buyer. Out of this arrangement, the pricing model is made to clarify and structure cost elements based on theory in this chapter as well as prior professional knowledge and consulting from advanced professionals in the assignment company. A key point of this chapter along with pricing and procurement is prefabrication and subcontracting environment. Pricing and procurement are also highly related to strategic partnerships, which are formed between the assignment company and Case A company.

2.1 Pricing and its strategies

From the manufacturer's perspective, one of the hardest decisions organizations has to make is how to efficiently and accurately price their products and services. If the price asked for the product is too low, it may not cover its costs or generate profit. Similarly, prices are too high and potential customers may never turn into paying customers. [40]. From a procurement point of view, several pricing methods can be used to determine whether the set product price is reasonable. The prefabrication price is a contractual price that is set for the completed work in an early phase of the project. Early phasing ensures that the fabricated products are ready on time once they are needed in the final product assembly. In the Nordic European countries, nearly all industrial manufacturers rely on subcontractors/fabricators. In the thesis execution country, industrial and metal engineering products are the dominant exports of the country. [42].

An obsolete cost system is revealing itself in several ways over time, which has been recognized in assignment companies. Inconsistent and inaccurate pricing which dates back to assumptions based on previous projects, how much was paid back then, and how the project went, is not perfectly suitable for a business that is continually under change. Industry and cost-related subjects such as materials are experiencing heavy

changes in technologies as well as in values because of the current global economic situation. [10]. Therefore, a more precise and constant way of pricing is urgently in the scope of the assignment company. A successful pricing strategy requires the support of effective organization, motivated management, and timely and accurate information. This means that everyone involved in pricing decisions must understand their role in the process. [51].

Costs are mainly divided into two categories when specifying the cost basis – direct costs and indirect costs [53]. Different cost classifications are commonly used in cost accounting, but they also provide a good perspective when discussing finding the cost basis for internal work, Marttila states in [45]. From an internal work perspective, direct costs are described as working costs that can be pointed to a particular cost object and indirect costs are overheads allocated to working hours. Many enterprises have accepted, that indirect costs are assumed as fixed costs. [16]. Direct costs can be attached to cost objects in an economically viable way, but indirect costs cannot [6]. Costs can also be split into variable and fixed costs, whereas variable costs change according to the cost driver, and fixed costs remain the same in total despite the changes in the cost driver, which is the cause of cost [6]. These approaches differ in a way that variable costs from the same perspective as previously, are covering direct costs, but also certain indirect costs. This makes more sense in the following chapters (4.1 & 4.2) when labour hour is defined in this study. Labour hour is set in the pricing model to contain working costs and certain parts of overheads (direct & indirect cost classifications), such as location-specific employer payments. Sometimes, depending on the company's policies costs are not allocated to certain contracts or internal work, either direct or indirect costs. These kinds of expenses can be e.g. SG&A costs.

In general, three listed types of pricing strategies are used to improve the economic conditions of businesses [59, 51]:

1. Cost-based pricing
2. Competition-based pricing
3. Value-based pricing

of which the first *Cost-based pricing* is the confirmed strategy in use in Case A company as well as most commonly used across the manufacturing sector. That's why this study is mostly focused on the theory of cost-based pricing. According to assignment company knowledge and experience, cost-based pricing can be seen to be in use in the majority of their prefabrication/subcontracting pricing. Oyer describes cost-based pricing in [60]

as a method that ”segregates activities with costs into their smallest component tasks, which are then supported with details such as bill of materials, used hours, or work-measurement standards and rates based on historical data and experience”. Once the costs of each component are determined, a true cost of production is summed from separated smaller parts. Ultimately, the final price is formed by adding a margin or profit to these estimated or actual costs [60]. This kind of approach is called the cost-plus method, which is one of the most common ways of approaching cost-based pricing [52, 39]. Costs in the case study are never actual, because of the state of the project and its affecting matters at the time of ordering. The cost-plus method is the most common price-setting setting method used by companies, which is one way of implementing cost-based pricing [52, 69, 39]. In general, a cost-plus-based approach means adding a fixed margin percentage on top of the total cost of executed work. The fixed margin is also called a markup. A simple example can be: if the product costs are 100 units, and desired margin would be 30%, the cost-plus method suggests the price to be 100, the price would be 130 units. The cost-plus method is simple to apply, justifies price clearly and due to markups provides a consistent rate of return.

Cost-based pricing is differing from other pricing methods in several ways [60]. Cost allowability and profit levels are irrelevant in other pricing methodologies in the sense that the price is determined by the potential customer in terms of the value of the goods or services instead of the costs to the seller or manufacturer [60]. As a downside, cost-based pricing ignores the price elasticity of demand and competing products in the market [69]. Mistakes in estimating sales volume can cause the pricing method not to cover all the costs. Shipley and Jobber [69] suggest that cost-plus pricing is often left to people who lack a throughout understanding of the market causing them to make indiscriminate and so on un-profitable pricing decisions. Along with that, there is a danger that the price is set too high.

Cost-based pricing includes the work breakdown structure concept, which is often used to sufficiently apply cost-based pricing methods [60]. Due to diverse and multidimensional factors, a feasible way to approach pricing elements in 4.2 is to split the factors into the most remarkable ones and ineffective ones to the total price. The purpose of WBS in pricing is to accurately and timely estimate the costs of the work at completion by defining the work or project scope and its tasks. Developing WBS starts from the end objective and subdivides components into more manageable forms in terms of size, duration and magnitude [60]. An objective must include all the necessary steps to provide a common framework of the work components. The work breakdown structure

sums all subordinate costs for work components into higher-level parent tasks and components. This kind of breakdown can be performed for each element of the priced work to find the most precise price for the structure. Pricing estimation can be calculated by parametric estimation techniques, using a statistical relationship between documented historical data and different variables, such as physical dimensions. [60]. CBS, which is closely related to WBS, is purposed to present the actual prices instead of the tasks of the broken structure based on remarkable elements or factors. In a diverse study like this, defining a scope of work is essential to get precise results. According to the internal discussion within the assignment company, determining the scope for example material costs in the research data has to be done instead of strolling through the massive data for every single material instead of the major, general ones.

2.2 Procurement

In the examined case study, the assignment company has purchased external work of prefabrication from Case A company. The case study work has been put out to tender by Case B, which was initially considered the more expensive option because of its location. Pricing summary changes this assumption the other way around, which is the driver for this thesis from a procurement point of view.

In the business world, procurement is a process where the company is purchasing goods and services from an external source under agreed contracts. Purchasing prices are mostly determined by global markets, tendering and agreed-on contracts. Competing in the global economy it’s fundamental to control purchasing costs, especially when the economies are growing slowly. Recently during the examined case study period when the economic growth has been rapid, cost control is very important as a competitive factor. Cost control and reduction are rising more concerning business success. [15]. Procurement as a term includes determining the process needs, selecting suppliers, price negotiating and setting, specifying terms and conditions, contracts and following up to ensure reliable delivery and payment [78]. In Figure 3 below procurement process model is illustrated.

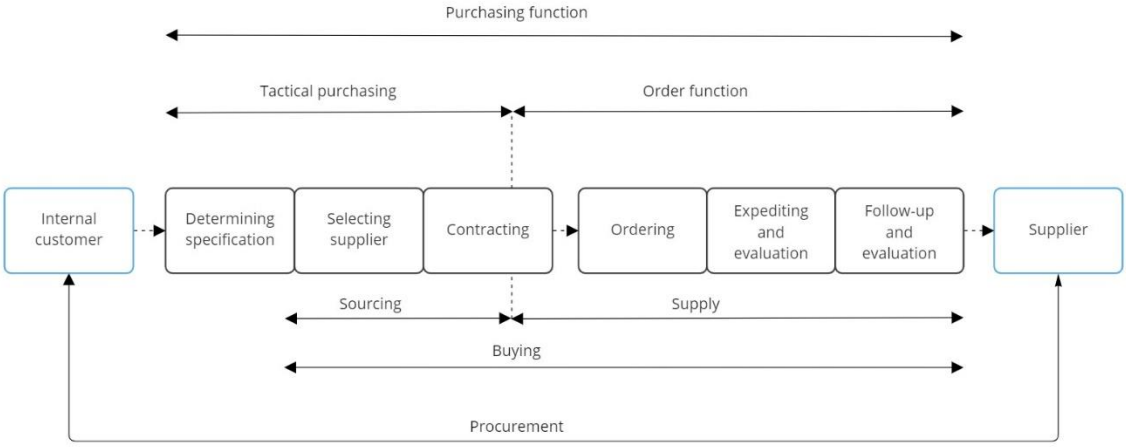

Figure 3. Procurement process model (according to [78])

The procurement process describes the relationship between internal customers and suppliers and the steps. Determining specification, selecting the supplier and contracting are steps before the actual supplying and ordering function. These early steps are part of sourcing and tactical purchasing, where the suitable supplier is chosen and process specification is made. The first step of the buying process is to identify what is needed to be purchased and determine its specification and conditions. After contracting with a selected supplier, the ordering function starts with order and continues with expediting and evaluation and finally follow-up and evaluation.

Procurement tasks can be allocated into three different levels, which are strategic, tactical and operational. The strategic level includes top management's purchasing decisions, that influence the company's market position in the long term and has an effect on competitiveness. Such decisions are for example large-scale investments or related to supplier and sourcing strategies like establishing long-term contracts such as partnerships. Tactical level procurement covers actions involving the purchasing function. Decisions affecting the purchasing of products, processes and supplier selection are for example preparing and developing value analysis and certification programmes or building cross-functional, cross-business category sourcing structures. This level of decision often has a mid-term impact from one to three years. Finally, the operational level involves all activities of ordering expediting function including all actions related to the requisition-to-pay process. Actions such as the ordering process and supplier performance monitoring are operational-level tasks. [78].

Recent world events have shown preparing for sudden global conflicts resulting in supply chain difficulties and inflationary markets should be involved in the company's strategy [23]. Risks are a significant factor when pricing and purchasing a product or service. Contractual coverage, the regional spread of supply sources, and scarce material availability all contribute to the company's risk profiles [38]. As the world has recently seen, material supplies are experiencing high increases in prices as well as often in delivery times [70]. To mitigate and brace organizations for such events McKinsey & Company's web article [23] suggests categorized, internal, and external preparation actions. Internally, risk mitigation is the key. External actions are focusing on outsourcing subjects. Actions like the expansion of the supply network and more specific contracting techniques additional costs can be reduced. [23]. Expanding the supply network, and a diverse supplier base for priority raw materials gives companies a better ability to replace old suppliers with other sources if prices spike, as we have seen recently in world economics [70]. Risks can be reduced also by forming partnerships, where companies share the rewards and risks in their common operations [68, 75, 78].

Partnerships and contracts are an important part of procurement and its processes. Contracts are defining the specification of the procurement process and the product, while partnerships are helping companies to improve their cooperation as well as individual processes. The contractual agreement of long-term partnering is a mutually beneficial contract to reduce the overall costs of prefabrication by 10%. As a key partner, Case A company is the first to receive work offers and is at an advantage in negotiations. Such a partnership's purpose is to develop and enhance the overall supply chain, production, and pricing procedures to lower the costs for both parties. This means both parties operate in the same field and share the risk. Forming such a contract usually means that the companies keep focusing on their core competence but have common goals and interests. [68]. Mutual trust and transparency are highly essential in partnership cooperation, which are both qualitative traits that can explain inconsistencies in the case study. Dainty et al. thinks in [11] that many subcontractor companies believe that general contractors treat them as subordinates and therefore do not understand the basic principles of cooperation or partnership relations [41]. This results in subcontractors charging higher prices [73, 41]. Relation's strength and value between linked companies are described as *Relationship value* (RV) in several studies [33, 64]. RV is an abstract term that focuses in essence on the value obtained from the previously exchanged connection between companies, especially in long-term relationships, and in business relationships that concern both benefits and costs as well as their tradeoff [33, 64, 41].

To develop a process, its weak points have to be recognized to improve its performance. Van Weele says in [78] that the performance of measuring and evaluating purchasing is not easily answered, yet it is a major concern for many companies. Overcoming this concern is hard because there is no practical approach developed that could produce consistent results for different types of companies [78]. A key factor in measuring purchasing results is how management looks upon the position or role in purchasing and the importance of the function. Depending on management's view on purchasing, the measurement and evaluation standards is differing. Such management insights of procurement can be an operational, administrative or commercial activity, part of integrated logistics or a strategic business area. All these areas have different valuation standards, which makes the general approach for performance measures in purchasing complex. [78, 41].

Table 1. Management purchasing viewpoint (according to [78])

Viewpoint	Position of purchasing	Performance measures
Operational administrative function	Low in organization	Number of orders, order backlog, purchasing administration lead-time, authorization, procedures
Commercial function	Reporting to management	Savings, price reduction, variance and inflation reports
Part of integrated logistics	Integrated with other materials-related functions	Savings, cost reduction, supplier delivery reliability, reject rates and lead-time reduction
Strategic business function	Purchasing represented by top management	'Should cost'-analysis, early supplier involvement, make-or-buy, supply base reduction

Table 1 presents the management purchasing viewpoints, their positions in the organization and performance measures. The operational administrative function sets in the lower structure of the organization, while the oppositely strategic business function is a function that involves top management and make-or-buy decisions, which are seen

in assignment company. Commercial functions and a part of integrated logistics are considered mid-organization level functions. The procurement's viewpoint in the assignment company is somewhat a blurry line, but due to the procurement's own department and stated performance measures in two internal interviews [29, 30], it can be treated as a commercial function even if it includes top management decisions mentioned earlier. The performance in the assignment company is measured highly based on annual and project-specific cost-savings and profit, even though there is no systematic approach defined. Numeric values are easy to measure, and won't require any specific analysis unlike some personnel performance measures, which are defined as personal goals, e.g. related to SRM or process development. Overall the procurement performance is measured by department-wide meters that management is looking to assess the performance. Variance is present in many activities, especially if there are cost savings concerning the budget. The savings should be around ±10%. If there are exorbitant cost savings in procurement processes, it may cause problems with the sales department due to too high estimated as-sold price which can cause losses in sales projects. [29, 30].

2.3 Prefabrication

Prefabrication means the shaping of a raw product into a finished, usable form for manufacturing the final product. Through prefabrication, formed materials can be shipped directly to the project site, where prefabricated parts can be assembled and built into the final product.

While businesses often maintain aspects of their organizations that reflect their core competencies [62] within the larger markets, while transferring other operations to outsourcing or subcontracting to utilize resources already in available markets [63]. This provides companies with diversity against risks in the industry and markets, reduces operation costs and secures competitive advantages to find the most suitable profit base [73]. Because of a large number of studies according to the profitability of subcontracting and its benefits, Tserng et al. [73] state that in the modern, fast-paced industry situation, companies that carry large projects are facing an environment that offers great use of subcontracting and points out that the importance of selecting appropriate subcontractors is essential. This statement is correlating with the assignment company's concern about the partnership with Case A company, whether it is the most suitable option or whether should it consider revising the continuation of the partnership following pricing issues. Tserng et al. [73] also state in their study that due to the intense level of

competition, businesses prefer to form long cooperative relationships with already known subcontractors whom they have a history with, which is proven to have a decreasing effect on costs [26]. Another point of view is the frequently used subcontractor load. If a common subcontractor already has say three projects under production, an analysis of the overall situation takes place whether it is smart to stack everything under one subcontractor is wise, even if they guarantee to get the work done. Key subcontractors are often tested for years of performance and quality-wise, which makes the risk in the delivery and quality much less likely compared to a completely new supplier. When selecting a completely new subcontractor for the prefabrication work, a costly and time-consuming auditing process is mandatory before any purchases or contracts can be done, which is always not even possible due to tight project schedules. As a key point, the price has always to be in relation to the risks, which leads to a conclusion that a new subcontractor is smart to be tested with smaller order quantities before a large, project-scale order.

The assignment company is benefiting from subcontracting prefabrication in several ways, mostly financially. A justification here can be seen as a make-or-buy decision.
Make-or-buy stands for the decision of whether something should be produced internally or sourced externally. Matters affecting the decision are resources and investments leading to cost comparison. While focusing on core competencies, investing in expensive machinery, workshop and personnel to produce prefabricated products internally is far more complex and expensive rather than using a subcontractor which is using their core competence to produce required fabrications.

3. RESEARCH METHODS

Due to limited research material and the scale of the research problems, the key factor to success in this thesis was to make the most suitable decision on how to approach the pricing data to find the most effective and precise way to detect and solve the issues in pricing. This chapter in this thesis is presenting considered research methods and focuses on finding the most suitable methodology to collect the most precise and constant results. The methodology as a term means seeking answers and in which way problems are approached [71].

The used research material is inconsistent and deeply detailed, meaning that the data is not similarly described between projects, and the separated items are detailed in such a way there is every detail and work step that has been made to the item amongst the main action. For example work A plus required specific work B, C, and D contributes to the final price. Inconsistencies, such as mentions of similar items in pricing data with differing prices are quite common in the material. Other discrepancies are for example misleading mentions of included material prices when the as-sold price tells a different story. These assumptions are qualitative, based on experience and general knowledge of what something should cost. The current method of assignment company's pricing is heavily relying on these kinds of assumptions.

Another general approach to this data is *quantitative*. By focusing on the number of actions, such as individual work steps, prices, and physical specifications, and their details a mathematical model from information collected from the research material can be presented, depending on the quality and quantity of the research material. A mathematical model of the data can take a form of a graph, chart, or calculations. This chapter also describes and compares other commonly used direct pricing methodologies like WTP and indirect pricing estimation methodologies such as Gabor-Granger and van Westendorp [40].

3.1 Qualitative methodology

Qualitative research methodology seeks to explain why things are the way they are and study the subjects from all perspectives [71]. Qualitative research is always empirical, so it is based on research materials and their analysis. Empirical research is not possible to

execute without at least some kind of theoretical point of interest. Empirical research is focusing directly on material and experiences and how they appear, while theoretical research is trying to wonder from questions and theories about them. Theoretical research can develop a model and these models can be used by empirical research. [2, 35]. It is impossible to give qualitative research a simple, unambiguous definition, because of the wide variety of analyses and approaches. However, some common characteristics that are usually present in qualitative research can be listed, such as preference for analysis, emphasizing how- and why-questions, and doubting the obvious. Analysis preference refers to empirical material, which is in the centric role during the research, but in analyzing phase some kind of theory must be included. [34]. In [71, p.18], Taylor states that qualitative researchers develop concepts, understanding, and insights from patterns found in the data. A worker in an assignment company who is handling purchasing and pricing can be seen as a researcher here in Taylor's statement. The current pricing in the company is heavily relying upon patterns – an experience, that something has been something before. In this context, the something is the price of prefabrication. The research is not meant to have fixed, rigid goals, instead the whole process should remain flexible both before and throughout the actual research [43]. A common way to start such research is to form vaguely formulated research questions [71], as presented in the Thesis structure. It's not rare that the formed research question starts to change over time, although it is the company's priority of this study to answer the desired questions regardless of what research method is ultimately used. Before anything can be proven out of research data, concern about its adequacy and limits to reliably answer the research questions is a point to be solved. DeVault pointed out in [13] that missing data may be just as important for theorizing as what is there. Even though DeVault's research leans toward the sociological academical field, the statement applies to this study as well. A qualitative hypothesis and assumptions can be made regardless of the amount of data, and a statement of its inadequacy is a scientific result. It also gives a direction toward alternative methodologies, such as the quantitative way to approach the research data.

Beliefs and expectations often influence judgments of products and services [67] and this can be seen as the basis of current pricing in the assignment company. Prior experience, for example, previous projects, creates an expectation of what something ought to be, that can be used as information to guide judgment [72]. That means in prefabrication pricing based on qualitative methodology, companies make decisions based on expectations and approximates, usually on previous projects. In other words, prices paid for prefabrication are estimated by previous projects. What makes it a

dangerous and unreliable way of decision-making in prefabrication is that the final product is not yet known once the order for prefabrication is made. The prefabrication needs to be ordered well in advance before the main assembly is scheduled to start. Due to strict delivery schedules, the main assembly of the final product has to be on time meaning all the prefabricated parts need to be completed and shipped to the final assembly location so the work can start. Therefore, the as-sold price is always below or higher than the actual price determined by the final design of the prefabricated parts. Also, because of the early ordering schedule, changes in design, tight schedule, and workshop workload affect the price on the way. Figure 4 below illustrates the interaction between sellers' and buyers' expectations and behaviours [52].

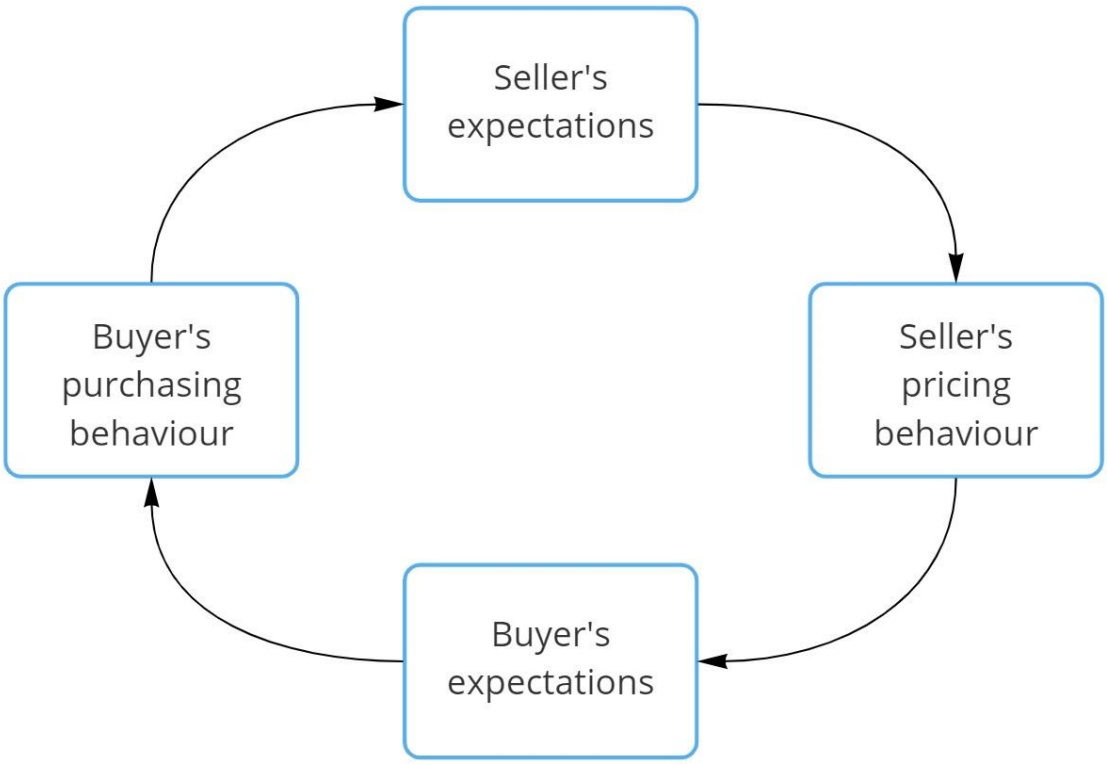

Figure 4. Interaction of expectations and behaviours (modified from [52])

Reading Figure 4 can be started from buyers' expectations, which are forming the behaviour buyers have in purchasing operations and engagement. The way buyers behave in such situations forms the seller's expectations and so on the seller's behaviour in pricing. The relationship between the factors goes in circles, where finally seller's pricing behaviour affects the buyer's expectations.

Alternative considered methodologies in pricing-related research are often determining the magnitude of pricing and its appropriateness from the buyer's perspective. These

kinds of methods considered are related to *WTP,* which is the key methodology to the optimal pricing decision for new and existing products and services [22]. The objective is to understand customers' willingness to pay. Generally, WTP solves the maximum price which customers are willing to pay for the products or services through surveys [14, 31]. Surveys or questionnaires can ask consumers to tell their willingness to pay for a product directly with either a single or multiple, unrestricted question formats, such as the *Van Westendorp* method [76, 22]. *Gabor-Granger* pricing methodology is used to create a buy-response curve, presenting consumer percentages of buying or rejecting a certain product at various prices. To execute this methodology, respondents are offered the item at several prices and asked to answer whether they intend or refuse to buy the item at each price. [77]. Question-related methods are viable to determine the value of the product by knowing how much customers are willing to pay for it. These methods are performed from the seller's perspective, whether the work or product is being sold. A prefabricator can perform a questionnaire for potential companies that how much they are willing to pay for the order, and vice versa manufacturing companies can perform a questionnaire to subcontractors about how much they are willing to charge for the work performed. Most of the time, this kind of price-solving methodology is performed for new products or services. In a long-lasting partnership, rather other methods are used to improve pricing and its accuracy.

In pricing-related research, monetary value can be estimated using qualitative research techniques, that allow a deep understanding of the customer's business model and for example personal finances. On the other hand, when looking at intangible psychological value drivers such as customer satisfaction, security, or brand value, they are not inherently quantifiable. Therefore, relying on quantitative methods is effective to quantify the monetary worth of certain elements. [51].

3.2 Quantitative methodology

Quantitative research always relies on research materials and is based on analyzing them. In quantitative research the purpose is to find similarities in research material, that can be generalized to a certain group of research topics. In this research, this can mean a pricing comparison of objectives with similar specifications in different projects and a comparison of how they differ pricewise. A generalized group of research topics always depend on theory and research problems. The theory can be seen as a systematic conceptual level description of the interdependencies between phenomena. When comparing two phenomena, for example, pricing and consistency, before being able to

prove whether the pricing has been consistent throughout the data these two phenomena must be somehow defined and measured. [50]. Defining concepts in such a way they can be analytically measured is called operationalization [61].

3.2.1 Theory of assumptions and hypotheses

A research theory can be created using different research material findings. For example, if pricing is suspicious or strange in several findings, a theory of its unreliability can be created. Before the created theory can be seen as a valid scientific theory, it has to be tested by looking for new findings or *hypotheses* according to the theory. If the hypothesis derived from the theory appears to be false, the whole theory is untrue. This kind of testing approach is referred to as *deduction.* This scenario is presented below in Figure 5. Creating and testing of theory. [50].

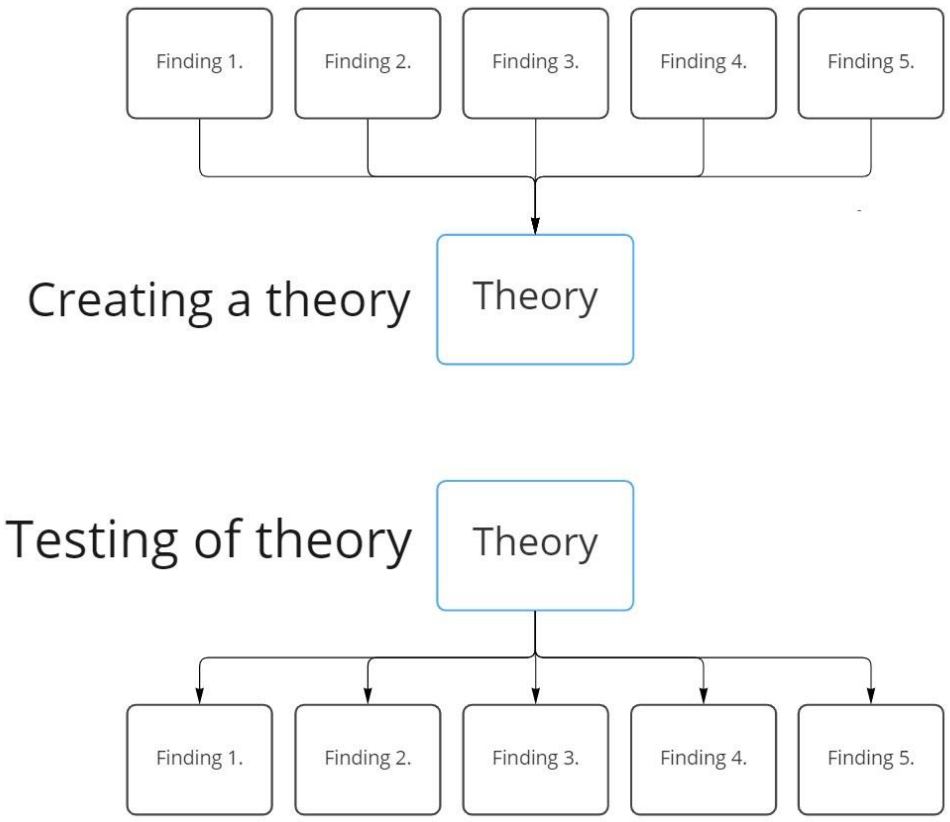

Figure 5. Creating and testing of theory (modified according to [12])

There are no pre-defined rules for creating a theory. As seen in Figure 5, as a starting point for a new theory can be recognized findings, that already existing theories can't explain. As findings work as a basis for theories, often the creation process of theories

starts with looking for those unexplained findings from empirical material. Due to the nature of the study, creating a hypothesis out of the theory that can be tested with calculations is essential. As Salsburg states in [65, p.114], that hypothesis testing is the most widely used statistical tool in scientific research. The variables regarding the hypothesis are evaluated whether or not the evidence is strong enough to demonstrate that a formed hypothesis is valid. Rejection and acceptance of the hypothesis are not definite – rejecting the hypothesis states that is unlikely to be correct and accepting the hypothesis does not necessarily prove that it is correct but implies that it remains plausible. [1]. In this study two types of hypotheses are considered, *null hypothesis* (H_0) and *alternative hypothesis* (H_a), where null hypothesis can be viewed as starting assumption and alternative hypothesis as comparing assumption towards null. Nickerson states in [55, p.242] that a null hypothesis can be viewed as a hypothesis, whose refutation would statistically be considered as statistical evidence in support of a specified alternative hypothesis. It can also have a ”no difference” approach, which is usually referred to as a *nil null hypothesis.* No difference means the statement is that there are no differences between two sets of data or experimental manipulation has no effect on the dependent variable of interest. [44, 55]. The null hypothesis is typically the one that is tested statistically. The alternative hypothesis is another speculative assumption about the relations between two or more variables and can be considered as an opposite outcome of the null hypothesis. A researcher develops one or more research hypotheses about the expected direction or results of the study. Depending on a preliminary understanding of what the outcome of the study will be, the hypothesis can be categorized as either a *directional* or *non-directional hypothesis,* where the nondirectional hypothesis is used when the researcher does not have an explicit presupposition of what kind of results the study will likely have. The directional hypothesis instead states a theoretical expectation for the outcome of the study. [12, 50, 35, 44].

When the null hypothesis is assuming the variables are only differing from each other instead of the magnitude assumption, for example, men are taller than women, the testing method used is two-tailed. An alternative option would be choosing for example that the assumption of the height of women is lower, which would use a one-tailed hypothesis test. [48]. Choosing the right statistical testing method is crucial to interpreting the feasibility. Figure 6. Statistical test choosing (according to [4]) below presents the choosing process of right the statistical test used to test the hypotheses.

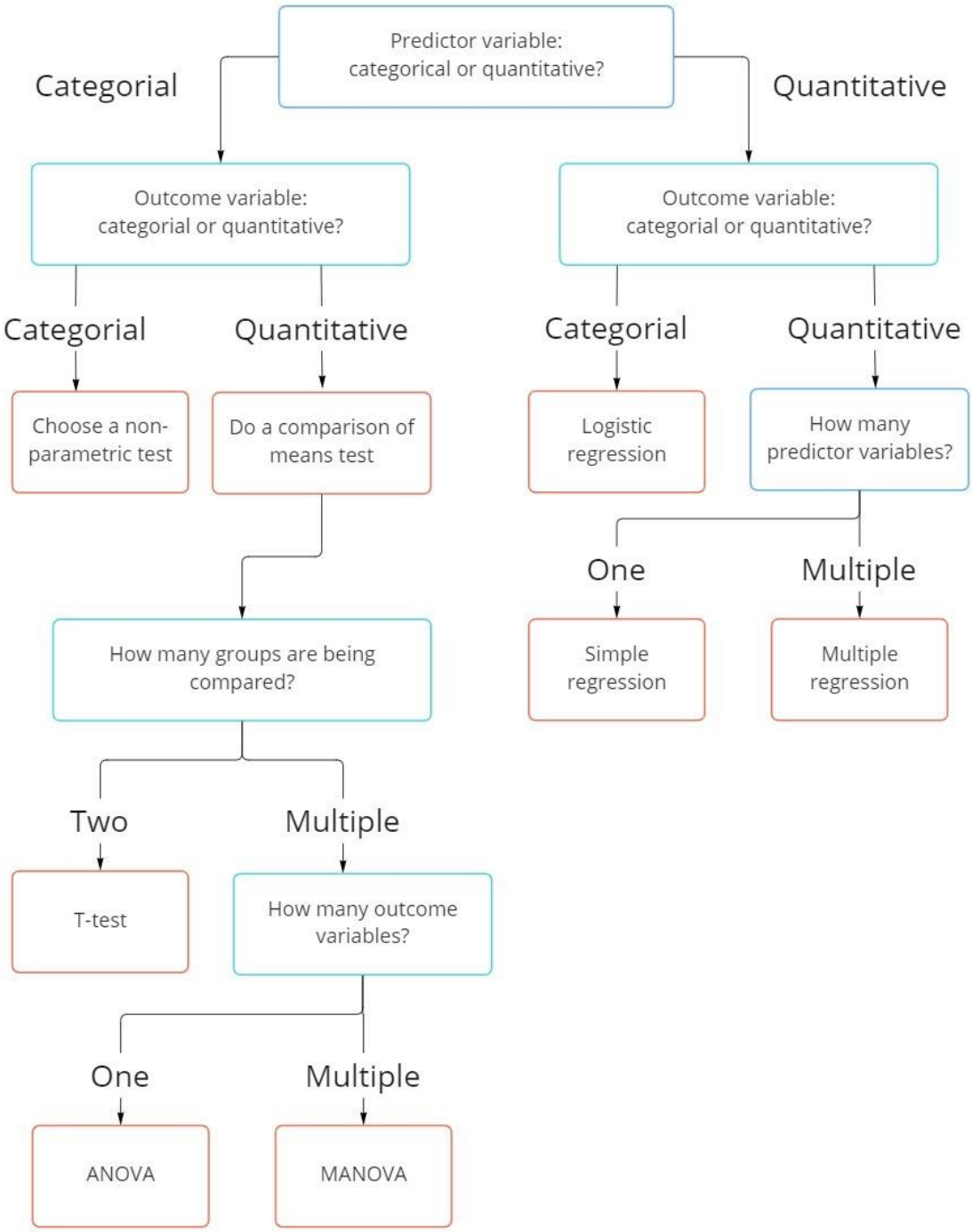

Figure 6. Statistical test choosing (according to [4])

In Figure 6 categorical and quantitative predictor variables are considered to take a path to decide the right statistical test to test hypotheses. The right path considers quantitative predictor variables in use and depending on the outcome and predictor variables, a choice of the right type of regression analysis is feasible to test the hypothesis. On the left side categorial predictor variables in use lead to non-parametric or mean tests depending on the outcome variable. Mean test comparison depends on the size of the

groups. With two groups a suitable test is a T-test and multiple groups lead to ANOVA or MANOVA testing.

In hypothesis testing, limits must be set. If all the values are within the set limitation range, the hypothesis can be considered true. The range is defined as $W = [x_1,\ x_n]$, when observed values are set into ascending order. x_1 refers to the first, smallest value, and x_n to the largest value. The range can be defined also as other values than numbers, such as observed items or variables. If the values differ from the range, the hypothesis is false. Type I error in the first test is marked as an alpha (α). In case the first test is false, the second Type II error beta (β) can be tested with new, different limits of variation. Common alpha levels are .001, .01, .05 and 0.10. This means for example in Type I error for rejecting a null hypothesis when $\alpha = 0.05$ is no more than five times in 100. So, in the other words rejecting chance is 5%. [44, 47, 55]. In F-tests confidence levels are set instead of alpha levels to determine the reliability of the result. Commonly used confidence levels are 95 and 99 per cent [1].

The overall research process in quantitative research can be seen below in Figure 7. Research process (modified according to [12]). In the bottom Figure 7, collecting research material can be seen as a starting point for creating the theory. From there on moving to arrow pointed directly into analysis and empirical results, which can create a completely new theory or lead to conclusions from the current one. As the theory is created it will go through deduction that creates the hypothesis. Hypotheses must be operationalized so empirical measures can be used to validate the hypothesis.

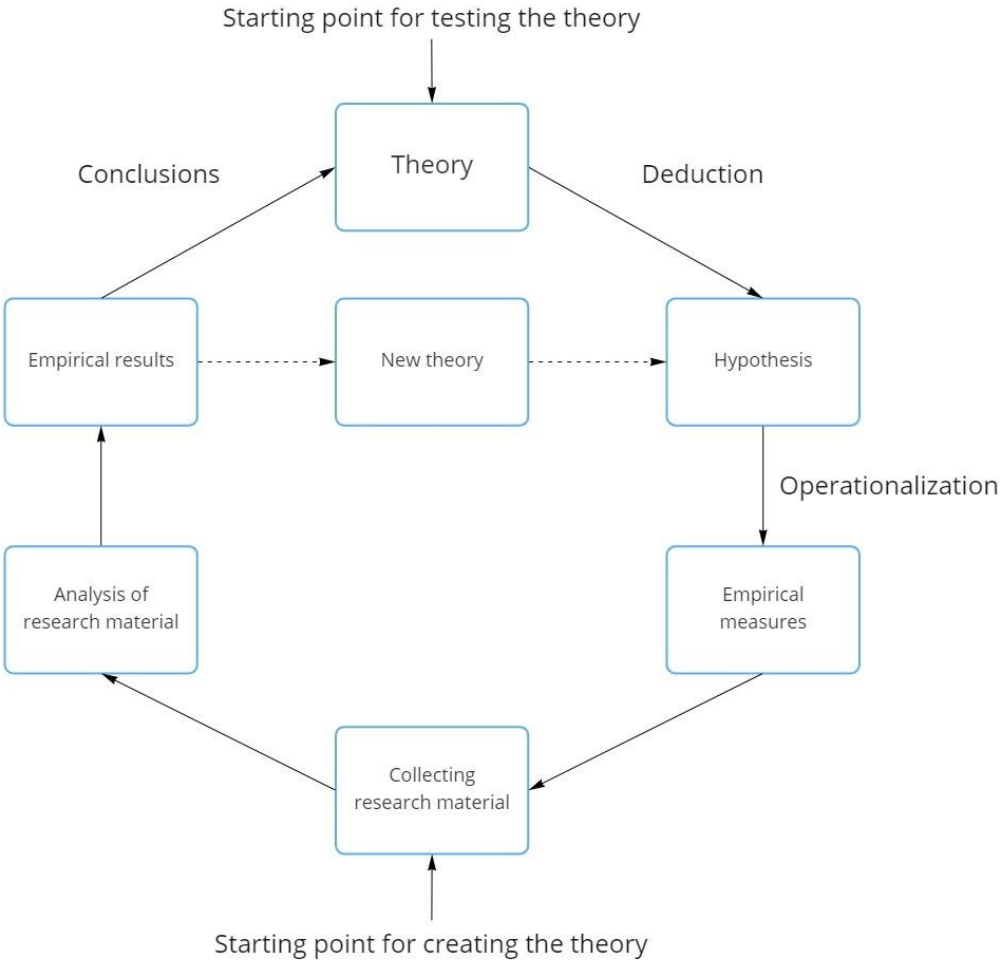

Figure 7. Research process (modified according to [12])

3.2.2 Factor analysis

Factor analysis is a widely used quantitative method of testing the theory. General approaches can be divided into confirmatory and exploratory methods. In the confirmatory method, the researcher already has a preliminary theory of the factorial structure of the study and the purpose of the analysis is whether to confirm or deny this. This means the researcher already has theoretical suspicions about what kind of findings the research material can contain. Then it is possible to form statistical key figures that can reveal whether the expectations were correct or false. These common factors are formed from the observed variables and their linear combinations of underlying statistical or hypothetical variables. [46].

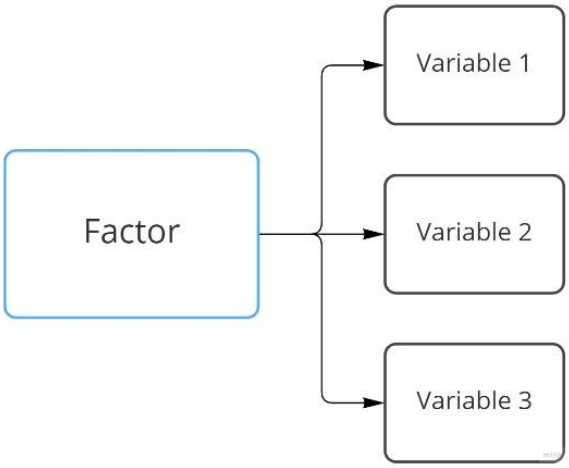

Figure 8. Factor analysis (according to [46])

Figure 8 presents the general idea of factor analysis. The analysis creates several variables (factor loadings), which tell the magnitude of how much the factor can explain the variation in the observed variable. All of these indicators are described between -1 and 1, meaning the higher the value is the better it explains the deviation of the variables and another way around. Eigenvalues indicate how much factors can explain the variation of the observed variables. Communality tells how much of the variation in a single observed variable is explained by the factors found. Some factors are commonly containing two or more variables and some are assumed just to be unique with individual variables. These unique variables are not included in covariance, due to their orthogonality to each other. Thus, covariance includes only common factors among the observed variables. [50, 37, 46]. Covariance means the variation of two continuous variables at the same time. The relation between variables is the opposite – when one variable deviates from the mean in one direction the other should move exactly in the opposite direction. The covariance coefficient describes the direction and magnitude of the variation. [36]. It can be calculated with the formula:

$$\boldsymbol{cov(x,y)} = \frac{\sum(\boldsymbol{x_i}-\bar{\boldsymbol{x}})(\boldsymbol{y_i}-\bar{\boldsymbol{y}})}{\boldsymbol{N-1}},$$

where $\boldsymbol{x_i}$ is i:th a value of x and $\bar{\boldsymbol{x}}$ is the mean of variable x. Correspondingly the same applies to y variables.

Based on the covariance coefficient the strength of the relationship between variables cannot be estimated, only the direction. Comparing covariances is often difficult, since the magnitude depends on variables measured on a scale, for example, euros or cents.

The values don't have upper or lower limits. [36]. The linear relationship between two continuous variables is presented by correlation. It is not dependent on the scales of the variables, which is why differently scaled variables can be compared. Pearson's correlation coefficient (r) is a regularly used key indicator, that measures the power of the linear relationship between two variables [20]. The correlation coefficient can be calculated with the formula:

$$\boldsymbol{r} = \frac{\boldsymbol{cov(x,y)}}{\boldsymbol{S_x S_y}},$$

where $\boldsymbol{s_x}$ is the standard deviation for x and $\boldsymbol{s_y}$ is the standard deviation for y. Another coefficient relatively similar to Pearson's is the non-parametric Spearman's correlation coefficient. It is used to describe the relationship between two variables instead of making any assumptions about frequency distribution or measuring linear relationships of the variables. Unlike Pearson's, which requires an assumption of the linear relationship between variables, Spearman's correlation coefficient uses an ordinal level ranking system to value the significance of the data set. [5, 21]. The Spearman's correlation coefficient is valued between -1 and 1 and is calculated with the following formula:

$$\boldsymbol{p} = \mathbf{1} - \frac{\mathbf{6}\sum \boldsymbol{d_i^2}}{\boldsymbol{(n^2-1)n}},$$

where d is square of the ranks and n is the number of observations. Standard deviation (*S*) describes how far individual values of a variable are on average from the arithmetic mean of the variable. It is calculated from the formula:

$$\boldsymbol{S} = \sqrt{\frac{\mathbf{1}}{\boldsymbol{n}}\sum_{\boldsymbol{i=1}}^{\boldsymbol{n}}(\boldsymbol{x_i} - \overline{\boldsymbol{x}})^{\mathbf{2}}},$$

where , where $\boldsymbol{x_i}$ is i:th a value of x, $\overline{\boldsymbol{x}}$ is the mean of variable x and n means the amount of the observations. [47, 36].

In this study, these indicators can be used to examine the identified variables and their relationships, as well as provide numerical representation and comparison, which is the approach in the exploratory method. The first step of exploratory factor analysis is to decide the number of common factors based on some kind of criteria. Using all possible dimensions may not be reasonable, because the idea of the factor analysis is to subtract the information into a small number of common factors. The goal is to pick the most

relevant ones commonly based on eigenvalues. The second step is the rotation of the factors, which is a process that makes the analysis into a more interpretable form. The rotation has two major options: orthogonal rotation, which produces factors that aren't correlating with each other, and oblique rotation which produces factors that can correlate with each other. [37, 46]. Structural equation models are combining factor- and regression analysis, in which causal relations between factors are described with regression analysis [46].

3.2.3 Regression analysis

Regression analysis is a versatile and flexible method for studying variable relationships. In regression analysis, the key figures are created by choosing only particular variables in the analysis. This kind of approach has confirmatory nature. Another approach leaning more toward the exploratory method of regression analysis is also possible to execute with all the significant affecting variables and see which are statistically remarkable. These both result in a group of key figures, that can be used to assess the explanatory power of variables. As a remarkable advantage, regression analysis can especially be used to examine the relationship of multiple affecting variables, often called outcome variables, to the explanatory variable simultaneously. Explaining causal relations between the phenomena requires a specific research design for the study, and they cannot be demonstrated by using regression equations. Building the regression model and interpretation of the results on theory and previous research is recommended. The regression model doesn't tell the direction of the effect relationship (whether x affects y or the other way around), so the explanatory variables are chosen based on the theoretical understanding. [50, 49]. Neter states in [54, p.437] that a regression model should have at least six to ten data points for every independent variable used, which are called also predictor variables.

The relationship between variables can be described with a regression line, which determines the direction and magnitude of the relation depending on whether the line is ascending or descending and the regression coefficient. The regression line can be marked with the formula $\boldsymbol{Y = a + bX + \epsilon}$, where a is a constant factor, X is the value of an explanatory variable, b is the regression coefficient, $\boldsymbol{\epsilon}$ is an error term of the predicted deviation of the value of the response variable. If regression analysis has multiple variables, the formula is: $\boldsymbol{Y = a + b_1 x_1 + b_2 x_2}$**.** The deviation of individual observation from the regression line is called *residual*. The *intercept* represents the mean of the

response variable when all the independent variables in the model are zero. Intercept is sometimes called a constant. [49, 1].

The approach in regression analysis is to test the magnitude and significance of every outcome variable's affection to the explanatory variables, and whether they differ statistically from zero. The analysis produces an *ANOVA* table, which stands for "analysis of variance", which displays the results [1]. Outcome variables are dependent and explanatory or predictor variables are independent. For this instance, the *t-test* is a feasible method to test the magnitude of the coefficient. Another feasible test used in regression analysis is the F-test. The T-test is a statistical method of testing the feasibility of observed variables' relationships in a matter of effect on each other. The bigger t-value is, the bigger the difference of the variables is from zero according to statistical criteria. The significance levels of the t-test are marked as *p.* R^2 and Adjusted R^2 presenting the explanatory power of the analysis (between 0 and 1), in which R^2 is the explanatory part and tells how much of the variation in the analysis can be explained by outcome variables. It can be calculated with variable values and model-produced estimates correlation squared. For instance, if the R^2 value would be 0,44, it means that 44% of variation can be explained by examined research values. Adjusted R^2 is used when comparing the results of two performed regression analyses by taking into account of several outcome variables. When adding more than one outcome variable into the analysis, it rises R^2-value, even in reality, these added variables can't enhance the explanatory power. The adjusted value is always equal to or lower than the original R^2. *The standard error of estimate* is presenting the standard deviation of the error terms containing the regression model. The higher it is, the higher the dispersion of the error terms and hence the lower the explanatory power of the model. F-test is more focused on generalized information of the regression results. It tells whether the variables can explain the variation, not necessarily the magnitude. F-test produces a p-value, which is then compared to the chosen level of confidence. [49, 1].

In this study, an expectation of the study outcome can be anticipated, since the data is revealing information that can be used to create assumptions about the direction of the outcome. Whether the pricing has been constant, is there a reduction in price levels, or are there comparable variables, the answers can be estimated in the early phase of the study. Instead, the affecting reasons behind the answers can be diverse. These affecting matters will be explained and solved in the Pricing model and qualitative analysis.

3.3 Comparison

As the current pricing methodology in the assignment company is based on experience and assumptions, it has been realized that more precise and constant pricing methods are highly desired. This means recognizing the problems in the current approach, which requires a reasonable chosen research method. A challenge of creating a constant pricing system for prefabricated products lies in the complexity and quantity of data. Due to massive amounts of different dimensions, materials, and options in a prefabricated product, it's too early to make fixed prices for each type of item based on the research data. With multiple changing variables for each item, a complete mathematical model of the whole pricing process is nearly impossible to make. Based on the research material a model that precisely compares the prices in used data to prices that should have been paid for the specific order can be observed. An idea of what should have been paid can be formed from the cost of working hours, cost of installed materials, workshop-, machine and management costs, design costs, and profits. These general factors are gathered and extended into a deeper overview of what are the affecting matters in pricing. This model is presented in 4.1. When considering quantitative methodology in pricing, several other numerical factors can be helpful such as the global market price for materials. This means that quantitative methodology can use more effective data for reasoning than quantitative methodology.

A research approach and used method for this study were chosen to be the most suitable approach to answer the research questions stated in chapter 1.1. The key objective of the study is to determine the value of the pricing model's individual variables, which require aspects of both qualitative and quantitative research methods. At the beginning of the analytical phase of the study, a hypothesis of the results based on known research material can be created. Because the study requires numerically determined affecting factors, the study leans more towards the quantitative approach. Once all the factors of the pricing model are determined, a quantitative research methodology comes into practice. A factor and regression analysis are used to present the deviation of pricing between the projects including all the common analytical demonstration techniques such as regression line, most loaded factors, and ultimately a mathematical verification of the pricing reliability. A method which is found to be most feasible to get the most effective information on the factors is the structural equation model, which is used to assess factors with regression analysis. A qualitative approach is used to reason between variables that cannot be directly converted to numeric form. These kinds of variables include for example unspecified social matters that still clearly generate value in pricing.

Figure 9 below presents the research process that is executed in this study. The pricing model as its core, social and numerical factors are determined and converted into comparable forms to establish factor and regression analysis. Before that, the common factors must be chosen. The choice is based on the most affecting ones, because when studying pricing and its reliability, factors that have a minimal percentage of effect are unrelated to the complete image of the study. The internal objective is to find supportive evidence that the partnership contractual goal of a 10% reduction in pricing level is seen on assessed projects. As the reduction goal is 10%, factors affecting significantly less than 1% of the price will most likely be unrelated to the question. If a factor is seen to be affecting for example 2% of the price, it can be considered as a common factor due to its effect on overall pricing according to the case study goal, which was to reduce the pricing level by 10%. A complete understanding of the pricing model and its elements as well as the research data includes analyzing the reasons behind the results provided by the quantitative research method. In other words, quantitative methods can prove that for example, price is differing between the projects, but the reason why is that so is a core objective for the analysis along with the results of the mathematical model itself.

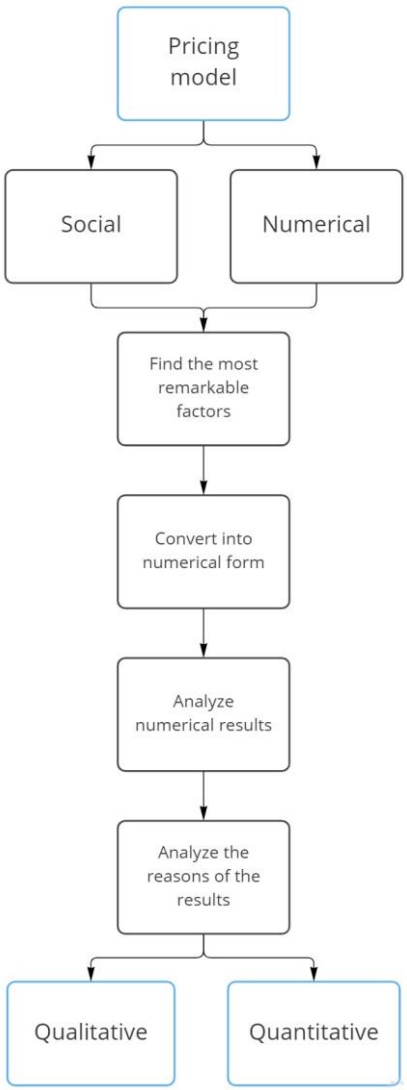

Figure 9. Research process order

4. CASE STUDY

In this chapter pricing model along with its affecting matters are presented in 4.1 and 4.2. The case study research data and its contradictions are presented in chapters 4.3 and 4.4. Finally, theoretical assumptions are formed and presented in 4.5.

4.1 Pricing model

Besides reviewing the data provided by Case A company, it's essential to have a deeper understanding of what factors affects the pricing along with just completed work, covering its costs and profit. To understand the reasons for research data variation a pricing model of prefabrication procurement was made. The model is presented in Figure 10. To successfully present a valid analysis with a quantitative approach, the mathematical effects of each element are needed to be clarified. An impact caused in the pricing is presented for each element in Figure 10 according to colour – red means increasing the cost, blue means decreasing the cost, and grey elements can be either. Orange elements are causing costs and purple elements are activators. Activators don't necessarily cause direct changes in costs, but they are activating reasons behind other elements that make them happen. This chapter explains the need for a pricing model and breaks the model into separate parts to recognize each part's effect in a research approach. The general need for a pricing model is to understand the elements of the total price and its factors, which are applied by the CBS mindset. The cost breakdown structure enables reviewing the value of each element and deciding the affecting factors for the case study price contribution.

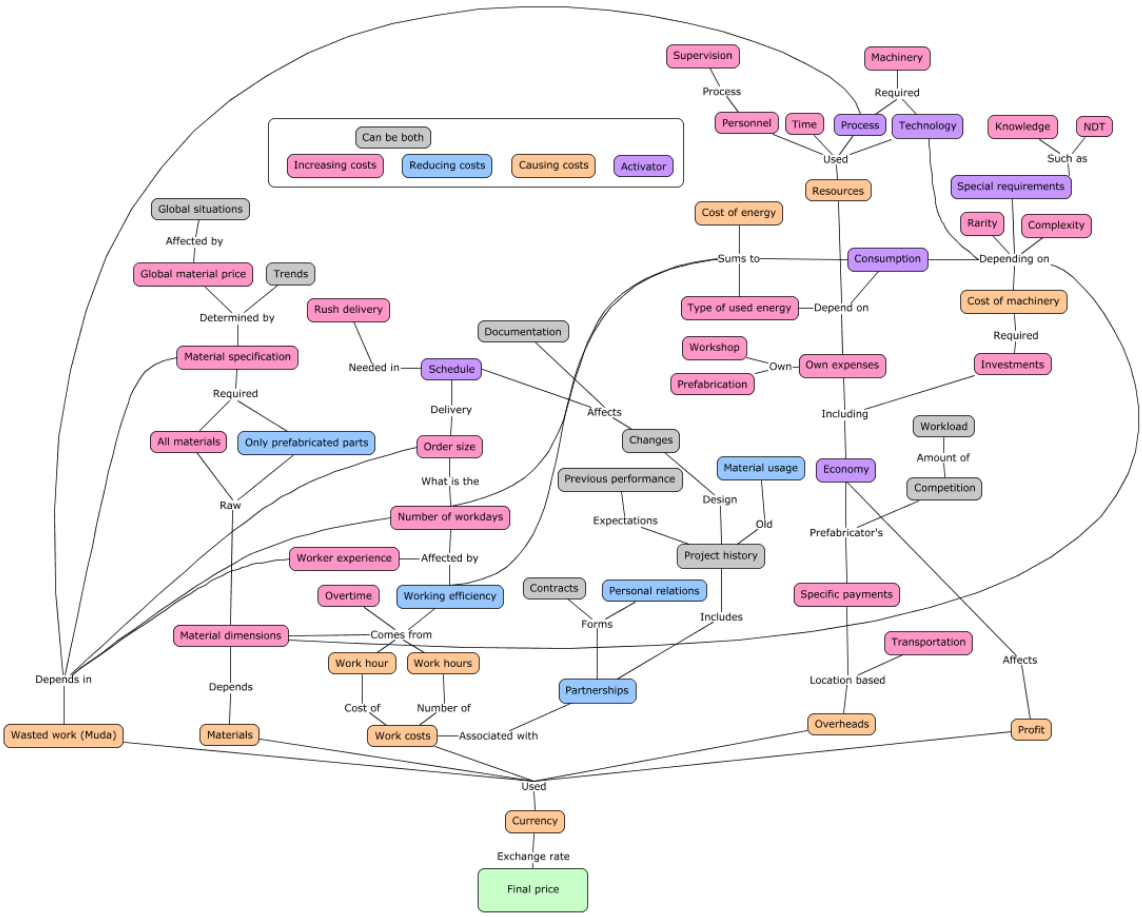

Figure 10. Pricing model

The pricing model includes all the elements consisting of the final price. Ultimately, the final price depends on the exchange rate of the used currency. In Case A euros were used, so the currency remains the same all the time. This is most likely contributing factor when trading takes place for example in China or America. The paid currency comes from the sum of general pricing elements: profit, overheads, labour costs, materials, and wasted work, which is also called *Muda*. These elements are all causing direct costs. Profit and Muda are pre-defined values, but materials, work costs, and overheads are extended into multiple, whether pricing-wise quiet or active sub-elements. *Material costs* depend on material dimension. If the dimensions of the workpiece are small, it spends less on the material. On the other hand, if the prefabricated product is large, the material consumption is higher and naturally costs more. It is also in affection with used work hours and machinery. Logically thinking the larger the processed product, the more time it consumes, and the requirements of the machine are rising. The material costs along with the amount of them depend on whether the whole material of the prefabricated product or just the prefabricated sub-parts are provided by the subcontractor. Materials may also have special requirements, depending on the use of the prefabricated products.

If the product is used in a challenging environment, the materials must meet the required standards which often have relatively huge affection on price compared to basic stock materials. The material price is determined by global material prices and trends, which are affected by possible global situations.

Another direct cause of costs is *work costs*. It is a sum of the cost of work hours and the number of used work hours. The cost of work hours can also be treated as labour cost, which includes all the costs of work hours, including location-based employer payments and used resources by the employer. Both amount and cost of work hours are affected by the processed material size and are dependent on overtime and working efficiency. Efficiency is the sum of the experience of the workers and the number of workdays, which is dependent on order size. Ultimately, an activator here is the schedule, which means how well in advance the order was made and at what time the order has to be delivered. If the order is needed in rush, meaning the workshop has to prioritize its work, causing rises in costs by affecting the pre-fabricators own schedule according to other ongoing work processes. Work costs are associated with partnerships, which is one key aspect of the case study. Partnerships form contracts and personal relations and include project history. Previous performance creates expectations in cooperation between the ordered and manufacturer. Also, depending on the project history, there may be old materials available that can be used. Project history may include changes in design, that has affected to schedule previously. These elements are always dependent on the relation of order and manufacturer. If the customer ship is new, there may not be these elements at all. However, in the case study, these are all essential and included in this model. *Overheads* are subcontractors' expenses, which the company needs to cover to keep the business profitable. Location-based factors are transportation and specific payments. These payments are included in the total labour cost in the case study. The overheads are also affected by the prefabricator's competition and workload. The economy overall is treated as an activator, which includes its expenses and investments. Own expenses are generated from workshop costs and possible own prefabrication. These expenses also depend on the type of used energy, consumption, and resources. Consumption and kind of energy are used to sum the cost of energy, which is a direct cause of costs. Resources hold multiple factors, such as process and technology, which are defining machinery needs. Also, time and personnel, which are related to the supervision of produced work are resources. Used technology is a defining factor in the cost of machinery along with its rarity, complexity, and special requirements, such as knowledge or NDT testing.

4.2 Pricing model elements and their impact on the price

As the research material is the main source of information in this thesis, a clear image of affecting matters behind the data is required to fully understand what affects the pricing. The general idea of this chapter, according to Figure 9 is to determine the most remarkable factors and determine their numerical value. Even though the pricing model includes a pricing structure at a detailed level, all the components are not relevant to the price contribution in the case study. WBS/CBS is applied here as an approach to split the model structure into effective and ineffective factors. For example, in general, quite a huge share of own expenses comes from the workshop and its monthly rent or property loan. In the case study, it's known that the subcontractor under review owns the property, so we can expect investment expenses to be close to zero. Therefore, it's irrelevant to include workshop costs into the total pricing model in this case, even though there still are maintenance and taxation of the property that cause costs. The same applies to the prefabricator's own prefabrication, which remains constant in examined projects due to the similar nature of the projects. However, we can consider these to be ineffective to the pricing model. Some of the elements have an unknown and project-based varying impact on the price. This means the elements are known not to remain constant or stable. Profit for example is a constant in the context under review, an unchanged value that has been contractually agreed upon between parties. It can be treated similarly to the workshop expenses mentioned earlier since it can't explain variations. Unknown and project-basis changing elements are such items that may be changing in each project in Case A review. This kind of element for example can be order size. When the order size is small, the setup time of machinery is causing a lot of costs for a small batch of prefabrication compared to the overall cost. On the other hand, if the order size is large, the setup time doesn't affect so much single work step price, because the cost of setup time is shared between large quantities. In other words, setting the machinery up for a day and prefabricating with the ready set up for another day rather than the next two weeks is not so cost-effective. Setup time is always added to the costs. It is acting a bigger role in overall cost if the price for the rest of the work is low, meaning the order size is small.

The Pricing treats contracts as both increasing and decreasing price drivers. With the right conditions agreed on, operating contractually allows for smarter and more agile planning and adapting than contracts with fixed timing and prices. For example, a certain ordering volume might be agreed upon for years to come, but pricing is updated frequently as the market changes. Another way to approach contracting is to use public

indexes or develop synthetic indexes, which generally means tying contract prices to a certain market price of a particular class of commodities or materials. [23]. Often prefabrication contracts between two key partners propose price reductions for upcoming cooperation and projects. In the case study of this thesis, the contractual agreement of pricing level reduction during the period of examined projects is 10%. On the other hand, contracts can increase the total price by adding extra requirements for the work, such as work site-specific, often safety-related colourings of the prefabricated products. Due to the qualitative nature of social factors in pricing, their value is difficult to quantify directly numerically. According to a personal interview [26] with an expert in the field, roughly a couple of per cent in the overall sales price can be decreased by a long-lasting corporation or personal relationships. The discounted prices are taken off the subcontractor's margin. On the other hand, linking partnerships with margin squeeze is dangerous, because partnership contracts should be mutually beneficial. If the companies are working together to improve their cooperation and cost-effectiveness, the price should be lowered by improving production and procurement processes, which benefits both parties. The annual price reduction in the case study under the contract can be spread throughout the research material projects from 2017 to 2021. Thus, the annual reduction in the case study would be 10% / 5 years = 2% per year.

Demand variability is a serious problem for fabricators [3]. Variations can be caused by changes in markets, seasons, and global situations. Project-wise variations also negatively affect pricing from an ordering perspective. Late receipt of design information, frequent changes in designs, or delivery timing disturb production schedules that cause fabricators to risk the loss of capacity [3]. This can be seen as a defining factor that increases the prefabrication price because subcontractors focus on keeping their workshops busy at all times. In a situation, where the workshop is lacking work a discount of a few per cent, estimating 2%, can be cut off the final offer price to ensure that the prefabricator receives an order for the work and maintains a good relationship with the ordering company. Alternatively, if the subcontractor has to deliver the prefabrication at a time when the workshop is overloaded, according to [26], the overtime costs will in most cases be added to the price. Case A and case B countries have similar overtime working benefits, that are contributing increasingly to the work hour price. Overtime working benefits are a +50% increase in base salary on weekdays and Saturdays and +100% on Sundays and night shifts. However, according to [58] in chart 1, labour costs include overtime pay. This means in calculations we can consider labour costs including overtime. Due to a period of a few years between the case study projects, workshop loads vary depending on the situation and other ongoing projects in the workshop during

each project, which is to be solved in the analysis phase.

The cost of work hours including location-based specific employer payments are presented as commonly used term labour costs. The term includes the same elements of pricing in both Case A and Case B countries [56, 57, 58]. This makes the scientific approach significantly more accurate since all country-specific employer payments vary by country and field of industry. Using statistical data about labour costs provided by research institutes makes the comparison between cases more relevant. Total labour costs consist of all costs incurred by an employer from the employment of labour [56]. These include the sum of gross wages and salaries and contributions to compulsory retirement, disability and sickness insurance paid by the insured employee and non-wage expenses, such as retirement contributions and training expenses according to [56, 58]. However, employer subsidies are not included in labour costs [56]. As labour costs are treated as a cost of work hours in the pricing model, it is affected by everything under work hours in the model along with specific payments in overheads. Data gathered from Eurostat [19] in Figure 11 presents the significant difference in average labour costs of manufacturing in Case A and Case B countries. The data used for labour costs is provisional for Case B, meaning that the final labour cost numbers for 2021 and 2020 will probably change just a bit in the future, since the data is changing most likely a few decimals when final results for recent years are released in late 2022. Nevertheless, the data is suitable for research.

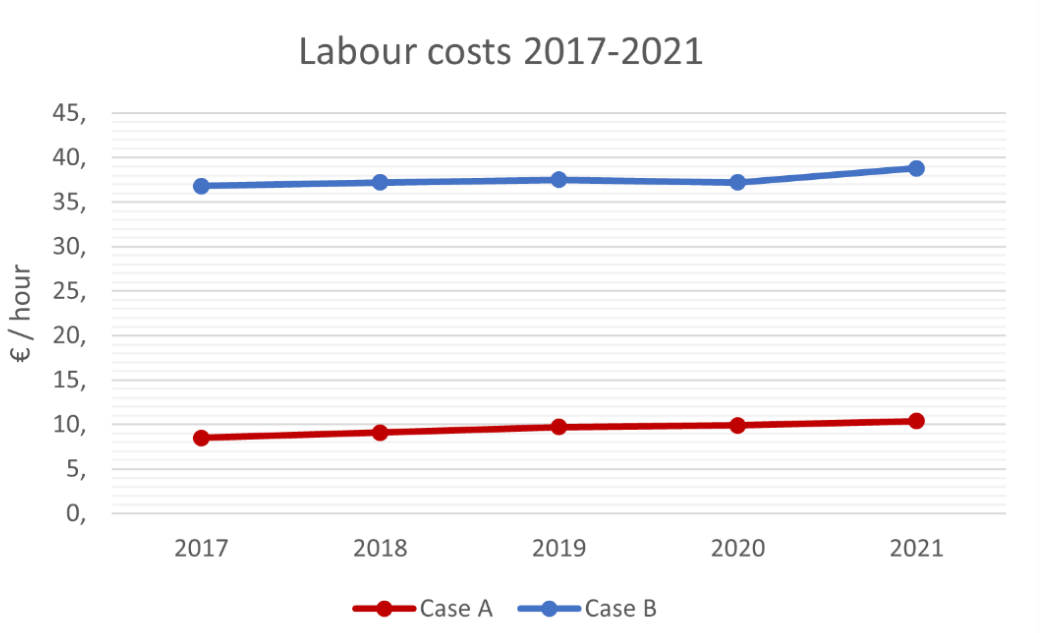

Figure 11. Labour costs [19]

As Figure 11 shows above, in Case B country's labour hour, is almost four times as valuable as it is in Case A country. This information is important when making the hypotheses about study outcomes in 4.5 by using Figure 1 as a guideline. The variation between observed years 2017-2021 is not high, yet slightly increasing annually. In the case of study Case A labour costs have increased during the examined period from 9.5 (10.1) to 11.5 € /hr so the overall percentual increase in studied projects is 21% (13,8%).

In general, work costs can be considered to have an increasing effect, if worker experience is at a special or highly demanding level. These kinds of demands may be related to special requirements in the Pricing , such as knowledge or NDT. According to an interview with Case A company engineer [31], a huge share of costs in specific, common work processes for larger work materials is coming from mandatory heat treatment due to its time-consuming and costly process. Also, when the material is heated to high temperatures, according to standard in the field, which is applied depending on the prefabricated product, destructive tests must be carried out for each heated point in the material. These are additional but mandatory costs, that increase the overall price highly. Although, since they are performed every time in most of the work processes, we can treat special requirements as well as worker experience as constants and therefore ineffective for the study. Working efficiency goes hand in hand with working experience. Efficiency is still considered to be constant at all times, since a lot of procedures during the prefabrication process are not hand-made work, but completed with machinery.

It is known, that there are generally two main work processes for examining prefabricated products, that cause the main costs in whole project prefabrication. These processes vary in a way for smaller parts in production are formed by mechanical processes, which are relatively fast and won't spend much energy. Larger parts require a specific, somewhat rare method for forming, which is slower and costly energy-wise. Therefore, for larger produced parts the cost of energy is significantly higher than for smaller ones, which should show as a peak in unit prices when moving from smaller ones to larger ones. This variety remains the same in every examined project, so it can be considered a constant. In this study, the critical defining dimensions or the forming methods are not specified further due to the concern of revealing too much information to competitors.

Wasted work is a cost that is summed into the overall offer price. Estimating the amount of inevitably wasted work depends on several factors, such as how long the work lasts, what kind of material is under process and what's its dimensions and how the work is

completed. According to [26], subcontractors are often estimating waste to be 7-10% highly depending on the factors mentioned above. For the case study its project-specific and what value is used. Due to a lack of specific project information, a numeric value of 10% of the overall price is chosen to present the waste. The value is chosen from the lower end due to a lack of precise knowledge and to ensure that the waste doesn't have an unnecessarily high impact on the price.

Metal forming processes are crucial for their environmental analysis [25]. Throughout the analysis of energy consumption and material parameters of each individual forming action is important, so environmental impacts can be detected and modelled, and then energy consumption minimized [24, 25]. Calculation-wise it would be useful to know the energy consumption of an individual machine in Case A, but according to the company contact person it cannot be calculated with the equipment in use at the moment. In the pricing model, a major share of overheads is energy and its consumption. Case A country's industrial energy sector is differing from Case B country by energy production sources, consumption, and energy prices. Industrial energy prices and their development over the research material period in Case A and Case B countries can be seen in Figure 12. Industrial electricity prices below.

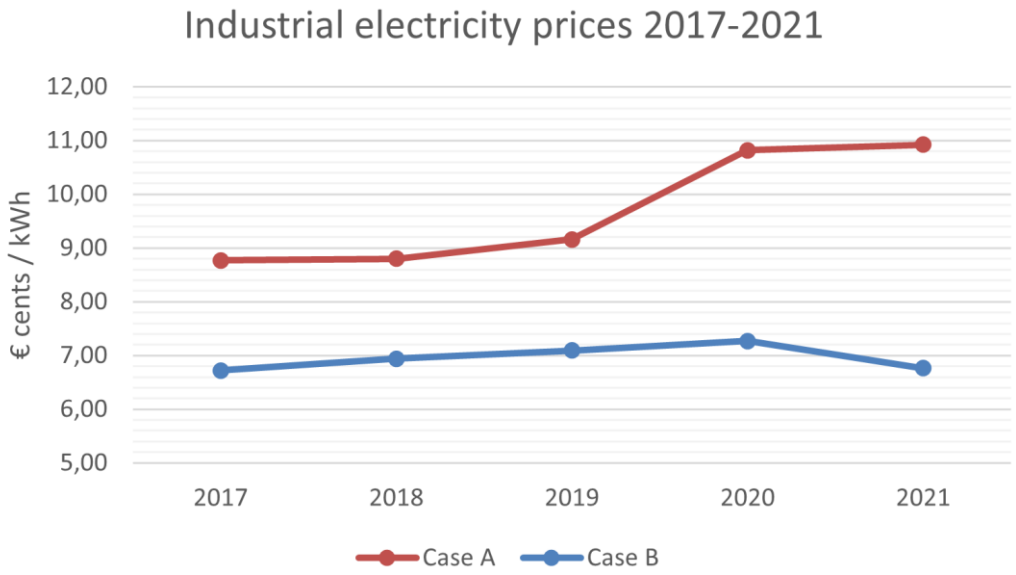

Figure 12. Industrial electricity prices [7, 8]

Even though the general price level in Case A country is lower than in Case B, an explanation for higher energy prices can be found in energy production methods and imports. Also, as energy prices have gone up in previous years, especially in an examined period in 2020-2021, according to [27] in Case A country it's common to add extra

costs to cover the increased prices in gas. In Case A country 53.6% of electricity is produced by hard coal power plants and 82.9% of all electricity was generated by fossil fuels in 2021 [74, 17]. In Case B country electricity is produced mostly by nuclear (33.6%), hydro (22.1%) and bio (17.5%) energies [18]. Regulations and general pricing levels of different sources, explain the cost difference in Case A and Case B countries. According to [28] Case A company uses gas, which is a commonly used energy source in Case A country, in the heat-treatment process. The consumption for the process is high and has a significant role in the price of the heat treatment and other work costs, even though it is treated as constant. Most of the used gas in Case A country is bought from foreign supplies and used by industrial companies [66]. Natural gas prices for the years 2017 to 2021 in the examined country can be seen in Figure 13 below.

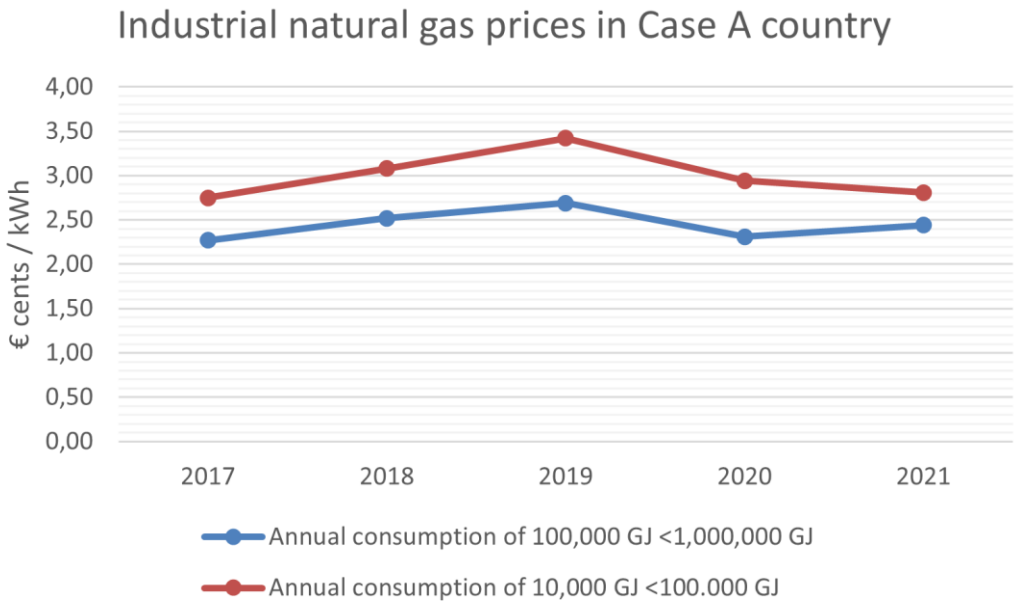

Figure 13. Industrial natural gas prices [9]

In Case A the consumption can be considered to be pictured in the red line, meaning the annual consumption is between 10,000 GJ and 100,000 GJ. There is a possibility that the actual annual consumption is even lower, but in the source industrial gas is treated within these limits. As can be seen, the prices of gas are varying, but not linearly rising over the examined period like labour or electricity costs. According to [28], around 5% of used energy in Case A company is gas, the rest is electricity.

In the pricing model overall cost of energy can be therefore treated as the same in the years 2017, 2018 and 2019, but due to the increase in the price of the highest consumption of energy, which is electricity, the years 2020 and 2021 will be treated as 18% more

expensive energy-wise. The number is coming from annual prices in Figure 12, in which 2017-2019 prices are roughly 9€ / kWh and 2020-2021 11€ / kWh.

According to pricing knowledge inside the assignment company, transportation does not affect the prefabrication price, due it's the cost the buyer is covering. If the prefabricator would have some contractual responsibilities, i.e., delivering the prefabricated parts somewhere for shipping, transportation costs could be treated differently.

Material prices are considered to be a sum of raw material plus processing the material into the right shape. In this case, the raw materials are transformed into workpieces which are further processed by the prefabricator into the form used on site. According to internal assumption, roughly 30% of purchased material prices are coming from raw materials and the rest are costs from processing them to workable form. Raw material prices can be assessed with global market prices, which were highly affected during the early Covid-period in 2020. Also, material supply chains were under high pressure to deliver materials during the later period of examined years, which can be considered to affect material prices. Internal pricing materials show that the price of generally used materials during the time of examined projects had risen approximately 50%, because of Covid and global supply chain challenges.

4.3 Research material

Research data provided by Case A company is used to rate, justify, and examine the formed assumptions by research methods and answer the research questions. The data is structured and categorized into certain work steps and produced items, that are seen to affect the outcome of the study.

The data involves seven executed projects and their detailed orders of prefabrication. Each project has its own excel file which is divided into sub-prefabrications identified with general assignment company codes. Each sub-prefabrication sheet listed has several work steps, special arrangements such as NDT inspections or heat treatment, possibly materials, and all the dimensions, amounts, and other specifications alongside the price in a form of an Excel sheet. Overall, there are 15 documented projects in the research material. All the projects were executed and documented in the years 2017-2021. There are differences in documentation, which is a challenge as data needs to be presented in a similar form. Therefore, some of the originally examined projects are needed to exclude from the numerical study. The first comparable project was executed in 2018 and the

latest in 2021. The nine available case study projects are called as numerically projects 1-7 according to their order number in the data. Table 2 presents the information on case study projects, which are arranged in chronological order. Pricing data items present the overall number of items in a specific project's research data, however, examined items are just a fraction of produced parts that cause the majority of the total costs.

Table 2. Case study projects

Project	Year	Pricing data items
1	2018	17
2	2018	34
3	2020	40
4	2020	72
5	2020	39
6	2021	15
7	2021	36

The pricing data items include all the documented objects that generate price or have a part involved in the total price. Each project has data items divided into categories, meaning what kind of product is prefabricated. These categories are presented as work numbers, which are hidden but explained in the following contradiction study and its tables. The general pricing study is done between categorized work steps that have the largest effect on total costs. Making decisions based on the effect in price makes comparing easier because of the large variety and number of smaller produced items that have little to none percentual effect on the total costs. The data is filtered based on data attributes shown below in Table 3.

Table 3. Data attributes

Scope	Dimension (mm)	Material	Size (mm)	Quantity (pcs)	Weight per unit	Total weight	Unit price (€)	Total price (€)

Scope defines the quality of the work and what has been done i.e., work steps. For every single activity, there's its own row with all the listed attributes and comments. Dimension is a simplified combination of all the physical specifications of the prefabricated product, e.g., diameter and wall thickness. The size is presenting the magnitude of prefabrication

– how large is the prefabricated part of the product. It is highly related to dimensions and is thought to affect pricing, because the larger the size the more time prefabrication takes, and larger machinery is needed. Unit price and weight per unit are numeric values for each individual action. The quantity represents the number of similar prefabrication actions done, which affects the total weight and total price. By observing the pricing data, a conclusion on how the quantity, weight per unit, total weight, unit price and total price are calculated could be seen by trying simple division and multiplication calculations. Research material attribute values are calculated as:

1) $Unit\ price = \frac{Total\ price}{\text{Quantity}}\ ,\quad or\ alternatively$

   $Unit\ price = \frac{Total\ price}{Total\ weight} * Weight\ per\ unit$

2) $Weight\ per\ unit = \frac{Total\ weight}{Quantity}$

3) $Total\ weight = Weight\ per\ unit * Quantity$

4) $Total\ price = Unit\ price * Quantity\ ,\ \ or\ alternatively$

   $Total\ price = \frac{(Unit\ price * Quantity)}{Total\ weight} * Total\ weight$

It is unknown which of the mentioned values are calculated and set first by the subcontractor. Weights are most likely known before prefabrication, and they are used to calculate the costs by knowing the order size. Often, such calculations are filled automatically by calculation software by setting primary values.

4.4 Findings from data

Detecting remarkable findings for the study started by dividing similar actions between case projects with identical specifications into the same sheets in Excel. A comparison of similar item attributes shown in Table 3 allowed precise information on how each item has cost. Prices are rounded to keep the study at a general level without revealing too critical information about project pricing. Figure 10. Pricing model has shown the affecting factors that cause the total costs, but findings have shown that certain proven factors are not applying to pricing in the data. This kind of factor contradiction is for example quantity, which has been stated to be affecting the unit price and so on total price due to the cost of setup time mentioned previously. In Table 4 an example of pricing

contradiction is presented, where quantity is not affecting decreasing unit price or total price. The reason behind the ineffectuality of quantity in price can be found by observing other affecting matters of pricing in 4.2. In listed projects 6 and 8 ordering schedules for example can be defining factor in why the price differs in an unexplainable way.

Table 4. Contradiction example 1

Project	Item	Dimensions	Material	Specifications	Quantity (pcs)	Unit price (€)	Total Price (€)
5	1	Identical	Identical	Identical	248	295	73160
7	2	Identical	Identical	Identical	178	36	6408

In Table 4 the first contradiction example is presented. The projects where listed items are found are 5 and 7. Prefabricated items are identical in dimensions, material and specifications. According to previous chapter 4.2, Figure 10. Pricing model and knowledge of quantity's affection in price don't apply in the presented contradiction. The assumption is when a certain size prefabrication product is made, setup time (approx. one day of working) will be added to the overall work costs reflected in the unit price. If the assumption of the lower quantity results in a cheaper unit price would apply, by all means, item 2 should have a little bit higher unit price instead of significantly lower. The first item has been produced 248 times and the second 178 times. The unit cost in item 1 is roughly 820% more expensive than in item 2, which is only explained by matters that vary the price in such magnitude. This kind of reason could be adding material price to the total price, even though this is not noted down in the data. The data states item 1 to be an enormously massive product by weight, which makes sense to the total price if all materials are added. This is relatively hard to justify without clarifying the issue with the Case A company.

Table 5. Contradiction example 2

Project	Item	Dimensions	Material	Specifications	Quantity (pcs)	Unit price (€)	Total Price (€)
4	1	Identical	Identical	Identical	14	274	3836
4	2	Identical	Identical	Identical	6	111	666

Similar price variations of identical items found in the same project can be seen in Table 5. In project 4 items 1 and 2 are identical otherwise but are they designed for different

parts of the final product. Nevertheless, despite different designs, the price for prefabrication actions should still be equal because of the identical processed material and its dimensions. Item 1 has been produced 14 times and item 6 times resulting in a similar variation than in Table 4, where the item that has been prefabricated over double as many is around 250% more expensive in unit price than the smaller batch items which should be slightly more expensive. Because of listings within the same project makes sense that the items are still prefabricated at the same time but listed separately. This results in the prices of one prefabrication action being recorded under separate work numbers. The possibility for inconsistent sharing of total costs of actions for similar-sized materials between different work numbers can be an explanation for high variation.

Table 6. Contradiction example 3

Project	Item	Dimensions	Material	Size	Quantity (pcs)	Unit price (€)	Total Price (€)
1	1	Comparable	Identical	Comparable	38	192	7296
4	2	Comparable	Identical	Comparable	21	217	4557
3	3	Comparable	Identical	Comparable	34	39	1326

Table 6 compares three projects 1, 4 and 3 where items are otherwise identical, but item 2 has slightly different but comparable dimensions, which shouldn't affect the price according to [26]. It is known that items 1 and 3 don't have the material price included in the unit price, but item 2 has. Items 1 and 3 are fully identical dimension-wise, and the unit price varies a lot. Explanation can't be found in quantity, little differing specifications or material prices, which affects hypothesis conclusions in 4.5. These kinds of contradictions are found everywhere in the research material. The best way to present the magnitude and number of contradictions and inconsistencies is to model a graph of the most remarkable item groups in each project into one chart, which is presented in Analysis.

4.5 Theoretical assumptions

Due to the findings and results presented in chapters 4.2 & 4.4, a theoretical assumption of the analysis results can be made. When looking at Figure 11. Labour costs [19], it can be seen that Case B company has over three times higher labour costs per hour than Case A company. This statistical find affects greatly on the offering starting point

presented in Figure 1 because the workshop salaries were expected to be somewhat equal between the two examined countries. Contradiction examples (Table 4, Table 5, Table 6) are used to justify the formed hypotheses to come. The used hypotheses are directional null hypotheses because according to previous chapters and findings an outcome can be estimated, and an alternative hypothesis is the opposite outcome of formed null hypotheses.

Based on findings and results following directional null hypothesis of study outcome is formed:

$$H_1 = \text{Quantity has an effect on the unit price}$$

, and the formed H_1 is compared against the formed alternative hypothesis:

$$H_{a1} = \ Quantity\ does\ not\ have\ an\ effect\ on\ the\ unit\ price$$

The second formed directional null hypothesis is:

$$H_2 = Projects\ have\ similar\ variations\ in\ unit\ pricing$$

, and compared against:

$$H_{a2} = Projects\ have\ unexplained\ variation\ in\ unit\ pricing$$

Finally, the third directional null hypothesis according to research question 3 is formed:

$$H_3 = The\ study\ is\ able\ to\ find\ comparable\ variables\ in\ the\ research\ data$$

, and compared to the alternative hypothesis:

$$H_{a3} = The\ study\ is\ unable\ to\ find\ comparable\ variables\ in\ the\ research\ data$$

Hypotheses are tested with identical items found in the range of projects (W) to determine whether the null hypotheses are valid or false. Also, all the hypotheses are discussed in the qualitative part of the analysis.

5. ANALYSIS

This chapter presents the quantitative and qualitative analyses of the research data. The data used in the study turned out to be very limited, which is making any mathematical analyses challenging to perform. The analysis is testing the hypotheses by assuming there is no automatic correlation between the tested variables, meaning they are not related. The qualitative chapter is explaining the reasons behind the results.
Pricing data variables compared are unit price and quantity, which are the most remarkable attributes that contribute to the total price. Unit price is treated as the dependent variable **y** and quantity as the independent variable **x**. Both compared quantitative variables are continuous variables, which can be measured.

The formed hypotheses are tested with a simple regression line and the decisions made are confirmed by factor and qualitative analyses. T- nor F-tests are not used because of the lack of observations and the type of hypotheses. Simple linear regression can be applied with one continuous predictor (independent) and outcome (dependent) variable to make decisions in the formed hypotheses 1, 2 and 3 along with factor- and qualitative analyses.

5.1 Quantitative

The quantitative analysis phase is focusing on finding solutions to research questions 1 and 2, how the pricing has changed during the case study period and whether there is a connection between variables. Quantitative analysis of research data was performed starting by forming null and alternative hypotheses in 4.5. Quantitative methods such as regression analysis were able to test the significance of the results statistically to see whether the assumptions were true or false. Chapter 5.1.1 deals with regression analysis and its results, while 5.1.2 is about factor analysis. Chapter 5.2 is explaining the qualitative nature of the chosen factors and speculates the results of the regression analysis and hypotheses.

5.1.1 Regression analyses

The regression analyses were done with a Microsoft Excel analysis add-in for two sample findings that had the most comparable items and had a different processing method due

to the dimensions of the material. The used observations were similar cases to contradiction examples (Table 4, Table 5, Table 6) presented in 4.4. All the findings used in the analysis were prioritized to have as many comparable variables as possible. Before each analysis, the findings are presented. Results included in analyses are regression statistics, coefficients and F- and *p*-values.

Analysis 1 was performed to a data finding described in Table 7 below:

Table 7. Analysis 1 attributes

Project	Item	Dimensions	Material	Specifications	Quantity (pcs)	Unit price (€)
2	1	Comparable	Comparable	Comparable	92	19
3	2				28	25
3	3				14	15
3	4				86	15
3	5				18	15
4	6				12	126
4	7				4	151
4	8				6	97
4	9				8	97
4	10				3	95
4	11				4	99
5	12				75	68
5	13				83	62
5	14				18	62
5	15				10	63
6	16				27	26
6	17				34	25
7	18				127	46
7	19				20	15
7	20				75	15
7	21				13	15

The first analysis attributes are similar findings of comparable items from a variety of projects. Dimensions are comparable, meaning there are slight changes which won't

affect the price. The decision on comparable dimensions and their acceptance is made according to [26]. Regression analysis statistics of the first analysis can be seen below in Figure 14. Regression analysis statistics 1. The analysis settings in Excel were standard and included residuals, and residual- and line fit plots.

Regression Statistics		*F*	*Significance F*
Multiple R	0,388529977	3,378097917	0,081756836
R Square	0,150955543		
Adjusted R Square	0,106268992	*Coefficients*	*P-value*
Standard Error	39,71464007	70,66391792	1,4788E-05
Observations	21	-0,44172312	0,081756836

Figure 14. Regression analysis statistics 1

In Figure 14 can be seen that Multiple R = 0,3885 (multiple correlation coefficient between -1 and 1) shows that the variables don't have a good linear relationship. R square = 0,1509 (Coefficient of Determination) values how good is the fit by measuring how many points fall on the regression line. This value is below mediocre, meaning only 15,1% of the values fit into the regression analysis model and the same per cent of the variation in unit price can be explained by independent variable quantity. Because these analyses are individual and done separately for different items, adjusted R square is not considered. Standard error = 39,7 which means the average distance of the data points is fairly long considering the unit price values. F and significance F tell that the analysis is not statistically significant – due to the volume of significance F of 0,0817, which should be less than 0,05 (5%), the test results of estimations are not reliable. The p-value in the intercept is 0,00001, which suits the analysis well, but the quantity p-value is 0,0817 which demonstrates the variation in the data that won't fit into the model.

This is an expected result due to the lack of similar items in data that were fully comparable. Only a few completely similar items were found between different projects and because of that comparison with regression analysis is narrow. However, hypotheses can still be tested regardless of prediction significance.
Residuals show that observations have high variation in changes. Residuals are plotted as below in Figure 15:

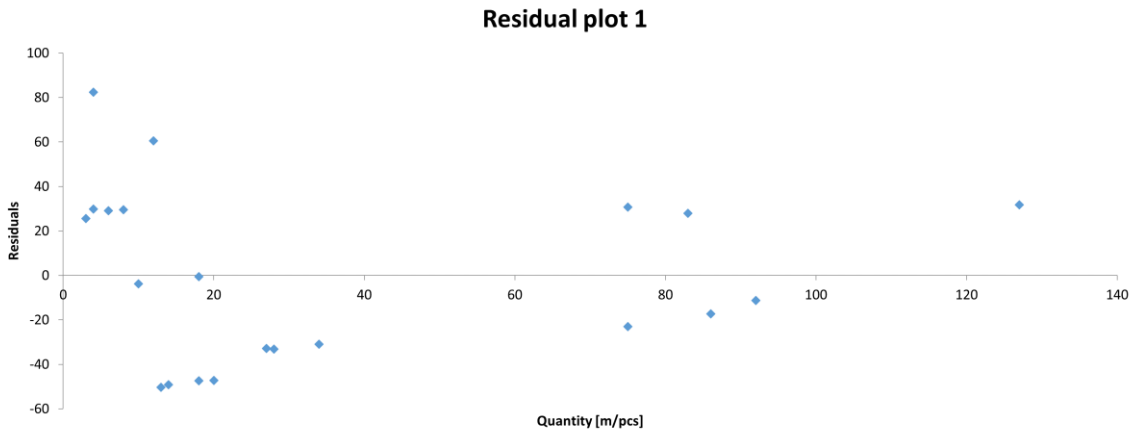

Figure 15. Residual plot 1

The residuals in Figure 15 vary from over 80 to around -50. Only two of the points are relatively close to 0, which indicates the high variances in the data. There is no clear pattern in the regression points.

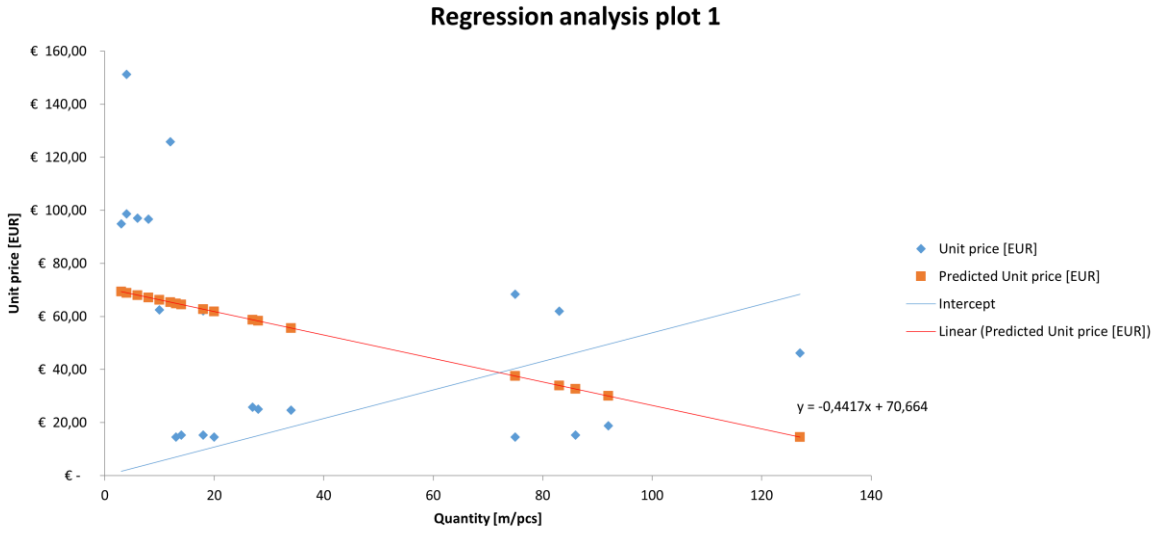

Figure 16. Regression plot 1

The Figure 16 above presents the unit prices of the finding and predicted unit prices. The blue diamonds represent the unit price, and the orange squares are predicted unit prices calculated by the analysis tool. The blue line represents the intercept, and the orange is the linear predicted unit price. Only one of the blue diamonds is taking place in the predicted unit price line, which signals unexplained variation that cannot be explained by regression analysis but gives an insight into the results of the study. The prediction line goes through all the predicted unit prices, which suggests predictions are linear.

Coefficients can be used to manually create the regression line and to forecast the drawn line in Figure 16 further. The function of the predicted unit price line is presented in the plot above:

$$y = -0{,}4417x + 70{,}664$$

The function can be read as:

$$y = Unit\ price = Quantity\ coefficient * x + Intercept = -0{,}4417 * x + 70{,}664$$

According to significance levels, the function is not accurate but can be taken as a directional estimate.

Analysis 2 was performed to data findings presented in Table 8 below. In this analysis, the used items are significantly larger and are prefabricated by different processing methods

Table 8. Analysis 2 attributes

Project	Item	Dimensions	Material	Specifications	Quantity (pcs)	Unit price (€)
1	1	Comparable	Identical	Comparable	8	1563
1	2				17	420
1	3				4	530
1	4				7	428
1	5				31	349
2	6				18	973
3	7				20	465
7	8				10	517
7	9				2	781
7	10				42	120

Regression statistics of the analysis which was performed on 10 observations similar way to the first one can be seen below in Figure 17.

Regression Statistics		*F*	*Significance F*
Multiple R	0,509233191	2,800862968	0,132749429
R Square	0,259318443		
Adjusted R Square	0,166733248	*Coefficients*	*P-value*
Standard Error	370,399014	873,9421151	0,00200845
Observations	10	-16,31915382	0,132749429

Figure 17. Regression analysis statistics 2

Similarly, as in the first analysis, Multiple R = 0,5092 and R Square = 0,2593 don't indicate a good relationship between variables. Standard Error = 370,4 is huge considering the unit prices and correlates well with the findings in the following plots of the analysis. F and Significance F are demonstrating the data to be not feasible statistically, where F = 2,8008 and Significance F from the lower variable p-value is 0,1327 over the limit which is 0,05.

Residuals of the Analysis 2 can be seen below in Figure 18.

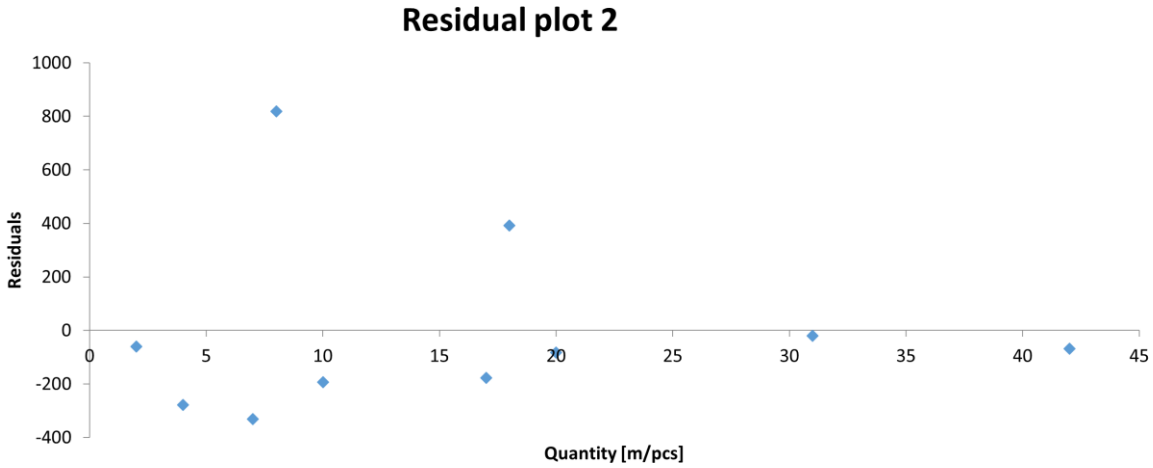

Figure 18. Residual plot 2

The residuals in the plot above are fairly higher than in Figure 15, because of higher dependent variable values. The variation ranges from around 820 to -330. Few variables hit close to the regression line and the variation is remaining somewhat stable below the regression line considering 0 to -200 regression, where 5 observations fit. Only one variable reaches the peak residual at around 820.

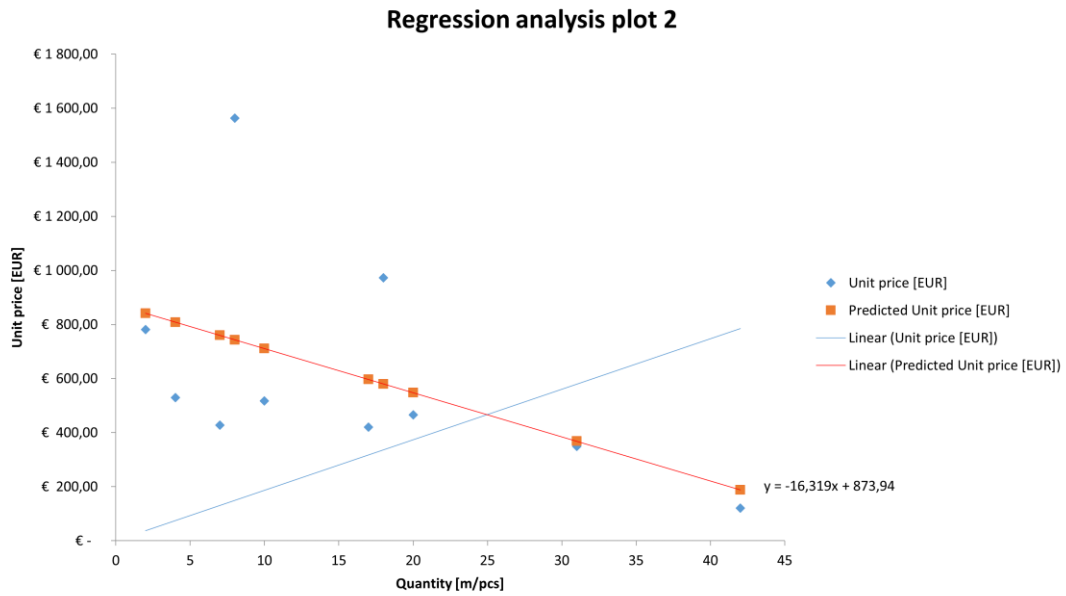

Figure 19. Regression plot 2.

Figure 19 above presents the regression plot of analysis 2. The indicators are similar to those in Figure 16. Unit price variation is high, but as seen in residuals plot five of the unit prices are remaining relatively stable between around 400€ and 600€ while not being dependent on quantities. The y function is presented next to the prediction line and it can be calculated from coefficients. The function is presented below:

$$y = -16{,}319x + 873{,}94$$

Due to bad levels of significance, the function is not accurate but helps the study to make conclusions about the results of the study.

5.1.2 Factor analysis

In this chapter, the most remarkable factors of the pricing models are presented and evaluated. The analysis was performed by comparing the two most remarkable variables in the research data, which were used as attributes to prefabricated items. The analysis also presents calculations of the two key indicators from the selected sets of data, correlation and covariance.

Correlation is the first key figure that is solved for both analysis 1 and 2 findings. Analysis 1 correlation is the negative value of the Multiple R in Figure 14, which is *-0,3391* which means the variables have a small negative relationship. The calculation was confirmed

according to the formula of correlation presented in Factor analysis. The covariance of the first analysis is *-310,04.*

Analysis 2 correlation is the negative value of the Multiple R in Figure 17. Hence, the value is *-0,5092* meaning the variables have a moderate negative relationship. The covariance of the second analysis is *-2354,69.*

5.2 Qualitative

The qualitative analysis phase is focusing on providing answers to research question 3, what are the causes of pricing variations. According to dialogue with the prefabricator [32], the research data contains hidden attributes, which means that certain comparable items contain more or fewer actions than are noted in the data. Hidden attributes are related to the size of the prefabricated item that is not noted down in the research data but has a significant effect on unit price. Also, similar items have different actions involved in item specification depending on the project, which also has an impact on price. Three projects (3,6,7) have only necessary actions according to the processing method included in the item price. In comparison, these necessary actions can be called basic actions. Project number 2 is documented as some of the actions are similarly stated as in the three above, and some actions have special actions in addition to basic actions included in the item price. In the following comparison, these actions are referred to as additions. Two other projects (1 and 5) also have special actions included in the item price, and finally, project 4 has material prices along with special actions included. These findings correlate well with the pricing increases. Compared items in projects 2 (some parts), 3, 6 and 7 are generally the cheapest ones, and project 4 has the most expensive ones. Overall, project number 3 is the cheapest one. Since the projects are numbered in chronological order, this finding supports the argument for a global pricing level increase, but not directly the contractual agreement of overall pricing level decrease since the projects (6 and 7) with similar pricing attributes are more expensive. Whether the increase in the price of these similar projects is due to the global pricing level development or non-compliance with the partnership contract is to be solved qualitatively.

Project	Quantity [m/pcs]	Unit price index	Including
2	92	1	Basic
3	28	1,34	
3	14	0,82	
3	86	0,82	
3	18	0,82	
4	12	6,71	Basic + Additions + Material
4	4	8,1	
4	6	5,18	
4	8	5,18	
4	3	5,1	
4	4	5,26	
5	75	3,64	Basic + Additions
5	83	3,3	
5	18	3,31	
5	10	3,33	
6	27	1,38	Basic
6	34	1,31	
7	127	2,47	
7	20	0,78	
7	75	0,78	
7	13	0,78	

Figure 20. Analysis 1 project pricing comparison

Figure 20 above shows the pricing comparison of analysis 1 projects. The prices are presented as indexes and projected to the first basic item's price. Blue rows include projects 2, 3, 6 and 7 which are the cheapest due to the price includes only basic actions. Indexes show that the bottom three rows in project 7 are the cheapest items, covering 78% of the price of a similar item in project 2. However, on the fourth row from below the similar item in the very same project is 147% more expensive than the index price. A similar finding can be seen in row two from the top in project 3. The findings are interesting since project 7 is the latest executed and assessed project in this case study. Because of the similarity of produced items, one reason behind an item being significantly more expensive is according to an interview with Case A company [31] the size that is not presented in the research data. Another reason considered can be false invoicing, meaning prices are vaguely spread between similar items by some internal logic or automated software. Three bottom rows and their affordable prices are contributing to the thought behind the partnership contract, which on the other hand not agree with global pricing development. As it can be seen in quantities, they don't correlate anyhow with unit prices in project 7, but supports the confirmed assumption of "less production more unit price" in project 6, where the upper row with less production

quantity costs slightly more than the row below it with larger quantity. Project 5 items are marked as grey and they include basic and additional actions. By observing quantities and price indexes a conclusion about the cost of additional actions can be made. The pricing indexes are at least 330% higher than the compared index. This means the price for additions can be considered to be about 200% to 230% of the index price. Again, the first grey row is more expensive than the other grey items following similar pricing. Project 4 items are painted red, and they include basic and additional actions as well as materials. This explains the high indexes, which are 510% to 810% higher than the comparison item. Also, in project 4 the production quantities are the lowest, which could be considered as a price increasing factor, however, according to data findings it won't apply to all items.

Generally, indexes in items with basic attributes are between 0,78 and 2,47 with an average of 1,11. Items with basic and additional attributes average at 3,4 index. When comparing the averages, it can be estimated that additional attributes generate roughly 2,28 index of the total price, which makes only additional attributes over twice more expensive than the actual cost of work. Similarly, items in project 4 that includes basic and additional attributes as well as materials sum up an average of 5,92 by index. Examining these results the leftover averages comparing additional attribute items and project 4 items show that the price for materials is 2,52 index on average.

Figure 21 below presents an analysis 2 project pricing comparison. This time, the grey-painted item in the first row from project 1 is used as a unit price index basis. The colour codes regarding the included actions are the same as in Figure 20, except for the last highlighted grey item, which is differing from the previous comparison project 2 items by including also additional actions instead of just basic actions.

Project	Quantity [m/pcs]	Unit price index	Including
1	8	1	Basic + Additions
1	17	0,27	
1	4	0,34	
1	7	0,27	
1	31	0,22	
2	18	0,62	
3	20	0,3	Basic
7	10	0,33	
7	2	0,5	
7	42	0,08	

Figure 21. Analysis 2 project pricing comparison

The unit price index item in this comparison is the most expensive. The following rows in the same project are 22-34% of the first items' price. Grey rows also include an item from project 2, which is priced at 62% of the index price. An interesting finding in this set is the prices are not correlating with the analysis 1 pricing comparison, because there are no clear differences between blue and grey items, even included actions differ. Most of the blue items are more expensive or similarly priced than most grey items, which raises an assumption of pricing inconsistency. Quantity and unit price relation is supporting the general assumption in blue items, while it does not hold in grey items.

6. RESULTS AND CONCLUSIONS

In this chapter, the results of the analyses and answers to the hypotheses are presented. The results include examination of regression analysis and plots and qualitative findings and conclusions about the studied data set. Based on the results, hypotheses are assessed in 6.1 and determined whether the null hypotheses are true or false. Both qualitative and quantitative methods were used to assess hypotheses. The first and the second directional null hypothesis mainly focus on quantitative research, but the third one is most logical to be solved qualitatively. Chapter 6.2 sums up the conclusions of the results and provides answers to research questions.

6.1 Hypotheses

The first formed null hypothesis is H_1 which presents an assumption of quantity's effect on the unit price. Alternatively, H_{a1} counters the assumption as an alternative hypothesis, stating quantity does not affect the unit price. Whether the quantity affects unit pricing can be assessed by regression analyses and its plots. Regression analyses compared both variables and their connection. As stated in 5.1.1, both regression analyses have only small variable connections and are exceeded at F and significance F-levels. Figure 16 and Figure 19 demonstrate the predicted unit price and the variation of the actual unit price. If there would be a connection between quantity and unit price, blue diamonds would be formed differently following the prediction line. The predicted unit price is following an assumption of a connection between quantity and unit price making the drawn prediction line decrease towards the higher quantities. The lower quantity the higher price of similar items produced is not true in the finding used in the regression analysis. Based on these results, the directional null hypothesis H_1 is rejected and alternative hypothesis H_{a1} becomes valid. Thus, it can be stated that quantity does not have an effect on unit price in examined findings.

The second formed null hypothesis H_2 presents an assumption of projects' unexplained variations in unit pricing that is challenged by alternative hypothesis H_{a2} assuming projects have similar variations. These hypotheses are highly related to the first ones. Unexplained variation can be seen in the same analysis data that is used in the comparison between quantity and unit price. Unexplained variation in 5.1.1 and 5.2 can be detected and valued by using quantitative methods but examined later on by

qualitative methods. According to analyses, there is unexplained variation in unit pricing to which answers are sought qualitatively in 6.2. Thus, H_2 is again rejected and H_{a2} becomes valid.

Finally, the third null hypothesis H_3 assuming the study is able to find comparable variables in the research data is compared to the alternative hypothesis H_{a3} assuming the other way around that the study is unable to find comparable variables in the research data. All of these three presented hypotheses are related to each other. The third hypothesis is using a similar yet wider examination of variables than the first hypothesis. Variables in the examination can be hidden and therefore excluded from regression analysis or finding tables presented in chapter 5. Hidden variables can be actions or attributes that each item includes, thus they are treated as numbers or affecting matters. This makes both qualitative and quantitative methodology a feasible approach to assessing these last hypotheses. According to [31, 32] the hidden attributes are affecting the unit prices, which makes assessing the true nature of the connection between variables with the available data hard and only reliable with data outside of this study. In the next chapter generalized information about these hidden attributes is used to analyze the relationship between them and the unit price to see whether the variables have a connection. As the study is examining hypotheses with the data that is available to this study, the null hypothesis is rejected even though the absolute truth of pricing variable connection and the cause of inconsistencies remain to be solved outside of this study.

6.2 Conclusions

Overall, the study has been following desired guidelines and found answers to the research questions that were internal aspects under review that ignited the idea of this thesis assignment. The study shows that the pricing has not changed in a more favourable direction over the period of examined products (*research question 1*). Comparing the average unit price of analysis 1 items from projects 3 and 7 show there is no reduction in pricing, however, the global market changes and covid are affecting project 7 prices increasingly. Project 3 items unit price is 17,78€ on average and project 7 items are averaging at 22,49€.

According to the results of the data, analysis hypotheses could be evaluated, however qualitative examination of results speculate an effect of hidden attributes related to the size of processed elements. Hidden attributes were solved and tested, to whether they have the claimed effect on tested variables in 5.1. The following analysis is using unit

price as a dependent variable similarly to previous regression analyses and solved size as the independent variable. The analysis is using same data as the first analysis in 5.1.1 excluding two project 6 items, where hidden attribute data was not found.

Regression Statistics		*F*	*Significance F*
Multiple R	0,343827186	2,279122621	0,149488267
R Square	0,118217134		
Adjusted R Square	0,066347554	*Coefficients*	*Standard Error*
Standard Error	41,60652921	69,26173373	12,17828538
Observations	19	-0,072923757	0,048304233

Figure 22. Analysis results of hidden attributes

As can be seen in Figure 22, variables don't have a feasible linear relationship and only 11,8% of values fit into the regression line, which is why the regression plot is not necessary to present. The significance F is over the limit (0.005 < 0.1494), which is used to determine the value of hidden attributes. Due to the insignificance of the Figure 22 results, it can be stated that hidden attributes do not contribute to the unit price in the way that it is claimed. Based on these and the analysis results are shown in chapter 5, it can be seen that no variables affect each other (*research question 2*). This finding makes discussion in the following chapter 7 even more highlighted to suggest effective and feasible actions for future cooperation with the prefabricator and evaluating pricing.

The *third research question* is the most complex to answer due to its wide range of possible answers. Anyhow, the last analysis shown in Figure 22 debunks the confirmed reason of hidden attributes affection for pricing variations claimed in [32], so it can be excluded from the examination of 3rd research question. Qualitative analysis shows in Figure 20 and Figure 21 that the differing documentation of actions listed in each item is a general reason for large pricing variations, however, it does not explain the variation within the same action categories. Therefore, Figure 10 and chapter 4.2 are used to assess the issue and explain the variations. The most remarkable factor in Figure 10 behind pricing variations in the data is documentation – the actions implemented in each item vary between projects, and therefore the prices are far from consistent within the comparable data set. A deeper review has revealed that even items with similar actions included in unit price don't have consistent pricing, which rises suspicions of margin maximizing, since logical reasons behind the pricing increases are ruled out. Logical reasons behind the pricing variations are referring for example to the prefabricator's claimed hidden attribute, general cost level increase caused by Covid and bad execution of previous projects. Even though the general global cost level increase in materials,

work and transportation undeniably happened during the period of Covid, the pricing level increase has not clearly affected the pricing data, shown e.g. in Table 7, where the latest project 7 items are generally cheaper than project 3 items which were manufactured prior Covid. Margin maximizing is a topic of further discussion between parties involved.

7. DISCUSSION

This chapter reviews the study' process and assesses the results' quality. Overall, the study was able to answer the desired questions which emerged the need for examining prefabricator pricing accuracy in the assignment company. The thesis research process was executed part by part, instead of systematic approach. A few of the chapters and topics of discussion were added later on in the study, which means an extension of the original research plan. This is not seen as a problem though, since new information is gathered during the research process and therefore new topics and extensions of the original plan is widening the observed perspective of the problem. The theoretical part of the thesis was heavily relying on literature and publications, but some of the questions required interviews to correctly answer the questions related to company policies and pricing model factors. In a study like this plenty of information is not available to the public, and therefore engaging with related parties, internal and external within the assignment company is mandatory. The general approach and research process that was used to execute this study is seen as the most feasible and effective way to study the problems which emerged the need for this thesis.

The data available was quite tight and there were too few original comparable elements to feasibly execute proper mathematical analyses. Widening observation points by expanding comparable items within researched limits, mainly material-wise was necessary to reach the required amount of comparable items for the analyses. This was the only viable method to reach a suitable number of observation points. Nevertheless, with larger data set the results would be unlikely to change since there are no repeated patterns in unit prices and they don't follow any certain factors. The reliability of the results is unquestionable, even the analyses could have been better data-wise. Generalizing these results scientifically is not necessary, because of the uniqueness of observed data and qualitative reasons for variance. However, Figure 10. Pricing model covers a wide range of price-affecting factors used in the manufacturing sector, which can be implemented for other studies, depending on the field. Also, the model can be reviewed and used in the assignment company to detect factors that may affect the price of future projects.

Based on the conclusions and results of the study, further discussion of recommended actions is essential in the assignment company. Recommendations can be used to

develop pricing accuracy and improve documentation in future procurement processes. To gain consistent information on how the pricing has developed, the data which is provided for completed work should be harmonized in a way it is similarly documented in each project. Also, so-called hidden attributes should be noted down along with all relevant information in each item. The similarity of listed items and what the actual unit and total price include goes hand in hand with transparency, which is one of the key points in cooperative business behaviour, which is expected especially from key partner companies. All the required attributes in the provided data should be formed and discussed together with involved parties to ensure the consistency and comparison of future project data. This makes following the pricing development more accurate and can reveal improving points clearly without the need of guessing what may have affected prices. Whether there are special circumstances, such as problems in project execution or schedule, that have increased the price temporarily, they should be clearly noted down instead of leaving gaps of uncertainty between parties. The pricing development in such a large company with lots of variety in prefabricated products is a challenging task. With proper cooperation, transparency, communication and systematic implementation of statistical approaches, accuracy in pricing can be enhanced without damaging profits or relations.

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APPENDIX A: PRICING MODEL