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Improving the offer calculation process in a technical consultancy

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For each new project, a technical consultancy must carry out an offer calculation process to quantitatively measure the project scope. The accuracy in the process is a key factor in terms of a company's tendering performance. The tendering performance of this study´s case company has been suffering as of late. To improve the company's offer calculation capabilities, this study takes a focus on a project review method called post-mortem process. The method can be utilized as a quality control tool of offer calculation. In a post-mortem process, project data is collected and analyzed. Based on the analysis, improvement actions are created to fix the root causes behind failures.

The objective of this study is to establish a common post-mortem process for the case company as it is currently missing one. In this study, the best practices to organize a post-mortem process were investigated through a literature review and a qualitative research. Based on the findings, this study proposes a holistic approach in establishing the post-mortem process at the case company. Through iterative experiments, the company can identify what kind of a post-mortem process suits it the best in projects of different character and different size. Many research teams studying the post-mortem process have observed that there is a low utilization rate of the method in companies. To increase the utilization rate, this study suggests that the case company should not make the post-mortem process obligatory in each project. Instead, this study highlights that an adequate balance between the costs and returns of the method should be ensured by setting boundary conditions which determine if the post-mortem process should be conducted for a project or not. For example, in a small routine project where only negligible failures occurred, it is not worthwhile to conduct a post-mortem process.

This study contributes to the existing theory by unifying the broad scope of post-mortem literature under a single study. Moreover, this study provides novel perspectives and analysis on the issues related to implementing the post-mortem process in practice in companies, especially in a technical consultancy.

Keywords: offer calculation, post-mortem process, workload estimating

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Teknisen konsultointiyrityksen täytyy uuden projektin kohdalla suorittaa tarjouslaskentaprosessi määrittääkseen projektin kvantitatiivinen laajuus. Prosessin tarkkuudella on merkittävä vaikutus yrityksen suoriutumiseen tarjouskilpailuissa. Tässä diplomityössä tutkittavan teknisen konsultointiyrityksen suorituskyky tarjouskilpailuissa on kärsinyt viime aikoina. Parantaakseen yrityksen tarjouslaskentaprosessia, tämä diplomityö keskittyy projektin jälkeen tapahtuvaan jälkilaskentaan. Jälkilaskennassa kerätään ja analysoidaan projektidataa. Tehdyn analyysin perusteella muodostetaan parannusehdotuksia, joiden avulla projektin aikana tapahtuneiden virheiden juurisyyt voidaan korjata.

Tämän diplomityön tavoite on luoda yleinen jälkilaskentaprosessi tutkittavalle yritykselle, jolta vastaava prosessi tällä hetkellä puuttuu. Alan parhaita käytäntöjä järjestää jälkilaskentaprosessi tutkittiin kirjallisuuskatsauksen ja kvalitatiivisen tutkimuksen kautta. Tutkimustulosten perusteella esitellään holistinen menettelytapa kuinka prosessi tulisi järjestää yrityksessä. Iteratiivisten kokeilujen kautta yritys pystyy tunnistamaan millainen prosessi sopii sille parhaiten eri tyyppisissä ja eri kokoluokan projekteissa. Aikaisemmissa jälkilaskentaa koskevissa tutkimuksissa on havaittu, että jälkilaskentaprosessin käyttöaste on yleisesti ottaen matala eri yrityksissä. Jotta käyttöastetta voidaan nostaa, yrityksen ei tulisi asettaa jälkilaskentaprosessia pakolliseksi jokaisen projektin kohdalla. Yrityksen tulisi painottaa prosessin kulujen ja hyötyjen tasapainon merkitystä asettamalla raja-arvot projekteille milloin jälkilaskentaprosessi tulisi suorittaa. Esimerkiksi ei ole mielekästä suorittaa prosessia pienessä rutiininomaisessa projektissa, jossa suurempia virheitä ei tapahtunut.

Tämä tutkimus edistää olemassa olevaa jälkilaskentaa koskevaa kirjallisuutta yhdistämällä suuren määrän löydöksiä yhden tutkimuksen alle. Lisäksi tämä diplomityö tarjoaa uusia näkökulmia ja analyysiä keskeisistä jälkilaskentaprosessin toimeenpanoon liittyvistä ongelmakohdista, erityisesti teknisessä konsultointiyrityksessä.

Avainsanat: tarjouslaskenta, jälkilaskentaprosessi, työmäärän arviointi

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1 Introduction

1.1 Background

Recently Rejlers Finland, a technical consultancy, became aware of its poor tendering performance after having lost a few key tenders. As other factors, such as quality presumptions and brand recognition were seen to be in most cases relatively well on par with its competitors, the company decided to look into its internal process of offer calculation. Even though the client side establishes the specifications and scope of a new project, Rejlers still needs to carry out an internal offer calculation process per each project. In this study, offer calculation stands for the quantitative measurement of the project scope. Kraus & Cressman (1992) define the scope of a project as a "detailed description of the objectives for that project". The authors determine project objectives as an end product or service which can be both described in concrete terms and rigorously examined in order to evaluate whether the project achieved its measurable objectives. Following these remarks, offer calculation is defined in this study as follows: the required workload for a company to carry out a specific project and meet its objectives is quantitatively estimated. In this study, a workload stands for the required assets to carry out a specific project and meet its objectives. Thus, when workloads are estimated for an engineering project, for example the amount of employees, how many working hours they require to get the defined job done, or the required quantity of installed electrical instruments and machines at the destination are quantitatively estimated. Taking various factors into account, Rejlers must conduct the offer calculation process carefully and individually per each project. Such analysis is required to determine an effective allocation of resources, a suitable price level and a feasible schedule for a new project.

A project review method called post-mortem process is recognized at Rejlers as a central part in the holistic offer calculation process. Myllyaho et al. (2004) define the method as "a series of steps aimed at examining the lessons to be learned from products, processes and resources to benefit on-going and future projects." Similarly, Ahonen & Savolainen (2010) define post-mortem process as an analysis performed to achieve an understanding of a project which is already completed. It is good practice to conduct a post-mortem process at the end of each project (Besner & Hobbs (2006), Collier et al. (1996), Myllyaho et al. (2004), Schieg (2007)). Ewusi-Mensah (1997) argue that the method should be made standard practice for all cancelled projects. The method can be used to analyze elements of a project which are successful or unsuccessful. Analyzing and determining such elements allows organizational learning for a company: the recurrence of desirable elements can be promoted while the recurrence of undesirable elements can be prevented. Post-mortem process is a quality control tool for analyzing and learning from human errors e.g. underestimated workloads in projects (Collier et al. (1996), Ewusi-Mensah & Przasnyski (1995), Terzieva (2014), Tiedeman (1990)). The method is a relevant way for a company to conduct reflective reviews and collect empirical knowledge on a project (Myllyaho et al. (2004), Stålhane et al. (2003)).

Similarly, Schieg (2007) states that post-mortem process "serves for the collection of experience in organizations" and that it "enables the identification and processing of experiences in the field of projects". In other words, the method allows collecting the gained implicit knowledge and experiences of individuals into analyzable project data. The results of the post-mortem process can be utilized as inputs in future project planning and in constituting improvement actions for the organization (Lyneis & Ford (2007), Schalken et al. (2004), Schieg (2007)).

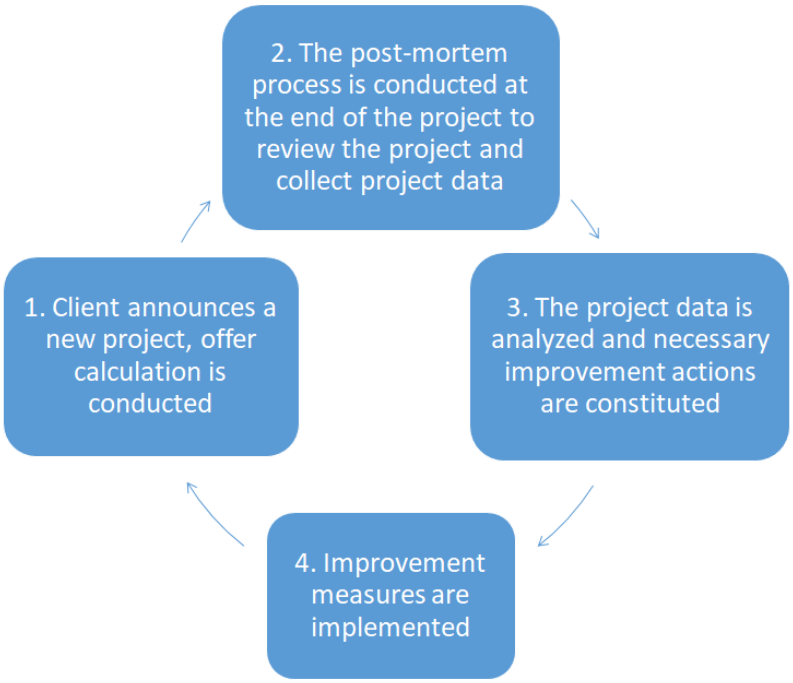

Figure 1: The relationship between offer calculation and the post-mortem process

1.2 Motivation for the study

1.2.1 Offer calculation at the case company

Rejlers has executed a rather aggressive acquisition strategy in Finland. The company's strategy emphasizes a high level of local presence and an entrepreneurial approach for its individual offices. Therefore, apart from enterprise resource planning (ERP), management and reporting system integrations, a newly acquired company remains fairly autonomous in Rejlers. Many of the acquired companies have historically been focused on a few specific key customers in their proximity and have centralized their operations on them. Each customer and their working policies are more or less unique, for example one customer, especially someone operating in the nuclear industry, will require a high level of documentation from their supplier. Then on the other hand, another customer might require less documentation but more site visits. Thus, as each of Rejlers' offices across the country have over the years focused and specialized their operations on specific key customers in their localities, also the ways of working are considerably different across the company.

Each office has had their own procedures and methods to carry out offer calculation. It has been a deliberate decision from the management of Rejlers to leave individual offices with high level of self-determination regarding the process. A strict offer calculation process with generic workload estimating methods has not been seen suitable. The customers, their projects and working policies differ considerably from each other across the company. This setup has worked well for the company. The company has managed to increase both its net sales and profitability, especially during the strong upward economic trend of the recent years. However, the situation is not as desirable as it first seems. There is room for improvement in the offer calculation process of the company. Rejlers' results in terms of won tenders has been positive in absolute terms but poor in relative terms. The percentage of won tenders per submitted offer has been undesirably low. Overestimated workloads have led to uncompetitive offer prices and lost tenders. Furthermore, underestimations have led the company to carry out projects with negative profits in some cases.

Darker forecasts in terms of global economic growth have been constantly in the discussions lately (Bank of Finland (2019)). If the market conditions get tougher, new investments and new projects will be in scarcity and even more players will compete for the same projects. Thus, improving its offer calculation capabilities to create competitive advantage is in the best interests of Rejlers. The evidence shows that enhanced offer calculation capabilities enable seizing benefits in terms of project cost and schedule savings, customer satisfaction, improved risk management, more optimal resource allocation and higher workforce morale. Chow & Ng (2003) argue that higher accuracy in project scope definition (i.e. offer calculation) enables a company to reduce the magnitude of risk and uncertainty factors related to a new project. Cho & Gibson (2001), Dumont et al. (1997) and Khan (2006) state that higher levels of pre-project scope definition can result in significant cost and schedule savings. For example, project scope, schedule and workload quantity changes, and the resulting cost overruns and potential disputes with the client can be better avoided (Dumont et al. (1997)). Similarly, Fageha & Aibinu (2014) emphasize that adequate offer calculation enables avoiding "major changes that may negatively affect project outcome". Low-cost, high-quality and in-time project delivery are critical in achieving maximum customer satisfaction (Niazi et al. (2005), Shenhar et al. (1997), Westerveld (2003)). Potential delays in project schedule and rework due to scope changes not only increase customer dissatisfaction but can also lead to lower productivity and morale of the workforce (Dumont et al. (1997)). When there is a clearer understanding about the workload and required resources to carry out a project, allocating redundant or insufficient resources and engaging in unprofitable or infeasible projects can be better avoided (Roy (2003)). The extra resources stemming from more optimal resource allocation can be utilized in other business opportunities (Odusami & Onukwube (2008)). This enables increasing the overall efficiency of the company.

1.2.2 The role of post-mortem process in offer calculation

In order to improve the company's offer calculation capabilities, a strong focus on the role of post-mortem process must be taken at Rejlers. Historically at Rejlers some individuals have utilized their own post-mortem methods but largely the process has been neglected. There has been an absence of a common company wide process and tools, which has hindered the systematic collection of project data. Schieg (2007) stated that one of the key results of the post-mortem process "is the identification of process errors and failures". The lack of proper project data has created a barrier for Rejlers in terms of conducting quality control of the offer calculation process. The key process errors and failures Schieg (2007) emphasized have not been identified and assessed. Similarly, Song & Abourizk (2005) argue that the lack of quantitative information (i.e. project data) is a significant deficiency for project performance evaluation and improvement methods at the postproject stage. At Rejlers, the gained new knowledge and experiences in terms of successes, errors and risks from past projects have not been consistently analyzed and documented into project data for utilization in process improvements and future project planning. The individual learning and gained empirical knowledge in projects have not been translated into explicit project data which could be utilized throughout the company to allow organizational learning to occur.

Myllyaho et al. (2004) argue for the importance of post-mortem process in enabling organizational learning. Similarly, Von Zedtwitz (2002) state that organizational learning "is at the basis of competence building and thus a source of competitive advantage". Having been unable to systematically collect explicit project data and accumulate organizational learning has had a negative impact on the company's competitive advantage. In order to enable Rejlers to improve its offer calculation capabilities and secure future competitive advantage, it is essential for the company to establish a common post-mortem process.

1.3 The case company

Rejlers is a Nordic group based in Stockholm, Sweden. The company offers technical consultancy services and IT solutions to customers in the areas of energy, buildings, industry, telecom and infrastructure. With its approximately 2000 employees at around 80 locations in the Nordics and net sales of around 230 million euros in 2018, the company is one of the biggest Nordic technical consultancy providers (Rejlers (2019)). Rejlers focuses its operations in the Nordic countries of Sweden, Norway and Finland. In addition, the company has business units in Estonia and Russia.

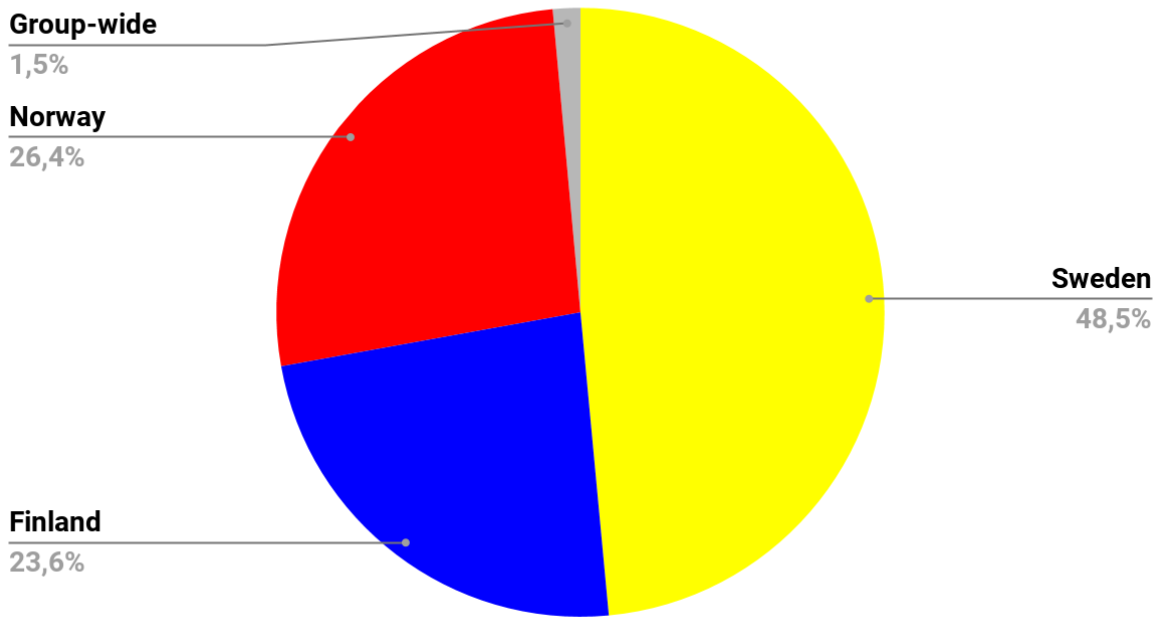

Figure 2: Year 2018 net sales per country (Rejlers (2019))

This study focuses on Rejlers' business activities exclusively in Finland. In Finland, the company started its operations in 1980 in Mikkeli. Since then, the company has grown steadily, nowadays it operates in 19 different localities all across Finland and has around 700 employees. Compared to the division of sales on the group level, Rejlers Finland has three strong divisions of somewhat equal size, however with an especially strong focus on industry.

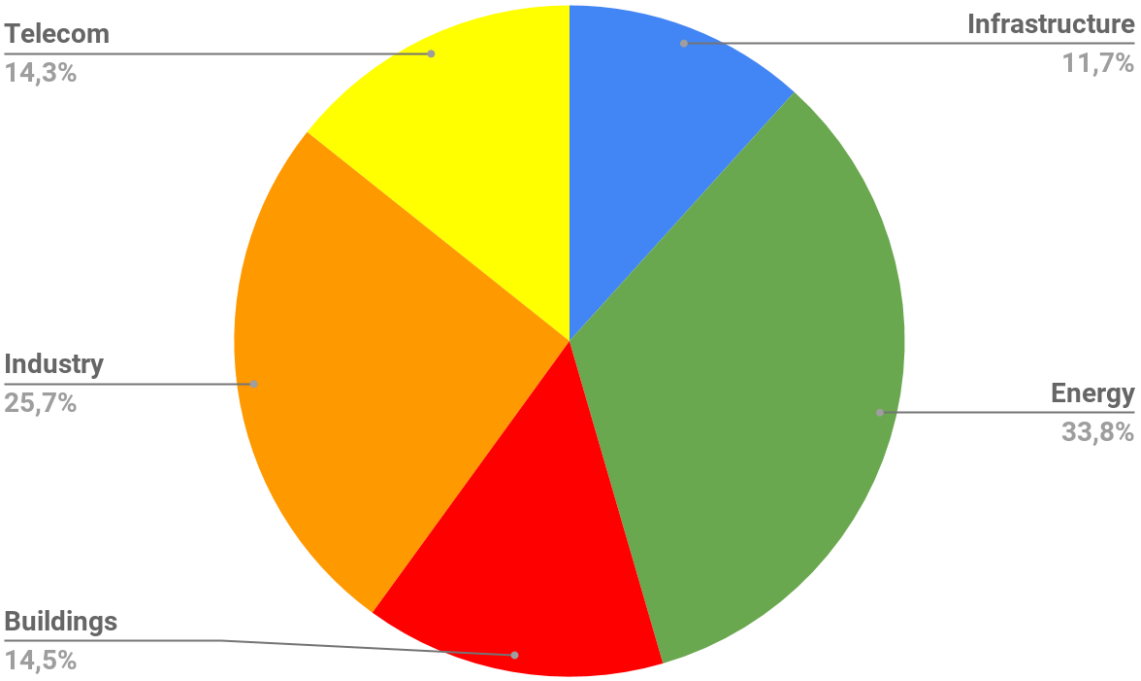

Figure 3: Group level sales by division (Rejlers (2018))

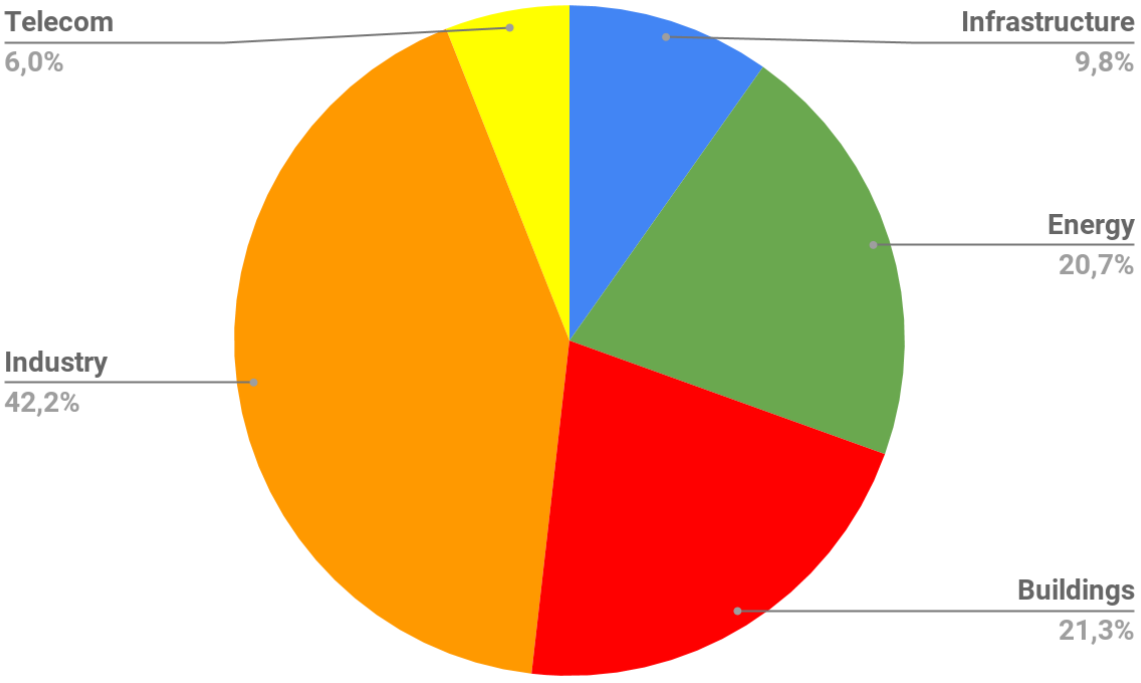

Figure 4: Sales per division in Finland (Rejlers (2018))

Rejlers' growth in Finland has been mainly based on both rapid organic growth, and a rather aggressive, yet successful acquisition strategy. In 2018, out of the year's new hires corporate

acquisitions accounted for 40 percent while new recruits accounted for 60 percent. Despite the company stating recruitment of competent new employees as its greatest challenge in Finland, with a total personnel growth of 15 percent, the company had around 700 employees in 2018 (Rejlers (2018)).

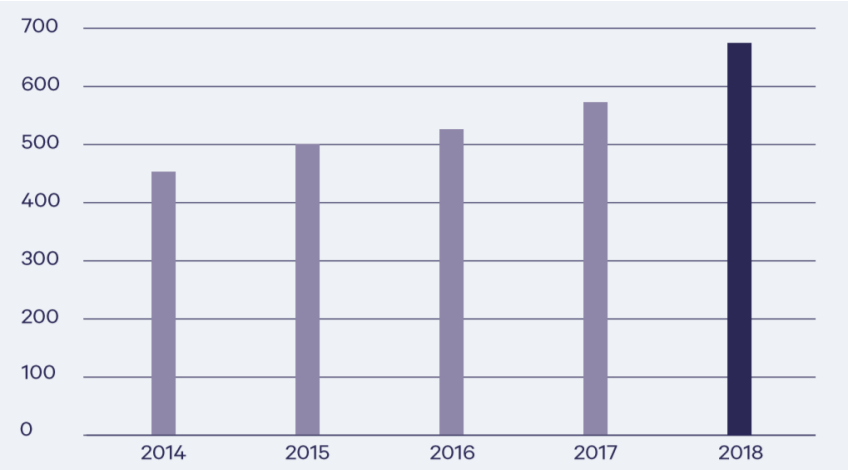

Figure 5: Number of employees in Rejlers Finland (Rejlers (2018))

The company has executed both smaller and larger acquisitions from one-man companies based on specialist competence to more strategic purchases. The acquisitions have helped Rejlers to both strengthen its position in its historically more established markets and to expand its business into new market areas and new fields inside the technical consultancy industry. Depicted in Figure 6, the growth strategy has been successful as it has resulted in both increased revenues and strengthened profitability.

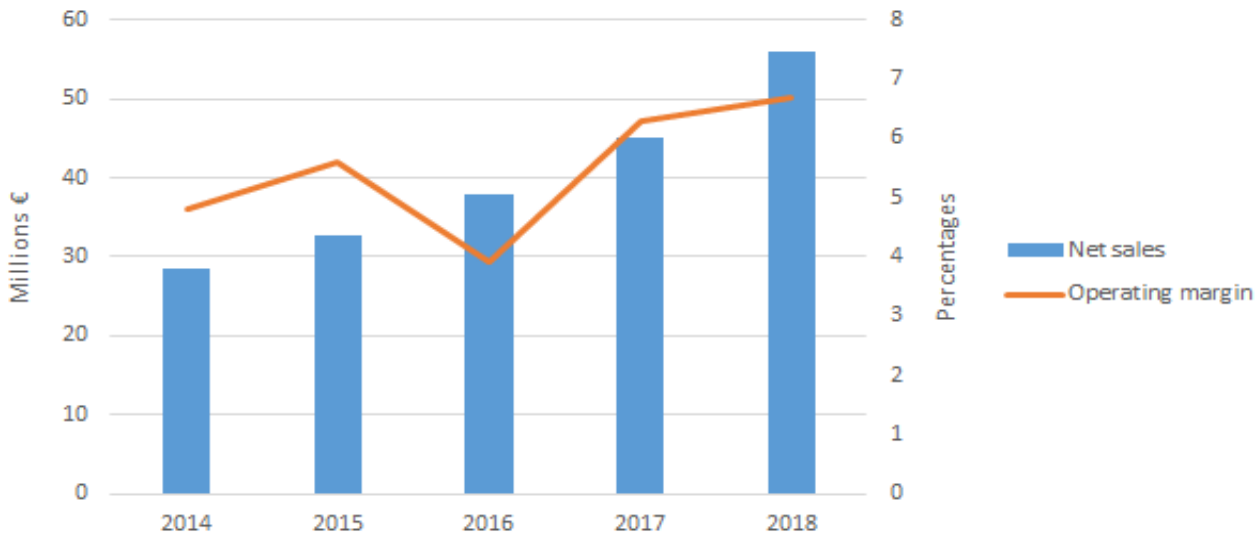

Figure 6: Net sales and operating margin of Rejlers Finland (Rejlers (2019))

1.4 Research objective

The objective of the study is to establish a common post-mortem process for Rejlers. The post-mortem process will enable the company to initiate quality control of its offer calculation. With systematic quality control, the company's offer calculation capabilities can be improved and competitive advantage created for the company. In order to reach the objective of the study, the following sub-objectives have to be met.

Sub-objective 1

The first sub-objective of the study is defined as follows: *Identify the current best practices in the industry to organize the post-mortem process.* The first sub-objective is addressed through a literature review where the currently broadly utilized post-mortem processes are examined and compared. Careful analysis of the different processes found in the literature enable a framework for establishing the post-mortem process at Rejlers.

Sub-objective 2

The second sub-objective of the study is to get a solid and unbiased understanding about Rejlers' offer calculation capabilities and the company's accuracy in estimating workloads. Thus, the second sub-objective is defined as follows: *Investigate Rejlers' historical performance in offer calculation.* To address the second sub-objective, a quantitative research method in the form of a data analysis is implemented.

Sub-objective 3

Despite the absence of a common process at Rejlers, some individuals have utilized their own post-mortem methods to conduct project reviews and quality control of how they have performed in offer calculation. However, it is not general knowledge in the company who, to what extent and what kind of methods have been utilized. Therefore, the third sub-objective of the study is defined as follows: *Identify what kind of post-mortem methods have been utilized at Rejlers.* The discovered best practices and the accumulated knowledge around them coupled with the findings of the literature review can be leveraged in establishing the common post-mortem process at Rejlers. The third sub-objective is addressed through a qualitative research method in the form of expert interviews.

Sub-objective 4

The fourth sub-objective of the study is to introduce a computational post-mortem tool. The tool will be developed based on the key findings of the relevant literature coupled with the results of the expert interviews at Rejlers. The tool will serve a key role in the post-mortem process. The tool will tackle the current lack of common methods for collection of homogenous project data. Up to this date, the collected project data has been scarce, incoherent and of poor quality.

The post-mortem tool will be shared and implemented throughout the whole company. Consistent and repeatable use of the tool allows Rejlers to start systematically collecting

standardized, high-quality project data. The purpose of standardization is to ensure that the data will be easily interpretable for everyone and comparable between different projects. Von Zedtwitz (2002) argue that standardization is necessary for comparative reviews between different projects. Individuals in a company "with different technical, functional, or cultural backgrounds do not share the same vocabulary or referential context, which leads to misunderstanding or reduced knowledge exchange" (Von Zedtwitz (2002)). Comparative reviews of multiple projects enable discovering repetitive failure patterns and identifying the effects of improvements between different projects (Collier et al. (1996)). Therefore with an extensive collection of comparable project data, Rejlers can detect these failure patterns, analyze their root causes and act upon them.

1.5 Scope of the study

The scope of this study was limited to examine Rejlers Finland's offer calculation process and used post-mortem methods in the organizational division of industry. The industrial division at Rejlers consists of the fields of electrical engineering and automation, and mechanical engineering. In the organizational structure of Rejlers Finland, electrical engineering and automation are considered as one common field. The interviewees were exclusively selected from these two fields. In addition, the computational post-mortem tool was designed to satisfy the specific needs and to include the specific features relevant to these two fields.

2 Literature review

2.1 The post-mortem process

A literature review was conducted to address the first sub-objective of the study of "*identify the current best practices in the industry to organize the post-mortem process.*" Relevant post-mortem literature shows that there are multiple ways to organize the process. Careful analysis of the proposed process descriptions help in providing frameworks for establishing the post-mortem process at Rejlers.

Schieg (2007) studied post-mortem processes in building industry projects. The author argues that the post-mortem process should be "a structured ritual at the end of every project" to ensure identification of the strengths and weaknesses in project operation. The focus of the post-mortem process is the processes occurring in a project. The method allows reviewing existing processes in terms of their quality and success of implementation, and to identify potential improvements. The method must be conducted by an expert who knows the project operations in detail. The project team members (including managers) and possible customer representatives take part in a post-mortem workshop. In the workshops interviews, moderated

group discussions and questionnaires are utilized as methods of gaining information. (Schieg (2007)) The post-mortem process presented by Schieg (2007) consists of five steps:

1. *"Identifying company success factors".* Examining processes in relation with the success factors of a company can help clarifying what the goals are for improvement measures. For example, cost and schedule compliance, and high performance quality can be considered as success factors.
2. *"Determining basic conditions".* Different projects take place "under different boundary conditions, demand and influencing variables." Therefore, the post-mortem process should be adapted and conducted differently based on the size of a project and the form of the examined organization. In addition, the goal must be that the results of the post-mortem process are achieved through minor costs and burden to the examined organization unit.
3. *"Designating objective and subjective data".* Objective and subjective project data are collected. Objective data consists of costs, deadlines and qualities. Subjective data contains e.g. perceived customer satisfaction, personal advancement of project team members, collaboration in the project team, motivation and commitment.
4. *"Collection of experience".* The findings of the post-mortem process are analyzed and a "strength/weakness profile" is created. This profile documents the observed advantages (strengths) of the project work and the apparent deficiencies (weaknesses) which reduce the efficiency and safety of project development, or even risk achieving the project goals.
5. *"Creation of a catalog of measures".* A catalogue is compiled of all the measures proposed for different process themes in the strength/weakness profile. For each individual measure the estimated implementation cost and length are defined. The measures connected to the success factors of the company are prioritized. Efficient implementation is crucial regarding the success (improvement of the processes) of the measures.

Similarly to Schieg (2007), Collier et al. (1996) argue that it is good practice to conduct the post-mortem process at the end of each project to not miss the important opportunity to learn from one's mistakes in a project. Collier et al. (1996) studied post-mortem processes in software industry projects. The authors emphasize that the method plays a key role in trying to "approximate a statistical quality control over the human failures that plague projects". These human failures must be catalogued in order to learn from their patterns (Collier et al. (1996)). In their research, Collier et al. (1996) found out that the post-mortem process is widely neglected in many companies. In a survey of 92 medium-sized Management Information System (MIS) -organizations, more than one fifth neglected the method completely. In addition, Collier et al. (1996) point out that "of the companies that did conduct them, more than half did so on fewer than half of their projects." Similarly, Von Zedtwitz (2002) discovered in a survey carried out between 1997 and 2001 for research and development (R&D) projects that only one out of five projects had carried out post-mortem processes. On the other hand, McAvoy (2006) observed that most organization do not conduct the process appropriately. The author argues that at the end of projects, project teams are "too exhausted, frustrated, cynical, and fed up to perform the task well". Another

potential explanation behind the low implementation levels is that there is a natural disincentive to conduct a project post-mortem. Open and frank analysis of project failures can be challenging and unpleasant for some individuals within the organization. (Ahonen & Savolainen (2010), Collier et al. (1996)) To alleviate this effect, a commonly well-understood and defined process description with e.g. agreed-upon criteria for evaluation should be established before the process is initiated (Collier et al. (1996)). In their researches, Wang & Stålhane (2005) and Reel (1999) made similar observations. Wang & Stålhane (2005) argue that the participants of the post-mortem process should made aware of the most important and common drawbacks before the process is started. Reel (1999) pointed out that one should announce at the beginning of a project that a post-mortem will be held and define what procedures it will involve.

Collier et al. (1996) further emphasize the importance of a well-defined post-mortem process by stating that "by itself, conducting a postmortem is no guarantee that beneficial change will occur: We have seen projects put out volumes of postmortem findings (80 pages or more) with results so unstructured and vague as not to be actionable." The authors recommend considering five key principles in defining a post-mortem process:

1. Establish "a set of documented, well-understood procedures and guidelines" which are available to each participant before the process is initiated.
2. Establish communication channels which allow discovering "even difficult findings without compromising individual safety." With individual safety, Collier et al. (1996) mean the social wellbeing of the participants. The participants must feel comfortable to take part in the process. They should not feel threatened to speak out on the negative events that occurred during a project.
3. Related to individual safety, ensure to all participants that the post-mortem process is positive and blame-free.
4. Address the frequent concern that "results are destined for a write-only repository and have no effect on future projects."
5. Ensure an adequate balance between the costs of the process, such as the precious working hours of key employees, and the returns on that investment. The returns on investment should include real changes in organizational behaviour.

Taking these five key principles into account, Collier et al. (1996) then present a five-step post-mortem process:

1. *"Design and promulgate a project survey"*. Electronic surveys are a quick and painless practice to collect project information from the project team about a wide variety of project-related topics. Individuals are expected to be more likely to fill them out compared to filling out a paper survey or showing up to a debriefing meeting. Surveys are anonymous and thus do not compromise the confidentiality of the respondents. This increases the sense of security and participation of the team members as they acknowledge that the source of feedback can not be identified. Anonymity also allows more negative feedback to occur which is beneficial in terms of finding areas of improvement in a project. The survey results enable informing and guiding the rest of the post-mortem process in two different ways. First, they help

estimating the severity of the different issues. This way the following post-mortem meetings can be focused to address the key issues. Second, they provide the company quantitative and comparable cross-project data which can be utilized in tracking improvement over time.

2. *"Collect objective project information"*. Collecting objective data that gives indications about a project's health, such as resource costs, schedule predictability and defect counts is crucial in tracking the improvement of a project team. Objective data coupled with measurable project metrics lets a team know if it has met its improvement and project goals. In addition, it allows identifying the real problems and also the magnitude of those problems the team has faced in a project. This knowledge can be utilized in the following post-mortem meetings where valuable time can be used effectively by focusing on the real key issues. Furthermore, in these meetings hard data enables easier discussions around the assessed issues as they are grounded in objective information rather than individuals' opinions and assumptions. Objective data collection also allows comparisons across multiple projects. This enables the project team to examine whether their improvement efforts have had an effect and what the magnitude of that effect has been. A common pool of objective project data also facilitates a learning process. Individuals can for example improve their accuracy in schedule setting as they are able to examine and compare schedule-slippage events in different projects.

3. *"Conduct a debriefing meeting"*. A debriefing meeting is a structured gathering of project team members which gives an opportunity for direct feedback and in-depth discussions about what did and did not go well in a project. It allows individuals to vent in a safe environment and for project managers to scrutinize more closely the positive and negative observed effects. The root causes of problems can be discovered and assessed. Everybody in the project team should be able to take part in the meeting. The survey results navigate the topics of the meeting. Other issues are also often brought up by the participants. The meeting should be coordinated by a distinct facilitator so that the flow and positive atmosphere of the session can be ensured. Another person should act as the bookkeeper, capturing the information and results of the debriefing meeting.

4. *"Conduct a Project History Day"*. Having collected a good amount of actual project data coupled with reflective analysis of project events in the previous steps, Project History Day shifts the focus to address the identified root causes. Based on the information compiled in the previous steps, project management formulates a specific problem statement which becomes the focus of the Project History Day meeting. An example of a problem statement could be "what are the root causes of project events that had an impact on the schedule?" The meeting is not for the entire project team. Rather, the project team members who have the best knowledge and understanding of the key issues, decisions made and project events relevant to the stated problem are gathered together. The selected team members are given the complete set of

postmortem information and data which are compiled up to that point. As with the previous steps, the Project History Day should be organized shortly after the actual project work is concluded. This ensures that the participants have project events fresh in their minds.

One way of arranging the Project History Day is for the participants to start by examining a schedule-predictability chart. The chart depicts all the predicted and actualized milestones in the project. The participants aim at developing a detailed timeline from the start to the end of the project of key project events that are linked to the established problem statement. After such events are identified, a root-cause analysis on each event is carried out. The question of "why did this occur?" is repeated in the search for the causes of each event and the causes of those causes. The best answers to the problem statement i.e. the root causes are then elaborated, compiled into a coherent format and categorized intuitively. The final task of the meeting is to analyze and organize the categories by causal relationships.

5. *"Publish the results"*. Having performed the previous steps, the project team has developed considerable insight regarding the underlying project. There is usually a strong consensus among the participants of the post-mortem process that the conclusions they have arrived at hold true. However, the true value of the post-mortem process is in turning these insights and conclusions into action. Therefore, as the last step of the process the project management team summarizes the findings and puts out a summary report. The summary report focuses on recycling the critical lessons learned in the post-mortem process to guide organizational learning and improvement. The report is delivered to project participants, peers and other project teams in the company. The report includes four parts. First, a brief overview of the project. Second, a summary of the positive findings identified in the process, e.g. successful process changes and working methods developed during the project. Third, a summary of the negative factors, e.g. the identified items during the Project History Day that hampered project performance and ability to meet project goals. Fourth, an improvement recommendation is introduced to fix typically one key issue or problem. This key issue is seen so important that it must be addressed before another project is initiated. In the recommendation, a clear and explicit problem description is provided. Everybody is then able to observe if and when the problem is getting fixed. In addition, specific metrics are introduced to apprehend the degree of the problem and to monitor the progress of improvement.

   To assure that a company benefits from the results of the post-mortem process, i.e. the lessons learned, all post-mortem output (survey results, objective project data, final summary report etc.) should be stored into a central archive that is accessible for everyone in the company. The lessons learned should be categorized based on their functional area or the process they affect. Specific persons should be assigned to be responsible for investigating and implementing a solution for each of the categories. No changes can be expected to happen if nobody in the organization is held responsible of taking action.

2.2 Differences in post-mortem processes

The post-mortem process of Collier et al. (1996) bears resemblance to Schieg's (2007) but is more comprehensive and puts greater focus on the social aspects and inclusivity of the process. Schieg (2007) mostly considers social aspects in terms of the learning of individuals. Figure 7 depicts how the post-mortem workshops enable individual and organizational learning to occur (Schieg (2007)).

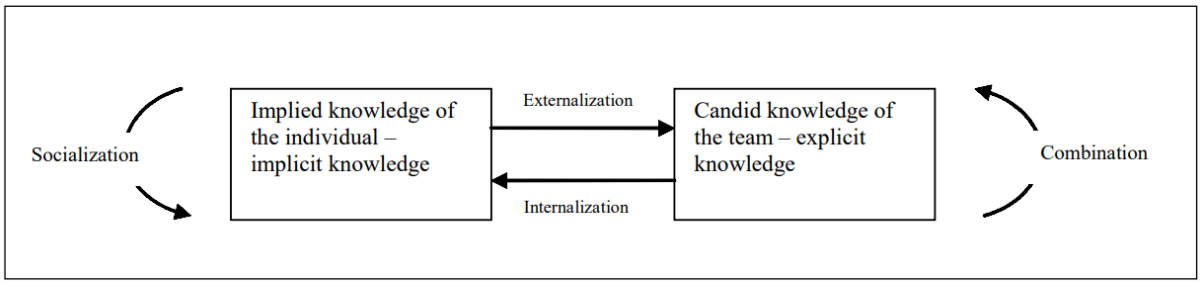

Figure 7. Learning in post-mortem workshops (Schieg (2007))

In the post-mortem workshops individuals reflect on their own methods of project operation and simultaneously receive feedback from other team members. Individual experiences which are difficult to be expressed in written form are shared with the other team members in open discussions. This way, individuals are able to learn from other members' experiences and e.g. get to know those project management and operation methods that were proven positive in the project. (Schieg (2007)) On the other hand, Collier et al. (1996) emphasize the sense of security of the team members in their five key principles. The authors identify that there is a natural disincentive to conduct the post-mortem process due to the proclivity of some individuals to find open and frank analysis of project failures unpleasant. Therefore, it is important to build a safe and structured environment. The sense of security increases participation of the individuals and allows more of the essential negative feedback to come about. (Collier et al. (1996)) Similarly in their research, Stålhane et al. (2003) observed that the post-mortem process needs to be structured. However, too much structuring, such as extensive use of time boxing was seen to have a negative impact on the quality of the process (Stålhane et al. (2003).

The post-mortem workshops work better if a distinct facilitator orchestrates the sessions (Birk et al. (2002), Bjørnson et al. (2009), Collier et al. (1996), Myllyaho et al. (2004), Schieg (2007), Stålhane et al. (2003), Wang & Stålhane (2005)). Bjørnson et al. (2009) argue that the facilitator is a bottleneck in terms of productivity of the post-mortem workshops. Stålhane et al. (2003) argue that the facilitator should be an external person from the project team as an internal person may hesitate to bring forth sensitive issues. On the other hand, Birk et al. (2002) stated that the facilitator can be either an external or an internal person. An external facilitator is regarded by the participants as more neutral and unbiased, but he may not know the company as well as an internal facilitator. Therefore, when an external facilitator is utilized, proper preparations are important. (Birk et al. (2002)) Collier et al. (1996) and

Schieg (2007) made a similar statement and highlighted that the facilitator should be an expert who knows the project operations in detail.

Unlike Schieg (2007) overlooks the issue, Collier et al. (1996), Myllyaho et al. (2004) and Reel (1999) argue for inclusivity of the post-mortem process in the sense of publishing the results for not just the members inside the project team but for everybody in the organization. Also unlike Schieg (2007), both Collier et al. (1996) and Myllyaho et al. (2004) argue for allocating responsibilities in the post-mortem workshops. The specific process improvement actions defined during the workshops should be assigned for specific persons in the organization. No changes can be expected to happen if nobody in the organization is held responsible of taking action (Collier et al. (1996)). Reel (1999) made a similar argument in his research. The author states that without putting the improvement recommendations into action, the benefits of the post-mortem process would remain only marginal.

2.3 Adapting the post-mortem process based on project size

Birk et al. (2002) argue that the post-mortem process is in general "an excellent method for knowledge management" especially for small and medium sized companies that can not afford extensive knowledge management investments. However, the authors observed that companies use the method mainly in large projects. Schieg (2007) and Collier et al. (1996) provide only little remarks about how the post-mortem process should be adapted based on the project size. Similarly, Stålhane et al. (2003) did not address the question of project size but suggested that either a general unfocused or a focused post-mortem process can be utilized. The general method covers a project broadly when the focused method is used to concentrate on understanding and improving a single activity (Stålhane et al. (2003)). Myllyaho et al. (2004) emphasize that it is essential to recognize a demand for a small or "lightweight" post-mortem process which manages to provide quick feedback for a company. A lightweight process consists of iterative post-mortem workshops rather than of one larger workshop held at the end of a project. The lightweight workshops are held between every one to four weeks. They are short and effective. The average duration can be less than two hours so that the sessions do not take too much time and effort but manage to yield prompt and visible results. The lightweight workshops consist of group discussions, problem-solving brainstorming and generating collective process improvement actions. A facilitator orchestrates the session. The focus is on improving and adapting current processes ongoing in a project based on the experiences of previous iterations, rather than merely learning from the experiences of completed projects. Outcomes of the lightweight post-mortem workshops allow the project team to change their daily working practices to better fit the ongoing project. These outcomes can also be utilized in wider perspectives in the organization. (Myllyaho et al. (2004))

In addition to smaller projects, the lightweight post-mortem process can be utilized in larger organizations which are broken into smaller and more manageable teams (Myllyaho et al. (2004)). For average and larger size projects, Myllyaho et al. (2004) recognize the feasibility

of the post-mortem process proposed by Collier et al. (1996). However, it is not trivial what determines whether a project is small, average or large sized. Finding a common definition is challenging due to project size being a subjective measure relative to variable factors such as culture and context. (Myllyaho et al. (2004)) In their research, Myllyaho et al. (2004) set the limit between small and large projects at approximately 30 people taking part in a project. In addition, they found the following definitions in the literature:

- Small projects have a project team of one or two people and a schedule of less than six months.
- An average sized project team involves 150 team members.

These definitions can be used as benchmark values at Rejlers when considering whether the lightweight post-mortem process should be utilized in a project.

3 Research methodology

3.1 Research design

Two different approaches in the study were implemented. First, to assess the company's historical performance in offer calculation in terms of accuracy, a quantitative analysis was implemented. A qualitative research method in the form of expert interviews was implemented in the second phase of the study.

3.2 Quantitative research

The quantitative research method was implemented to get an unbiased view of Rejlers' current offer calculation capabilities i.e. to clarify how accurately Rejlers has historically performed in estimating workloads. The quantitative research method enabled addressing the second sub-objective of the study of "*investigate Rejlers' historical performance in offer calculation."* The quantitative research was implemented in the form of data analysis. The data analysis was conducted by analyzing the historical real numeric project data of Rejlers Finland. The data analysis was carried out both on the whole company level (including all of the divisions of Rejlers Finland), and individually for electrical engineering and automation, and mechanical engineering. Analyzing the whole company gives the two individual fields a useful reference point i.e. a benchmark to compare and assess their relative performance.

The desired project data was available in Excel format and it was abundant. The analyzed data set covered Rejlers' projects between the years 2014 and 2018. The data contained the information of the estimated and actualized workloads per each project. The estimated and actualized workloads were denoted as sums of working hour in the data. The workload estimations were based on the initial offer calculation process. The actualized workloads were based on the amount of realized and invoiced working hours per project.

Only projects marked as complete in the project database of Rejlers were included in the data analysis. Completed projects which were not still underway at the time of this study give proper indication about Rejlers' estimating abilities. Very small projects (workload estimate less than 50 working hours) were excluded from the data. A proper offer calculation process is not conducted at Rejlers for such small projects. The workload estimates are subjective, i.e. they are purely based on the intuition of the project manager. In addition, clearly corrupted projects were excluded. The exclusions were carefully assessed and conducted. Each of the excluded project was deemed to be corrupt in one or more ways:

1. The estimated workload was absurdly low compared to the sum of actualized working hours. For these projects the estimates were usually recorded at exactly 10 working hours. The minimum working hour requirement to open a project in the enterprise resource planning system of Rejlers is 10 hours. Therefore, it was assumed that when a project finished with significantly more hours, the initial estimate of 10 hours had not been updated accordingly as the project proceeded. The initial (corrupt) estimate was left uncorrected and recorded to the final project data.
2. The actualized workload could be absurdly low compared to the initial estimate. In these cases although a project was marked as completed, it was assumed that the project had not been finished as was originally planned. In other words, it was assumed that the project was for whatever reason discontinued before planned completion. For example, the customer could have ran into financial issues.

The corrupted projects were excluded within certain boundaries. To avoid subjective failures in judgement, the boundaries were considered together with a small team of experts from Rejlers. Finally, deliberate boundaries were set. Only projects where the relative difference between the estimated and actualized workload was more than 75 percent were excluded. For example, a project where 1000 working hours were estimated and upon conclusion 200 hours were actualized, the relative difference is 80% (>75%) and the project was excluded.

3.3 Qualitative research

3.3.1 Expert interviews

The qualitative research method was implemented to get a deeper view of how project reviews and quality control of the offer calculation process have been historically conducted at Rejlers without a common post-mortem process. The qualitative research method enabled addressing the third sub-objective of the study of "*identify what kind of post-mortem methods have been utilized at Rejlers."* The qualitative research was implemented in the form of expert interviews. The expert interviews were perceived to reveal insights and justifications which the data analysis alone could not have done. For example, the numeric results of the data analysis, their validity, and potential reasons explaining the observed results could be reflected to reality on a practical level with the interviewees.

3.3.2 Selection of the interviewees

Due to the limits set by the scope of the study, the interviewees were exclusively selected from the fields of electrical engineering and automation, and mechanical engineering. Additionally, a 50/50 balance between people participating in the study from both fields was sought after. In addition to currently working in either of the fields, there was only one mandatory prerequisite for being a candidate for the interviews. A candidate had to have major experience in the offer calculation process either at Rejlers or at another technical consultancy. Fortunately, such candidates were in abundance.

Due to the abundant candidate base, the candidates were ranked based on a few factors. First, from the project data of Rejlers it was possible to find out the amount of offers each person had created and submitted to a client. It was assumed that when a person was in charge of creating an offer for a project, he also conducted the offer calculation for that project. Secondly, the date of each created offer was known. Hence, the higher number of offers created and the more recent the offers, the higher the ranking of the person. The best ranked candidates were regarded to possess the most topical knowledge and experiences about offer calculation specifically at Rejlers.

Depending on the geographic location of their home office, the candidates were first contacted by email or face to face. When contacting a candidate by email, each was sent a generalized interview request where the underlying subject and motivation of the study were explained. The best ranked candidates were preferred in the order of contacting. Not every person agreed to the interview request. Most of the declining candidates stated that they had major scheduling issues.

3.3.2 The interview questions

The interview questions were formulated together with the thesis instructor from Rejlers. The questions were built on the gathered post-mortem process knowledge from the literature review. The three key principles of Yin (2009) regarding how interview questions are composed in case studies were utilized in formulating the questions.

1. The questions should be posed in a *"why"* or *"how"* format. These formats are explanatory in their nature and manage to provide more comprehensive answers compared to *"what"* questions.
2. The behavioural events of the interviewee should not be controlled by the interviewer to a large extent. For example, the interviewer must not navigate the direction of the interviewee's answers too much by putting words to his mouth or suggesting predetermined answer alternatives.
3. Questions should be related to finding answers to the key issues of the present day. Questions where the past is assessed the main sources of evidence for the interviewer are "primary documents, secondary documents, and cultural and physical artifacts". Unintended manipulation and flawedness of the answer data may occur due to inaccurate reflections of the history by the interviewee.

The first interview was used to validate the questionnaire form. Based on the received feedback, the final questionnaire form (Appendix X) was composed and utilized for the rest of the interviews. The interviewees were well informed in the contacting phase about the topic of the study. The questionnaire form was not sent or shown to the interviewees in advance. By utilizing the ranking method, it could be assumed that each of the interviewees was familiar with the subject and could provide proper answers without major preparation. It was considered that major preparations could have led to biased results. Most of the interviewees are tightly networked and engage in discussions with each other on daily basis. Thus, as most of the interviewees were contacted within a short time frame, some of the interviewees could have started to contemplate the questions together in advance. This could have led to some degree of undesired homogenization in the answers.

3.3.3 The interview sessions

Due to the highly scattered geographic structure of Rejlers, many interviews took place online via Skype or Microsoft Teams. All of the online interviews were recorded by the approval of the interviewees. All of the face to face interviews took place at Rejlers' office in Vantaa. One hour of time was initially reserved for each interview. The questionnaire form dictated the direction and frames of the interviews. However, occasional elaborating questions outside of the questionnaire form were used if the original answer was not clear enough or remained too open without concrete substance. Table 1 summarizes information about the interviews.

Number of interviews	Average working experience in technical consulting (years)	Average length of interviews (minutes)
24	20	30

Table 1: Interview information

3.3.4 Transcribing the answers

After each interview, the online recordings or notes from the face to face interviews were assessed and the answers were transcribed into the questionnaire form. Unnecessary filler words and irrelevant sections of the answers not related to the scope of the study were excluded. The answers were assessed critically in order to assure that the interviewees had fully understood each question and answered accordingly. If it was considered that the interviewee had not understood a specific question and provided an odd answer, the answer was excluded. To avoid subjective failures in judgement, the exclusions were considered together with a small team of experts from Rejlers.

4 Results

4.1 Quantitative research

A quantitative research method in the form of data analysis was conducted to address the second sub-objective of the study of "*investigate Rejlers' historical performance in offer calculation."* The data analysis was carried out by analyzing the historical real numeric project data of Rejlers Finland. The numeric data analysis could produce the most unbiased results and give an objective review of the company's offer calculation performance. When examined through expert interviews, the interviewees could have had lacking information and bias regarding their own or their colleagues' performance.

The analyses were conducted on the whole company level (including all divisions) and individually for the fields of electrical engineering and automation, and mechanical engineering. Comparable project data outside of Rejlers was not available for this study. Examining the performance of mechanical engineering and electrical engineering and automation alone would not tell much about their relative performance in the bigger picture. Therefore, it was essential to also examine the performance of the whole company. Including the whole company into the analysis gave a reference point for the two individual fields to compare and assess their performance in more depth.

In the analysis, each initial workload estimate of a project (based on the initial offer calculation process) was compared to the final, actualized workload for that project. The differences between the estimated and actualized workloads were analyzed on two levels.

1. The absolute differences were analyzed in terms of how many working hours were originally estimated versus how many working hours were ultimately actualized for a project. A positive difference implies that the initial estimate was bigger than the sum of actualized working hours. For example, if 1000 hours were estimated at the offer calculation phase and 1500 hours were actualized, the absolute difference for such a project would be -500 hours.
2. The relative differences were analyzed in terms of how many percent the sum of actualized working hours differed from the initial estimate for a project. A positive difference implies that the sum of actualized working hours was bigger than the estimate. For example, if 1000 hours were initially estimated and 1500 hours were actualized, the relative difference for such a project is 50 percent.

The results were plotted on frequency histograms. The histograms represent the frequency, or number of times an observation occurs in a data set.

1. The frequency histograms for the absolute differences show on the y-axis the amount of projects where the absolute difference in working hours is within certain values shown on the x-axis. For example, if the absolute difference for a project is 100 hours, the project is counted towards the group with the threshold values of 50 and 150.
2. The frequency histograms for the relative differences show on the y-axis the amount of projects where the relative difference in working hours is within certain values shown on the x-axis. For example, if the relative difference for a project is 10 percent, the project is counted towards the group with the threshold values of 5 and 15.

4.1.1 Mechanical engineering

First, the division of mechanical engineering was analyzed. In total, 329 projects carried out between 2014 and 2018 were analyzed. Figure 8 represents the distribution of the absolute differences for mechanical engineering.

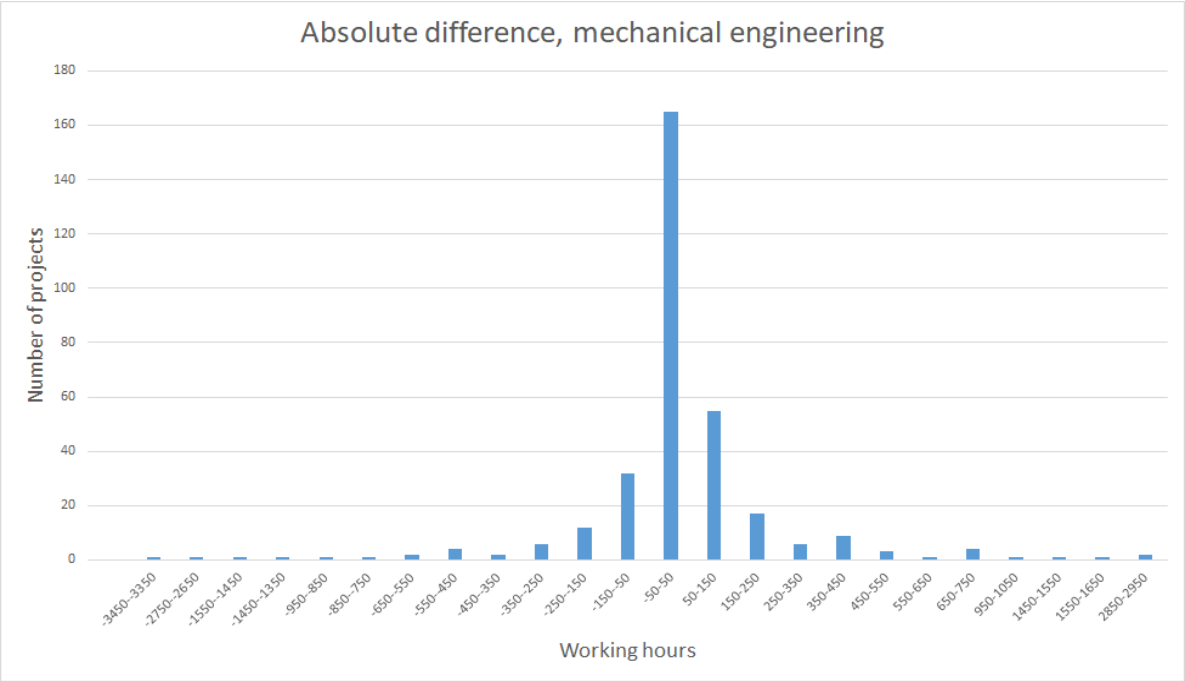

Figure 8: Absolute differences, mechanical engineering

Figure 9 represents the distribution of the relative differences for mechanical engineering.

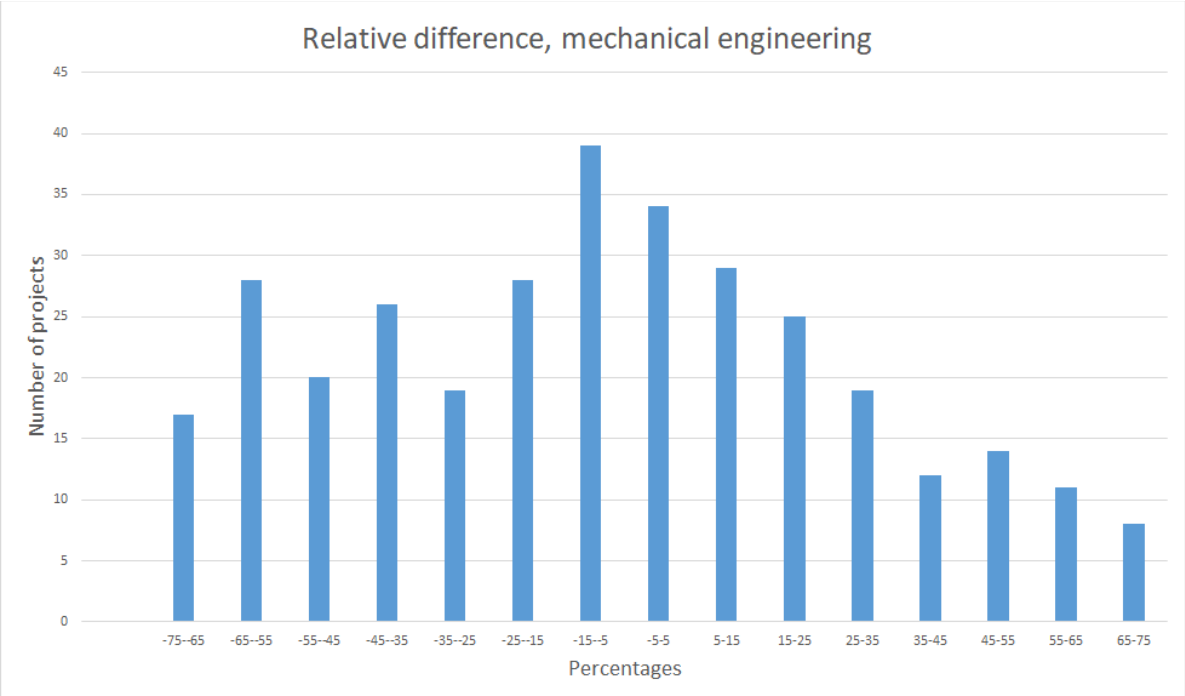

Figure 9: Relative differences, mechanical engineering

4.1.2 Electrical engineering and automation

Second, the division of electrical engineering and automation was analyzed. In total, 331 projects carried out between 2014 and 2018 were analyzed. Figure 10 represents the distribution of the absolute differences for electrical engineering and automation.

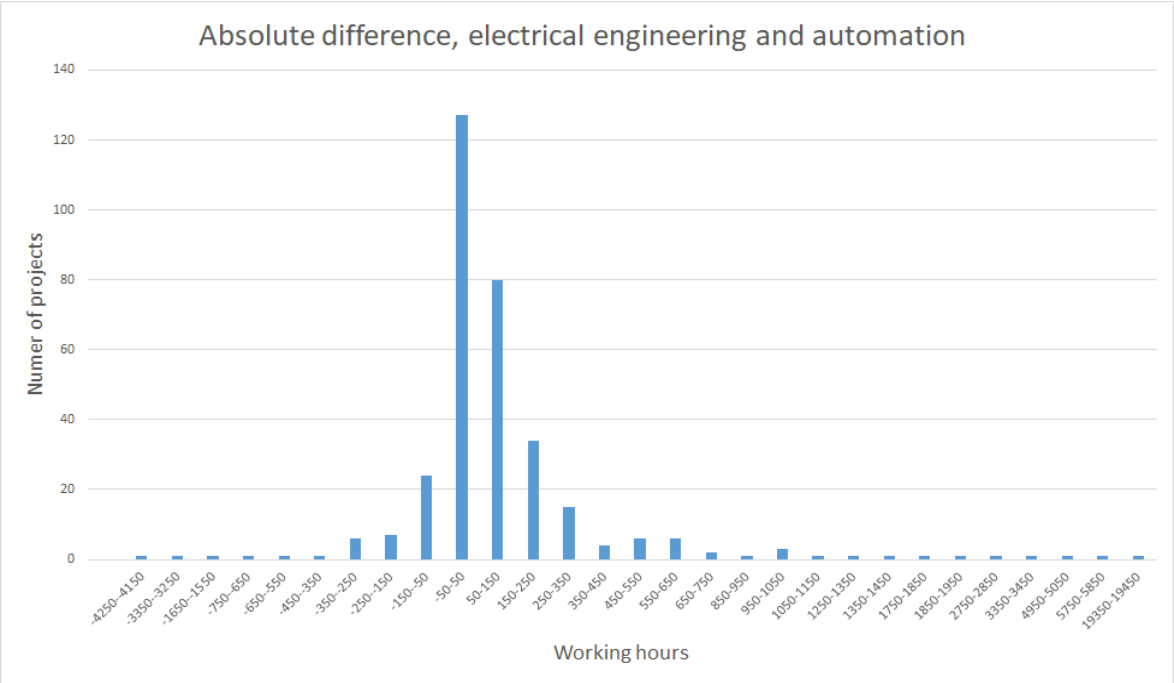

Figure 10: Absolute differences, electrical engineering and automation

Figure 11 represents the distribution of the relative differences for electrical engineering and automation.

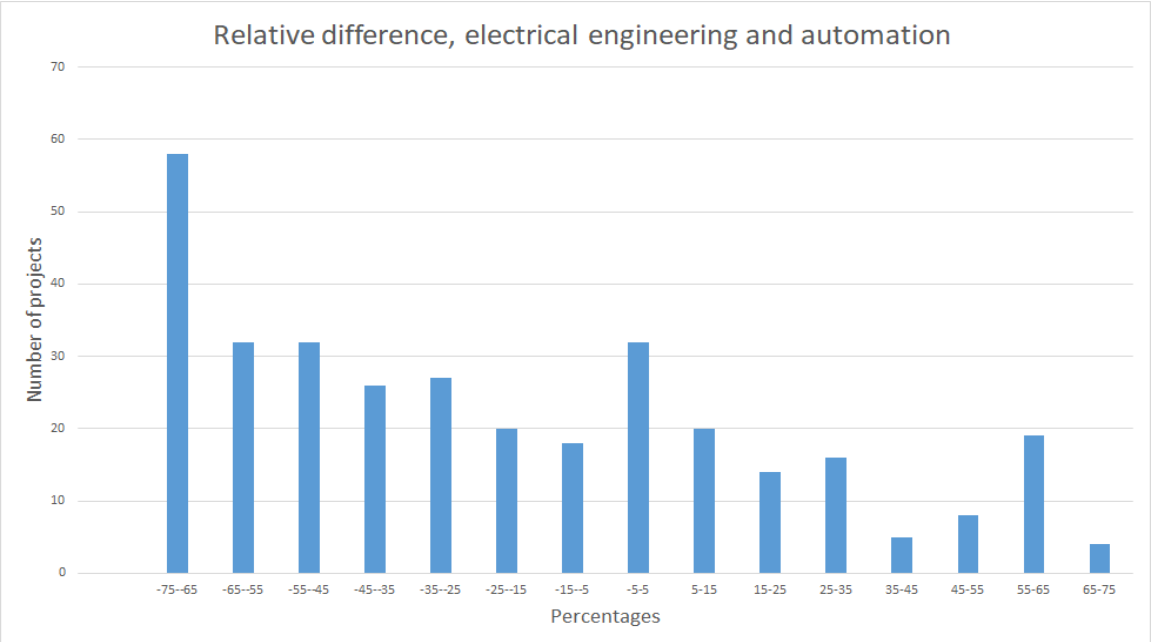

Figure 11: Relative differences, electrical engineering and automation

4.1.3 Whole company level

Third and finally, the whole Rejlers Finland including all of its divisions was analyzed. In total 1185 projects carried out between 2014 and 2018 were analyzed. Figure 12 represents the distribution of the absolute differences for all divisions.

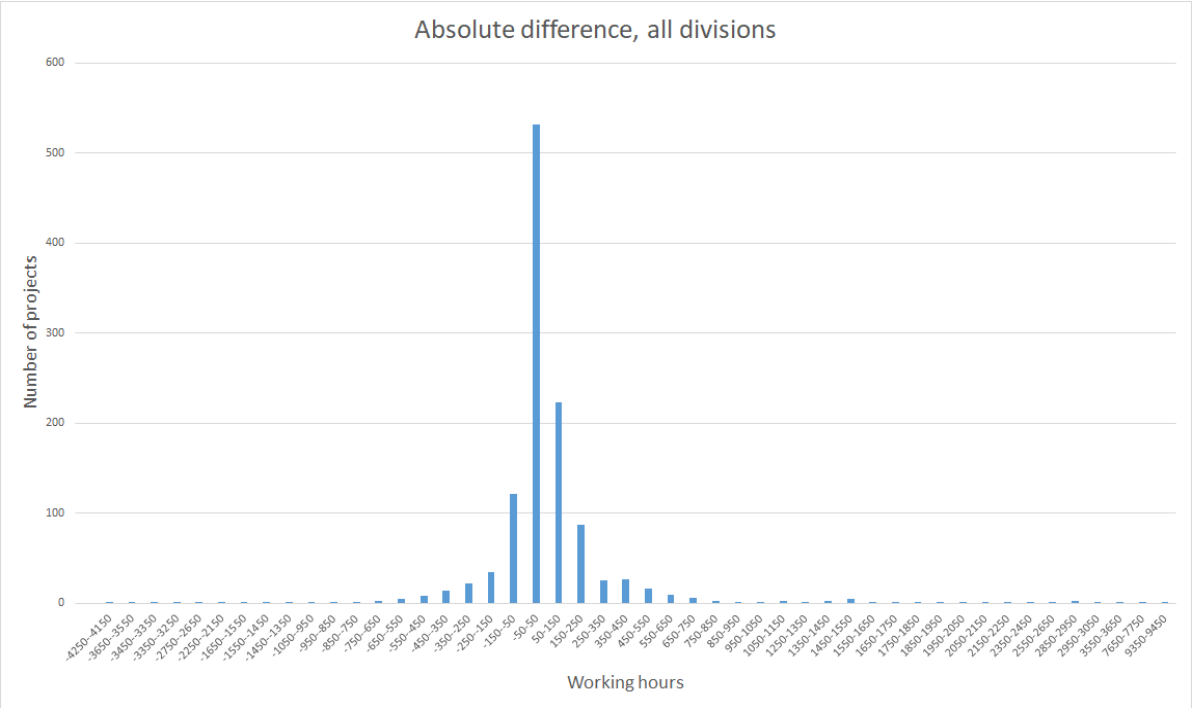

Figure 12: Absolute differences, all divisions

Figure 13 represents the distribution of the relative differences for all divisions.

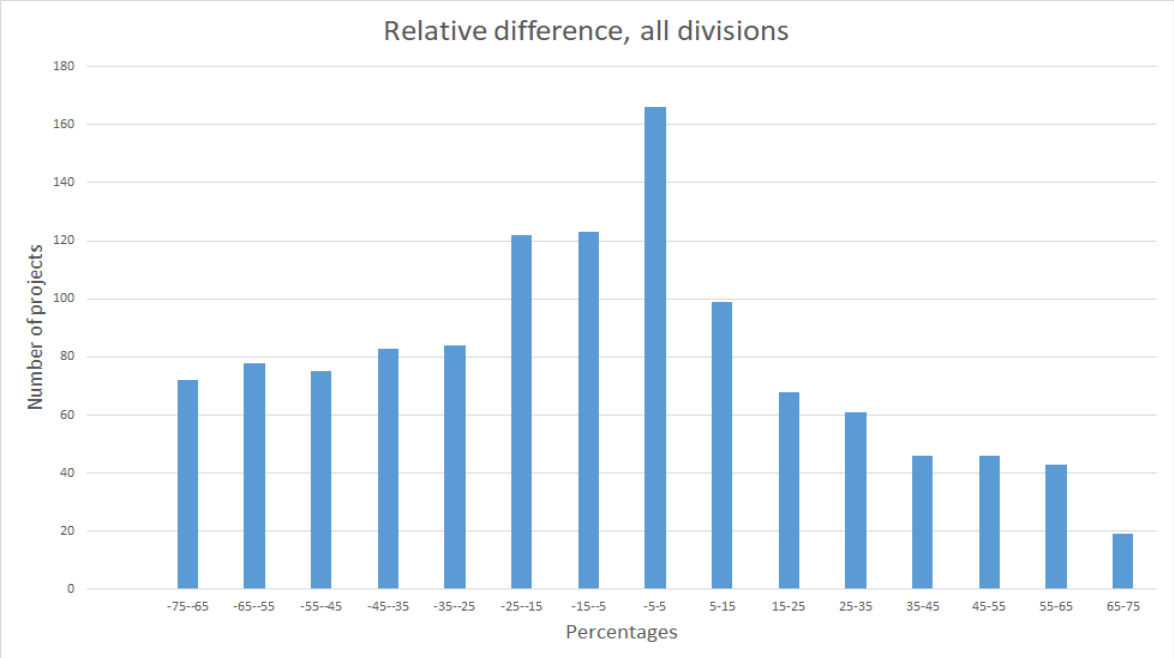

Figure 13: Relative differences, all divisions

4.1.4 Comparing the results

Table 2 summarizes relevant project information and the results of the data analysis.

Division	Mechanical engineering	Electrical engineering and automation	All divisions
Number of projects	329	331	1185
Average estimated workload (hours)	501	669	703
Median estimated workload (hours)	190	235	255
Absolute difference average (hours)	21	183	69
Absolute difference median (hours)	9	45	17
Relative difference average (%)	-8	-21	-9
Relative difference median (%)	-9	-28	-9
Number of absolute misetimations of over 450 working hours	25	34	112
Number of relative misetimations of over 45%	98	179	416

Table 2: Project information and summary of results

Table 2 indicates that mechanical engineering has had the best performance in offer calculation. There are many variables and different factors prone to human failure in the offer calculation process. When taking these factors into account, the experts at Reljers consider an average overestimation of 21 working hours, or 8 percentages a good result for the company when the average estimated workload has been around 500 hours. On the other hand, an average project at mechanical engineering has been smaller compared to the other two fields.

On the whole company level and at electrical engineering and automation an average project has entailed almost 200 hours more. This would partly explain the bigger absolute differences for them. As the projects are larger, also the impacts of errors are larger.

Compared to mechanical engineering and the whole company, electrical engineering has the most room for improvement. The average relative difference at electrical engineering and automation is over 100% higher compared to the other two fields. Furthermore, the ratio between the number of projects where major relative misestimations of over 45% have occurred and the number of all projects per division is significantly higher for electrical engineering and automation compared to the other two fields. This ratio is slightly over 0.5 for electrical engineering and automation. This means that over half of all projects carried out at electrical engineering and automation have resulted in an misestimation of over 45%. The ratio of electrical engineering and automation is almost double of mechanical engineering's even though the two fields have almost the exact same number of projects.

Another observation implies that electrical engineering has the most room for improvement. At electrical engineering and automation, the gap between the average absolute misestimation and the median absolute misestimation is significantly higher than for the other two fields. Simultaneously, the relative amount of projects where major absolute misestimations have occurred does not substantially differ from the other two fields. This would suggest that there is a small number of projects where extremely high misestimations have been made. In general in each of the three cases, the gap between the average estimated workload and the median estimated workload is over 100%. This suggests that the majority of the analyzed projects involve below 250 hours but a relatively small number of extremely large projects raise the average.

4.2 Results of the qualitative research

A qualitative research method in the form of expert interviews was conducted to address the third sub-objective of the study of "*identify what kind of post-mortem methods have been utilized at Rejlers."* The discovered best practices and the accumulated knowledge around them coupled with the findings of the literature review could be leveraged in establishing the post-mortem process at Rejlers. The questionnaire form (Appendix 1) set the structure of the interviews. The interviews started with general questions about the background of the interviewee.

How does Rejlers support its employees in conducting a post-mortem process?

It has been an apparent issue inside Rejlers that the company is lacking a common post-mortem process which the individuals could follow and utilize in conducting post project reviews. Questions 1-3 aimed at revealing if any supporting functions exist to conduct the process. All of the interviewees acknowledged that supporting functions, such as common

instructions, training or tools have not been established. Some individuals have occasionally conducted post-mortem processes utilizing their own methods.

> *"The individuals have been left with the responsibility of organizing and conducting the process by themselves. Common procedures or guidance do not exist."*

> *"On a general level, post-mortem processes are not conducted that often. The systems [of the company] have not historically supported conducting the process."*

The interviewees saw two main reasons to why the post-mortem process has been neglected in the company. First, there has never been an organizational culture which encourages or requires a project manager to conduct the process on even a basic level. Second, although the benefits of the post-mortem process are widely recognized at Rejlers, the process has not been established due to short sightedness. As a project is finished, there is pressure to advance to the next one rather than pause for a while and assess the past project. Most of the interviewees thought that establishing a common post-mortem process at Rejlers would be essential for the development of the company.

> *"There is not a culture which would encourage or even oblige project managers to conduct a post-mortem process. There is always pressure to advance to the next project as soon as possible. Precious learning is not gained as the time is not dedicated to reflect on the done tasks."*

> *"Now it is up to the project manager whether a post-mortem process is conducted or not. A common process does not exist which would tie the project manager to conduct a post-mortem. In many cases there is a rush to the next project so the method is neglected."*

The significance of post-mortem processes in terms of conducting quality control of the offer calculation process was also brought up many interviewees.

> *"At the moment it is difficult to examine our accuracy in offer calculation as post-mortem tools are missing. Without proper data we can not realistically assess and develop our performance."*

> *"Comparisons [between the estimated and actualized hours] are rarely done. There is not a routine to do them. In addition, the project data does not allow detailed analyses. With better data we could e.g. identify where the biggest successes and mistakes were made in a project. Also averages between comparable projects could be calculated and used to make the offer calculation phase more efficient for similar future projects."*

Only a few interviewees stated that a common post-mortem process would not be necessary. The main argument was that there is not enough time to conduct post-project reviews when

new projects are coming up right after the last one has been finished. Many of the more critical individuals were fearful that a common post-mortem process would result in additional mandatory tasks and organizational bureaucracy. These post-mortem related tasks were seen to take valuable time away from more important tasks, such as starting a new project.

Question 4 requested the interviewees to rate how well the company supports individuals in conducting a post-mortem process. The issues brought up in questions 1-3 were given as justifications for the ratings. All of the 24 interviewees gave a rating. The average rating was 1.7, indicating that general view of the interviewees was that the company has room for improvement in terms of providing individuals with further support. Table 3 below shows the results of Question 4.

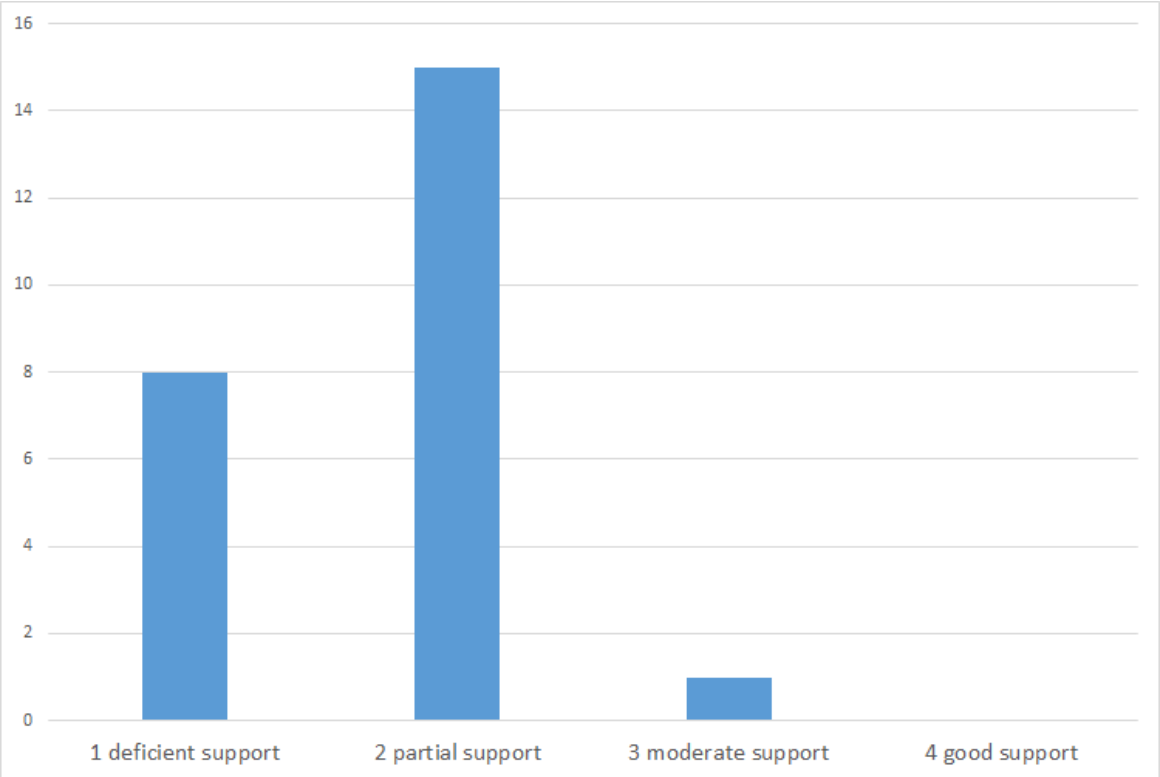

Table 3: Score of how well individuals are supported in conducting the post-mortem process

How do individuals conduct the post-mortem process in practice at Rejlers?

Questions 5-7 focus on the methods of how the post-mortem process in practice is carried out by individuals at Rejlers. Most of the interviewees stated that due to the lack of organizational culture, common practices and time issues they have only rarely conducted post-mortem processes. Comprehensive project assessment and quality control of the offer calculation process are not substituted by some other means but are largely neglected. Post-project debriefing meetings are held for all of the bigger projects and for some smaller ones, especially if something has gone particularly wrong. The debriefing meetings are used for general project assessment. The failures, successes and some key figures are discussed

together with the project team. However, the purpose of the debriefing meetings is more to recap and discuss the project rather than to go deep into specific events or failures and analyze their root causes. According to the interviewees, when the post-mortem processes have been carried out at Rejlers, they have been attached to the post-project debriefing meetings as additional post-mortem workshops.

> *"A post-mortem workshop does not have to take too long. During the post-project meeting an additional 1-2 hours are enough to write a report about the project and produce some key documentations. For example, the final working hours and the deviations [to the initial estimate] due to additional tasks and changes which have occurred during the project should be assessed and documented."*

Common predefined procedures or instructions do not exist on how a post-mortem workshop is organized. Each of the interviewees told that generally speaking the project manager and the project team members have participated in the workshop. The workshops have been based on common discussions where the participants have had the opportunity to discuss about the project and give feedback to each other. Compared to the debriefing meetings, a stronger focus is taken on analyzing the failures in project operations and constituting improvement actions for them. Subjective data has been documented in the form of a project report which includes information about e.g. the successes and errors in project operations. In the workshops objective project data has been collected mostly related to the working hours.

How is knowledge shared inside Rejlers?

Question 8 focuses on a major issue at Rejlers which is that information is not shared throughout the company at a desirable level. For example, to a large extent, the results gathered during post-mortem workshops have not been distributed to other project teams. Many interviewees argued that the company's decentralized geographic structure is largely the reason behind this.

> *"There are so many different offices across the country. It has resulted in the situation where the people from different locations are in general rather disconnected from each other. Generally speaking, each office tends to live in their own bubble. Due to the disconnect, people do not know each other in the sense of who does what and where, who they could best ask for help or who would enjoy a specific piece of information."*

Another interviewee pointed out that the communication systems of the company have historically been poor in terms of promoting knowledge sharing.

> *"Traditionally, there have been no routines regarding knowledge and information sharing. However, recently there have been some changes, for example, the launch of Microsoft Teams [a common communications software] where common channels between different offices have been created. We have been encouraged to actively use*

these channels, which has helped in creating a better culture around information sharing."

Many interviewees pointed out that the launch of Teams has increased information sharing between the offices. However, mainly general information is shared while some useful information is withheld. This has hindered organizational learning to occur.

> *"There is competition to some extent between the offices about, for example, bonuses and budgets. Therefore, some relevant information may be withheld from others. As a result, the different offices and teams might struggle with the same issues which another team has already found the solution to."*

Some interviewees pointed out that there might be trust issues due to the general disconnect between each other coupled with the competitive setting inside the company. Although there may not be any personal issues and the general atmosphere between different offices is good, there is a threshold to engage in an interaction with each other.

How is project data gathered and utilized in the everyday project work at Rejlers?

Post-mortem workshops have been the main method of collecting data at the end of a project for project assessment. Questions 9-10 focus in more detail on the current methods to collect and utilize project data in the everyday work at Rejlers. Many interviews expressed their frustration about systematic data collection methods not existing in the company.

> *"Currently the [project] data is gathered disorderly. The data may not be even found from the same location and the information which the data includes can be extremely confusing. For somebody who has not participated in a specific project it can be close to impossible to interpret the data of that project. It is even problematic for somebody who worked in a project to later go back and assess that project."*

> *"Having one data format which everybody could understand inside the company would be essential. For example, it would be extremely beneficial to be able to look at finished projects when conducting the offer calculation for a new project. If there is a similar past project as the new one, one could obtain and utilize benchmark values from the old project when estimating the workload for the new project. This way the amount of uncertainties in the estimations could be decreased as there is data backing them up."*

Individuals in general tend to neglect any more extensive data collection than what is required from them. For example, when a project is opened or concluded in the database, the project manager is required to give certain project information. In addition, during a project the working hours are recorded but depending on the project manager even that might be done vaguely, resulting in poor data. Besides these mandatory tasks, the organizational

culture and common methods have not been established which would support persistent, detailed data collection and utilization for the long-term development of the company. Some individuals tend to collect more comprehensive data. However, many interviewees stated that they have collected the comprehensive data for their own use. This data can not be found from the company's common systems. These individuals have utilized the data mainly to monitor and review project operations, for example, during the post-mortem workshops.

> *"I often track and record certain factors during the project. Then upon project conclusion, I compare the initial numbers [estimates] with the final ones to spot where the biggest mistakes were made. I can identify for example distinct failures in the offer calculation, or if a certain individual or function has clearly underperformed in that project."*

The main method of collecting more comprehensive project data in the everyday work is that the individuals have their own Excel tool. The tools are used to track and record different factors as a project proceeds. For example, working hours and quantities of different units such as machines, pipelines or electrical circuits are tracked. The interviewer requested the interviewees who had their own Excel tool to share the tools so that they could be utilized in creating the common computational post-mortem (data collection) tool. The best features of each individual tool could be brought together in the common tool.

How have the utilized post-mortem methods performed?

Questions 11-12 addressed how the utilized post-mortem methods are seen to have performed and where they originate from. The general sentiment was that when a post-mortem workshop has been organized, it has been both a positive experience for the project team and a productive utility for the project manager. For the project managers, the workshops have been a success in terms of achieving the objectives set for the sessions. For the project team the workshops have felt like any other regular team meeting.

> *"I tend to organize a post-mortem workshop after a project if clear failures in project operations have occurred. Usually the causes behind the failures can be properly assessed and figured out with the project team."*

> *"During the workshop the most important events which have occurred during the project are discussed together with the project team and some key numbers are examined. This sort of post-mortem workshops are extremely efficient compared to how little time and effort they require. They can produce surprisingly valuable results which are extremely unlikely to come up in normal project operations."*

At Rejlers, common predefined procedures or instructions do not exist on how a post-mortem workshop should be organized. The individuals have learned how to organize the workshops with experience. Also, the utilized Excel tools for data collection have not been provided by the company but developed throughout the years by different individuals themselves.

Would it be worthwhile to tie individuals to follow a predefined post-mortem process?

Question 13 addressed whether the interviewees think it would be essential to tie individuals to always follow a specific, predefined common post-mortem process. Doing so would arguably require significantly more resources than what has traditionally been allocated towards post-project reviews. The general sentiment was that requiring project teams to always follow a specific process would be worthwhile in terms of the long-term development of the company.

> *"[Currently] when a task is finished, very little of the precious learning is gained. The time is not dedicated to adequately reflect on the done tasks. I think it would be useful to have one dedicated individual in the company responsible of organizing and carrying out the post-mortem processes."*

> *"I would allocate adequate resources for a post-mortem process in every major project. In bigger projects, the impacts of systematic failures in project operations and offer calculation are both more evident and significant. In smaller projects, failures are more difficult to observe. It is more efficient for the company to invest into the larger projects where by using the same time, one can achieve much more meaningful results and improvements."*

A few interviewees had critical views about an obligatory process to be followed. Although identifying the benefits, some potential drawbacks were discerned.

> *"It would be obviously beneficial to always conduct the process as some results can be achieved. However, I do not think it would be beneficial to always follow the same common process as the projects and people [in different offices of Rejlers] are so different to each other."*

> *"There is always a rush to start working on a new project right after the last one has finished. Therefore, finding the time for some additional tasks due to a new process would be difficult."*

How is the post-mortem process organized in other technical consultancies?

Question 14 addressed the interviewees' experiences and views about what the best practices are in other technical consultancies to carry out the post-mortem process. Besides the interviews, no further in-depth examination was carried out in this study about the contemporary post-mortem process practices of other technical consultancies. The general sentiment of the interviewees was that generally speaking the post-mortem process is more comprehensively organized by Rejlers' competitors. A majority of the interviewees stated that during their time in other technical consultancies, the utilized methods were mainly similar to the ones that have been used at Rejlers, i.e. post-mortem workshops. However, in many technical consultancies the post-mortem workshops are organized for most projects. In

addition, unlike at Rejlers, some companies have utilized surveys on top of the workshops to collect project data.

> *"I know that many big technical consultancies have their own dedicated post-mortem function. At my previous employer we [project teams] participated in the post-mortem workshops and answered to surveys. The workshops involved discussions with the project team, orchestrated by an outsider from the post-mortem function. However, we did not get to see what they [the dedicated post-mortem function] did with our data and what kind of results were produced by them. The process was like a black box, we submitted our answers but almost never heard anything back related to them."*

A few interviewees stated that they do not have any extensive experience about post-mortem processes in other companies. The situation had been to a large extent similar or inferior to what it is at Rejlers.

Reflections on the results of the data analysis

Questions 15-16 assessed the results of the conducted data analysis from the practical point of view of the interviewees. The practicalities of the data analysis were first clarified to the interviewees, followed by a presentation of the results.

First, the interviewees expressed their views whether the results of the data analysis corresponded with reality. Second, the different behavioural factors which could explain the observed patterns in the results were contemplated. The results show that the absolute misestimations cluster close to zero and major errors have occurred less frequently. In addition, Rejlers has tended to generate overestimations more frequently compared to underestimations. The general sentiment was that the results are logical. Some critical views were also expressed. One explanation to why overestimations have occurred more often than underestimations was that financial incentives motivate the project team to work harder.

> *"The results make sense to me. Especially it is common that people work more efficiently when there is a financial incentive if the project is finished within certain boundaries. The project team tends to push hard so that the incentive is achieved."*

> *"When there is an incentive, the subordinates are more motivated and also the project managers tend to monitor the working hours more closely because they want to secure that the budget is not overrun."*

A few interviewees pointed out that not only do people work hard but it also common to intentionally set a buffer to the workload estimate as a measure of risk management. This would partly explain the frequent overestimations.

"Oftentimes the workload estimate is multiplied with a factor of X so that X-percent of the initial estimate is kept as a risk reserve. Then if the project finishes according to the initial estimate, the risk reserve is still received as it was included in the contract price which the customer is committed to paying."

"Because it can be extremely hard to justify to a customer why the initial budget was or is about to be overrun and why the customer should pay for that "extra" work, safety coefficients are commonly added on top of the initial workload estimate to avoid such inconvenient situations. It can never be assumed that the customer will agree to pay for the "extra" hours, so the potential losses which would occur for Rejlers can also be avoided."

There are a few explanations to why still most of the observations in the results clustered close to zero regardless of the tendency to deliberately generate overestimations or to work harder, which artificially results in overestimations in the project data.

"When the customer pays per performed working hour rather than a fixed price for the whole project, an agreement is still made about a certain workload and schedule for a project. For example, an agreement may be made that the customer pays X price per hour for the first 200 hours, 50% of X for the next 50 hours and so on. Then there is a natural economic incentive to at least utilize the whole 200 hours for that project because the customer is committed to paying the full price from them."

This would imply that in many projects, especially when the customer pays per hourly rate, the working pace is adjusted so that all of the reserved working hours are utilized and invoiced from the client. However, there are also other reasons to why the observations in the results of the data analysis cluster close to zero.

"It happens a lot that at the end of the project, if the initial workload estimate was exceeded, the customer makes an additional work order from the exceeded hours. Then the workload estimate is updated in the enterprise resource planning system accordingly to adjust the balance [estimated versus actualized] to zero."

"The enterprise resource planning system of Rejlers has some built in automation for handling projects. It is possible to allow the system to automatically update the estimated workload section based on the recorded, actualized hours. For many of the projects the balance [estimated versus actualized] has been automatically adjusted to zero by the system."

These observations imply that there are factors which may have caused manipulation in the analyzed projects. However, it was not possible to identify and exclude specific projects where such manipulation had occurred.

Critique on the validity of the results of the data analysis

In addition to the limitations related to the project handling practices and enterprise resource planning system of Rejlers, also other rather critical views about the validity of the data analysis came up. One interviewee highlighted that there are too many variables which can not be adequately measured in order to draw conclusions from the results.

> *"It can be extremely hard to draw any definite conclusions of the workload estimating accuracy of Rejlers. There are too many variables which influence the results but are impossible to weigh. For example, people and project teams adjust their working efficiency based on the job situation. When there is much work to be done and new projects are coming up, people work much harder. However, when new projects are not in sight, it is made sure that every hour which can be invoiced is utilized. Therefore, in many cases one can not say if the initial estimate was accurate or inaccurate compared to the actualized hours as project teams adjust their working pace depending on what is considered best in that specific situation."*

One interviewee pointed out that when a financial incentive is set for a project, some individuals tend to manipulate how they record their working hours.

> *"When there is a financial incentive for a project, some people may occasionally optimize how they record their working hours and other expenses towards the project. Some of these expenses are recorded elsewhere where an incentive is not set. This way, the incentive is reached as the budget artificially stays within the set limits."*

Another person pointed out that when an incentive does not exist, quite the opposite can occur.

> *"In some cases when there is a fixed contract price but no incentive exists for the project team, some individuals may record extra hours towards the project. The client is not there to complain about these extra hours because the client is committed to paying the fixed contract price."*

These two observations arguably speak of the same phenomenon: when an incentive does not exist for a project, some extra working hours both inside and outside of that project can be falsely recorded towards it. Assuming that a financial incentive exists in most projects, such phenomenon has arguably artificially boosted the frequency of overestimations in the analyzed projects.

5 Discussion

5.1 Data analysis

5.1.1 The past performance in offer calculation

Based on the results of the quantitative research method, the company's offer calculation performance has room for improvement. Mechanical engineering has performed relatively well while for electrical engineering and automation there are still more areas of development. In general, there are opportunities for further enhancements in mechanical engineering, electrical engineering and automation, and the whole company. Figures 9, 11 and 13 each indicate that major relative e.g. greater than +/- 50% over- and underestimations have occurred frequently. Similarly, figures 8, 10 and 12 each indicate that major absolute misestimations have occurred frequently. These observations would imply that there are major issues with the offer calculation practices at Rejlers in terms of accuracy. However, the situation is not necessarily as alarming as the observations might suggest in the first place. Figures 8, 10 and 12 each indicate that most of the misestimations cluster close to zero. For a clear majority of the projects, the absolute magnitude of the misestimations is on the level of 0-150 working hours. This would imply that most of the more radical relative overestimations and underestimations in the company have occurred in the relatively smaller projects. For example, for electrical engineering and automation, a major misestimation of over 45% has occurred in 179 projects. On the other hand, a major absolute misestimation of over 450 working hours has occurred only in 34 projects. This observation implies that at electrical engineering and automation, the clear majority of the major relative misestimations have occurred in smaller projects. In a smaller project a misestimation of tens of working hours can cause a major relative difference. Such a small absolute misestimation, although obviously undesirable, does not arguably cause major damage in terms of project quality or finances.

5.1.2 Overestimations versus underestimations

The results show that the offer calculation process at Rejlers has tended to generate pessimistic workload estimations. On average, the projects have finished with less actualized working hours than what was estimated. An overestimated workload in a project is not always necessarily bad for Rejlers. This is the case especially when a project is sold with a fixed price i.e. a piecework pay. The contract price of a project is based on the workload estimate derived from the offer calculation process. The bigger the workload estimate the higher the price for a project. If the project finishes with less actualized working hours than what was estimated, the surplus hours are still paid due to the customer being committed to paying the agreed fixed price.

Overestimations have their downside too. An overestimation of resources for one project implies less resources available for other projects and business opportunities (Odusami &

Onukwube (2008)). When a project's invoicing is based on an hourly rate, i.e. the customer pays per performed working hour, an overestimated workload leads to non-optimal resource allocation and efficiency losses. Efficiency losses occur when Rejlers is not able to charge all of the estimated working hours from the customer after having already allocated its resources according to the estimate. For example, employees may have been committed towards a project which is finished sooner than planned. If a new project where they can be allocated to is not found quickly, they might remain unoccupied for a while.
An overestimation can also create the problem that the estimate becomes self-fulfilling. The tasks in a project take longer than what they would have done with a more accurate estimate. There are two common theories in the literature to why such behaviour repeatedly happens. First, Student's Syndrome argues that people oftentimes do not start working until close to a deadline. Second, Parkinson's Law argues that work expands to fill the time available. However, as also many interviewees pointed out, as long as the customer pays for the tasks, the cost of overestimation is low for the company. The tasks might take longer than they should do but as long as the customer is happy, no major negative impacts occur.

An overestimation is arguably less bad than an underestimation. When not enough resources are allocated towards a task, two things can happen. First, the task is done at lower quality. Second, the task is not done on time and the schedule is overrun. Any tasks dependent on the delayed task are pushed out. In addition, with an overestimated workload the schedule is not overrun. Schedule compliance can be regarded as an success factor for a company. Project schedule delays increase customer dissatisfaction and potential for disputes. Delays can lead to lower productivity and morale of the workforce. (Dumont et al. (1997)) Underestimating and mismatching project design and requirements can come with great costs later in the project if changes and adaptation actions turn out to be necessary. Late project dynamics can ultimately make the project take longer than it would have with a more pessimistic estimate. For example, in his research, Clark (1989) observed that even modest changes (on the order of 10 percentage points) in project scope may change overall project lead time by four to five months. Such delays can have a major negative impact on the profitability of a project.

5.2 Expert interviews

5.2.1 Overview of the current situation

The expert interviews give a pessimistic view on how post-mortem processes are utilized at Rejlers. A common process and the supporting functions are missing. The organizational culture at Rejlers does not particularly encourage individuals to conduct post-mortem processes. As a project is finished, there is rush to start working on the next one right away. Only a few individuals tend to conduct post-mortem processes more often. Unlike what a few interviewees stated about other technical consultancies and what e.g. Collier et al. (1996) suggested, project surveys have not been utilized at Rejlers. Bjørnson et al. (2009) argue that by using a nominal group technique, such as surveys, certain issues related to large group discussions can be avoided. First, production blocking i.e. the impossibility of participants to

speak at the same time can be prevented. Second, the influence of evaluation apprehension i.e. the fear of negative appraisal from other participants can be alleviated. Third, the amount of free riding can be decreased. During a large group discussion, it is easy to remain silent and leave the discussion to the others. (Bjørnson et al. (2009))

A sub-objective of this study was to identify what kind of post-mortem methods have been utilized in the company. Post-mortem workshops attached to the post-project debriefing meeting at the end of a project have been the preferred method of carrying out the post-mortem process at Rejlers. Usually, the project manager and the project team members have participated in the workshops. Collier et al. (1996) and Stålhane et al. (2003) suggested that a separate debriefing meeting should be organized for the whole project team. The meeting is used for common discussions, feedback and project data collection. The meeting is coordinated by a distinct facilitator. A separate "project history day" meeting is then organized for the key project team members where the data gathered at the debriefing meeting is analyzed (Collier et al. 1996). At Rejlers, an outsider facilitator has not been utilized in coordinating the post-mortem workshops. The downside is that the workshops might turn out to be unprofessional. Some interviewees admitted that when they have organized a post-mortem workshop, the workshop has not been effective. A large portion of the time the focus may be on something irrelevant, for example, discussing the daily news. Here, a distinct facilitator would ensure efficient use of time. Also, only one meeting (the post-mortem workshop) has been organized at Rejlers rather than two separate meetings. The risk here is that a single workshop may only provide superficial results. Some of the interviewees mentioned that they typically reserve 1-2 hours for a post-mortem workshop. During a single meeting that is such short, the time is likely not enough to collect a significant amount of project data and to analyze it in depth.

According to the interviewees, the outcome of post-mortem workshops at Rejlers has been a project report. The report includes information about the identified successes and errors in project operations. However, little focus on improvement actions are given. Collier et al. (1996), Reel (1999) and Schieg (2007) emphasize that the insights and conclusions gathered during the workshops should be turned into action. The authors argue that this happens by e.g. introducing improvement actions in the project report to fix the observed issues. Responsibilities of implementing these improvement actions should be assigned for specific persons in the organization (Collier et al. (1996), Myllyaho et al. (2004)). Another issue with the project reports produced at the post-mortem workshops at Rejlers has been that the results have been largely withheld inside the project teams. The reports have not been actively shared across the company. Collier et al. (1996), Myllyaho et al. (2004) and Reel (1999) argue for publishing the results to project participants, peers and other project teams in the company. This way the lessons learned in the post-mortem process of one team are recycled across the company, allowing organizational learning to take place.

5.2.2 Knowledge sharing

Many interviewees stated that the launch of the new communications channel has increased the amount of knowledge sharing inside the company. Still the geographic disconnect and the competitive situation between different offices have contributed towards retaining some barriers. Taylor & Wright (2004) argue that the main barriers to implementing knowledge management are people related. This observation implies that at Rejlers, establishing the communications channels alone do not suffice in improving knowledge sharing between the different offices to a desirable level. Rather, as for example Guptara (1999) emphasizes, building a collaborative culture is essential. The organizational climate has a significant impact on promoting knowledge sharing in a company. When individuals perceive a higher degree of collaborative atmosphere inside a company, they are more likely to build up interactive relationships with each other (Chen & Huang (2007)). If the atmosphere is bad, other attempts to increase knowledge sharing may be pointless (Tohidinia & Mosakhani (2010)).

According to many interviewees, the atmosphere between the different offices has been good as such. However, the issue at Rejlers has been what Tohidinia & Mosakhani (2010) called "the lack of an aspiring culture to communicate". Some interviewees pointed out that historically each office has lived in their own bubble. There has been room for improvement in terms of establishing routines which would encourage tight communication between the different offices. Through the implementation of the new communication channel the collaborative culture around knowledge sharing has only recently started to significantly develop. Tohidinia & Mosakhani (2010) highlight that the absence of a clear reward and recognition system can discourage individuals to share their knowledge. Similarly, Taylor & Wright (2004) state that the lack of perceived benefits may act as a major knowledge sharing barrier. At Rejlers besides social rewards, such as getting complimented or thanked by a colleague, there have not been incentives for individuals to share knowledge with others. By establishing a rewarding system, the company could further incentivize knowledge sharing. In addition to the reward system, reciprocity i.e. a "give and take" attitude should be promoted inside the company. Jeon et al. (2011) argue that reciprocity functions as a crucial motivational driver for individuals engaging in social exchanges such as knowledge sharing.

5.2.3 Data collection methods

Many interviewees argued that there is room for improvement in the project data collection methods at Rejlers. Schieg (2007) and Collier et al. (1996) emphasize the role of project data in the post-mortem process. During project operations project data gives indications about a project's health. As a project is finished, project data can be used to assess project operations and formulate improvement actions. Guptara (1999) observed that many organizations are simply too busy to make a knowledge management system function well. Based on the expert interviewees, this observation applies to Rejlers as well. At Rejlers, only a few individuals have collected comprehensive project data during projects. These individuals have used their own unique data collection methods as common ones are missing. The data has been largely

kept to oneself. This has resulted in the situation where the common project database of the company has become meager in terms of the quality of the data. Many interviewees stated that the project data is disordered, i.e. the data is found in many different formats. The different formats are in many cases impossible for others in the company to understand, making the data unusable for them. As a result of the plurality of the formats, it has been difficult to make comparisons across multiple projects. The computational post-mortem tool will specifically be developed to tackle this issue. Collier et al. (1996) argue that comparisons across projects allows e.g. examining whether improvement efforts have had an effect and what the magnitude of that effect has been. Similarly, many interviewees highlighted that it would be essential to be able to look at past projects when conducting the offer calculation for a new project. One could obtain and utilize benchmark values from past similar projects when estimating the workload of the new project. Being able to compare projects also facilitates a learning process. Individuals can examine other projects and learn from them. For example, when the failures of a past project are carefully documented, others can learn from them and prevent making the same mistakes in their own work.

5.2.4 Post-mortem workshops

The general view of the interviewees was that the post-mortem workshops organized at Rejlers have been a positive experience for both parties, the organizers and the participants. For the organizers i.e. the project managers, the workshops have been successful in terms of achieving the goals set for the sessions. The participants i.e. the rest of the project team felt that the workshops had been just like any other team meetings. However, when considering how the post-mortem workshops should be organized in the future at Rejlers, a factor highlighted by Ahonen & Savolainen (2010) and Collier et al. (1996) must be taken into account. There is a natural disincentive to conduct a post-mortem workshop. Certain individuals can find it challenging and unpleasant when project failures are openly analyzed together. To alleviate this effect, the authors emphasize the importance of a safe and structured environment in the workshops. Security increases participation of the individuals and allows even difficult issues to be discussed (Collier et al. (1996)). More of the negative feedback is received when the participants feel safe and are comfortable to speak their mind honestly. Negative feedback is essential for the company in terms of identifying the root causes of failures in project operations and creating improvement actions to fix them. At Rejlers common guidelines on how to organize the workshops have been missing. Collier et al. (1996), Reel (1999) and Wang & Stålhane (2005) argue that it is essential to establish a set of documented, well-understood procedures and guidelines on how the post-mortem process is organized. These should be made public inside a company. To ensure the safety of each participant, they should understand and approve the common evaluation criteria and rules before the post-mortem process is initiated.

It must be recognized that regardless of any kind of process guidelines, not every person will feel comfortable to speak their mind during common discussions in post-mortem workshops. Therefore, other communication channels should also exist. Collier et al. (1996) state that

during the post-mortem process it is important to establish channels which allow assessing difficult things without compromising individual safety. At Rejlers, such channels already exist on a general level. Employees can give anonymous feedback to the management. The management periodically publicizes their responses to the given feedback for the whole company. This method has been proven to function well. It could be extended to the post-mortem workshops. For example, the post-mortem surveys should be anonymous to not compromise the confidentiality of the respondents (Collier et al. (1996)). In addition to the more specific questions in surveys, the respondents could have the opportunity to give open feedback.

5.2.5 Establishing a predefined post-mortem process

The general sentiment was that requiring project teams to always follow a specific, predefined post-mortem process would be worthwhile in terms of the long-term development of Rejlers. According to many interviewees, doing so would be essential for the company even though it would arguably tie additional resources from other tasks. For example, many interviewees stated that currently as post-mortem processes are not conducted, the learning which could be gained from assessing project operations is lost. After a project is finished, the project team rushes to the next one. If attempts are made to assess a past project, it can be impossible to remember specific events in detail or understand the project documentation. Myllyaho et al. (2004) made a similar observation in their own research. However, Schieg (2007) and Collier et al. (1996) argue that an adequate balance between the costs and returns of the post-mortem process should be ensured. To ensure the balance, the post-mortem process should be adapted and conducted differently in each project. What this could mean at Rejlers in practice is that different post-mortem process guidelines are established for different project sizes. It would be inefficient to use the same exact practices for a large project and for a small project. For example, in a large project the post-mortem workshop could require multiple hours. For a smaller project, a quicker one suffices. Myllyaho et al. (2004) emphasize that it is essential to recognize a demand for a "lightweight" post-mortem process. The lightweight process could be utilized at Rejlers especially in larger projects. Myllyaho et al. (2004) proposed that lightweight workshops should be held between every one to four weeks. These are short and effective. By organizing workshops (even though quicker ones) regularly and between shorter time periods, the workload does not stack till the end of the project. Also the collected data and discussions can be expected to have higher quality as project events are fresh in mind. The improvement actions can be implemented and changes made during project operations rather than after the project. This way the changes will already affect the performance in the ongoing project and not only the tasks in future projects.

5.2.6 Post-mortem processes at other technical consultancies

According to most of the interviewees, Rejlers' average competitor has managed to organize the post-mortem process more comprehensively. Unlike at Rejler, both post-mortem

workshops and surveys have been used. Post-mortem processes are conducted more frequently, in some technical consultancies for most projects. However, the situation is not necessarily as alarming as it may first seem. Some interviewees signaled that although the post-mortem practices of Rejlers' competitors might be at a higher level, that level may not be that high after all. There had been some major shortcomings. For example, one interviewee pointed out that after his project team had participated in the post-mortem workshops, they rarely heard back from the workshop facilitators. There was a disconnect between the participants and the facilitators. The results of the post-mortem process were not shared with all of the participants of the workshop. Such observations imply that closing the gap between Rejlers and its competitors is not beyond the company's reach. Also, a few interviewees stated that based on their experiences, the situation had been inferior to Rejlers in some technical consultancies.

6 Limitations and evaluation

6.1 Case studies

There is a certain general limitation related to case studies that is identified in the literature. Case studies commonly provide little basis for scientific generalization (Yin (2009)). Case studies are prone to addressing certain issues and features specific to a single case where only a small number of subjects are examined (Zainal (2007)). In this study, only a single company was analyzed. There are multiple variables specific to the analyzed company. For example, compared to other technical consultancies, Rejlers is quite unique in terms of its decentralized structure where the offices are scattered across Finland and have a high level of autonomy. However, although only a single company was analyzed, the analyzed data consists of a vast amount of subjects due to multiple separate divisions of Rejlers and over 1100 unique projects being covered. In addition, the interviewee base in this study was broad and covered experts with different backgrounds from the various offices of Rejlers. These factors must be considered when formulating generalized theories and utilizing the empirical findings and conclusions of this study on a broader scale.

6.2 Quantitative research method

There are multiple limitations that must be taken into account when evaluating the validity of the results of the data analysis. First, the analyzed data was constricted in terms of its quality. Each project contained the information about the estimated and actualized workloads as sums of working hours, without any further details. No other information was available about, for example, which employees had participated in a project or how many units of a specific component (e.g. machines or electrical instruments) were allocated for the project. The sole information about working hours manages to indicate whether there was an over- or underestimation. Besides that, it gives no explanation to why the observed conduct could have taken place. Therefore, the analysis of the results remain on a fairly superficial level.

The results imply that there is clear room for improvement in the offer calculation process of Rejlers. However, the results do not manage to point out where the issues are, where they stem from or what kind of failure patterns occur between different projects.

The second limitation has to do with only analysing projects where Rejlers had won the tender. Data about lost tenders was not available. Assuming that other key factors, such as quality presumptions and brand recognition are on par with its competitors, the amount of lost tenders would have given additional evidence about Rejlers' offer calculation capabilities. Analysis showed that overestimations have frequently taken place at Rejlers. If there was data available showing that the ratio of lost versus won tenders was relatively high, this would have supported the results of the data analysis. Overestimations have occurred frequently and resulted in excessive contract prices and lost tenders. On the other hand, if the data showed that the ratio of lost versus won tenders was lower, this would have contradicted the results of the data analysis. In this case, despite frequent overestimations and high contract prices, Rejlers would have won tenders with a good success rate. Such observation would imply that the initial assumptions may be wrong, and that the customers highly value the Rejlers brand and are willing to pay extra for it.

The third limitation has to do with what many interviewees stated about how working hours are recorded at Rejlers. Individual employees are responsible of recording their own working hours. The working hours are designated to the appropriate objects of expenditure. For example, an employee conducting internal research and development work would designate his hours to the internal research and development expenditures. Similarly, a project worker designates his hours towards the project's expenditures. The problem is however, that some individuals tend to optimize how they record their hours. A financial incentive oftentimes exists to finish a project under its initial workload estimate. To reach the target, some individuals may designate their hours to another project or internal expenditures where such incentives are not set. For the managers, especially when the project teams are big or multiple projects are running simultaneously, it is practically impossible to monitor how individuals record their working hours. Manipulated recording of working hours contributes towards the inaccuracy in the results of the data analysis.

The fourth limitation to be considered was also brought up by many interviewees. It can be difficult to draw conclusions of Rejlers' workload estimating accuracy with a high level of confidence as individuals and project teams substantially adjust their working pace depending on the situation. The changes in working pace significantly influence how many working hours are actualized towards a project. For example, if no new projects are in sight for the near future, project teams tend to slow their pace down and utilize every possible invoiceable working hour. This happens especially when the customer pays per performed working hour rather than a fixed price for the project.

The fifth limitation in the quantitative research method is related to only examining the project data of Rejlers. Comparing the performance of Rejlers to other technical consultancies would have enabled getting an even deeper view of the offer calculation

capabilities of Rejlers. However, such data is extremely hard to obtain. Companies do not want to share their business sensitive data, especially to competitors. Instead in this study, the whole company of Rejlers (including all of the divisions) were used as a benchmark to assess the performance of mechanical engineering and electrical engineering and automation in offer calculation more broadly.

The sixth limitation is related to how projects are handled in the enterprise resource planning system of Rejlers. The minimum working hour requirement to open a project in the system is 10 hours. In many cases, a project where 10 hours (or another low estimate) was recorded as the initial workload estimate, the project would finish with significantly more actualized hours. Obviously some of these cases could be natural estimation failures. However, it seems that in many cases after opening the project, the initial workload had not been updated accordingly as the project had proceeded. The most obvious corrupted projects were deliberately excluded from the analysis. Yet not all of the projects where the initial workload was not updated could be identified and excluded. In addition, another fact brought up by some of the interviewees must be taken into account. The enterprise resource planning system of Rejlers allows automating how project information is handled. One can enable the system to automatically correct the balance between estimated versus actualized working hours to zero for a project. Also, in many cases the customer might make an additional work order for the exceeded hours to zero out the balance. These could have artificially generated observations in the analyzed projects where misestimations equal to zero, which in turn would give an over optimistic look of Rejlers' workload estimating accuracy.

6.3 Qualitative research method

The interview method is subject to specific vulnerabilities. First, unlike in written format, the interviewer receives social cues along with the verbal answers. Observing and reacting to the social cues may result in the interviewer navigating the interview session in a specific direction. This decreases the reliability of the study. To minimize this impact, a predefined interview structure i.e. the questionnaire form was utilized in this study. A predefined interview structure also enabled that the interviews were comparable with each other. Many times case studies produce a massive amount of incoherent documentation (Yin (2009)) where the data is not managed and organized consistently (Zainal (2007)).

Second, the subjective flaws and biases of the interviewer may influence the direction of the findings and conclusions. Similarly, the interviewer may have not followed systematic procedures and has allowed equivocal evidence to impact his data and results (Yin (2009)). On a practical level, this could appear as either deliberate or unintentional hand-picking of the interview answers in order to manifest a specific stance in the study more forcefully. To minimize this effect, transparent descriptions of the conducted interview method and produced evidence are given in this study. Additionally, the studied subject is analyzed from multiple perspectives (literature review, data analysis and expert interviews) and various sources are utilized.

The third limitation has to do with the responsibility of the interviewer to share an understanding of the subject under investigation with the interviewees. If the interviewer's comprehension of the studied subject is lacking, there are a few risks involved. The interviewer may be unable to fully comprehend the experiences and perspectives of the interviewee. The interviewer may come to only a partial understanding of the interviewee's viewpoints and create biased meanings from the responses. (Partington (2001)) To tackle this issue in the study, notably a literature review was conducted in order to gain insights into the subject.

The fourth limitation when evaluating the results of the interviews is related to the issue that only one company was analyzed. The interviewee base consisted only of employees from Rejlers. The objective of this study was to establish a common post-mortem process for Rejlers. Arguably, looking beyond the company and investigating other relevant technical consultancies in detail would be beneficial in finding the best practices to organize the process. Instead in this study, the literature review and expert interviews were conducted to discover the best practices utilized in the industry to conduct the post-mortem process. Most, if not all of the interviewees, had previously worked at other technical consultancies. In this study, the average experience of the interviewees in the field of technical consulting was 20 years. One could naturally question whether that is a lot or little in terms of experience in the field. In this study, 20 years was assumed to ensure that the average interviewee had relevant experience about how post-mortem processes have been carried out in other companies. However, the time between an interviewee had worked at another technical consultancy and the interview session for this study took place could be multiple years, or even over a decade. The best practices proposed by the interviewees could be out of date.

7 Recommendations for action

7.1 Offer calculation

There are several improvement actions which Rejlers must take in terms of improving its offer calculation capabilities. First, due to the many variables and factors prone to natural human failure in the offer calculation process, smaller misestimations can be considered acceptable in the company. However, a focus should be taken on the clear, severe absolute misestimations which have occurred frequently. At Rejlers between 2014-2018, in total 112 projects finished with an absolute misestimation of over 450 working hours (about 3 man months). The negative impacts of such major misestimations can be significant for the company. These cases should be examined in detail. The root causes which explain the main errors in project operation and offer calculation should be investigated. Conducting adequate analysis of the root causes, accumulating organizational learning and creating improvement

actions to fix them ensures that the frequency of major misestimations can be decreased in the future.

Second, Rejlers should focus on preventing underestimations. Contrary to being beneficial to intentionally overestimate in some cases, the company should not intentionally underestimate. The negative consequences and their risk potential are higher for underestimations than for overestimations. An underestimation can negatively impact other interconnected project tasks and the overall quality of the project delivery. An overestimation is wasteful in terms of resources, but it is less prone to negatively impacting other tasks or overall project quality. However, although overestimations are not that undesirable for Rejlers, the company should in general strive for more accurate estimations for a few reasons. First, more accurate workload estimations enable higher efficiency in terms of resource allocation. As resources are not wasted they can be effectively utilized in other business opportunities. Second, as the contract price of a project is based on the workload estimate, an overestimation can lead to a high price which is uncompetitive. The higher the offered price the greater the potential that the customer rejects the offer. Therefore, intentional overestimations with the aim of capturing extra profits should be avoided. The price might inflate too much and the project is captured by a competitor with a lower price.

Third, the company must start collecting higher quality project data. To address this issue, a computational post-mortem tool will be created and shared throughout the company. The tool is developed based on the key findings of the relevant literature coupled with the results of the expert interviews. The Excel tools utilized by the interviewees are leveraged in creating the common tool. The new post-mortem tool will track and collect data on the progress of a project by registering variables relevant to engineering projects. For example, in a project carried out by the division of electrical engineering and automation, the tool will register each new electrical circuit diagram created and added to the company's project database. At the end of the project, the tool has rigorously catalogued the relevant data which it was set to register. As projects tend to be complex and stretch in terms of schedule, a tool that tracks the progress of the process such closely assures the validity of the data.

As the tool is standardized throughout the whole company, the tool enables collecting project data which is both homogenous and comprehensive. Comprehensive data enables more detailed analyses. Furthermore, in the post-mortem workshops, hard data enables easier discussions around the assessed issues as they are grounded in objective information rather than individuals' opinions and assumptions (Collier et al. (1996)). On the other hand, homogeneity of the data allows comparative reviews between different projects (Von Zedtwitz (2002)). Comparative reviews of multiple projects enable discovering repetitive failure patterns and identifying the effects of improvements between different projects (Collier et al. (1996)). With an extensive collection of homogenous (comparable) and comprehensive project data, Rejlers can detect these failure patterns, analyze their root causes and accordingly act upon them. Moreover, many interviewees highlighted that it would be beneficial to be able to examine the data of past projects when conducting the offer calculation for a new project. When the data is both comparable and comprehensive, one

could obtain and utilize benchmark values from past similar projects when estimating the workload of the new project.

Fourth, data of lost tenders must be collected. Monitoring its tendering performance allows the company to identify red flags in its operations and act upon them. In addition, the practices of how working hours are recorded and how projects are handled in the enterprise resource planning system must be improved. Currently the attitude of some individuals to perform these steps appropriately appears to be indifferent. Personal motives, e.g. financial incentives may lead to individuals occasionally optimizing how they record their hours. Arguably most of the managers at Rejlers are unaware of the issue. Informing them about the issue should be the first step to correct the issue.

7.2 The post-mortem process

The objective of this study was to establish a common post-mortem process for Rejlers. The post-mortem process this study recommends for Rejlers is as follows. First, the company should establish and publicize a set of documented procedures and guidelines on how the post-mortem process is organized. This step is taken to ensure the sense of security for the individuals participating in the process. The company must recognize that for many individuals, there is a natural disincentive to conduct the post-mortem workshops (Ahonen & Savolainen (2010), Collier et al. (1996)). Therefore, a focus must be taken that the introduction of the post-mortem process is accepted by the employees of Rejlers. Otherwise the risk is high that the process receives major backlash and is quickly abandoned. The documented post-mortem guidelines need to show that the process is positive and blame-free. The evaluation criteria must be understood and agreed by the participants before the process is initiated. In addition, communication channels which allow individuals to give anonymous feedback during the post-mortem process should be established. To further increase the acceptance of establishing the post-mortem process, an adequate balance between the costs and returns of the process should be ensured. The goal must be that the results of the post-mortem process are achieved through minor costs and burden for the project team (Schieg (2007)). To assure the balance, Rejlers should establish different guidelines for different project sizes. In addition, boundary conditions should be set which determine if a post-mortem process is conducted for a project or not. For example, for a small routine project where only negligible failures occurred, a post-mortem process is not necessary. Then on the other hand, as was suggested by Ewusi-Mensah (1997), a post-mortem process should be organized for all cancelled projects.

Second, the post-mortem process should consist of two separate post-mortem workshops, as was suggested by Collier et al. (1996) and Stålhane et al. (2003). Two distinct workshops ensures that the process can provide adequate results. The first workshop is for the whole project team to collect project data. In addition to discussions during the first workshop, the company should utilize electronic surveys to collect project data from the project team. The surveys should be answered anonymously to increase the sense of security and participation

of the respondents. Anonymity also allows more negative feedback to occur which is beneficial in terms of finding areas of improvement. The second workshop is for key project team members to analyze the data gathered during the first workshop and gained from the surveys. A distinct facilitator should be utilized to ensure that the workshops are effectively organized. Stålhane et al. (2003) suggested that the facilitator should be an external person from the project team as an internal person may hesitate to bring forth sensitive issues. Another option to organizing two workshops is to utilize the lightweight post-mortem process proposed by Myllyaho et al. (2004) and have shorter workshops between every one to four weeks. Moreover, Stålhane et al. (2003) proposed a focused post-mortem process which concentrates on only understanding and improving a single activity. Recognizing which of the proposed post-mortem processes would work best for which project can be difficult. Therefore, Rejlers should try out the different processes. As more experience is gained, the company can determine which process suits the company best in which situation.

Third, responsibilities of implementing the improvement actions should be assigned for specific persons, as was suggested by Collier et al. (1996) and Myllyaho et al. (2004)). This happens at the end of the second workshop, as the project data gathered in the first workshop has been analyzed and improvement actions have been constituted. Allocating responsibilities is essential for Rejlers because the company must recognize that conducting a post-mortem process as such is not a guarantee that beneficial change would occur. The company must focus on turning the results of the post-mortem process into action. No changes can be expected to happen if nobody in the organization is held responsible of taking action. Reel (1999) emphasizes that without putting the improvement recommendations into action, the benefits of the post-mortem process would remain only marginal.

Fourth and finally, a strong focus must be taken on overcoming the remaining barriers of knowledge sharing in the company as they hinder organizational learning to accumulate. For example, one team might struggle with a problem which another team has found the solution to during a post-mortem workshop. To address this issue, as was suggested by Collier et al. (1996) , Myllyaho et al. (2004) and Reel (1999), the results of the post-mortem process should be published to project participants, peers and other project teams inside the company. Another solution to promote knowledge sharing at Rejlers is to introduce an appropriate reward system. The system would incentivize individuals to share knowledge inside the company. For example, Guptara (1999) observed in his research that some organizations award monthly prizes for the best-quality knowledge entered into a common knowledge repository. In addition to introducing a reward system, reciprocity i.e. a “give and take” attitude should be promoted inside the company to further improve knowledge sharing.

8 Conclusions

8.1 Impact of the study

The objective of this study was to establish a post-mortem process for Rejlers. The best practices to organize the post-mortem process in the industry and at Rejlers were identified through a literature review and a qualitative research method. Based on the identified best practices, this study has taken a stance to propose a holistic post-mortem process for the company. The main impact of this study for Rejlers is that establishing the post-mortem process will enable the company to initiate quality control of its offer calculation. As darker forecasts of global economic growth have been constantly in the discussions lately (Bank of Finland (2019)), improving its offer calculation capabilities will create vitally important competitive advantage for the company. With improved offer calculation capabilities, Rejlers can seize benefits most importantly in terms of project cost and schedule savings, customer satisfaction, improved risk management and more optimal resource allocation. A sub-objective of this study was to introduce a computational post-mortem tool at Rejlers. The tool will be introduced as a key part of the post-mortem process. The tool will tackle the current lack of common project data collection methods. With comprehensive project data, the company can carry out detailed analyses on its project operations and constitute improvement actions. In addition, this study revealed issues in the company's knowledge sharing culture and project handling practices which were not broadly recognized by the company's management before. These issues need to be addressed in order to secure that the post-mortem process can function well and provide applicable results for Rejlers.

A sub-objective of this study was to investigate the company's historical performance in offer calculation. A quantitative research method in the form of data analysis was conducted to analyze the company's historical numeric project data. The data analysis showed that there is room for improvement in the company's performance in offer calculation. Both major relative and absolute workload misestimations have occurred frequently. However, the evidence indicates that most of the more radical relative misestimations have occurred in smaller projects. In a smaller project, even a larger relative misestimation, although obviously undesirable, does not arguably cause major damage for the company's finances. The data analysis also displayed that Rejlers has tended to generate overestimated workloads. Albeit not the optimal default approach, the evidence shows that in some cases it can be beneficial for the company to intentionally overestimate the workload for a project. For example, many interviewees emphasized how they deliberately set a buffer on top of the initial workload estimate. The buffer acts as a risk reserve. It can be utilized in project operations if necessary. The other alternative is that if a project finishes according to the initial estimate, Rejlers receives the buffer which is included in the contract price that the customer is committed to paying. On the contrary to deliberate overestimations, Rejlers should not intentionally underestimate its workloads. The risk potential and magnitude of negative consequences related to underestimations are more severe than they are for overestimations. An underestimation can impact interconnected project tasks and cause schedule delays, lowering the overall quality of the project delivery.

8.2 Theoretical implications

On a broader level, this study makes several contributions to the post-mortem literature. First, this study supports the findings of Collier et al. (1996), McAvoy (2006) and Von Zedtwitz (2002) who discovered in their research that the post-mortem process is neglected in most projects. Based on the expert interviews, this has been the case both at Rejlers and in other technical consultancies in which the experts had worked at. In his research, McAvoy (2006) observed that at the end of projects, project teams are many times too exhausted, cynical and fed up to perform the post-mortem process. On the other hand, Collier et al. (1996) emphasized that individuals can find the method unpleasant as project failures are openly analyzed together with the project team. This study provides another explanation behind the low implementation levels of the post-mortem process. When the post-mortem process is not a standard, obligatory procedure to be carried out at the end of a project, project teams choose to neglect the method because there is a rush to start the next project. The post-mortem process is widely regarded by project teams as an uncritical procedure in which they do not want to invest their time if not necessary. Instead, the project teams view starting to work on the next project more value adding.

To increase the utilization rate of the method, this study proposes that a company should not establish an obligatory post-mortem process which is to be carried out in every single project. The evidence shows two reasons for this. First, project teams may dislike the additional mandatory tasks and organizational bureaucracy which the post-mortem process entails. Therefore, there is a good chance that project teams object to implementing the post-mortem. This deteriorates general workforce motivation and may ultimately lead to the project teams abandoning the method. Second, an adequate balance between the costs and returns of the post-mortem process should be ensured. In some cases it may not be worthwhile to engage in the process. For example, in smaller projects the efforts to organize the process may be out of proportion with the size of the project. To avoid these two issues, companies should set boundary conditions which determine if a post-mortem process should be conducted for a project or not. For example, a small project with a project team of only a few persons and a schedule less than six months could be the lower boundary below which the post-mortem process is not conducted. Then on the other hand, for each cancelled project organizing a post-mortem process should be made standard practice (Ewusi-Mensah (1997)).

Another action to increase the acceptance of the post-mortem process´s introduction among project teams is to establish different post-mortem guidelines for different kinds of projects. However, the post-mortem literature provides vague positions about how the method should be adjusted per different projects. Myllyaho et al. (2004) highlight that there is a demand for a lightweight post-mortem process which can be utilized in both small and large projects. The post-mortem process described by Collier et al. (1996) is better suited for large projects. Then on the other hand, Stålhane et al. (2003) introduce a focused post-mortem method which specifically concentrates on a single activity. This study proposes that companies should experiment with the different post-mortem methods. Through iterative experiments, a company can identify what kind of a post-mortem process best suits the company in projects

of different character and size. Furthermore, the literature does not provide a uniform stance on whether a single or more post-mortem workshops should be organized at the end of a project. This study recommends companies to organize two separate workshops. The first workshop is arranged to collect project data with the whole project team. The second is organized for key project team members to analyze the data gathered during the first workshop. The risk with only a single workshop is that the results may remain insufficient when not enough time is allocated.

8.3 Future research

The obvious next step for further research would be to test the introduced post-mortem process and practices at Rejlers. Further examination of how the process is welcomed and experienced by the project team would be of great importance for further conclusions. Investigating which specific kind of post-mortem method is most suitable in projects of different size and character would give valuable implications for the post-mortem literature. Moreover, a long-term investigation on the impacts of establishing the post-mortem process at Rejlers would be of great interest. This could be done by comparing the current offer calculation performance of the company with that of a few years later when the post-mortem process has been applied in the company for a relevant time period. Composing such a research setting is challenging. Variables contributing to the accuracy in offer calculation, such as workforce experience must be controlled to achieve reliable results. Corresponding research has not been carried out in the relevant contemporary post-mortem literature. Investigating whether implementing the method can improve the offer calculation performance and create competitive advantage for a company would bring forth valuable evidence of the argued benefits of the post-mortem process.

Once more comprehensive results of implementing the post-mortem process have been found at Rejlers, it would be valuable to investigate whether a similar approach would work in other technical consultancies. If possible, utilizing similar organisations such as Rejlers would strengthen the value of the conclusions drawn in this study. For in-depth findings in the further research, a combination of quantitative and qualitative research methods is suggested.

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Appendix 1: Interview questionnaire

Support to individuals in conducting a post-mortem process

Q1. As a common holistic process is not established, what kind of functions exist to support individuals in conducting post-project reviews at Rejlers?

Q2. Does Rejlers provide individuals with any training, instructions and tools, i.e. resources to perform the post-mortem process? Are there any common methods and tools available for everyone at Rejlers?

Q3. Why has the process been neglected? Would it be beneficial to establish a common process?

Q4. Rate the current conditions for conducting a post-project review at Rejlers, from 1 (unsatisfactory, deficient) to 4 (well functioning). Rating is done based on assessing factors, such as training, tools, frameworks and other resources the company provides regarding the post-mortem process.

Current post-mortem practices

Q5. How is quality control of offer calculation and project assessment carried out by individuals? What kind of methods and tools have been utilized?

Q6. Are post-project review workshops organized where projects are reviewed and project data is collected? Are there common predefined procedures and instructions on how to organize the workshop?

Q7. Which parameters and factors are taken into account during the workshops? What kind of project data is collected?

Knowledge sharing

Q8. How well are the knowledge and learning (results) gained due to the post-mortem process shared with other teams inside the organization? Are there barriers of knowledge transfer?

Project data collection and utilization

Q9. How is project data documented in the everyday work at Rejlers? How is the data utilized?

Q10. Are there structural barriers for collecting and utilizing high-quality data?

Performance of the utilized post-mortem methods

Q11. How have the utilized post-mortem methods performed? What kind of results have they provided?

Q12. How have these methods been developed?

Predefining a post-mortem process

Q13. Do you think it would be essential/worthwhile to tie individuals to always follow a specific, predefined common process (with normalized procedures, instructions and tools) in conducting a post-mortem, even though it would require more resources than what is currently allocated to it?

Post-mortem process in other technical consultancies

Q14. Based on your previous knowledge in working on the field and in other companies, how is the post-mortem process organized in other technical consultancies? How would you compare Rejlers to other companies you have experience of in this regard?

Reflections on the results of the data analysis

Q15. Give comments on the findings of the carried out data analysis on Rejlers's past performance in offer calculation. Do the results correspond with reality?

Q16. What do the results tell you? What could be the key behavioural factors explaining the observed patterns from the results?

Appendix 2: Elaborated data analysis results of mechanical engineering

A data analysis on the division of mechanical engineering was carried out. In total, 329 projects carried out between 2014 and 2018 were analyzed. The average estimated workload was 501 working hours with a median of 190 hours.

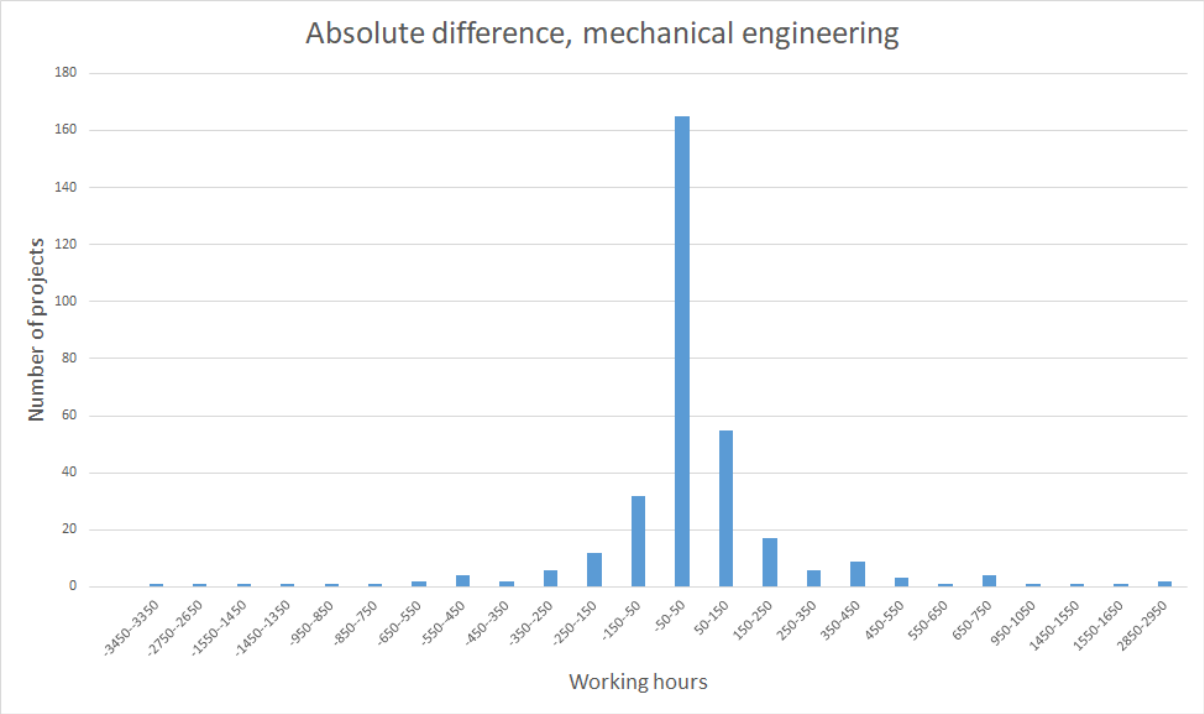

Figure 8: Absolute differences, mechanical engineering

Figure 8 depicts the results of mechanical engineering in terms of the observed absolute differences. The average difference in estimated versus actualized working hours was 21 hours with a median of 9 hours. This means that during the examined time period, the projects at mechanical engineering finished on average 21 working hours under the initial estimate. Figure 8 indicates that major absolute over- and underestimations have occurred rather frequently. In the division between 2014-2018, 25 projects finished with an absolute misestimation of over 450 working hours (about 3 man months).

The distribution of the results in Figure 8 resembles a normal distribution. The mean is close to zero and most of the observations cluster around the mean. The curve is rather symmetric. The frequency for values further away from the mean taper off almost equally in both directions. However, as the median (greater than zero) indicates, the curve is centered to the positive side. The frequency of absolute overestimations is higher than that of underestimations.

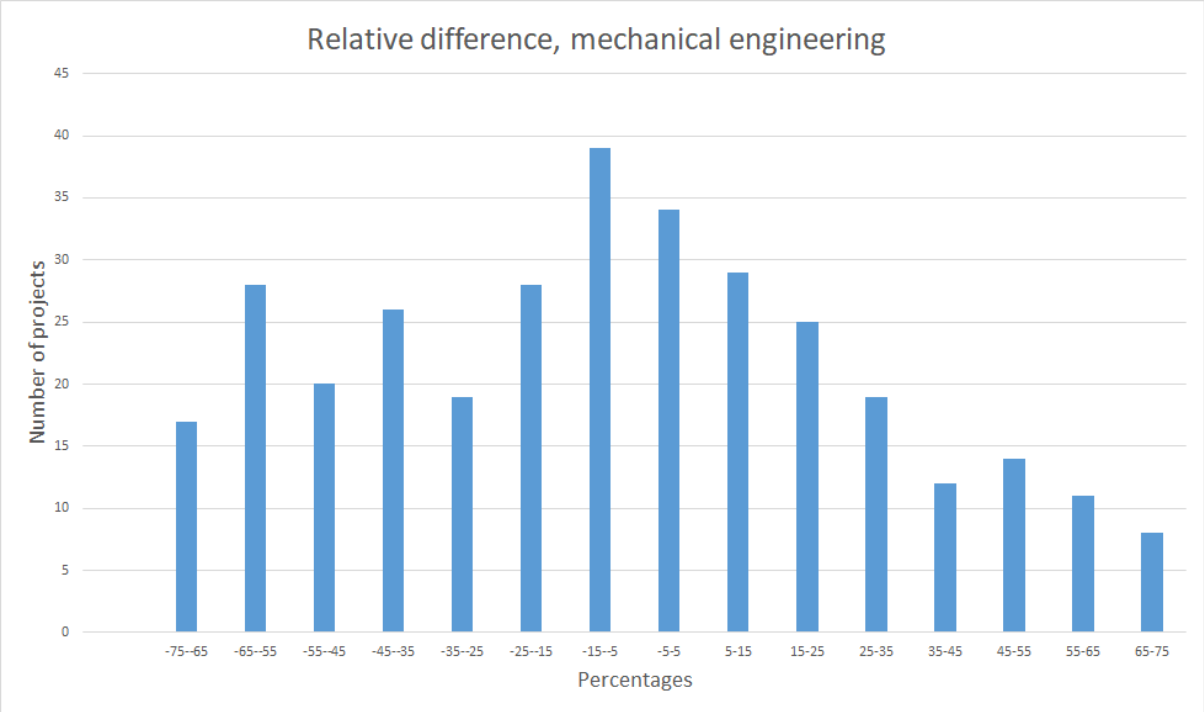

Figure 9: Relative differences, mechanical engineering

Figure 9 depicts the results of mechanical engineering in terms of the observed relative differences. The average relative difference between the actualized workload and the estimation was -8 percent with a median of -9 percent. This means that during the examined time period, the projects at mechanical engineering finished on average 8 percent under the initial estimate. Figure 9 indicates that major relative over- and underestimations have occurred frequently. Between 2014-2018, 98 projects finished with an relative misestimation of over 45% working hours.

The distribution of the results in Figure 9 vaguely resembles a normal distribution. The mean is rather close to zero and most of the observations cluster around the mean. The curve is rather symmetric. The frequency for values further away from the mean taper off somewhat equally in both directions. However, as the median (smaller than zero) indicates, the curve is centered to the negative side. The frequency of relative overestimations is higher than that of underestimations.

Table 4 summarizes the relevant project information and results of mechanical engineering.

Amount of projects	Estimated average	Estimated median	Absolute difference average	Absolute difference median	Relative difference average	Relative difference median
329	501	190	21	9	-8	-9

Table 4: Project information and summary of results, mechanical engineering

Appendix 3: Elaborated data analysis results of electrical engineering and automation

A data analysis on the division of electrical engineering and automation was carried out. In total, 331 projects carried out between 2014 and 2018 were analyzed. The average estimated workload was 669 working hours with a median of 235 hours.

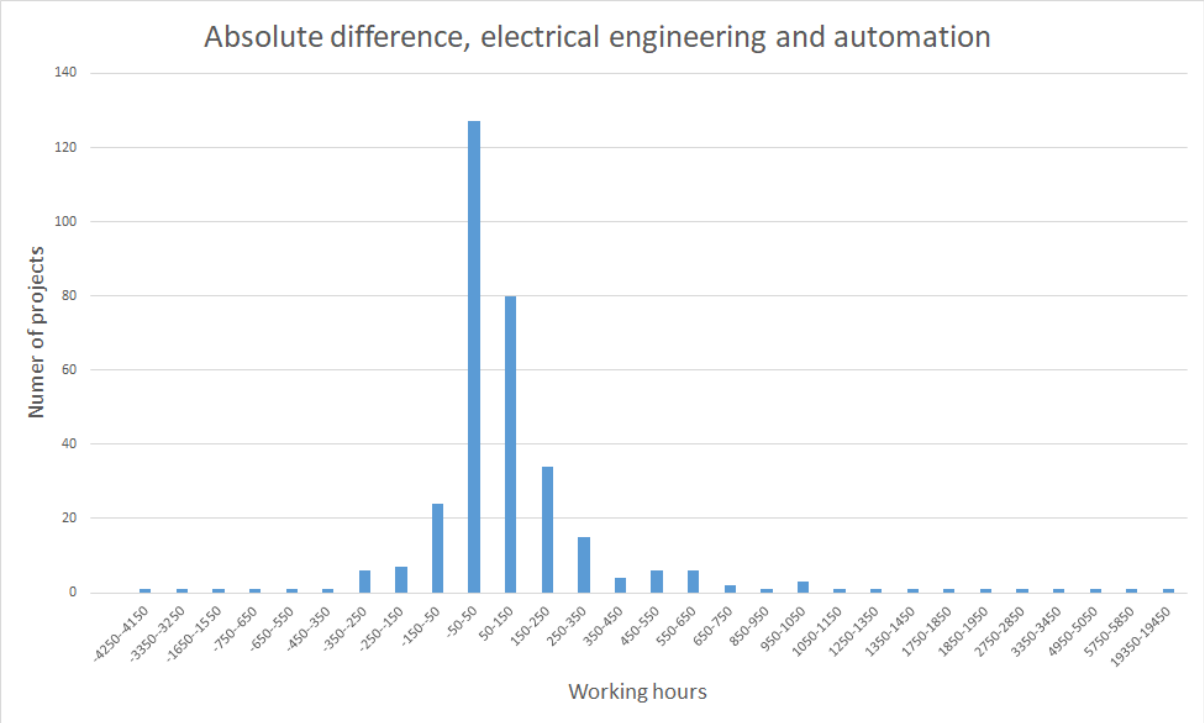

Figure 10: Absolute differences, electrical engineering and automation

Figure 10 depicts the results of electrical engineering and automation in terms of the observed absolute differences. The average difference in estimated versus actualized working hours was 183 hours with a median of 45 hours. This means that during the examined time period, the projects at electrical engineering and automation finished on average 183 working hours under the initial estimate. Figure 10 indicates that major absolute over- and underestimations have occurred rather frequently. In the division between 2014-2018, 34 projects finished with an absolute misestimation of over 450 working hours (about 3 man months).

The distribution of the results in Figure 10 vaguely resembles a normal distribution. The mean is rather close to zero and most of the observations cluster around the mean. The curve is rather symmetric. The frequency for values further away from the mean taper off almost equally in both directions. However, as the median (greater than zero) indicates, the curve is centered to the positive side. The frequency of absolute overestimations is higher than that of underestimations.

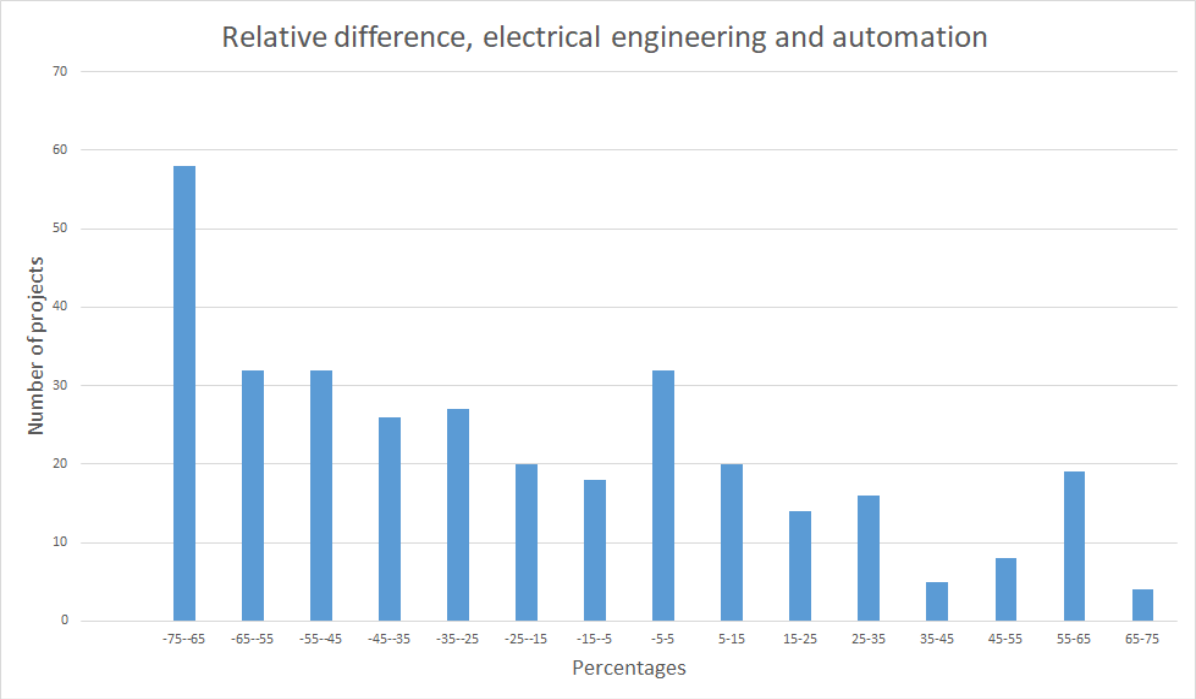

Figure 11: Relative differences, electrical engineering and automation

Figure 11 depicts the results of electrical engineering and automation in terms of the observed relative differences. The average relative difference between the actualized workload and the estimation was -21 percent with a median of -28 percent. This means that during the examined time period, the projects at electrical engineering and automation finished on average 21 percent under the initial estimate. Figure 11 indicates that especially major relative overestimations have occurred frequently. Between 2014-2018, 179 projects finished with an relative misestimation of over 45% working hours.

The distribution of the results in Figure 11 is random. However, as the median (smaller than zero) indicates, most of the observations are on the negative side. The frequency of relative overestimations is higher than that of underestimations.

Table 5 summarizes the relevant project information and results of electrical engineering and automation.

Amount of projects	Estimated average	Estimated median	Absolute difference average	Absolute difference median	Relative difference average	Relative difference median
331	669	235	183	45	-21	-28

Table 5: Project information and summary of results, electrical engineering and automation

Appendix 4: Elaborated data analysis results of all divisions

A data analysis on the whole Rejlers Finland including all of its divisions was carried out. In total 1185 projects carried out between 2014 and 2018 were analyzed. The average estimated workload was 703 working hours with a median of 255 hours.

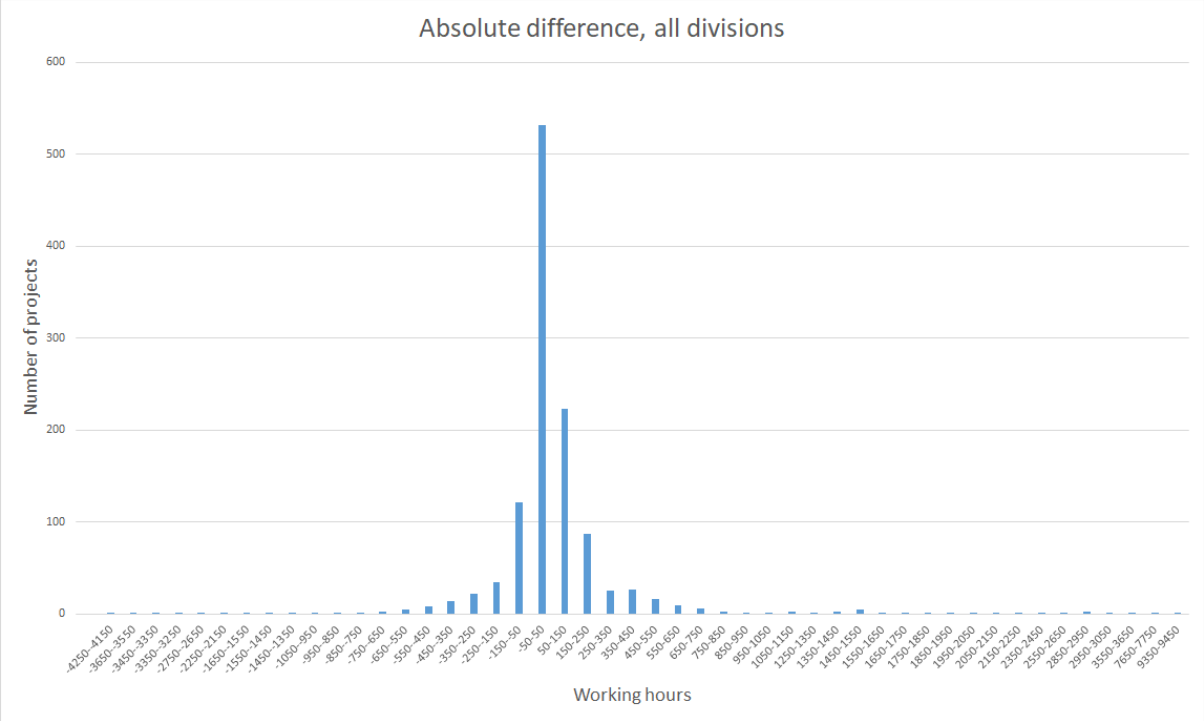

Figure 12: Absolute differences, all divisions

Figure 12 depicts the results in terms of the observed absolute differences. The average difference in estimated versus actualized working hours was 69 hours with a median of 17 hours. This means that during the examined time period, the projects at Rejlers finished on average 69 working hours under the initial estimate. Figure 12 indicates that major absolute over- and underestimations have occurred rather frequently. At Rejlers between 2014-2018, 112 projects finished with an absolute misestimation of over 450 working hours (about 3 man months).

The distribution of the results in Figure 12 resembles a normal distribution. The mean is close to zero and most of the observations cluster around the mean. The curve is rather symmetric. The frequency for values further away from the mean taper off almost equally in both directions. However, as the median (greater than zero) indicates, the curve is more centered to the positive side. The frequency of absolute overestimations is higher than that of underestimations.

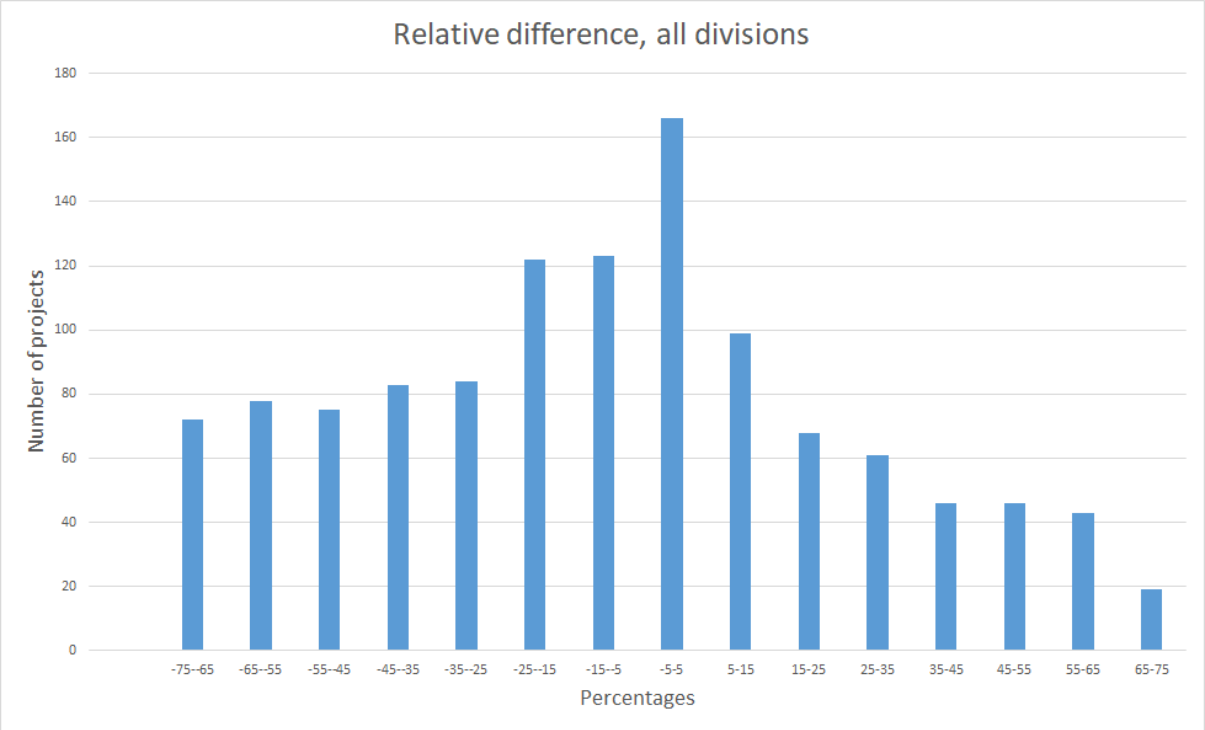

Figure 13: Relative differences, all divisions

Figure 13 depicts the results in terms of the observed relative differences. The average relative difference between the actualized workload and the estimation was -9 percent with a median of -9 percent. This means that during the examined time period, the projects at Rejlers finished on average 9 percent under the initial estimate. Figure 13 indicates that major relative over- and underestimations have occurred frequently. Between 2014-2018, 416 projects finished with an relative misestimation of over 45% working hours.

The distribution of the results in Figure 13 resembles a normal distribution. The mean is rather close to zero and most of the observations cluster around the mean. The curve is rather symmetric. The frequency for values further away from the mean taper off somewhat equally in both directions. However, as the median (smaller than zero) indicates, the curve is centered to the negative side. The frequency of relative overestimations is higher than that of underestimations.

Table 6 summarizes the relevant project information and results of the whole company.

Amount of projects	Estimated average	Estimated median	Absolute difference average	Absolute difference median	Relative difference average	Relative difference median
1185	703	255	69	17	-9	-9

Table 6: Project information and summary of results, all divisions