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Enhancing quality and productivity in maintenance field service by scheduling - a case study

Master's Thesis

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Abstract of master's thesis

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Abstract:

The importance of workforce scheduling in different service industries has been widely emphasized in recent research. The effects of scheduling to service quality and productivity are recognized, for example, in field services, where travelling causes significant costs which can be minimized by effective scheduling. Despite the vast academic research of effectiveness of different scheduling systems in field services, the constraints related to transfer from environment where structured scheduling doesn’t exist to automated scheduling remain mostly unstudied.

This thesis studies workforce scheduling in maintenance field service. It represents the elements of an effective scheduling system, and examines how scheduling affects to service quality and productivity. This study also investigates real-life constraints in scheduling of a case organization and how those identified constraints are related to the scheduling literature. The empirical analysis of this study is conducted using the Theory of Constraints (TOC) Thinking Process (TP) methods. TOC is a management philosophy that focuses on the factors that are constraining the performance of a system, and TP contains set of logic tools to solve unstructured and complex problems.

In this study, the application of TOC to maintenance field services exposed several deficiencies in case organization’s service process that are preventing effective scheduling. For the most part, those deficiencies are related to lacking information throughout the service process. Information relevant for scheduling is either, lacking, not available when needed, or undocumented. In addition, policy constraints, that complicate the scheduling process, were revealed concerning the prioritization of tasks and allocation domains. Attempt for fast responses fragments the day of the field technician, which cause difficulties to follow the schedules. Strict boundaries between allocation domains, in turn, cause unlevelled demand and sub-optimized schedules. Design propositions are given in this thesis to improve the documentation and the level of master data, as well as clarifying the premises for prioritizing and levelling demand.

Keywords workforce scheduling, field services, maintenance services, service quality, Theory of Constraints, TOC

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Tiivistelmä

Työvoiman aikataulutuksen merkitystä eri palvelualoilla on painotettu laajalti viimeaikaisessa tutkimuksessa. Aikatauluttamisen vaikutus palvelun laatuun ja tuottavuuteen on tunnistettu esimerkiksi kenttäpalveluissa, joissa matkustaminen asettaa merkittäviä kustannuksia, joita voidaan minimoida tehokkaalla aikatauluttamisella. Viimeaikainen tutkimus on painottunut laajalti eri aikataulutusmenetelmien tehokkuuteen, kun taas manuaalisesta aikatauluttamisesta automaattiseen aikatauluttamiseen siirtymiseen liittyviä rajoitteita ei ole kartoitettu.

Tämä diplomityö tutkii työvoiman aikatauluttamista kenttähuoltopalvelussa. Tutkimus esittelee tehokkaan aikatauluttamisen tekijöitä ja tarkastelee, mitä vaikutuksia aikatauluttamisella on palvelun laatuun ja tuottavuuteen. Lisäksi tämä työ tutkii esimerkkiyrityksen kautta mitä todellisia käytännönrajoitteita aikatauluttamisessa ilmenee ja miten nämä löydetyt rajoitteet liittyvät aikataulutuksesta tehtyyn aiempaan tutkimukseen. Kenttähuoltopalvelun rajoitteita tutkitaan tässä diplomityössä kapeikkoteorian (Theory of Constraints TOC) ajatteluprosessien (Thinking Process TP) avulla. TOC on johtamisfilosofia, joka keskittyy järjestelmän esteisiin, jotka rajoittavat järjestelmän suorituskykyä. TP puolestaan sisältää joukon loogisia työkaluja, jotka pyrkivät ratkaisemaan monimutkaisia ja jäsentämättömiä ongelmia.

Tutkimuksessa osoitetaan, että TOC:in soveltaminen kenttähuoltoon paljastaa useita puutteita esimerkkiyrityksen palveluprosessissa. Nämä puutteet estävät tehokkaan aikatauluttamisen. Puutteet liittyvät pitkälti puutteelliseen informaatioon: informaatiota palveluprosessin eri vaiheissa ei ole joko olemassa, saatavilla tai dokumentoitu. Lisäksi työssä löydettiin priorisointiin ja töiden allokointiin liittyviä menettelytapoja, jotka vaikeuttavat tehokasta aikataulujen luomista ja niiden toteuttamista. Pyrkimys nopeisiin vasteaikoihin pirstaloi kenttäasentajan työpäivän, mikä vaikeuttaa aikataulujen noudattamista. Töiden allokointialueiden tiukat rajat puolestaan aiheuttavat epätasapainoa eri allokointialueiden työkuormaan. Tutkimus antaa kehitysehdotuksia havaittujen rajoitteiden eliminoimiseksi sisältäen muun muassa dokumentoinnin ja masterdatan tasojen parantamisen, priorisointiparametrien tarkentamisen sekä resursoinnin helpottamisen eri allokointialueiden välillä.

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My studies in Aalto University have been all but an easy ride. Several sidesteps and moments of suspect have accompanied my journey through the road of education, and more than once I have doubted whether to reach the end at all. On these bases, I have to admit that it has been a bit of surprise for me how painless the process of creating this thesis has been.

I am not saying that conducting this research has been an easy task. Naturally, I have faced difficulties and frustration along the way, but the goal has all been bright and all actions aimed to reach it since the very first days I have spent with this project. For this, I have brilliant people to thank who have surrounded me during this process and helped me follow through.

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Ville Ilmonen

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Definition of concepts and abbreviations

CLR	**Categories of Legitimate Reservation**. Rules of the TP logic (Scheinkopf, 2010).
CM	**Corrective Maintenance**. Maintenance that is provided for preparing defects.
CRD	**Conflict Resolution Diagram**. A logical Thinking Process tool that reveals conflicts and the false assumptions that are leading to the conflict (Scheinkopf, 2010).
CRT	**Current Reality Tree**. A logical Thinking Process tool that attempts to reveal core problems of a system where Undesirable Effects exist (Dettmer, 2007).
ERP	**Enterprise Resource Planning**. A packaged business software system for managing processes and sharing information (Marnewick & Labuschagne, 2005)
Field Service	Service that is provided in customers' properties by mobile service operators (Petrakis et al., 2012).
MRS	**Multiresource Scheduling**. ERP scheduling tool used in Case Co.
PPM	**Planned Preventive Maintenance**. Maintenance that is provided for preventing defects according to a plan.
SERVQUAL	Service quality model, which investigates the gaps between customer's expectation and perceived service (Ladhari, 2008).
SO	**Service Order**. Referred as a service task in ERP of the case organization.
TOC	**Theory of Constraints**. A management philosophy that focuses on constraints. TOC divides complex systems to chains of actions

	where there is always very small number of actions, perhaps only one, that limit the system's effective operation (Dettmer, 2007).
TP	**Thinking Processes**. TOC methodology. Set of logic tools to solve unstructured problem (Groop, 2012).
UDE	**Undesirable Effect**. Symptom of a core problem in the observed system. Used in TP. (Dettmer, 2007)

I INTRODUCTION

1 Introduction

This thesis studies the scheduling process of a maintenance field service organization. Conducted as a case study, this thesis attempts to explain how the scheduling should be addressed in maintenance field service organization and how scheduling affects service quality and productivity. The study includes theoretical and empirical analysis focusing on the system factors which are constraining the scheduling of a case organization. In addition, investigation will be made of how those constraints can be resolved in order to reach better service quality. The empirical case data of this study consist of interviews and observations concerning the scheduling system of the case organization. The analysis of the empirical data is performed with two Theory of Constraints Thinking Process tools: Current Reality Tree and Conflict Resolution Diagram.

The theoretical contribution of this thesis is to provide knowledge how the observed constraints in the maintenance field service organization affect service quality. The practical contribution of this study is to reveal the core problems that are complicating the scheduling in the case organization, and to provide suggestion how to overcome those problems.

This chapter outlines the research setting of the study. In the beginning of this chapter the background and motivation of this research is discussed. Then, this chapter presents the objectives, research questions and scope of this study. Finally, the structure of the research is represented.

1.1 Background and Motivation

The subject of workforce scheduling has been studied widely in the recent decades in several industries, including manufacturing, maintenance services and health care services among others (Ernst et al., 2004; Van den Bergh et al., 2013). The scheduling methods have evolved from manual rule-based allocation to complicated automated scheduling procedures that are based on algorithmic computation providing optimized schedules for large number of employees. The importance of scheduling has been widely addressed in terms of more effective use of resources and reduced costs (Van den Bergh et al., 2013) as well as improved service quality (Haugen & Hill, 1999). Van den Bergh et al. (2013) remark that labor cost is the largest single cost component for many companies. Cutting this cost by only a few percent by enhancing the scheduling process could therefore prove very beneficial.

Scheduling is examined in this study in the context of maintenance field services. Field service environment is especially difficult for scheduling due to high degree of dynamism (Voudouris et al., 2008). Service technicians are constantly on the move and new tasks arrive that require fast responses, which cause alterations to the schedules. Therefore, it is challenging to provide effective schedules for field service environment, which easily leads to inaccurate schedules. However, ineffectiveness in scheduling leads to overdue, wrong technician for a task with wrong equipment and increases the tendencies to multiple visits (Haugen & Hill, 1999). Therefore, even though being a difficult task, effective scheduling is important part of effective field service operations.

Original motivation for this study emerged from the case-company, Case Co., where a need to improve the scheduling process was encountered. Observations which insinuated inefficiency with current scheduling practices had been made in Case Co. In addition, Case Co. has recently faced organizational changes through acquisitions and a demerger, and currently no common organization-wide process is in use for scheduling. This thesis is, thus, a part of the actions that aim for coherent and effective scheduling procedure of Case Co.

1.2 Research Objectives and Research Questions

The objective of this thesis is to research how the quality of service can be improved by enhancing the scheduling process in field service environment. To reach the objective, a literature review and empirical research are included. The literature review focuses on examining the literature of service quality, existing scheduling solutions and the impact that scheduling has on service quality. The empirical research consists of an investigation of scheduling system of the case-organization, which will be conducted by following the Theory of Constraints Thinking Process methods in order to investigate the constraints in the scheduling system. Once the constraints have been determined, their influence to service quality and design proposals can be then discussed in the light of the findings from literature.

On the basis of the objectives of this thesis, three research questions are formulated:

RQ1: What are the elements of an effective field service scheduling system and how scheduling affects service quality?

RQ2: Why scheduling is currently not effective in the case organization?

RQ3: What changes should be made to enhance the scheduling system and, thus, service quality in the case organization?

First research question contains the scope of the literature review. Second research question contains the TP analysis for locating the constraints on the current scheduling system of the case organization. Third research question seeks design solutions for the identified constraints based on the findings in literature review and empirical analysis.

1.3 Research Approach and Scope

The research approach of this study is qualitative. The purpose of the qualitative research is to understand social or human problems and their meanings to individuals or communities involved (Creswell, 2003). The data of the qualitative research is expressed as a form of text and is based on the interpretations of the researcher (Eskola & Suoranta, 2000). In addition, qualitative research data is affected by the researcher's individual comprehension of the investigated subject (Creswell, 2003). The research objective of this thesis answers the question "how", as is typical for qualitative approach.

This thesis is conducted following the case-study methodology and applying design science research principles. According to Yin (2003) case study is an empirical study which investigates a certain phenomenon in its operational context. Typical for case study is that the researcher has very little control over the investigated phenomenon, and the focus of the study is on real-life matters (Yin, 2003). Case study methodology is selected, because it fits the objective of this study - to explain effects of scheduling in real-life context. Design science research attempts to combine problem-solving and theory oriented research approaches, and it is represented more accurately in section 4.1.

The empirical data of this research is gathered from the employees of the case organization. All units of the case organization were not involved in the research due to the size of the company. The participants for the interviews and observations were chosen based on the author's initial understanding of the problem and the recommendations made in Case Co.

1.4 Structure of the Research

The structure of this thesis is divided into four parts: introduction (I), literature review (I), empirical study (III) and discussion (IV).

The first part includes the chapter 1, *Introduction*, where the background and motivation, objective, research questions, research approach, scope and structure are presented.

The second part of this thesis consists of the literature review of the relevant scientific literature related to the topic of this thesis. The literature review contains two distinct chapters. The first one is chapter 2, *Quality and Productivity in Field Services*, where the concepts field services and service quality are represented followed by the discussion of how service quality influences productivity. The second chapter in this part is chapter 3, *Work Schedulin*g, where the requirements, constraints and methods for work scheduling are presented followed by the discussion of how scheduling affects service quality.

The third part describes empirical case study of this thesis including four chapters: Methods, Case, Analysis, as well as Interventions and solution suggestions. *Methods* chapter contains the presentation of data collection and analysis methods used in this study. *Analysis* chapter contains the TP analysis of the empirical data revealing the constraints in the scheduling practices. *Interventions and solution suggestions* chapter provides suggested interventions and solutions to overcome the constraints.

The fourth part of this study, Discussion, consists of two chapters. Chapter 8, *Responses to Research Questions and Conclusions*, summarizes the results of the study by responding to the research questions, and it provides conclusions of the results relating to the literature review. In chapter 9, *Implications and Limitations*, the contribution of the study is presented in the form of managerial and theoretical implications followed by the discussion of the limitations and future research topics.

II LITERATURE REVIEW

2 Quality and productivity in Field Services

This chapter forms the first part of the literature review of this thesis. In order to be able to evaluate the impacts of scheduling, the quality and productivity aspects of services need to be discussed first. This chapter begins by presenting the concept of field service. Then, service quality is discussed and a SERVQUAL service quality model and its implication to field services are presented. Finally, the impact of service quality to profitability is briefly discussed.

2.1 Field Services

Many service organizations operate in environments where services are provided in spatially distributed locations with mobile workforce. That kind of services with high degree of mobility is often called field services (Petrakis et al., 2012). Organizations involved in field service operations typically consist of several field operators working on different jobs at different customer sites (Groop, 2012). Therefore, according to Fehl (2006), modern field service technicians are required to be competent in technical knowledge and know-how as well as in customer service in means of considering and dealing with customer needs.

Field services hold some same features as many other services. Sampson & Froehle (2006) define four typical service characteristics, which can be linked also to field services. Those characteristics are inseparability, heterogeneity, perishability and intangibility. *Inseparability* means that services are produced at the same time as they are consumed. *Heterogeneity* in service context holds the assumption that every service event that is delivered is unique due to the customer involvement to the service production. *Perishability* denotes the time-sensitive nature of service meaning that all customer inputs need to be present in order to begin the service production. Therefore, services cannot be pre-produced and stored. Last characteristic, *intangibility*, means that services produce value without obtaining ownership of a tangible product. (Sampson & Froehle, 2006.) However, field services include also a tangible element: the maintenance or installation is provided to tangible equipment (Fehl, 2006).

The nature of field services can be described in several ways. Field service jobs can be one-off jobs (installations) or repetitive jobs (maintenance), where operators visit the same location multiple times (Groop, 2012). Fehl (2006) divides field services to people-based services such as consulting, training and caring, and product-based services including installations, repair and preventive maintenance of different equipment. There are certain characteristics that determine especially the nature of field services. One is the role and importance of travelling. Voudouris et al. (2008) note that due to the spread service locations in field services, long travel distances and times are inevitable and can’t be avoided, even though travelling doesn’t bring any value to either customer or provider. Travelling is, therefore, often called the necessary evil (Voudouris et al., 2008). In addition to travelling, another typical characteristic for field services is the timecriticality (Groop, 2012). The demand in field services has to be satisfied within a certain time-window and, often, it is not possible to postpone the task easily without consequences, like contractual penalties or loss of customers.

2.2 Service Quality

Defining service quality is difficult due to the characteristics of service discussed in the previous section. Compared to tangible products, the properties of services are much more difficult to observe and measure objectively. Because no unambiguous and explicit measurements exist, also defining the quality is much more complicated for the services than for the products (Zeithaml et al., 1990). In addition, due to the inseparability, the experiences and perceptions of the customer are in the pivotal role when service quality is defined.

Unlike with products, the quality of service cannot be evaluated based on the sole outcome of the interaction. Instead, also the process of producing the service has to be considered (Olivia & Sterman, 2001). Grönroos (1984) specified those two areas of service quality as technical quality and functional quality. *Technical quality* consists of what the customer receives as a result of the interaction with service company, and *functional quality* includes the process of how the technical outcome of the service is provided and received. Those concepts have been later used widely in the service quality literature (Fehl, 2006).

For measuring service quality, several different models exist (Seth et al., 2005; Ladhari, 2008), but, according to Seth et al. (2005), neither well-accepted conceptual definition of a service quality nor a generally accepted operational definition of how to measure service quality exist. However, common to most of the different service quality models seems to be that they evaluate service quality by comparing expectations of the customers with perceptions of the experienced service quality (Seth et al., 2005). Therefore, customers are in important role when service quality is defined.

According to Ladhari (2008), one, of the most widely applied, valued and referred service quality models, is SERVQUAL, which is developed by Parasuraman

(Parasuraman et al., 1988). In SERVQUAL, originally named as gap-model, the service quality is studied through different gaps between expectations and perceptions from the service along different service dimensions. SERVQUAL consists of five different gaps that have been defined to exist in the service providing process (Seth et al., 2005):

- Gap1: Difference between consumers' expectations and management's perceptions of those expectations
- Gap2: Difference between management's perceptions of consumers' expectations and service quality specifications
- Gap3: Difference between service quality specifications and service actually delivered
- Gap4: Difference between service delivery and the communications to consumers about service delivery
- Gap5: Difference between consumers' expectation and perceived service

The quality dimensions that are measured in those gaps can be found in Table 1.

Table 1. Quality dimensions of SERVQUAL model (Based on Parasuraman, 1988)

Dimension	Description
Tangibles	Appearance of physical facilities, equipment, personnel and communication materials.
Reliability	Ability to perform the promised service dependably and accurately, as well as meet the schedules. Reported as the key dimension in multiple studies.
Responsiveness	Willingness to help customer and provide prompt service.
Assurance	Knowledge and courtesy of employees and their ability to convey trust and confidence.
Empathy	Caring, individualized attention the company provides to its customers.

Even though SERVQUAL has been extensively used, it has also received some criticism. According to Seth et al. (2005), the SERVQUAL dimensions only consider functional quality, while technical quality is neglected. Seth et al. (2005) also assert that SERVQUAL has received vastly criticism about its applicability for specific industrial contexts. Thus, several studies have been conducted to create industry specific scales for SERVQUAL.

Fehl (2006) has analyzed the SERVQUAL model whether it would match the requirements for field services. He questions the suitability of SERVQUAL to the field services, as he claims that the technical quality of the services holds often a significant importance in the field services. However, as the topic of this thesis concerns scheduling, which affects mainly functional quality as will be discussed in section 3.8, the SERVQUAL model is decided to be investigated in this study.

2.3 The Effects of Service Quality on Productivity

Service quality has effects also to the productivity of the service provider. Zeithaml et al. (1990) suggest that a good service quality leads to more productive service operations. That can be issued by describing the negative effects that poor quality has to productivity. Zeithaml et al. (1990) argue that service errors and foul-ups increase significantly costs to the service delivery system, and mention that even third of the total workload of company with poor service quality may consist of reworks caused by that poor quality and ineffective customer communication. Poor service quality has also tendency to cause lost sales and customer defects (Oliva & Sterman, 2001).

In addition, Oliva & Sterman (2001) also have studied the effects of poor service quality to financial performance. They revealed that the quality of the service has a tendency to erode unless attention is paid: the employees tend to reduce the time they spend with each customer to reach throughput goals of the company. It leads to cutting corners and eroding service norms within the organization. If no quality measurements exist, management interprets the reduction in-time per order as a gain in productivity and they reduce the service capacity which causes that the employees need to cut the time for one task even more.

Olivia & Sterman (2001) found that the results of quality erosion led to significant drops in sales of services, resulting in lower profit, slower growth and financial pressure to improve productivity. That led to intensifying the workload of an employee and the pressure to cut corners. Furthermore, Oliva & Sterman (2001) suggest that the erosion can be prevented by reducing the effect of work pressure on time per order and creating quality pressures to employees. The former can be reached by increasing standardization and improving documentation in service processes to be better able to control the workload of an employee. In addition, the attractiveness of overtimes should be increased in order to reduce the tendency to cut corners. The latter can be attained by increasing the awareness of the implication of poor service to the employees and making a priority to avoid those implications. In addition, it is important to create relevant measurements for service quality. (Oliva & Sterman, 2001)

3 Work Scheduling

This chapter presents literature review and theoretical framework for work scheduling focusing on field services. First, a brief introduction to the work scheduling is given, which is followed by the overview of concepts and the prerequisites for scheduling. Then, the principles and different scheduling methods are represented followed by the discussion of implementing issues of scheduling system. Finally, the exploitation of mobile tools in scheduling is reviewed and how scheduling affect service quality is discussed. The perspective of field services is emphasized throughout the whole chapter.

3.1 Introduction to Work Scheduling

Work scheduling is an issue that practically every service organization has to deal with. Work scheduling consists of assigning workforce to jobs in order to deliver the promised services to the customer. More precisely, work scheduling can be seen as sending a right resource (workforce) to the right customer at the right time with the right equipment (Leisant et al., 2000; Voudouris et al., 2008). Still, work scheduling is a complex and complicated task that contains multiple variables and challenges, including dynamic operation environment, numerous scheduling objectives and constrains considering workforce and customers, regulations, and the business objectives of the organization (Voudouris et al., 2008). To attain a fluently working scheduling system requires balancing between the different requirements and objectives.

There are numerous methods to execute the scheduling, for example, several rule-based systems and scheduling principles that can be followed. In small organizations, the scheduling is usually practical to do manually but when the scale and complexity grows, it is often recommended to use an automated scheduling system based on algorithmic computation (Voudouris et al., 2008). There is no one single universally optimal scheduling system and every organization should find a solution that fulfills its own needs.

Success in scheduling is vital to any service organization. It affects directly the service quality and costs and, therefore, is an essential factor regarding the productivity of the whole organization. Fluent workforce scheduling contributes attaining high service quality and achieving large productivity with low operational costs (Leisant et al., 2000). Poor scheduling, therefore, leads to underutilized capacity, unnecessary costs and inaccuracy in target times (e.g. Voudouris et al., 2008). Work scheduling affects directly also the workforce of an organization. For example, if the schedule is not updated to reflect the current situation, the schedule is not considered as useful and reliable and workers are not, therefore, able to use it in their everyday work. In addition, the mentality "work takes as long as it takes" will more likely emerge among the workers who have to deal with unreliable schedules (Hietala, 2009).

3.2 Concepts and Prerequisites of the Work Scheduling

Work scheduling process can be defined in multiple ways depending on context. Therefore, the concepts used in scheduling and the prerequisites for scheduling process also vary to some extent. However, some similarity exists and next, the basic concepts are represented following by overview of required input data of the scheduling process.

In literature, there are several basic concepts that are generally used in context of work scheduling studies (e.g. Crowling et al., 2006; Voudouris et al., 2008; Leisant et al., 2000). Two most fundamental concepts typically used in scheduling studies are *resources* and *tasks*. Tasks are the actions that are allocated to resources and resources represent any unit that can perform tasks. Resources have *capabilities* (skills or experience) and the set of resources available is defined as *capacity*. Tasks, in turn, have different attributes, like location, duration, travel time, required capabilities and dependences between tasks. Allocating different tasks to resources is called *dispatching*. As a result of allocating several tasks to a single resource for a certain time-windows, *sequence* of tasks will form. Set of those sequences combined with unallocated tasks, consistency and cost information form the actual schedules (Voudouris et al., 2008).

A fluent scheduling process needs accurate input data, on which the schedules can be built. According to Voudouris et al. (2008), input data includes information of the amount and nature of available resources (technicians, equipment and material), the nature and properties of those resources (technician skills and location), confirmed and forecasted demand, and the details of the scheduled tasks (diagnosis, required skills, location, and travel and job duration). Ala-Risku (2009) points out that, especially in field services, the criticality of the maintained equipment, access constraints in customer's sites, and the service history of maintained equipment have to be known in order to allocate tasks effectively and provide the technician prerequisites for the work.

The challenge concerning the input data is that, in most scheduling environments, the form, source, accuracy and quality of the data are not constant and they will rather vary depending on external factors such as customers or traffic (Voudouris et al., 2008). Therefore, the data is more difficult to process and standardized scheduling methods and strategies are more difficult to exploit. There is, though, significant part of the input data properties of which the organizations can and should influence: for example, the details of resources should be properly documented and the data should be available to those affecting the schedule creation (Voudouris et al., 2008).

However, there is some information relevant to the work scheduling that can never be entirely precise in advance. Examples of that kind of information are travel and task durations. Task duration will depend on the executor of the task (routines and skills), accuracy of the task details received from the customer and the task execution environment - all variables that may not be known in the scheduling phase. The variables concerning travel duration are for example traffic conditions, roadwork and weather (Leisant et al., 2000).

However, Voudouris et al. (2008) emphasize that there are methods to create good estimations: for travel times there are several computational systems and task duration estimations can be enhanced by using the historical data of the company. Borenstein et al. (2009) studied the work scheduling with stochastic task durations and they suggested that the performance of the schedule will improve if the task duration estimations will be rather overestimated than underestimated. They found out that underestimations will increase the idle time while overestimations will decrease the probability of lateness and make the schedule more robust. Furthermore, in context of their study, Borenstein et al. (2009) showed that decreasing the probability of lateness was more effective than decreasing the idle time in their research setting. They stated, though, that more research would be needed for better understanding of the issue.

3.3 Complexity in Work Scheduling

The complexity of work scheduling has been emphasized in multiple studies (Voudouris et al., 2008; Leisant et al., 2000, Borenstein et al., 2009). This complexity is comprised of several distinct factors, and perhaps the most stressed ones in literature are different constrains that are limiting the scheduling options. In addition to the constraints, scheduling objectives, the scale of scheduling and dynamic operating environment also increase the complexity of the system. Next, the complexity in scheduling is discussed.

There are several constraining features limiting the scheduling process. Most typical constraints according to Voudouris et al. (2008) and Leisant et al. (2000) are listed below in Table 2.

Table 2. Typical constrains in scheduling process (Voudouris et al., 2008; Leisant et al., 2000)

Constraint related to	Constraints
Resources	– Limited personnel capacity – Limited equipment capacity – Scattered locations of resources – Variety in personnel competencies – Variety in equipment properties
Regulations	– Obligatory breaks – Working hours – Authorizations to certain tasks (e.g. electrical works)
Customers	– Available and desired time-window – Desired personnel – Limited premises to customer's sites

Groop (2012) argues that, especially in field services, time-critical demand create temporary constraints because the works have to be accomplished in a certain time-window. Thus, according to Groop (2012), it is sometimes necessary for a field service organization to maintain excess capacity to meet the demand during peak-times. Groop (2012) also emphasizes that, therefore, it is important to distinguish the time-critical need clearly from the non-time critical when determining the schedule.

In addition to the constraints, other important determinants in scheduling decisions are the scheduling **objectives**. Those objectives are derived from organization's business objectives and influenced by customer preferences and nature of the operating environment (Leisant et al., 2000). Objectives can be seen as a way to qualitatively estimate schedule options to find the best solution among them (Voudouris et al., 2008). Typical scheduling objectives appearing in scheduling studies are mostly related to resource utilization, cost efficiency, flexibility, delivery precision and responsiveness (e.g. Crowling et al., 2006; Haugen & Hill, 1999; Leisant et al., 2000; Voudouris et al., 2008). However, the objectives are closely related to scheduling and organizational environment so there is variation between the objectives that are used in different scheduling environments.

The **scale** of scheduling process affects also on the complexity. There is a huge difference to allocate tasks for a few drivers in a small transportation company compared to allocate 50,000 tasks per a day for 10 000 technician in a large maintenance company. In large organizations the scheduling process becomes more complicated: allocating such a large number requires huge resources and finding an optimal solution would be extremely difficult (Voudouris et al., 2008).

Dynamism in scheduling occurs in several ways. According to Borenstein et al. (2009) dynamism in scheduling consists of arrival of new tasks in a day, stochastic estimation of travel duration and stochastic duration of tasks. Voudouris et al. (2008) points out that also the environment surrounding work scheduling, as task cancellations, delays and sicknesses, can be seen as dynamism. Petrakis et al. (2012) argue that the impact of dynamism to scheduling is virtually negative: changes emerging during the day cause deviations from the planned schedule, after which, rescheduling will be required. Therefore, the dynamic elements in scheduling should be avoided for as much as possible.

Voudouris et al. (2008) divide scheduling into two distinct cases based on dynamism: static and dynamic scheduling. In static scheduling all inputs for the scheduling would be precise and received forehand which would lead to optimal schedules that could be executed as they are. In dynamic scheduling, information is imprecise and updated concurrently with the determination of the schedules. Therefore, the decisions must be made before all information needed is known and long time schedules are impossible to create. Due to high degree of dynamism, the need for dynamic scheduling is relatively common for field services (Petrakis et al., 2012). Suggested solution for high level dynamism is that the schedules should be updated fluently when changes arrive (Petrakis et al., 2012; Leisant et al., 2000).

3.4 Scheduling Principles and Optimization

After defining the prerequisites and elements influencing the scheduling process, the next step is to pay attention to the actual creation of the schedules. Next, the basic overview of the scheduling principles is given followed by the discussion concerning the optimization in scheduling.

The goal of a work allocation process is to find a match between a task and a resource so that the properties of the resource fulfill requirements of the task (Ursu et al., 2005). In other words the tasks must be allocated so that no inconsistency occurs (schedule is feasible among the constraints) and business objectives are met. The allocation can be done either manually by dispatcher based on dispatching rules or automatically by computational algorithms. Dispatching rules handle tasks individually obeying certain allocating functions based on objectives (Hill, 1992). Automatized scheduling notices rather the whole batch of tasks need to be allocated and seeks to find an optimal solution based on the selected objectives. These two different scheduling perspectives are discussed more in section **3.5.**

As mentioned earlier, scheduling consists of sequencing tasks to the resources while complying with the requirements and trying to reach the scheduling objectives. Schedules are typically visualized in Gantt chart (Figure 1) which shows the sequences of allocated activities for each resource (Jia et al., 2007). Scheduling solutions can also be displayed on a map where the location of each tasks can be visualized. The map display is especially practical in field service scheduling where planning the travel routes is an essential part of scheduling (Borenstein et al., 2009).

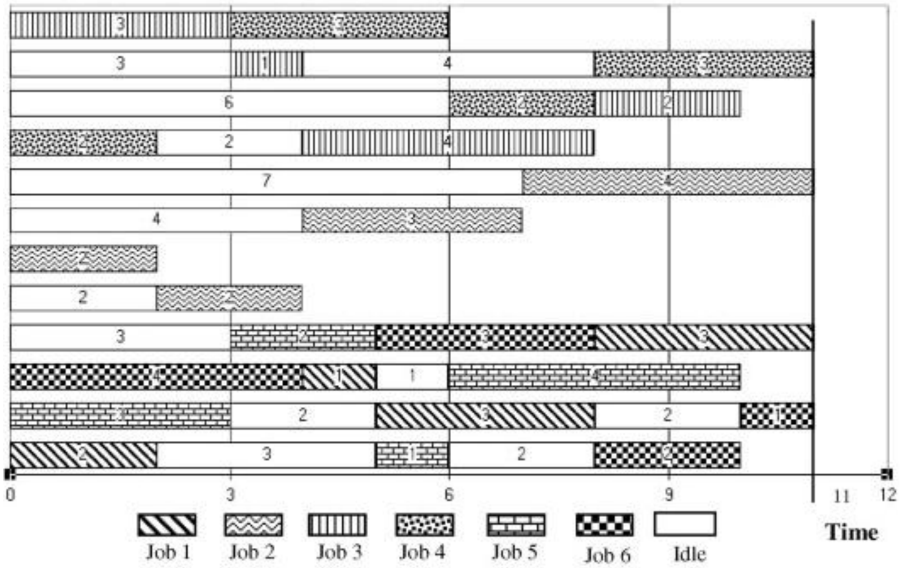

Figure 1. An example of Gantt chart visualizing the sequences of allocated tasks for each resource (Jia et al., 2007).

Workforce scheduling can be considered as an **optimization** problem (Zerdin et al., 2011). Optimizing schedules is mostly compromising, and finding the best solution among adequate ones regarding to objectives is rather challenging. The complexity often increases because those different objectives may conflict: for example, if an organization has defined ‘high capacity utilization rate’ and ‘quick response to emergency works’ as its objectives, then, if capacity is continuously fully utilized it would be difficult to react to the incoming emergency tasks. Therefore, besides choosing objectives carefully, also the weights of the different objectives have to be considered: what objectives hold most importance to the organization’s operations (Voudouris et al., 2008). On the other hand, Cowling et al. (2006) emphasize that in real world problem it is often impossible to define the relative importance of different goals and thus assessing the correct weights to different objectives might be difficult. They found out, in their study, that scheduling system without weighted objectives would provide almost as good results as the ones with weighted objectives. They executed their research by simulation and the result proved that the fitness of the non-weighted scheduling was within 2% of those with the weighted objectives.

Prioritization of the different tasks is a significant part of the optimization problem. Different tasks have properties which define the urgency of the task execution: for example response times, customer expectations and the importance of the customer. The prioritization criteria are usually based on the scheduling objectives of the organization: they describe which of those properties hold importance (Voudouris et al., 2008). In dynamic scheduling environment, as field services, handling different priorities is especially challenging. High priority tasks arising during the day has to be allocated immediately which may cause deviations from the planned schedule (Petrakis et al., 2012). According to Lin & Jun (2009), typical prioritization methods are often based on heuristic rules or commonsense derived from experience, which may lead to increased downtime and wasted resources. They suggest that prioritization should be, instead, constructed analytically and all involved character values of tasks should be "*quantitatively represented based on their relative preference over each other*".

As discussed earlier, travelling is considered as one of the key elements in field services. Therefore, according to Borenstein et al. (2009), the optimization solutions used in field service literature are vastly focusing on vehicle routing: schedules are created in order to minimize the travel times and distances and, thus, keep the excess expenses low and productivity of the work high. Borenstein et al. (2009) remark, though, that the importance of travelling is often also overemphasized, and more attention should be paid also on other variables. For example, Groop (2012) presents that optimizing the travel distance in scheduling may actually decrease the efficiency of the whole system. In his study of home care services, he observed that schedules, which minimized the travel distances, lead to artificially accumulated demand in the morning, when timecritical tasks emerged most. As a solution, Groop (2012) suggests that the level demand should be prioritized over minimizing travel costs and excess capacity consisting of skill group buffers should be maintained in a common resource pool, because excess capacity buffer enables to adjust the capacity according the actual demand in local units. Moreover, Groop (2012) outline that, in field services, minimizing travel times may lead to a situation where non time-critical tasks are executed when time-critical demand exists. Therefore, the travel distance should not be the only optimizing parameter that should be taken into consideration.

Final part of the optimization issue is the partition of the scheduling problem. As discussed earlier, large-scale scheduling systems are complex and therefore difficult to process as an entity. Therefore, according to Ursu et al. (2005), it is practically mandatory to divide the workforce to smaller, more manageable domains. They point out that the partition is usually made based on the location or the different service disciplines of the company. However, locational partition place issues on schedule optimization. Ursu et al. (2005) emphasize, that if all domains are scheduled separately, then the solution will not be very optimal in global level and scheduling leads to sub-optimization. For example, if two contiguous domains face completely different demand for some period of time, the result might be that the other domain will have adjacent capacity, while the other will suffer from resources shortage. To prevent that kind of loss in optimization, Ursu et al. (2005) suggest that after local allocation, an interactive global allocation process emerge where excess resources and unallocated tasks are matched to avoid simultaneous demand peaks and resource shortages.

3.5 Scheduling Methods

3.5.1 Dispatching Rules

There are several different methods to schedule tasks for resources. Perhaps the simplest way to do it is to allocate every task separately based on scheduling rules (Borenstein et al., 2009). Hill (1992) represents typical dispatching rules for field service operations, which can be divided to call-initiated rules and technician initiated rules. Those rules are suitable rather to real-time scheduling in dynamic environment than to proactive schedule-creation. Call-initiated rules applies when a new task arrives and there are more than one technicians idle. An example of a call-initiated rule is *Nearest technician rule* (NRT), which assigns the task always to the nearest technician. Technician-initiated rules are adopted when there are tasks in queue and a technician becomes available to be dispatched to a task. Examples of technician initiated rules are:

- *First-come-first-serve* (FCFS), where technician is assigned to the task that has arrived to the system first. Optimize processing time.
- *Nearest call* (NC), where technician is assigned to the nearest task. Optimize travel distance.

- *Earliest expiration time* (EET), where technician is assigned to the task which has the earliest expiration time. Optimize due date.
- *Negative or positive slack-times,* where technician is assigned to the task, which has either largest negative or positive slack-time. Optimize due date or shortest processing time.
- Composite rules. If the first rule is not met, then the allocation will be done by following the latter rule. Especially the slack-time rules are often used in composite-rules, because there are not necessary always free tasks with a certain slack-time.
  (Hill, 1992.)

According to Hill (1992) a composite rule (Travel Time Expiration Time) which combined the shortest processing time and due date objectives performed best according to different performance measurements in simulated field service environment.

The weakness of rule based-scheduling is that every task is handled separately and, therefore, global optimization will unlikely be reached (Voudouris et al., 2008). Haugen & Hill (1999), for example, found out in their study that a certain scheduling process based on optimization of all tasks outperformed different scheduling rules in all service quality measurements they used (mean response time, mean tardiness, mean promise time and mean technician response time). Rule-based scheduling is not suitable for large-scale scheduling problems, where several different scheduling objectives are involved (Haugen & Hill, 1999). Instead, rule-based scheduling is practical for manual scheduling in small, dynamic environments when the arriving tasks has to be allocated fast and there is no time for large-scale optimization (Voudouris et al., 2008). According to Li et al. (2012), in dynamic environments, the experience of the operator can be best utilized through manual scheduling to response the disturbance events. Therefore, instead of using sole automatic systems, they propose human-computer collaboration when creating and renewing schedules also in large-scale scheduling environments.

3.5.2 Automated Scheduling Approaches

In addition to manual scheduling, automated scheduling approaches exist. As soon as the scale of scheduled tasks increases, the scheduling process becomes more complex and complicated. Voudouris et al. (2008) claim that *"... on medium and large sized organizations it is virtually impossible for scheduling planners to manually schedule jobs and, at the same time, consider business rules and quality targets*". Therefore, in those cases, automated scheduling is often a better solution. Automated scheduling is generally based on algorithmic optimization that complies with scheduling constraints and objectives. According to Voudouris et al. (2008), different computational scheduling approaches can be divided to two categories: exact searches and metaheuristics.

Exact searches are based on algorithms that are guaranteed to find and prove an optimal solution, or the non-existence of it, to the particular optimization problem (Puchinger & Raidl, 2005). Therefore exact algorithms are often considered as ones of the most efficient approaches in optimization problems (Voudouris et al., 2008). The weakness of the exact search is that the run time of the algorithm increases enormously with the instance size (Puchinger & Raidl, 2005). As discussed earlier, automated scheduling becomes relevant only when instance size is large and, in most real-life scenarios, schedules need to be generated in relatively short time due to the dynamic environment. There is no use to spend hours for creating an optimized solution for circumstances that are no longer valid when the solution is ready. Therefore, the exact search approaches rarely fit to workforce scheduling as they are (Voudouris et al., 2008). Exact search algorithms types include for example linear programming, tree search, branch & bound, integer programming, dynamic programming and constraint programming (Puchinger & Raidl, 2005; Voudouris et al., 2008).

Instead of using sole exact searches, **metaheuristic** (MH) methods are often more appropriate. MH methods are based on algorithms, but in addition to that, heuristic criterion is used for guiding the search process through the set of possible allocations (Voudouris et al., 2008). MH is an iterative process where starting point is a feasible solution. That solution is then modified incrementally and evaluated to the original based on the heuristics. Repeating that process iteratively will lead to more optimal solution. MH methods don´t usually find the most optimal solutions to a certain problem, but using heuristics to assist the computational process, reduces the search time radically. Therefore, using MH methods instead of exact algorithms can be seen as trading optimal solutions to get good ones in a limited time. (Puchinger & Raidl, 2005) Some typical MH searches are simulated annealing, tabu search, iterated local search, variable neighborhood search and various population based models (Puchinger & Raidl, 2005; Voudouris et al., 2008).

3.6 Rescheduling

Pivotal concerning scheduling process is to figure out the frequency of renewing and updating the schedule, i.e. frequency of rescheduling. Voudouris et al. (2008) suggest two different approaches to rescheduling: proactive and reactive. **Proactive scheduling** proposes the schedules in advance for the whole set of resources and tasks. Because proactive scheduling deals with the whole set of resources and tasks, it can create optimized schedules. On the other hand, it is dependent of the accuracy of available information and forecasts, and therefore tolerates very little dynamism or changes for the scheduled time span. **Reactive scheduling**, therefore, consists of fast production of short term schedules with only limited number of tasks. It provides quick responsiveness, but in the expense of global optimality.

Voudouris et al. (2008) note, that real-world scheduling problems are often highly dynamic and demand optimization. Therefore, neither of previously presented rescheduling strategies typically fit as they are. Instead, scheduling systems that combine both proactive and reactive strategies are widely used in work scheduling. A combining scheduling procedure that is referred widely in scheduling literature was first introduced by Leisant et al. (2000) in context of scheduling for British telecommunications workers. Later, that procedure has been developed by multiple researchers, and used widely, particularly in field service scheduling (Voudouris et al., 2008). The elements of such dynamic scheduling process are represented in Figure 2.

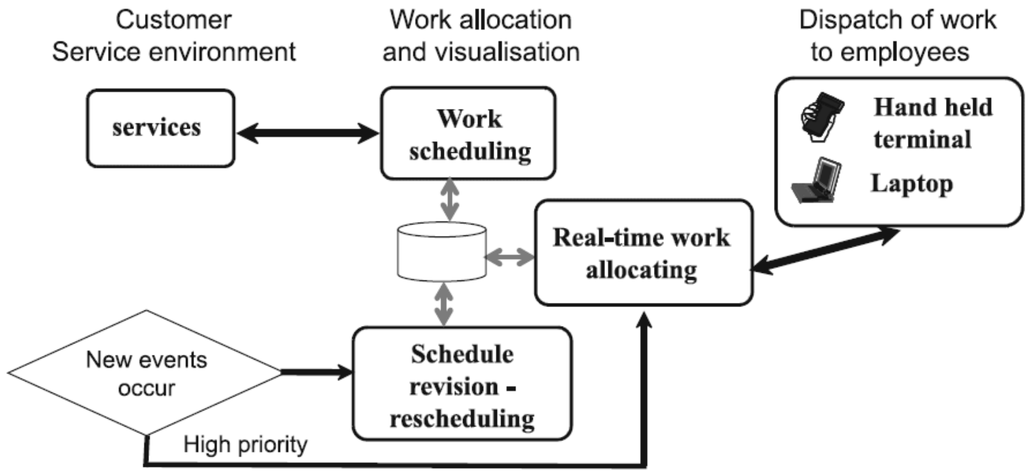

Figure 2. Dynamic work allocation process according to Voudouris et al. (2008).

The process consists of the Customer Services environment, proactive scheduling component (*Work scheduling*), reactive scheduling component (*Real-time work allocating*), mobile platforms of field technicians and a schedule controller (*Schedule revision - rescheduling*). The phases of the process are following:

1) Proactive component periodically creates a new optimized schedule based on the information available of the forecasted and confirmed services for customers. (Voudouris et al., 2008)

2) Reactive component dispatches the work assignments to the technicians and sends allocated tasks to the mobile platforms of the particular technician.

The reactive component operates based on the provisional schedule but it is triggered by external events like urgent incoming tasks or early finished task of a technician. (Voudouris et al., 2008; Leisant et al. 2000)

3) When new events occur, the urgent tasks are handled in reactive component and non-urgent are left to be waiting rescheduling. Information of all changes goes to schedule controller, which evaluates the gap between original and existing schedule and decides when to do the rescheduling process. (Voudouris et al., 2008; Leisant et al. 2000)

4) Rescheduling may be also tied to a certain period of time and it may be partial or complete depending on the volume and nature of the changes since the last reschedule. Rescheduling is also often based on the previous schedules observing the changes happened since the last scheduling. (Voudouris et al., 2008)

3.7 Effective Schedule Execution

Executing a fluent running scheduling system in field services is not only a result of the planning and schedule creation phase. In addition, also the activities executed after the scheduling are affecting the process: tracking the location of resources and status of tasks help to react on dynamic changes, while standardized work reporting enables the exploitation of history data on planning (Voudouris et al., 2008; Ala-Risku, 2009). Effective schedule execution requires two-sided feedback transmission between workers and organization (Voudouris et al., 2008). For that feedback process, a mobile platforms and GPS based tracking systems are often considered as vital tools to give dispatchers and service managers a visibility of the ongoing work.

Mobile platforms and GPS help scheduling in several ways. Tasks are sent to technicians via the device by dispatchers, which after they are received and accepted or declined, and finally, after finishing the task, reported by the field operator. Thus, dispatchers know the location of every field operator and they can report whether a task is running over its scheduled time or has been completed early (Voudouris et al., 2008). Online allocation in dynamic field service environments will get easier due to that up-to-date information. For example, Petrakis et al. (2012) suggest that automated scheduling system integrated with mobile solution enables dynamic re-scheduling throughout the day, as technicians can be reassigned or rerouted effectively. It requires, though, that the mobile solutions allow dynamic changes to the allocated tasks.

In addition to the scheduling process, mobile platforms benefit also the work of a field technician in his daily operations. All incoming tasks can be received and accepted online while operating on a customer's site. The platform is also able to provide the technician task information of the ongoing task including history information, guidance and trip planning.

3.8 Service Quality Through Scheduling

Service quality was discussed in chapter 2 including the presentation of service quality model SERVQUAL and its dimensions. Now the impact of scheduling is set into context of service quality, and effects of the different quality dimensions of SERVQUAL are studied through based on the previous analyze of scheduling in this chapter.

The SERVQUAL dimensions that were presented in section 2.2 are tangibles, reliability, responsiveness, assurance and empathy. Two of those dimensions, tangibles and empathy, were not observed to be directly affected by scheduling. Tangibles relates to all physical elements involved in the service process. From the literature, no support was found that scheduling could affect the customers' perceptions on those tangible elements. Instead, another pre-execution step, material planning, is strongly involved in tangibles dimension. Empathy includes the "*Caring, individualized attention…to its customers"* (Parasuraman et al., 1988), and, therefore, it can be affected more by good treatment of the customer than effective scheduling. However, poor scheduling can indirectly affect the perceived empathy: too fitted schedules will pose a constant hurry to a technician which may lead to restricted attention to a customer.

The dimensions reliability, responsiveness and assurance were observed to be influenced more or less by the schedules. First of those dimensions, *reliability*, includes an assumption that the agreed schedules will be met and lateness will exist as little as possible. The accurate realization of a schedule and scheduling are, naturally, in direct interaction. *Responsiveness* includes the aspect of prompt service, which, according to Fehl (2006), consists of fast response times among others. According to Haugen & Hill (1999), effective scheduling will contribute to abbreviating response times. The last dimension, *assurance*, includes the communication with customer (Ham et al., 2003). Scheduling creates possibility to inform customers of the planned execution times, which contributes to better communication.

Based on the investigation, scheduling affects directly into three SERVQUAL dimensions and indirectly to one dimension. Thus, it can be stated that the success of scheduling has significant impact on the customers' perceptions of the performed service process.

In addition to the effects of scheduling to SERVQUAL dimensions, this thesis discusses the effects of scheduling to service quality also in the specific context of field service. In field services, where the service process is taking place in customer's premises, the functional quality of the service has an essential role (Haugen & Hill, 1999). According to Haugen & Hill (1999), the functional field service quality consist mainly of responding fast to customer requests, keeping customers informed and fulfilling the customer's expectations. They defined four key measurements for those service quality attributes:

- Response time - time elapse from the first contact of the customer to the arrival of the technician.
- Tardiness - the actual arrival time to the customer's site compared to the agreed response time; defines the level of arriving late to the customer's site.
- Technician phone response time – time elapse from the first contact of the customer to the moment when the maintenance time is agreed with the customer.
- Promise time – the time elapse from the first contact of the customer to the finishing of the maintenance work that is promised to the customer in advance.
  (Haugen & Hill, 1999.)

Haugen & Hill (1999) argue that good scheduling can influence positively to all of those measurements. With effective scheduling, the response times and tardiness decreases and, thus, better promise times can be provided. They emphasize the importance of the technician phone response time by declaring that, often, it is more important for a customer to be quickly informed of the planned maintenance time, rather than get the actual maintenance operation conducted fast.

Apte et al. (2007) question the validity of service quality measurements presented by Haugen & Hill (1999). They argue that the typical service quality measurements related to scheduling, like response times and tardiness, are only valid for the type of field services which consist of emergency tasks. They point out that many field service organizations deal with nonemergency situations, where the first priority of the customer is not necessarily to get service executed immediately but rather at a certain period of time that is convenient for the customer. In their study of non-emergent field services, Apte et al. (2007) observed that some of the customers were even willing to pay an additional amount of the service if they would receive the service at a more convenient time. They also suggest that better measurements for field service quality for nonemergent service tasks would be performance quality and conformance quality. *Performance quality* measures the gap between the customer’s preferred time and the promised service time, while *conformance quality* measures the gap between promised service time and actual service time.

III EMPIRICAL STUDY

4 Methods

This chapter introduces the methodology used in this thesis. First, the design science methodology that is applied in this study is briefly discussed followed by the representation of the data gathering methods. Last part of this chapter includes the presentation of Theory of Constraints (TOC) and Thinking Process (TP) principles including the more precise descriptions of Current Reality Tree and Conflict Resolution Diagram focusing on the parts relevant for this thesis.

4.1 Design Science Methodology

This thesis follows a design science methodology, while applying the problem-solving techniques of TOC TP. **Design science** research combine theory-oriented academic research to problem-solving-oriented research. Thus, the objective of the design science research is to solve field problems and that the results will hold practical relevance (Holmström et al., 2008; Denyer et al., 2008). According to Denyer et al. (2008), characteristic for design sciences are that "*research questions are driven by field problems and a justification of research products are based largely on pragmatic validity*". Design science research complies with CIMO-logic, which includes four concepts: Context, Intervention, Mechanism, and Outcome. Denyer et al. (2008) summarizes the CIMO logic as following: "in this class of problematic *Contexts*, use this *Intervention* type to invoke these generative *Mechanism(s)*, to deliver these *Outcome(s)*".

The design science research is applied in this study due to the problem solving perspective and relevance to solving field problems. As discussed earlier, an essential objective of this study is to solve the real-life problem of the case organization. Therefore, a methodology that permits combining the scientific research method to practical problem solving will be appropriate in order to reach the objective. The different CIMO concepts apply in this study as follows:

- **Context** is the maintenance field service, and especially scheduling in maintenance field service.
- TOC identifies the constraints in the context. What to change to improve the performance of constraints is the **intervention.**
- The actions targeted to the scheduling process, ensuing by the intervention, embodies **mechanism**
- Improving the performance of the constraint translates into better performance, meaning the improved service quality and productivity as **outcome**.

However, this study doesn't apply the CIMO logic entirely: the interventions are suggested, ensuing mechanisms identified and the assumed outcome defined, but no empirical validation of the intervention is provided in this thesis.

4.2 Data Gathering

The qualitative data was gathered to gain understanding of the scheduling process of the case organization. The main objectives were to define the current scheduling process and capture undesirable effects relating to the scheduling process for the TP analysis. The methods for gathering data in this research included interviews and observations, which are typical methods for qualitative research approach (Eskola & Suoranta, 2000). In addition to interviews and observations, initial understanding was perceived from meetings and discussions with the members of the Case Co.'s service efficiency team, as well as from the internal presentations and documents of Case Co.

The participants involved in the empirical data gathering were chosen based on the initial understanding of the author mentioned above influenced by the recommendations received from the case organization. The qualitative data was documented in the forms of memos and recordings. The amount and details of observations and interviews made can found on the Table 3.

Table 3. Interviews and observations

Role	No	Locations involved	Method
Dispatcher	5	Helsinki, Turku, Södertälje, Stockholm, Oslo	Observations (5), and interviews (2)
Service Manager	9	Helsinki, Turku, Södertälje, Stockholm, Oslo	Interviews
Technician	1	Helsinki capital region	Observation
Other (HR, contracts, master data)	3	Headquarters	Interview

Observations

The main method for data gathering in this study was participant observations which followed ethnographic methodology. According to Silverman (2010), an objective of ethnographic observation is to "*learning the code [of the participants]…in order to understand the meaning of their actions*". A participant observation includes a direct, interactive contact between observer and participant in the natural environment of the participant (Silverman, 2010). In this thesis, five dispatchers were observed in three divisions and five units. In addition, observation was conducted to one service technician to reveal how the elements relating to scheduling are reflected to the work of a technician.

Interview

In addition to observations, also interviews were made to increase the understanding of the studied phenomenon. Unstructured interviews were used due to the problem-solving nature of the survey. As Robson (2002) describes, in unstructured interviews the interviewer decides the frames for the discussed topic, but within those frames, the conversation may develop freely. Those frames of the interviews of this study concerned the participants' tasks related to the scheduling process. Notes and memos were drawn from every interview and part of the interviews was also recorded. The interviews were targeted mainly to the service managers: observing the work of service managers was found to be difficult due to the abstract nature of their work. Therefore, interviews were preferred over observations. In addition to service managers, few dispatchers and other internal employees were interviewed. The dispatcher interviews took place before the dispatchers were observed and the objective of those interviews was to sharpen the focus for observations. Rest of the interviews concerned human relations, service contracts and the master data of case organization, and those interviews were conducted in the headquarters having internal experts of those topics as participants.

4.3 Analysis Method

4.3.1 Theory of Constraints (TOC)

The analysis of the empirical data is conducted with the TOC TP methods. More precisely, two TP tools, Current Reality Tree (CRT) and Conflict Resolution Diagram (CRD) are used for the empirical analysis. TOC is a management philosophy that deals with manageable systems. As its name relieves, it focuses on constraints. More accurately, it focuses on finding and fixing the factors that are constraining the system most. TOC was originally created and introduced by Eliyahu M. Goldratt (Dettmer, 2007) and it is later developed and contributed by numerous authors (Groop 2012).

In TOC, the observed system is seen as networks of chains which consist of numerous links of actions that are involved in the system (Dettmer, 2007). Among those links, there are one or few weakest links preventing the system working more efficiently than it currently is. This is based on the assumption that if there were nothing limiting the throughput of the system, the throughput would then be infinite (Dettmer, 2007). The objective in TOC is to identify the weakest links and resolve the constraints. After eliminating the constraints, the system will work more effectively, but, however, another weakest link will then emerge. Therefore, the TOC process is often continuous and iterative in its nature (Dettmer, 2007).

The constraints in TOC are divided to three groups: 1) *resource constraints* occur when demand exceeds capacity, 2) *policy constraints* include formal or informal rules limiting the capacity, and 3) *market constraints* are external and indicate that the demand is limiting the productivity of the system (Watson et al., 2007). This thesis focuses on the policy constraints, which are, according to Groop (2012), most essential in the context of services. Policy constraints include operating policies, practices or measurements, and examples of typical policy constraints are sub optimization of sub processes, or incorrectly set incentives which are both leading to local optimization rather than global (Groop, 2012).

TOC has multiple components and tools for identifying and revealing the constraints. Those components are often divided to three branches: Logistics or operations strategy tools, performance measurement and Thinking Processes (Mabin & Balderstone, 2000). The logistics branch includes "*tools and methodologies for transferring TOC's underlying ideas into a variety of operational context, such as production, distribution and projects*" (Groop 2012). Performance measurements consist of measurement techniques that aim for global optimization rather than local. Thinking process techniques are constructed for locating and overcoming policy constraints and are discussed more in the next chapter. A summary of different branches and the components they comprise can be seen in Figure 3.

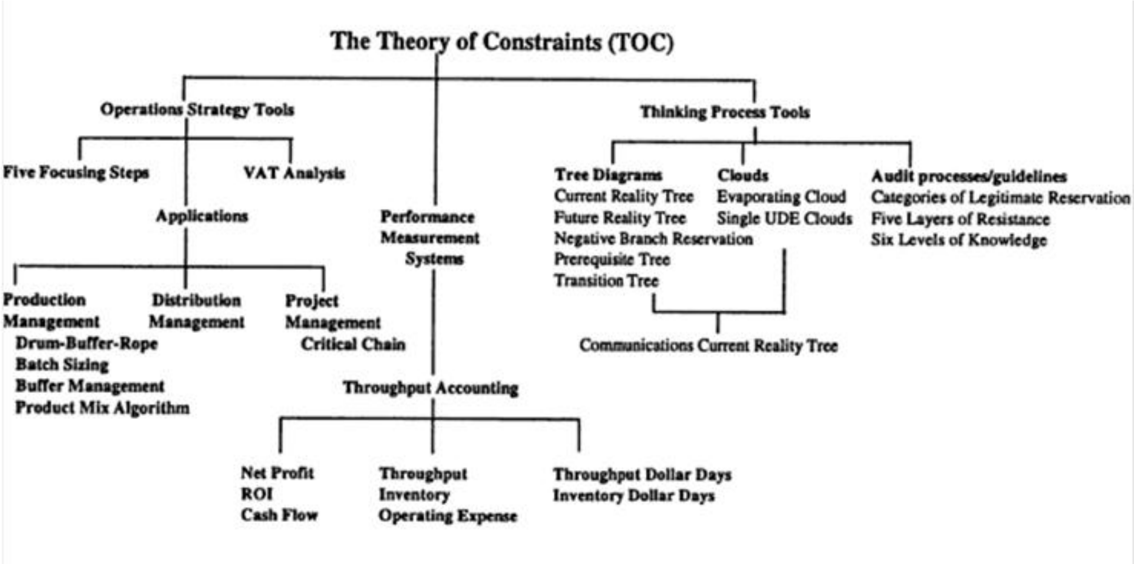

Figure 3. Components of TOC (Mabin & Balderstone, 2000).

4.3.2 Thinking Process (TP)

TP is a TOC solving technique that focuses finding the core problems of a system. TP consist of several different techniques which provide logical approaches to identify and remove especially underlying policy constraints (Dettmer, 2007). The objectives of TP can be summarized into three questions: 1) what to change? 2) what to change to? and 3) how to cause the change? (Goldratt & Cox, 2004). TP essentially tries to provide answers to these questions with different tools.

For the first question, TP offers a tool called Current Reality Tree (CRT). It is used to figure out the underlying reasons that are causing the symptoms of the system. Conflict Resolution Diagram (CRD) and Future Reality Tree (FRT) try to answer to the second question. The earlier tries to solve the discovered core problems and the latter evaluates the impacts of the solution to the system. To the third question there are tools such as the prerequisite tree (PRT) and the transition tree (TT), which strive to define intermediate objectives, identify potential obstacles to the realization of the objectives, produce a detailed sequential implementation plan and communicate the rationale and overcoming resistance to change (e.g., Dettmer 2007). This thesis fill focus on the first two TP questions and, thus, CRT and CRD, which are the tools exploited in this study, are represented later in this chapter. The latter TP question, and tools related to it, is not discussed more explicitly in this thesis.

TP tools act as guides for decision-making process as well as representation of logic (Mabin & Davies, 2010). They are represented in a form of logically constructed diagrams, and examples of CRT, CDR, FRT, and their relations can be seen in Figure 4. TP diagrams include entities in a form of rectangles and the relations of those entities illustrated as arrows. An entity represents an element of a situation. The construction of the TP diagram is based on three building blocks (Scheinkopf, 2010). Two first building blocks includes two logic categories: sufficiency based cause-effect logic (arrow on the diagram represents cause between entities) which underlies in CRT and FRT, and necessity-based *in order to* logic (arrow on the diagram describes what condition is needed to achieve a certain objective) is utilized in CRD (Mabin & Davies, 2010).

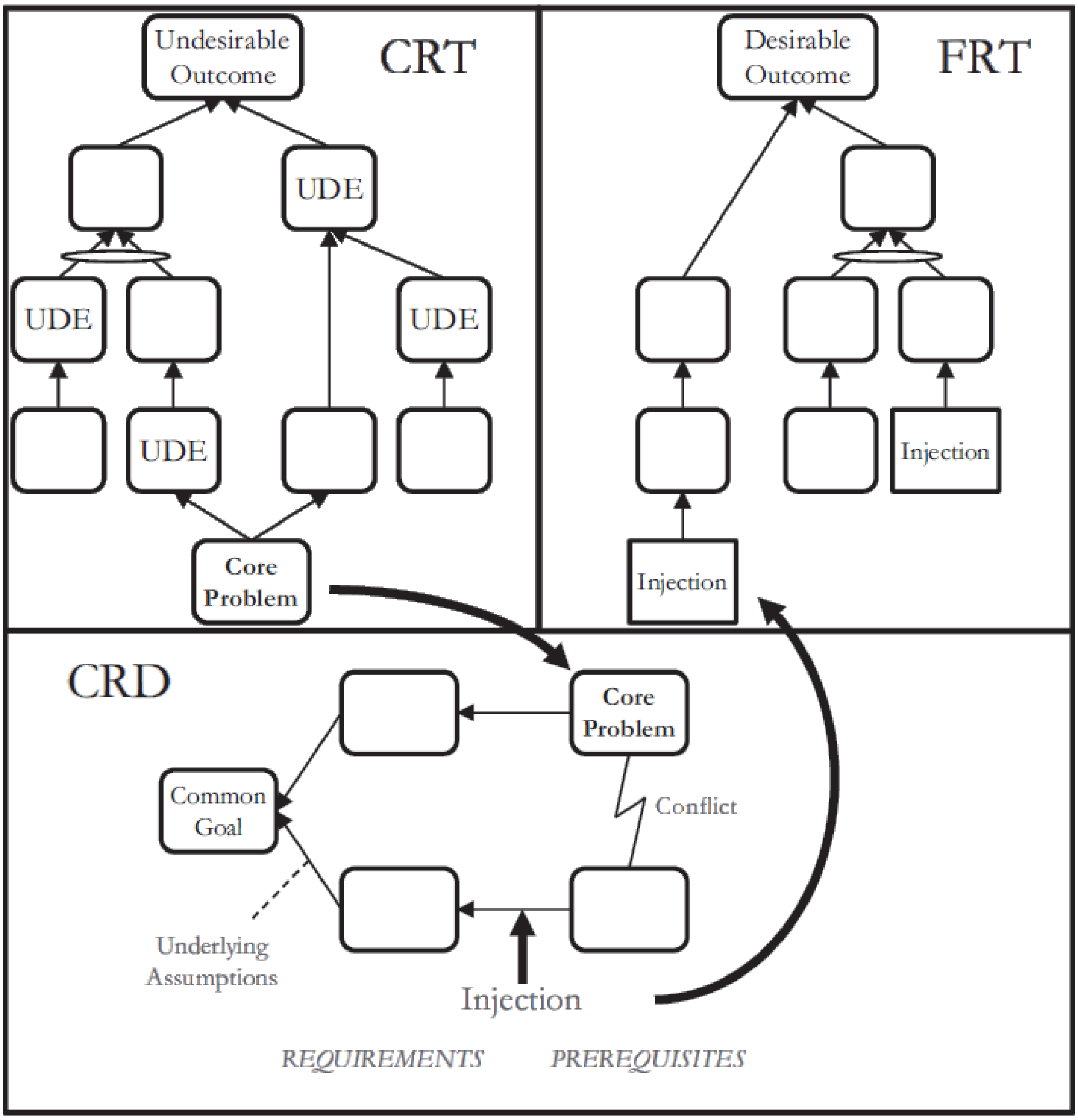

Figure 4. CRT, CRD, FRT, and their relations (Groop, 2012).

The final building block comprises the rules of the TP logic, known as Categories of Legitimate Reservation (CLR). The purposes of the CLR are to evaluate the logic of TP diagram either while constructing or interpreting one (Scheinkopf, 2010).

CLR are, thus, rules for constructing TP diagrams and they describe the relations of different TP diagram elements. CLR consist of three levels, and with each level, the logic is going deeper investigating the logic structure. CLR is illustrated in Figure 5.

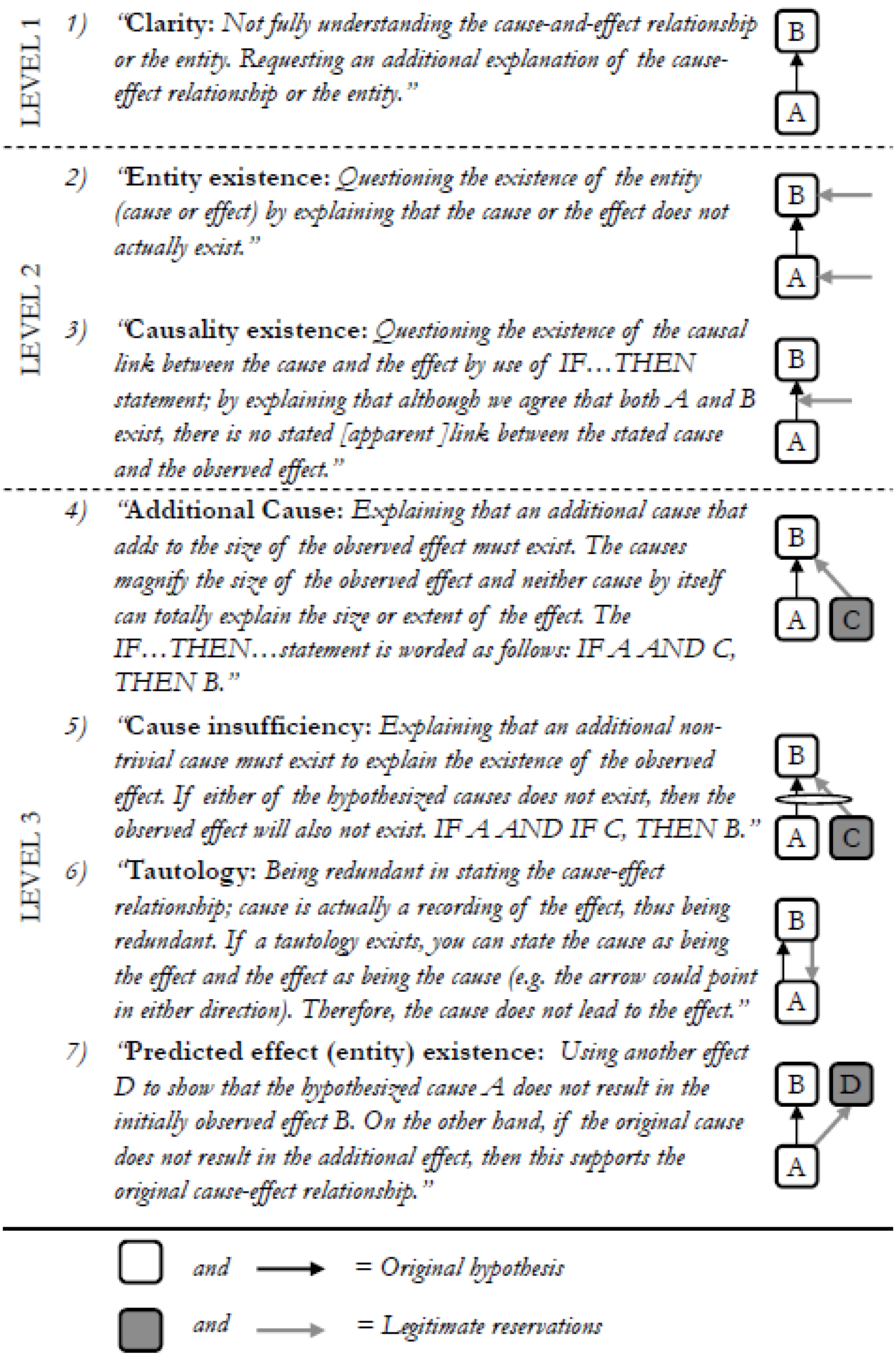

Figure 5. Categories of Legimitative Reservation (CLR) (Groop, 2012; Scheinkopf, 2010).

UDEs and Current Reality Tree (CRT)

The CRT is used to answer the first question of TP, what to change. It tries to provide the root causes for the system malfunction following a logical cause-effect reasoning and determine why the current situation of an organization differs from the desired one (Dettmer, 2007). Constructing of a CRT starts with collecting undesirable Effects (UDEs) of the observed system. UDE is a phenomenon that apparently indicates a problem in a system, but is not necessarily the problem itself. Dettmer (2007) stated that UDEs are the things that we see in our system that we don’t like. Most of the time, UDEs are not really problems, but indicators and resultant of underlying causes (Dettmer, 2007). Therefore there is no use to try to solve single UDEs but rather try to seek those underlying causes to eliminate the whole problem.

After identifying the UDEs, CRT starts to tackle the root causes by depicting probable causes to the different UDEs. Those causes can be either other already observed UDEs or completely new ones. As a result of the process there should construct a logical cause-effect tree representing the relationships between the system’s entities with the underlying causes to the UDEs on the bottom of it. CRT is considered particularly effective if the symptoms are caused by a policy instead of physical constraint (Mabin & Davies, 2010) what is often the case in service operations. A set of steps for constructing a CRT is provided e.g. Noreen et al. (1995):

1) Identify a list of UDEs that describe the area being analyzed. It is recommended to begin with a list of five to ten UDEs.

2) Connect one or more UDEs to other UDEs if they are causally related. Depict cause and-effect relationships with an arrow as shown in the categories of legitimate reservations (CLR).

3) Connect all other UDEs to the result of step 2. Scrutinize each [entity] and arrow along the way via the CLR. Stop when all the UDEs have been connected.

4) Read the tree from the bottom up, again scrutinizing each arrow and [entity] along the way via the CLR. Make any necessary corrections.

5) Ask yourself if the tree as a whole reflects your intuition about the area being analyzed. If not, check each arrow for additional cause reservations (CLR #4).

6) Do not hesitate to expand the tree to connect other UDEs that exist but were not included in the original UDE list.

7) Present the tree to someone or some group who will help you surface and challenge the assumptions captured within.

8) Decide that the CRT is complete. Identify the core problem or problems. (Noreen et al., 1995)

Conflict Resolution Diagram (CRD)

CDR is a problem solving tool and tries to answer the second question of TP, what to change to. CDR deals with problems that derive from conflicting actions that are executed to reach a common goal. The objective of CDR is to make visible the hidden assumptions that prevent identifying solutions to those problems (Scheinkopf, 2010). The core problem(s) identified in CRT can be often viewed as such problems (Mabin & Davies, 2010). Dettmer (2007) asserts that in well-developed management system the existing problems are nearly always a result of a conflict, because if there were no underlying conflicts that prevent a straightforward solution, the core problems wouldn't even exist. CDR takes the output of the CRT (i.e. the root causes of the UDEs) as its inputs (i.e. the problem that needs to be solved).

Groop (2012) represents a typical setting of a CRD, which can be seen in Figure 6. CRD displays the problem in a diagram with following components: one objective (A), which have two requirements (B,C) with prerequisites (D, D') that are conflicting. According to Dettmer (2007), for a single objective there are always at least two distinct requirements that must be met. And for those requirements, there are prerequisites, actions that are needed to fulfill that requirement. The conflict often arises between these two prerequisites. CDR starts to seek the solution to the problem by examining the underlying assumptions concerning the relations of the different components. Mabin & Davies (2010) suggest that some of those assumptions are often found to be weak or false when they are verbalized, and thus the conflict will be eliminated. And even if the assumptions are recognized as valid, there are still possibilities to intervene on those to solve the problem.

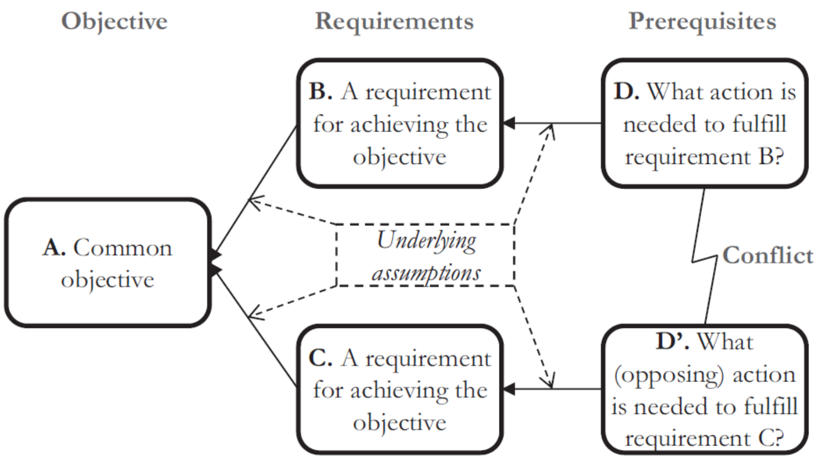

Figure 6. Conflict Resolution Diagram (Groop, 2012).

Thinking process in field services

TOC was originally developed for manufacturing environment and later expanded to cover also service operations. However, there are some limitations with the use of TOC in services due to the different nature of those two operational environments. In order to apply TOC in this study, the suitability of TOC to field services is next investigated briefly.

The traditional TOC tools outside TP investigate inventories and throughput of the system. Because services cannot be stored and service workflow consists of multiple parallel processes, those TOC tools are not quite suitable for services. Instead, TP is considered extensible and has a generic nature and, therefore, TP is considered to be to most suitable TOC tool for services (Dettmer, 2007; Moss, 2002). Groop (2012) studied the feasibility of TOC TP to field services in his research on health care services. He suggests that TP is most suitable for field services among TOC tools, because it provide effective way to discover the reasons underlying poor productivity in service environment, where the measures concerning throughput and performance differ from manufacturing.

5 Description of the case organization

In this chapter, the studied service organization, Case Co., is presented. First, this chapter gives a general view to Case Co.'s operations followed by more thorough representation of Case Co.'s service operations. Finally, the current scheduling principles and practices of Case Co. are reviewed.

5.1 Subject Organization of the Case Research, Case Co.

Case Co. is operating in building systems and industrial services. Case Co.'s services are used, for example, in business premises, retail stores, airports, hospitals, apartments, public properties, infrastructures and in industrial plants. In 2013 the revenue of Case Co. was approximately 2,5 billion euros. Case Co. has nearly 18 000 employees in 13 countries in Northern and Central Europe. (Case Co. website)

The history of Case Co. is diverse: it is formed of several distinct organizations during the last few decades. Due to the relatively short period of joint existence, different Case Co. units are still acting somewhat based on their own routines and practices. Therefore, unifying and upgrading the processes, methods and tools to increase service efficiency is noted as one of the key strategic targets for 2014-2016 (Case Co.'s annual report, 2013). This thesis is also involved in reaching that target by researching the scheduling process.

The organizational structure of Case Co. is following: Case Co. is divided to eight division mainly based on the operating nations. Within each division, there exist several regions and branch offices, which consist of service teams. Service team includes a service manager and 7-15 service technicians. The service teams are divided based on disciplines, location and customer, meaning that significant customers may have own service teams.

The service offering of Case Co. consist of wide range of services related to building systems and industrial services. Case Co. has identified several client segments and service areas including consulting and executing. The technical solutions that are delivered by Case Co. are divided into nine technical disciplines, which are:

- Heating & Sanitation
- Ventilation & Air Conditioning
- Cooling
- Electricity
- Information and Communication Services

- Security & Safety
- Automation
- Industrial Installations
- Process Piping

Case Co.'s service operations can be defined as field services excluding service tasks concerning planning and consulting activities. Other tasks include technicians working remotely at the different customer's sites.

5.2 Technical Services

5.2.1 Technical Services in Case Co.

The focus of this thesis is on the technical maintenance services of Case Co., which are now represented more thoroughly from the perspective of how the work is actually executed. In addition to scheduling itself, other phases of the service process from order receiving to work reporting are also affecting the scheduling process. Therefore, the technical service process is now presented with broader perspective rather than describing only the scheduling phase.

The technical maintenance services, including maintenance of buildings and industrial plants, are seen as core competence of Case Co., and the process of technical services is considered as one of the core processes (Case Co.'s annual report, 2013). The technical services process consists of three stages: contract creation, work execution and follow up. In this thesis, only the work execution stage is discussed. The work execution sub process includes several roles and stages that require certain actions from the roles. Those stages are identified as followings: order receiving, planning, scheduling, execution, work reporting and invoicing. The roles involved in the work execution are customer, help desk, dispatcher, service manager, technician, administrator and system (ERP). The more precise service process descriptions are presented later in this section.

Technical services in Case Co. are divided into preventative planned maintenance (PPM), corrective maintenance (CM) and service projects. PPM is addressed for the value preservation of the property and effective long-term cost management, while CM and ad-hoc interruption repairs are intended to tackle urgent defects. Service projects are for upgrading existing equipment and systems. Next, the service types of CM and PPM, and the processes lying below them, are presented more thoroughly. The presentation is based on Case Co.'s process descriptions, i.e. the processes are presented as they are intended to be, not as they are observed to be. The process, in general terms, is re-examined in chapter 6 to correspond the empirical observations. The examination of service projects is not included in the scope of this study due to the different prerequisites for scheduling.

5.2.2 Corrective Maintenance (CM)

CM is a maintenance activity carried out after a failure has occurred, and it is intended to identify and isolate the fault and restore the item to the to the state in which it can perform its required function (Ben-Daya et al., 2009). CM differs from PPM primarily in such a way that, in CM, a problem must exist before a corrective action can be taken. In Case Co., CM works are called ad-hoc works defined as small hourly invoiced works for contract customers and other customers. Case Co. has contractual response-times for only few CM works. Those so called ‘emergency works’ exist only for a few customers, while, for most customers response times are not included in the contracts. Thus, the different priorities defined for works are equally priced for customer. The intended service process of CM works is illustrated in Figure 7 and it is next explained in respect to different phases of the process.

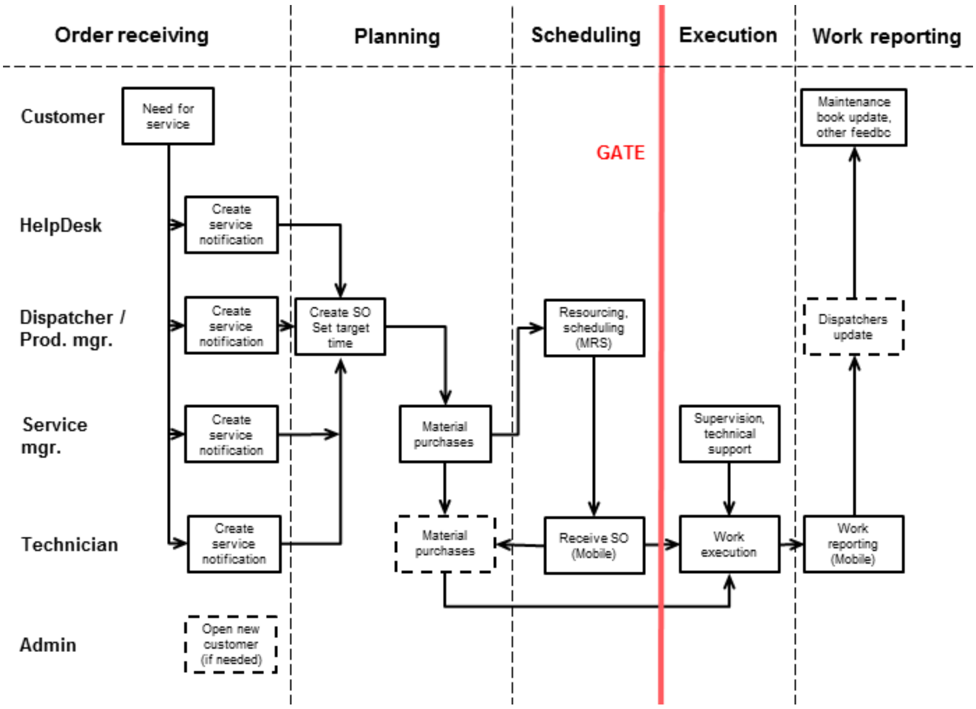

Figure 7. The intended CM service process concerning scheduling.

Order Receiving

The first impulse for the service process comes from the customer: a need for service arises when customer detects a defect or a malfunction in his equipment. Customer has several ways to contact Case Co. for the preparation: customer can contact help desk, service manager or dispatcher by calling or email, or contact the technician right on the site. In addition, the customer can report defects by filling a form in Case Co.'s web pages in some Case Co. units. After the customer's announcement, the receiving Case Co. employee creates a notification to ERP (SAP) based on that announcement. Creating a notification requires acquiring all necessary information for the work that can be received from the customer.

Help desk doesn't exist in all Case Co. units, but whenever it does, the customers are advised to contact primarily the help desk. That is to simplify the order receiving process and ease the burden of other roles. When the incoming orders are received and notifications created by a restricted number of actors, it is easier to keep the form and content of the notifications compatible. On the other hand, the process has to be flexible to react in urgent situations and, therefore, the paths for incoming works can't be too limited. The technicians' abilities to create notifications are also limited due to the available tools they have in field.

Case Co. offers help desk service also for customers whose buildings are maintained by another service organization. In those cases, the notifications are forwarded to the organization responsible of the work execution.

Planning

The planning phase begins with the service order (SO) creation. The dispatchers create SOs to ERP based on the notifications. Compared to notifications, SOs includes more precise information of the work. For example, task duration, priority, task type and customer details have to be defined. The information required to create SOs is available, for the dispatchers, in ERP as a form of notifications, history data of past works and customer details.

After the SOs have been created, the planning phase includes material purchasing, which is primarily on the response of service managers. In some cases, the technician may also handle the material purchasing. It is important to purchase the materials in advance because pre-ordering provides discounts of the materials, and purchasing materials only during the work will increase travel costs and travel time.

Scheduling

After planning, the next phase in the service process is scheduling. Scheduling is executed by dispatchers with MRS, which is a scheduling tool in ERP. The works are allocated to technicians based on the information of the work on the SO and the information of the technicians. The information of the work consists of the technical discipline, service team, customer, possible response time, and preferred time-window. The information of the technicians that are relevant in scheduling includes service team, technical discipline, current schedule and working hours. All that information should be available in ERP.

After allocation, the SOs are sent to the technicians' mobile platforms, and if the task is urgent, the technician is also informed by calling. The allocated works compose a schedule, which is visualized as a Gantt chart in MRS.

Gate

In Case Co.'s service process, a clear difference between the planning and execution phase is defined, which is called a "gate", and, which is illustrated in the process description as a red line. The function of the gate is to signify the importance of planning, which in this context includes all phases before execution. Once the planning has been conducted successfully, the execution can then be performed more fluently and faster, while, if the execution is started with rush and without proper planning, the total time and resources will increase. The objective of Case Co. is that the gate should not be passed until all preliminary tasks are performed.

Execution

After the work has been allocated, the technician receives it with the mobile platform. Then, according to the daily schedule, the technician starts the work with the mobile device, executes it and, if needed, consults the service manager of the work details and additional billable work. When a work is ready, the technician reports it finished with the mobile platform. The report includes details of work done, used materials, billable hours and driven kilometers.

Service manager provides support for the technician in the execution phase. Service manager also monitors the completion of the works, contacts customers, responses of the approval of emerging additional work and, after the execution, invoices. In addition, service manager also operates as a supervisor for the technicians.

5.2.3 Planned Preventive Maintenance (PPM)

PPM is scheduled preventive maintenance to customer's assets. The goal of the PPM is to improve system reliability, as well as decrease replacement costs and downtimes due to breakdowns (Hadidi & Al-Turki, 2012). For PPM works, Case Co. has a specific service concept. It is a flexible agreement that lets the client build their own maintenance service of more than 100 available services into a functional whole. In the PPM contract, the upcoming maintenance need is estimated and planned ahead: PPM works are executed based on previously agreed timespans and the content of the tasks are defined precisely in concept description.

The intended service process for PPM works can be seen in a Figure 8 and is explained with respect to the differences compared to the CM service process.

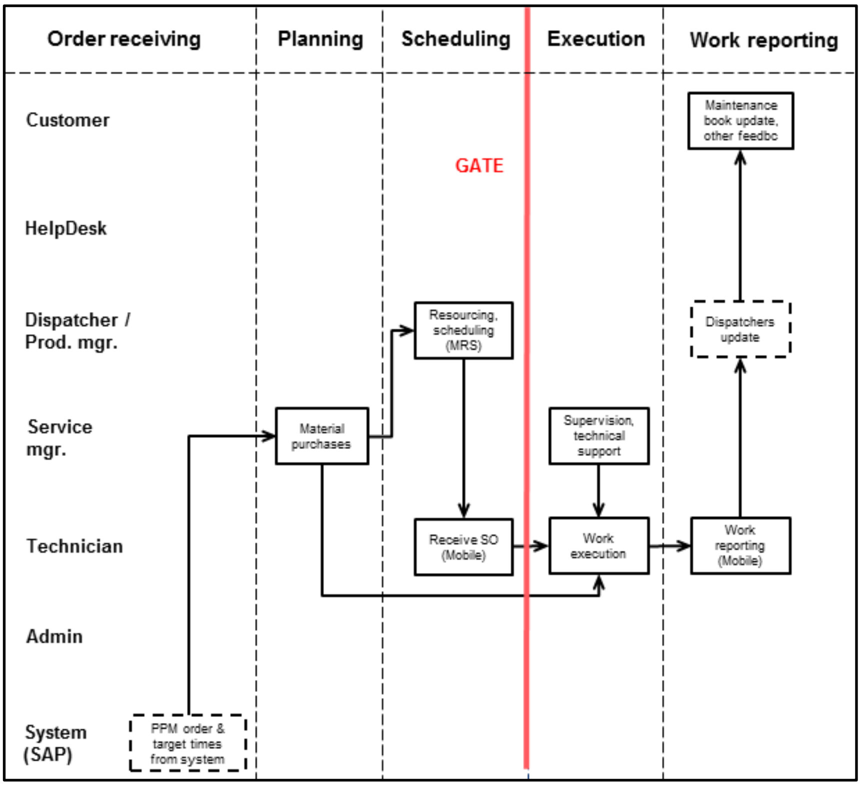

Figure 8. The intended PPM service process concerning scheduling.

The process follows more or less the same paths as the CM ad-hoc process. The only differences consider the order receiving and roles of ERP: the content of PPM contracts can be imported to Case Co.'s ERP system. If that data exists in ERP then the new SO for PPM works can be generated automatically according to the maintenance plan. Hence, the dispatcher doesn't have to create SOs manually. However, currently only some of Case Co.'s service units have imported the PPM contracts to ERP, while, in the majority of the units, the SOs for PPM works are still created manually.

6 Analysis

This chapter discusses the findings of the research. The chapter begins by presenting a brief current-state analysis of technical service process, based on the qualitative data. This is followed by the overview of UDEs found during observations and interviews. A thinking process analysis based on the UDEs is used to determine the policy constraints preventing the effective scheduling process to take place. The analysis divides the constraints to five distinct groups which are represented on the CRT. Conflict causing the constraints was found concerning prioritization, PPM, and allocation boundaries caused by service teams. CRD analysis is performed to reveal the weak assumptions leading to those conflicts. For other constraints revealed in the CRT, no conflicts were identified and, therefore, no conflict resolution was required.

6.1 Identifying the Current Service Process

6.1.1 Corrective Maintenance (CM)

The starting point of the empirical research was to create a current-state analysis of the Case Co.'s technical services process. The objective was to perceive understanding of the current scheduling system in different divisions of Case Co., and reveal the differences compared to the intended processes. The focus on the current-state analysis was on the scheduling phase, but as mentioned earlier, the whole process was included until the execution phase, in order to expound the effects of distinct phases to scheduling. The current state analysis was created based on the qualitative data and a reference was taken from the service operation processes presented earlier. As a result of a current-state analysis, renewed process diagrams of CM and PPM service processes were created. Renewed CM process is visualized in Figure 9 and explained next regarding to the differences to the intended process.

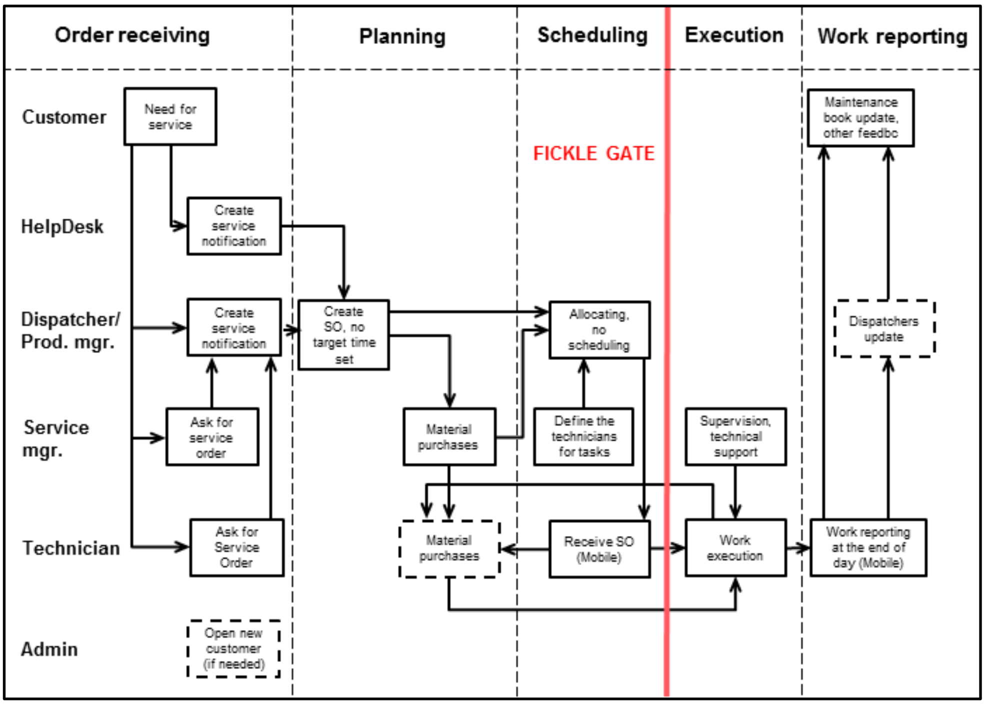

Figure 9. As-is version of Case Co.'s CM service process concerning scheduling.

Different regions had somehow quite different practices and processes concerning the service operations. The roles were similar in title-level: service operations process in each region included dispatcher(s), Help-desk, Service Managers and technicians. The contents and responsibilities of those roles concerning the scheduling, however, differed from each other. Next, the as-is process of CM service process is presented phase by phase.

Order Receiving

The practices concerning incoming defects varied in the different regions. Generally, customer had a possibility to report defects to all those same roles as in the intended process. However, the observation revealed also differences to the intended process. For example, part of notifications were created in the control room based on the data they received. Furthermore, in most cases, if a technician or a service manager received the defect announcement, they did not open the notification by themselves. Instead, they tended to call to the dispatch and ask dispatchers to "open a SO for me/this technician". In those cases the information considering that certain task was not documented properly: the technician didn't feel it necessary to report the details of the work to the dispatcher because that particular technician knew already those details and was going to execute the work. Thus, tacit knowledge existed.

In some regions, the only way for a customer to report defects was to contact help desk. That relieved more time for the other roles to execute their actual tasks. That procedure was considered viable according to dispatchers, service managers and technicians, while no customer opinion was gathered in this study.

Planning

The planning phase was observed to be quite close to the intended process. Dispatch was creating SOs from notifications in every observed unit. However, the contents of SOs are not as accurate as they were intended to be. In the intended CM service process (Figure 7), the most critical task in SO creation was the setting of the target time. Based on observations, no target time estimations were made to any CM works in none of the observed units. Also other information, like priorities or customer's contact details were not always included in SOs. Based on the observations, the material purchases were conducted by both service managers and technicians.

Scheduling

The most significant differences between the intended and as-is processes were observed to exist in the scheduling phase. Scheduling was defined earlier in section 3.2 to be allocating tasks to resources to be executed in a certain moment of time (Voudouris et al., 2008). The observations revealed that scheduling like this doesn't exist in Case Co.'s service process. Currently, the dispatchers allocate works to technicians without actually defining when those works are going to be executed. The start time of the allocated work has to be entered to MRS, but those times didn't correlate with the reality: works were just drag-and-dropped to the timeline of the technician to the position where the previous work, allocated in the same day, ends. Each technician has, thus, a work queue from where the technician execute his or her works.

The observations revealed that the execution order of the works varies in different units: in some units the technicians can define by themselves the order, while in the others the service manager had control over his technicians. However, those schedules were not documented. The priorities of the tasks were taken account, but they weren't obeyed precisely. The dispatch didn't truly have any control over the execution order of the tasks in any of the observed units, even though the scheduling was defined to be in their response in the intended service process. The schedules that technicians or service managers created were not updated to MRS and, according to the observation, no systematic documentation was made of those.

In addition, allocating works to technicians didn't prove to progress as straightforward as described in the intended process. The technician's skills are not listed in Case Co.'s IT system and SOs isn't always detailed so that the required skills or materials for a work could be known. Therefore, the ability to allocate works to capable and suitable technician depends vastly on the experience of the dispatcher: experienced dispatchers knew the technicians and what kind of works can be allocated to them, while, the ones with little experienced reported that they have to constantly ask for advice from other dispatchers or service managers. In some units, every allocation went through service managers, i.e. service managers defined technicians for every single work.

Fickle Gate

The gate between the planning and execution didn't appear to be as clear as it was intended to. Tasks that were supposed to do before the work execution were observed to be done often after the work had been started. As explained in the *Scheduling* section, the actual decisions of the execution order of the works are often made by the technicians during their working day. In addition, interviews revealed that the materials were sometimes purchased on site, which interrupts the work of the technicians.

Execution

The work execution phase didn't differ much from the intended process. However, the use of the mobile device were not observed to be as detailed as it is supposed to be. The starting and finishing of tasks are nearly never reported real-time and, thus, the timestamps in ERP are not correlating the actual execution times. In addition, the daily schedules of technicians are often altered due to new incoming CM tasks and, sometimes, exact schedules for technicians do not necessary exist at all. In those cases, the technician has to do rescheduling throughout the day.

6.1.2 Planned Preventive Maintenance (PPM)

Differences existed also in the service process of PPM works: between the intended and as-is processes, as well as between different Case Co. units. The renewed PPM process is illustrated in Figure 10. As mentioned earlier, the PPM service process differs from CM service process only in terms of order receiving and, therefore, only that phase of the process is discussed.

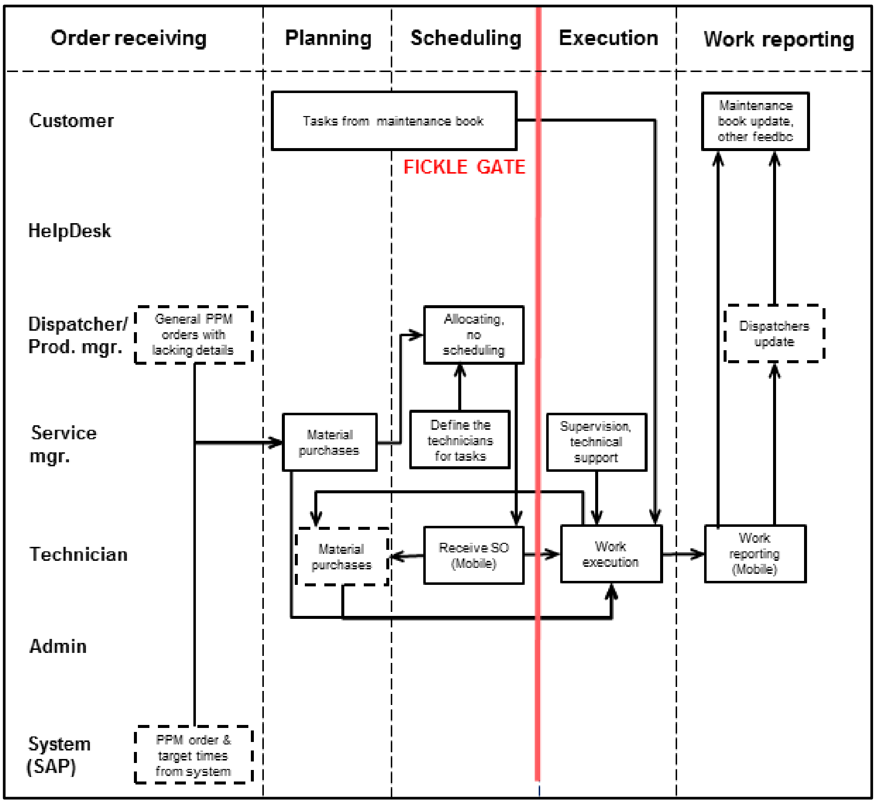

Figure 10. As-is version of Case Co.'s PPM service process concerning scheduling.

In some units the PPM process was almost as it is described in the intended process description: works are generated in ERP and the dispatchers allocated them to technicians that were defined in advance. The practices related to automated PPM work generation were observed to be very effective in those units. However, the information of the technicians didn't exist in ERP, but in separate excel-files. On the other hand, in some units, none of the PPM works were created automatically and the rest existed somewhere between.

In addition, part of the planned maintenance data exists only in customers' IT systems. In those cases, the work reporting is executed and details of the works exist only in the IT system of the customer and no SOs are created to ERP. Therefore, those PPM works are not visible in Case Co.'s scheduling tool causing the planning and monitoring are difficult to execute.

6.2 Core Problems

6.2.1 Undesirable Effects (UDEs)

As described in the current-state analysis (section 6.1), no explicit scheduling is made for Case Co.'s technical service operations. To find out the reasons to that, TP was conducted, starting with the creation of the CRT. The first step of constructing a CRT is to identify the UDEs in the process that is examined. UDEs are the indications of the core problems in the system. The research revealed several UDEs concerning different roles involved in service operations. They were concerning not only the actual scheduling phase, but also service execution phase that was seen to reflecting the problems in scheduling. Next, some pivotal UDEs that were notified extensively, by several informants during the research, are represented. The list of all original UDEs can be seen in Appendix 1.

UDE#1. No explicit scheduling is done for the technician's day.

As discussed in the current-state analysis, the service process of Case Co. doesn't currently include explicit scheduling. In different Case Co. units, different roles may do scheduling up to some level, but a detailed and documented scheduling, where tasks are allocated to technicians to be executed at a certain time, were not discovered during the empirical research. Instead of schedules, the outcomes of the current dispatching process are tasks allocated to queues for every technician. Those tasks don't have usually preferred execution time.

UDE#2. No realistic estimations of the durations of the CM works.

This UDE was one of the starting points of this study. Case Co. had identified that no reliable estimations for the durations of CM works are provided in dispatch. The empirical research proved this initial observation to be true. Currently, the dispatch doesn't have both ways or motivation to make the realistic estimations and, therefore, those are not done. The current process and used systems don't provide enough support to dispatch for making the estimations. The motivation is lacking, because, as observed in the first UDE, the dispatchers don't schedule the work of the technicians and, therefore, the wrong estimations don't hinder their work in any way.

The observations in dispatch revealed that the estimated duration of every CM work is often constant for a single dispatcher. The length of that constant duration is defined based on the properties of the scheduling system, MRS: in MRS, schedules are visualized in Gantt chart, where every technician have a timeline and their works are shown as bars. The length of every CM work is set by dispatcher so that the size of a work bar is optimal for showing all necessary information of the work. Two to four hour task durations were observed to be used in the units involved in this research.

UDE#3. All necessary information of the work is not available or documented.

There are several essential information components that are needed for effective scheduling and task execution which are currently not always available in Case Co.'s service process. That information was revealed to be somewhat undocumented and somewhat missing completely. That information that was discovered to be lacking were observed to be followings:

- **Task durations of CM works**. As mentioned in UDE#2, the estimations of the task durations were not made in any observed dispatching units and therefore not available.
- **Contact information of customers.** The contact information usually does exist in work orders, but was reported to missing sometimes – especially when the notifications came from service managers or technicians who already possessed that information and, therefore, didn't feel necessary to attach it to the notifications.
- **Fault and work descriptions** are often not enough detailed for effective work execution. In those cases, the technician has to inspect the defect first before he could execute the preparation. This may lead to multiple visits, because the technician doesn't necessary have all required materials, or the technician dispatched to the work may even be incompetent for the particular work.
- **Installed base data of the maintained building**. The relevant information concerning the maintained target and equipment is not properly documented and exists as a tacit knowledge among the technicians. In some units, where contract information has been imported to master data, information of the equipment exists in ERP. However, the technician doesn't have access to that data from the field. Lacking installed base data of the maintained building include:
    - Location of the maintained equipment.
    - Access constraints – (keys and permissions to properties and equipment areas, and the contact information of the customer and external service contractors).

All above mentioned information were not lacking for all works, and, again, differences exist between different units. However, the lack of information was reported as a problem in some level in every observed unit.

UDE#4. Dispatchers don't know what the technicians are doing and where they are.

Currently the dispatchers don't have awareness of the location of the technician and what task the technician is executing. In some units, GPS tracking system for service cars is available, but not exploited, because GPS locators are not installed in every car. Thus, the dispatchers do not know whether the car shown in the GPS map is actually the nearest. In addition, the dispatchers felt they didn't need the location information because the allocation of the urgent tasks often went through the service managers.

UDE#5 The nearest available technician doesn't always get allocated to occurring urgent work

Due to the previous UDE, dispatchers don't know what the technicians are doing and where they are, the occurring urgent CM works are not allocated systematically to the nearest competent technician. The procedure of allocating new CM tasks included often calling to the suitable technicians and the work was offered to the one who will response. Alternatively, the service managers might allocate the tasks among the technicians of their teams, but then the technicians from other service teams are counted out for the allocation. In addition, even very few of the interviewed service managers said that they knew what the technicians of his team are doing at a certain moment of time.

UDE#6. Defining the priority of a task is based on customer's request and common sense of the dispatcher.

The priority of a task is defined by a dispatcher when the dispatcher creates the SO. The observations and interviews revealed that there are no common guidelines for the prioritizing. There are multiple different priority levels included in ERP, while only five of them were observed to be used. Most dispatchers explained that the most important tools they use for prioritizing are their own experience and common sense. In addition, interpreting the needs of the customers was considered important. If the customer emphasized the urgency during the call the dispatchers tend to set higher priority for the work. One dispatcher explained that "if the customer shouts the whole phone call and tells he has an emergency situation, it is better listen to him to avoid trouble".

UDE#7. Help Desk workers and Dispatchers are not technical specialists.

The educational background of help desk workers and dispatchers is miscellaneous. The skills emphasized in recruiting process are rather emphasized to customer interaction than technical competence. Therefore, the help desk workers and dispatchers reported that they find it often difficult to identify 'what to ask' from customer concerning the technical details. Also the identification of essential details for work execution while creating work orders was described to be challenging.

UDE#8. In most units, PPM works are not generated in ERP.

As mentioned in the current state analysis in the section 6.1, the PPM works are generated automatically in ERP only in part of the units. When a PPM work is opened manually, the details of the tasks are usually not documented properly: inadequacies exist, for example, with task descriptions and duration estimations. Those units, in which the PPM works were created in ERP, were discovered to be a minority among the units involved in the research.

UDE#9. Some PPM works exist only in customer's IT systems

In one Case Co. division involved in the study, some of the PPM works has to be reported directly to customer's IT systems. In those cases, the SOs of individual tasks are never opened in Case Co.'s ERP and therefore the information of those tasks exists only in customer's IT systems. Thus, those works are not visible in Case Co.'s scheduling system, MRS, and the completion of those can be only monitored by going through the customer's IT system. The responsibility of executing that monitoring is on Service Managers and technicians, but due to the difficulties, they are often executed on the last acceptable moments or then they might even expire.

UDE#10 Multiple channels for incoming works, some very informal.

The observations at different dispatch units discovered ten different channels for incoming works. Some of those were noticed to be very informal, and the amount of documented details varied remarkably depending on the different channel. For example, as discussed in current-state analysis (section 6.1), when customer orders a work directly from Service manager or technician, the details are often not documented accurately. That creates possible problems if the technician changes during the execution, and in addition, invoicing will be difficult. A table of different channels for incoming works with pros and cons is presented in Appendix 2.

UDE#11 Technician skills not listed in ERP

There is no information available in Case Co.'s ERP about the skills, competences and experience of the technicians. Therefore, the scheduling and dispatching process requires lots of tacit knowledge about the technicians: it is not possible to allocate tasks if the competences of the technicians are not known. This UDE also eliminates the possibility to transfer from manual dispatching into using an automated scheduling system: in order to create matches between tasks and resources, the details of both have to be known and tacit knowledge can't be exploited in automated scheduling.

UDE#12 Finished works aren't often properly reported - no details what is done

As well as the details in the work orders were considered to be insufficiently documented, also the details concerning the finished work reporting were observed to be frequently inadequate. Poor reporting impedes the possibility to avail the history data for identifying new occurring defects.

UDE#13 MRS isn't optimal tool for dynamic scheduling

During the observation, several roles reported problems with the current scheduling system, MRS. The main problem seemed to be that the functionality of MRS doesn't enable any changes to schedules once the SOs have been sent to technicians. Therefore, there are no possibilities to react on dynamic changes in MRS, which decreases the suitability of MRS for scheduling in dynamic environments. Summary of different defects on MRS reported during the observations are listed below:

- Old tasks are not visible in MRS
- If delays occur, tasks cannot be updated to MRS
- Technicians are sorted by the service team and searching the technicians by their name is not possible in MRS
- MRS is slow and doesn't interact properly with other Case Co.'s system
- No shortcuts – in order to change something requires complex actions
- The geographical locations of tasks are not visible in MRS
- No view to see all the open tasks of a single technician
- If mistakes are done in allocating tasks, it is impossible to correct those in MRS. Instead, old SOs need to be cancelled and completely new SOs created

UDE#14. Urgent CM works interrupt the ongoing work of a technician and clutter the schedule.

The investigation revealed that technicians receive several new CM works weekly. Because the priorities of the CM works are not clear, the technicians have a tendency to treat many of those CM works as urgent. Arriving of new tasks that need fast reaction tends to clutter the initial schedule and sometimes also interrupt the ongoing work, and therefore, increase the travel distances and times for a technician. The observations revealed that some technicians even avoid creating the schedules for a whole day in first place because they thought that “the expected incoming CM work will ruin those, anyway”. Instead of scheduling the whole day, the technicians only take a brief look on the works they have in the queue.

6.2.2 Current Reality Tree (CRT)

The second step in constructing a CRT is to rearrange the UDEs in the form of a tree to illustrate causality of the effects. During this process, some new UDEs emerged which were supporting the logic of the tree, and which were also possible to address from the qualitative data. As a result of the rearrange, the CRT was formed. CRT reveals the set of core problems that are causing several UDEs and ultimately preventing the scheduling to take place. However, according to TOC principles, only few core problems should be discovered to be causing rest of the problems (Dettmer, 2007). The reasons for the existence of several core problems will be discussed in the section 9.2.

The CRT is broken into five different parts which are next presented separately for the purpose of simplicity. Each part expresses a separate issue that is currently hindering the possibility to schedule works for technicians. The whole tree is presented in Figure 11, where opposing parts of the CRT are illustrated in different colors. Some entities are included in several parts. A larger-size illustration of the CRT can be found on the Appendix 3.

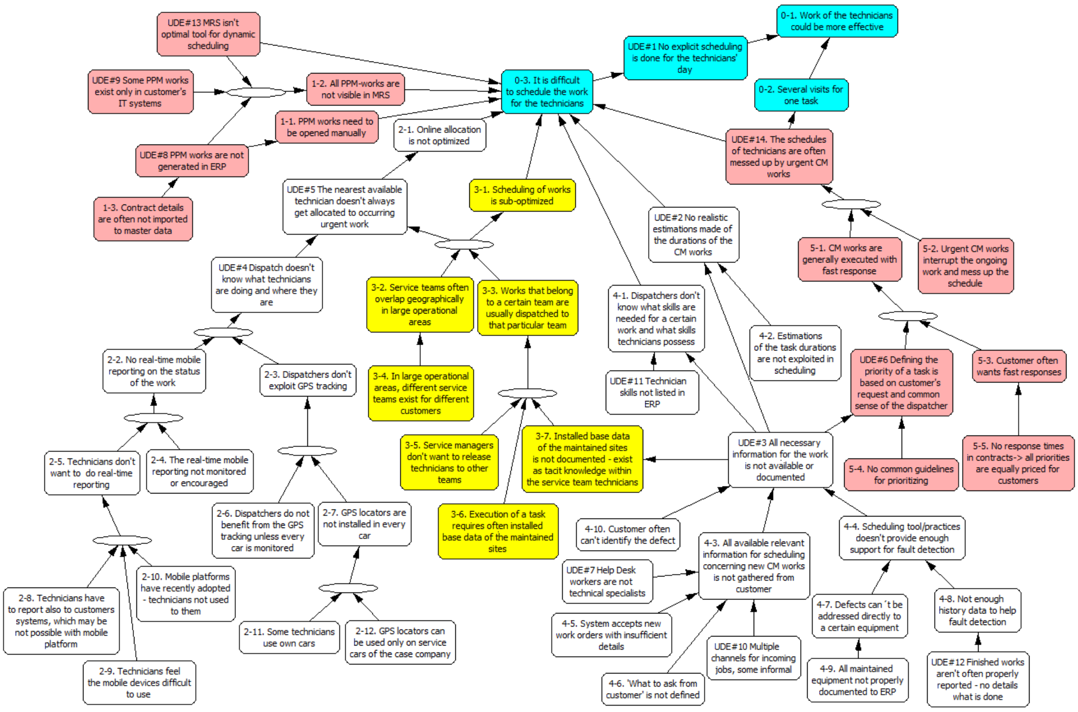

Figure 11. CRT

Top of the CRT

The top of the tree (Figure 12) illustrates the common symptoms of all involved problem areas. All other CRT parts lead to the same entity, it *is difficult to schedule the work for the technicians*, which in turn, leads to the current non-existence of scheduling. The top of the CRT illustrates also the ineffectiveness caused by lack of scheduling.

Figure reads: Because *it is difficult to schedule the work for the technicians* (0-3), *no explicit scheduling is done for the technicians' day* (UDE#1). Because, *no explicit scheduling is done for the technicians' day* (UDE#1) and *one work requires several visits* (0-2), *work of the technicians could be more effective* (0-1).

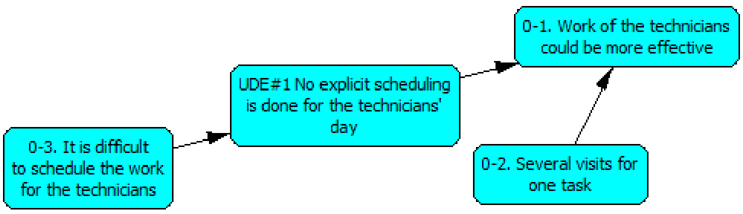

Figure 12. Top of the CRT

Part One – Planned Preventive Maintenance

The first part of the CRT handles PPM with respect to the master data in ERP (Figure 13). CRT illustrates how the core problems of *contract details are often not* *imported to master data* (1-3) and *some PPM works exist only in customer's IT systems* (UDE#9) hinder the scheduling. In addition, the weaknesses according to the scheduling tool are underlined in this section, even though it could be seen as a background contributor also in every other part of the CRT. As mentioned earlier, this part of the CRT is not an issue in every Case Co. unit observed during this study, while, in some units all the PPM data existed and were utilized in ERP. However, in those units, where the problem exists, it was found to be a major factor preventing the scheduling from happening as the PPM works were not available and visible for the dispatchers in the scheduling phase.

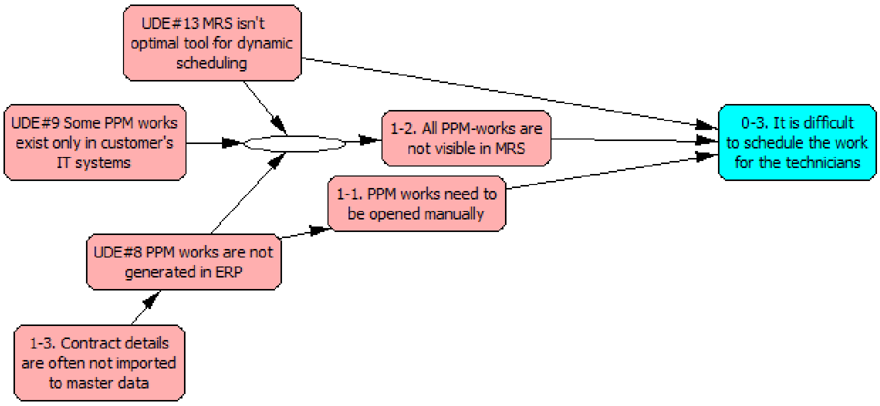

Figure 13. CRT Part One – Planned Preventive maintenance

Figure reads: Because *contract details are often not imported to master data* (1-3) *PPM works are not generated in ERP* (UDE#8) leading to that *PPM works need to be opened manually* (1-1). In addition, because *some of the PPM works exist only in customers IT systems* (UDE#9), *MRS is not optimal tool for scheduling* (UDE#14), and *PPM works are not generated in ERP* (UDE#8) cause that *all PPM works are not visible in MRS* (1-2). Moreover, if *all PPM works are not visible in MRS* (1-2), *MRS is not optimal tool for scheduling* (UDE#14), and if *PPM works are not generated in ERP* (UDE#8), *scheduling tasks for technicians complicates significantly* (0-3).

Part Two – Online Allocation

Part two of the CRT (Figure 14) demonstrates how the *unawareness of the location and status of the technicians*, together with the *limited allocation options caused by service team boundaries* that will be discussed in CRT part three, are blocking the possibilities to handle the online allocation of urgent CM works effectively. If there is no awareness of the location of the technicians or the status of the work, there are no possibilities to allocate new occurring urgent works optimally to technicians.

This happens, even though Case Co. possess the potential methods, mobile platform reporting and GPS tracking, to gain that awareness.

Issue with mobile reporting seemed to be that most technicians didn’t report their daily work until the end of their day, while if they would start and finish their individual tasks real-time with mobile platforms, the awareness of their location would be gained. Three core problems revealed in this CRT that were related to mobile platform reporting: 1) the lack of the monitoring and encouraging to mobile reporting (2-4), 2) the difficulties with the usability of the mobile platform (2-9), and 3) the obligation to report some of the works to customers IT systems (2-8). The real-time reporting procedure has been instructed, but apparently no monitoring of it is not taking place. Also some usability issues with the mobile platform have been identified that complicates the reporting. The requirement to report the tasks also to customers systems reduced the technicians’ willingness to report real-time, because they had to anyway report those tasks with laptops at the end of the day.

The issue with the usability of the mobile platform, as well as with the issue with scheduling system MRS discussed in part one, were found during the interviews and are not validated in this thesis. Therefore, more specific user testing would be required to confirm these core problems, as well as specify the requirements for both of those tools. This kind of user testing will remain to be conducted in the future.

In addition to the mobile reporting issue, another core problem was found, in this part of the CRT, which is preventing the utilization of GPS tracking. Some technicians use own cars, which are not possible to track due to regulations. Thus, all cars are not involved in the tracking and dispatchers didn’t feel useful to use the system: if all cars are not involved, no truthful information of the nearest car is available.

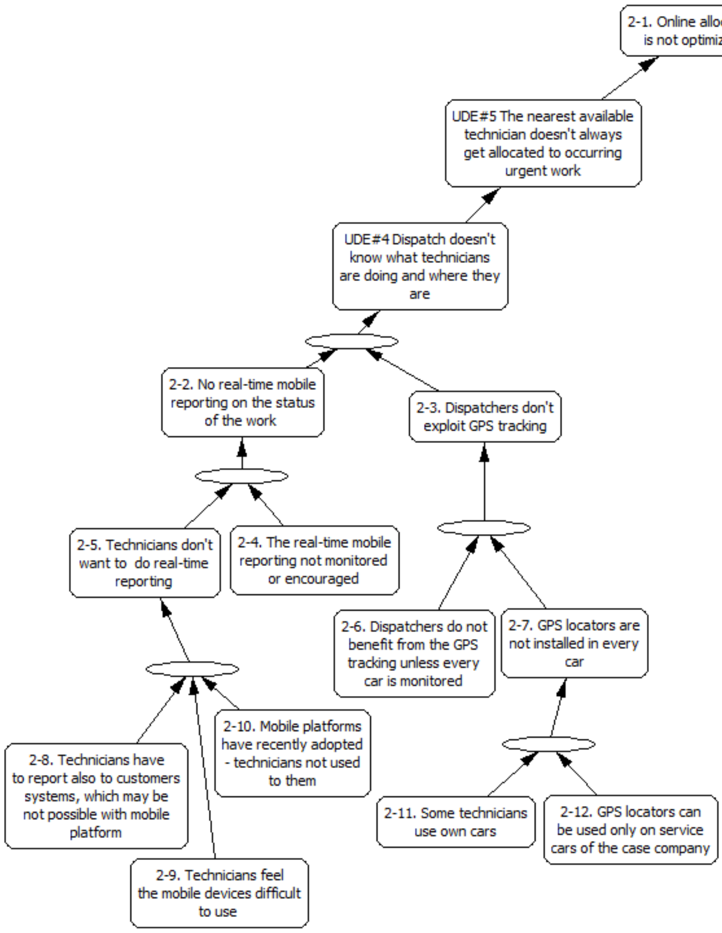

Figure 14. CRT Part Two – Online Allocation.

Starting from the branch, which considers mobile reporting, the second CRT reads: *Technicians don't want to do online-reporting with mobile platform* (2-5) because *they have to do reporting to customers system which have to be done anyway with laptop at the end of the day* (2-8), *they are not used to the mobile platforms which are recently implemented* (2-10), and *they feel the mobile devices difficult to use* (2-9). In addition to that *technicians don't want to do online-reporting* (2-5), *the real-time reporting is not either encouraged or monitored in the service process* (2-4), which leads to that *no real-time reporting is done on the status of the work* (2-2). Therefore the *dispatch doesn't know what the technicians are doing* (UDE#5) in a certain moment.

Continuing on the branch considering GPS tracking, the CRT reads: Because *GPS locators can be used only in Case Co.'s service cars* (2-12) and *some technician use own cars (*2-11), the *GPS locators are not installed in every car* (2-7). Furthermore, because *dispatchers don't benefit from the GPS tracking unless every car is tracked*

(2-6), *they don't use GPS tracking at all* (2-3). Therefore, the *dispatch doesn't easily and collectively get information on the locations of the technicians* (UDE#5).

Due to the *unawareness of the location and status of the technicians* (UDE#5), together with the existing dispatching habit that guides tasks to certain teams (discussed more in CRT Part three), the *nearest available technician doesn't always get allocated to the occurring urgent CM work* (UDE#6), which makes the *online allocation not optimized* (UDE#2-1).

Part Three – Service Teams

The third part of the CRT is visualized in Figure 15, and it considers the partition of the resources and allocation principles. It illustrates how the prerequisites for dispatch prevents optimized schedule creation, which is caused by inadequate documenting of installed base data of the maintained buildings and internal policies concerning allocation between service team boundaries.

Observations revealed that some service managers felt that the service team that releases a technician for executing a task to another team doesn't benefit anything from the release. Therefore, the service managers don't like to release their technicians to other teams. In addition, for executing a task it is necessary to be aware of the installed base data of the maintained building. However, currently that installed base data is not documented to master data, and therefore, it cannot be reached from the field with mobile platforms. Instead, technician's experience of the building is required for the task execution. For those two reasons only a little work exchange takes place currently in Case Co.'s technical services. Thus, resource differences between teams are not levelled, and due to geographically overlapping service teams the online allocation for urgent tasks is not optimized.

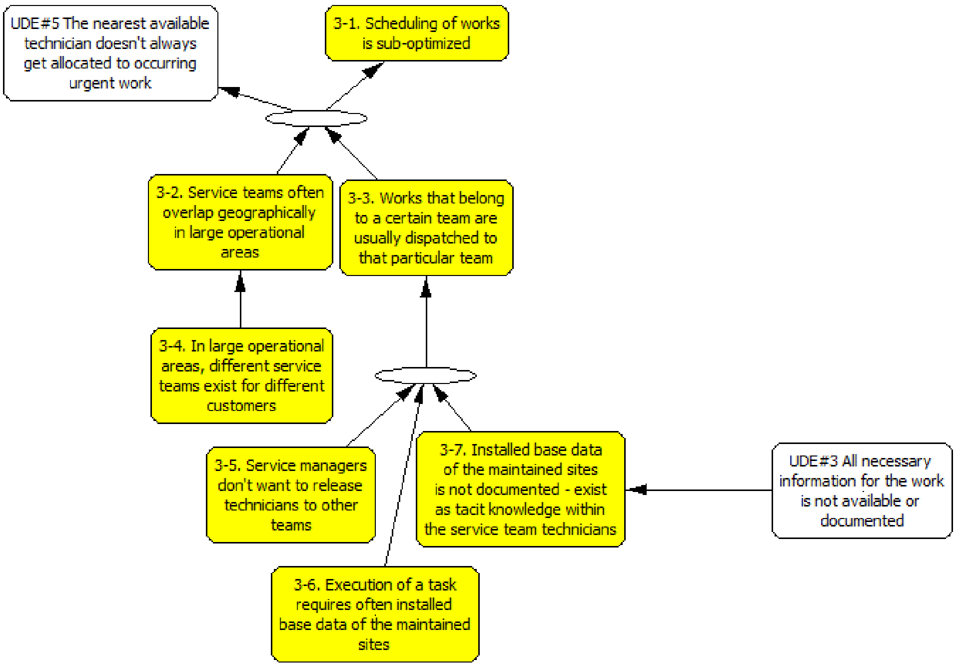

Figure 15. CRT Part Three – Service Teams.

Part three CRT reads: *All necessary information for the work is not available* (UDE#3), including that *installed base data of the maintained buildings is not documented - exist as tacit knowledge within the service team technicians* (3-7). Because *the installed base data is undocumented* (3-7), *execution of a task requires often installed base data of the maintained buildings* (3-6) and service *managers don't want to release technicians to other teams* (3-5), *works that belong to a certain team are usually dispatched to that particular team* (3-3). *In large operational areas, different service exist teams for different customers* (3-4) and, therefore, *service teams overlap geographically* (3-2). If *works that belong to a certain team are dispatched to that particular team* (3-3) and *service teams overlap geographically* (3-2), then the *scheduling of the works is sub-optimized* (3-1) and the *nearest available technician doesn't always get allocated to occurring urgent work* (UDE#6).

Part Four – Inadequate Information

Part four of the CRT (Figure 16) provides root causes to one of the most pivotal UDEs, *all necessary information for the work is not available or documented* (UDE#3) and presents its consequences. No core problems were found in this part of the CRT, but several smaller issues leading to the inadequate information were identified. The tools and methods for of gathering the information from the customer are not supporting the help desk workers adequately during the interactions with customers. Also, the master and history data are not sufficiently exploited when gathering the data and creating SOs. In addition, the lacking technical competence of the end-customers and the dispatchers complicates the defect identification.

The consequences of the UDE#3, *the inadequate information of the work*, reflect to the scheduling process in multiple ways: the UDE#3 contribute also to the problems in CRT parts one, three, and five. The issues that UDE#3 cause to allocation and the task duration estimation are visualized in this part of CRT. In order to create matches between tasks and resources, the properties of resources and details of tasks have to be known. Due to the UDE#3, the task details are not necessarily known, and due to UDE#2, t*echnician skills not listed in ERP*, the resource properties might not be known either. It depends on the dispatcher, whether he or she knows what competences the technician possesses. In addition, if automated scheduling system is to be implemented sometime, it is inevitable that the information of resource properties is implemented to the master data.

As mentioned, the UDE#3 complicates also the estimation of CM task duration. The history data is not exploited to make estimations of those durations. In addition, because *no scheduling is done* (UDE#1), the estimations of task durations are not even needed in the current scheduling process. Thus, *no realistic estimations are made* (UDE#2) at all.

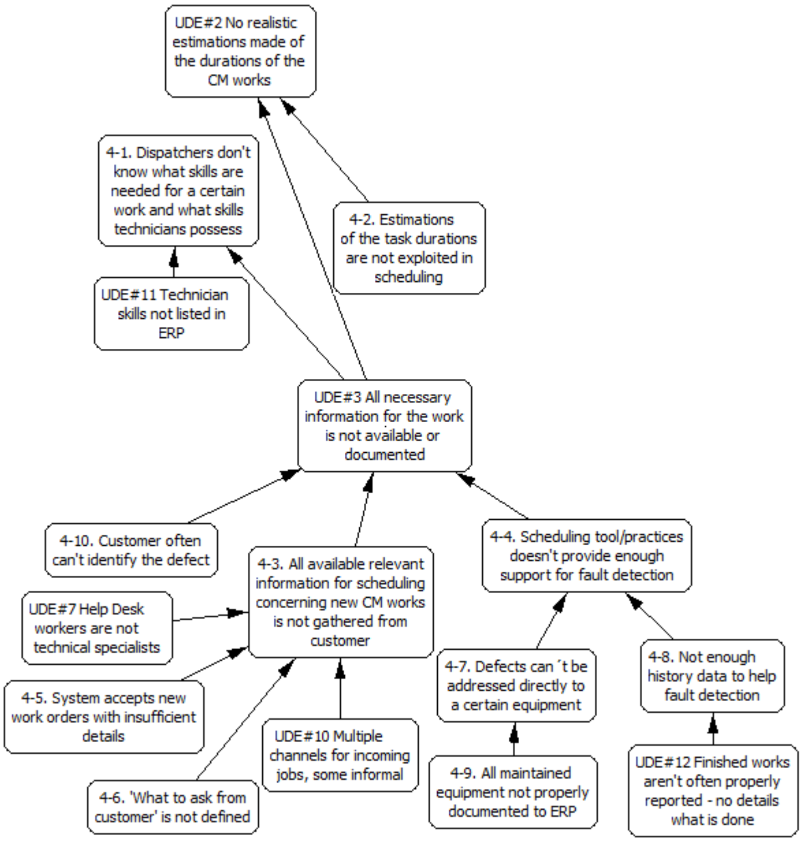

Figure 16. CRT Part Four - Inadequate Information.

Part four reads starting from bottom right: *The finished service works aren't often properly reported, hence, no details exist what is done* (UDE#12) and, therefore, Case Co. has *not enough history data that could be exploited in fault detection* (4-8). In addition, *all maintained equipment is not properly documented to ERP* (4-9), so *defects can´t be addressed directly to certain equipment* (4-7). Because Case Co. has *not enough history data that could be exploited in fault detection* (4-8) and *defects can´t be addressed directly to a certain equipment* (4-7), the *Case Co.'s scheduling tool and practices don't provide enough support for fault detection* (4-4).

The middle bottom branch of this CRT reads: *Help Desk workers are no technical specialists* (UDE#7), Case Co.'s *system accepts new work orders with insufficient details* (4-5), *'what to ask from customer' is not defined* (4-6), and *multiple channels for incoming works* (UDE#10) exist, so *all available relevant information concerning new CM works is not gathered from customer (4-3).* Finally, because *customer often can't identify the defect* (4-10), *all available relevant information concerning new CM works is not gathered from customer* (4-3), and *Case Co.'s scheduling tool and practices don't provide enough support for fault detection* (4-4), therefore, *all necessary information for the work is not available or documented* (UDE#3).

The top of the part four CRT reads: because a*ll necessary information for the work is not available or documented* (UDE#3) and *technician skills not listed in ERP* (UDE#11), *dispatchers don't know what skills are needed for a certain work and what skills technicians possess* (4-1), which *complicates the whole scheduling process* (UDE#0-3). In addition, because a*ll necessary information for the work is not available or documented* (UDE#3), and *estimations of the task durations are not exploited in scheduling* (4-2), *no realistic estimations made of the durations of the CM works* (UDE#2), which also *complicates the whole scheduling process* (UDE#0-3).

Part Five - Prioritization

The last part of the CRT concerns the prioritization of the works. As discussed earlier, the observations revealed that currently there are no clear guidelines for defining the priority. The prioritization decisions are made by the dispatch based on the limited information available on the work combined to common sense and experience of the dispatcher. Main parameter that affected on the priority was observed to be the communication of the customer: if the urgency was well articulated, then the SO had better possibilities to get a higher priority status. Customers seemed to require urgent reactions frequently, which caused that CM works are executed usually with fast responses, which, in turn, fragment the work of the technician (UDE#14). The core problems in this part are inexistent guidelines for prioritizing (5-4) and equally priced priorities (5-5), which lead customers to require fast reactions.

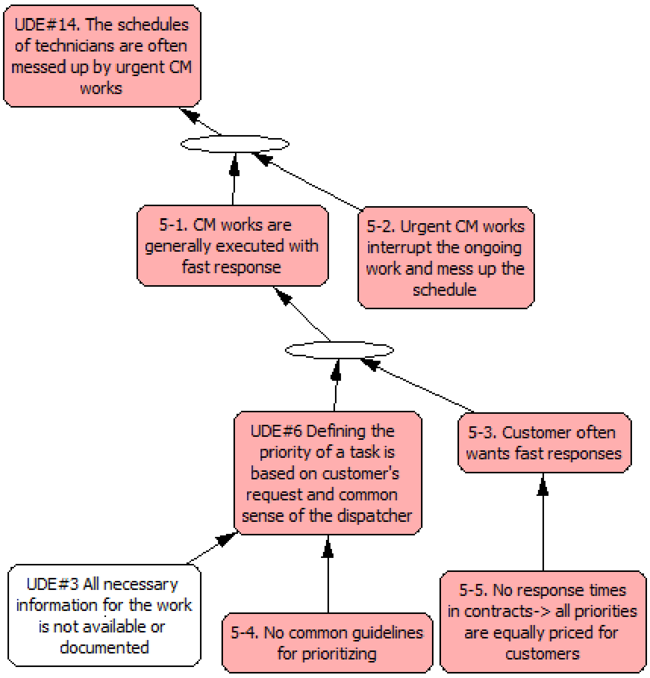

Figure 17. CRT Part Five – Prioritization.

This CRT reads: Because *all necessary information for the work is not available or documented* (UDE#3) and *no common guidelines for prioritizing* (5-3), *defining the priority of a task is based on customer's request and common sense of the dispatcher* (UDE#5). *No response times exist in contracts and, thus, all priorities are equally priced for customers* (5-4), leads to that *customer often wants fast responses* (5-2). Because *customer often wants fast responses* (5-2) and *defining the priority of a task is based on customer's request and common sense of the dispatcher* (UDE#5), *CM works are generally executed with fast response* (5-1). Because *CM works are generally executed with fast response* (5-1) and *urgent CM works interrupt the ongoing work and mess up the schedule* (5-2), *the schedules of technicians are often messed up by urgent CM tasks* (UDE#14), which *complicates the scheduling for technicians* (UDE#0-3).

6.2.3 Conflict Resolution Diagrams (CRDs)

The problems found in CRT were then analyzed to define the reasons of their existence. As discussed in the section 4.3.2, the core problems often appear as conflicts between two or more opposing conditions, required to reach a common objective (e.g., Dettmer, 2007). However, some of the identified problems seemed to comprise no conflicts, and a straightforward solution was seen to exist for those. The core problems without conflicting conditions are discussed more in section 7.1.

In three parts of the CRT, 1., 3. and 5., conflicts were discovered and CRDs were created for explaining those. Next, the three CRDs are represented and discussed.

CRD#1 - Contract details don’t often exist in ERP

The first revealed conflict concerns contract detail importing to master data. The conflict arises from the CRT part one, and the core problem involved is *contract details don´t often exist in ERP*. As discussed earlier, the possibility to generate PPM works in ERP was exploited to varying degrees in different Case Co. units. Those, who didn’t use it, explained that importing all the required contract data for PPM generation to ERP was too laborious and was not worth of doing. In those units, the PPM workload was handled manually by opening every task independently, based on, depending on the unit, excel files or paper lists containing the contract data. Those informal sources of information, though, were created on basis of the contracts. A remarkable observation concerning the manual opening of PPM works was that single PPM tasks were not documented in details to ERP. Instead, typical description could have been just “annual maintenance” and no equipment were included into SO. The detail level was much higher when the SOs were created automatically, and, thus, the information available for scheduling was also more significant.

Those units, where automated PPM work generation was exploited, in turn, explained that once the data has been imported, new SOs will be opened automatically until eternity. Hence, in long-term, importing the data to ERP will be more efficient. The discussed conflict, which is illustrated in Figure 18, arises between the procedures of generating the PPM works manually or in ERP.

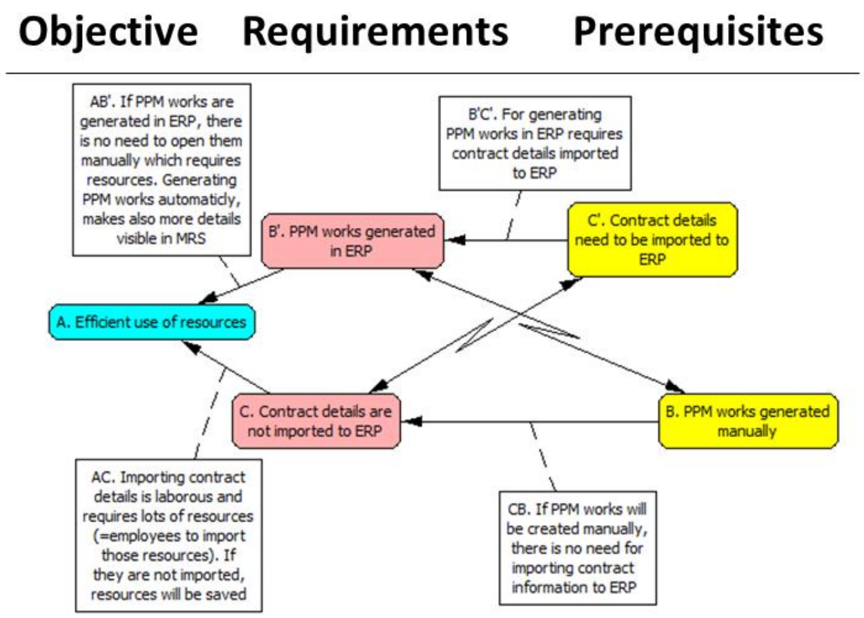

Figure 18. PPM and master data CRD.

The CRD reads: for *efficient use of resources* (A) it is necessary to use *generate all PPM works in SAP* (B'). The assumption is that *If PPM works are generated in ERP, there is no need to open them manually which requires resources. Generating PPM works automatically, makes also more details visible in MRS* (AB'). Prerequisite for *generating all PPM works in ERP* (B') is to *import contract details to ERP* (C'). Assumption is that *generating PPM works in ERP contract details need to be imported to ERP* (B'C'). On the other hand, the *use of resources will be more efficient* (A) if *contract details don't need to be imported to ERP* (C). That is, because i*mporting contract details is laborious and requires lots of resources (=employees to import those resources). If they are not imported, resources will be saved* (AC). The prerequisite is that the *PPM works should be created manually* (B) because then there is *no need to import the contract details to ERP* (CB).

In the first CRD, two weak assumptions were found. The first one is *Importing contract details is laborious and requires lots of resources (=employees to import those resources)*, and the second one *If they are not imported, resources will be saved* (AC). As discussed earlier, even though the operation of importing the data to ERP requires resources, it only has to be conducted once for every contract. Afterwards, every PPM work will be generated automatically and, in long-term, resources are might be even saved. To ratify the assumption, essential would be to define the average lengths of single contract and make a comparison between the resources required to 1) open PPM works manually for average contract length and 2) import contract details to ERP.

The second weak assumption is *if PPM works will be created manually, there is no need for importing contract information to ERP* (CB) and it can be proven false. Besides of the automatic generation of PPM works, there are also other advantages to have the contract information in master data. The installed base data, discussed in CRT part three, consist for the most part of the contract information: all maintained buildings and equipment are defined in the contracts. Having that data documented, makes it available on site for the technicians, which makes the work more efficient and easier and reduces the significance of tacit knowledge.

CRD#2 - Limitations to allocation set by the service team boundaries

The second conflict were found from the third part of the CRT, service teams, and it lies underneath the core problem *using technicians from other teams increases the costs of the team*. The conflict forms between the needs to increase the productivity of a service teams by minimizing internal expenses and to create optimal allocation solutions. Minimizing expenses of a service team include avoiding giving technicians to other service teams. This, combined with the undocumented installed base data discussed earlier, lead to situation where the boundaries between service teams are strong and no technician exchange between teams exist. However, as discussed in the literature review, Ursu et al. (2005) argue that allocating domains involved in scheduling separately will lead to sub-optimized solutions. Thus, the conflict forms between these two prerequisites.

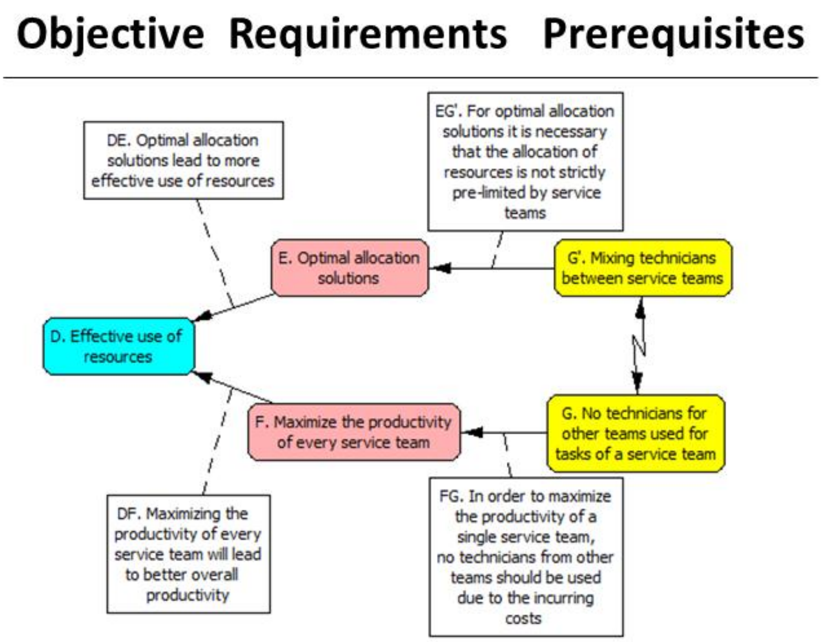

Figure 19. Service team CRD.

The CRD reads: for *effective use of resources* (D), it is required to create *optimal allocation solutions* (E) because *optimal allocation solutions lead to more effective use of resources* (DE). *Mixing technicians between service teams* (G') is prerequisite for creating *optimal allocation solutions* (E), because *for optimal allocation solutions it is necessary that the allocation of resources is not strictly pre-limited by service teams* (EG').

In addition, for *effective use of resources* (D), *maximizing the productivity of every service team* (F) is required, because of the assumption that *maximizing the productivity of every service team will lead to better overall productivity* DF. *The productivity of every service team is maximized* (F) if *no technicians for other teams used for tasks of a service team* (G). The assumption is that *in order to maximize the productivity of a single service team, no technicians from other teams should be used due to the incurring costs* (FG).

The weak assumption in this CRD is *maximizing the productivity of every service team will lead to better overall productivity*. Optimizing the efficiency of a single unit may not necessary increase the efficiency of the whole system. If every service team operates individually trying to reach as good result as possible for that single team, then the advantages of cooperation within the company are lost. Therefore, in order to reach global efficiency, service teams cannot be considered as isolated entities. Instead, the influence the service teams have on each other should be recognized.

CRD#3 - Prioritization of tasks

The last two conflicts arise from the prioritization part of the CRT. Two core problems were identified in CRT concerning work prioritization: *no common guidelines for prioritizing* and *No response times in contracts, which leads to that all priorityclasses are equally priced for customers*. The prioritization issue was then analyzed through CRD, and two related conflicts were revealed illustrating especially the latter core problem. For the first core problem, no conflict were exposed and a more straightforward solution were seen reachable, which is, however, linked to the proposed conflict solution.

Prioritization of tasks, conflict #1

When work prioritization was being discussed during the observations and interviews, an understanding that "a good customer service is to react fast to customers' requests" was encountered. In Case Co.'s context, meaning that when a customer announces of a defect, the SO will be opened and a technician will be sent for the CM work as fast as possible. Quick responsiveness to CM works was considered even as a key essential strength of Case Co. and as one of the key elements that was believed the customers would value most. In practice, this translates into a tendency to execute the CM works with fast response in daily operations.

On the other hand, there exists a clear purpose in Case Co., to enhance the scheduling in order to utilize the resources more effectively. The often observed vision during the empirical research was that the current ineffectiveness of scheduling is leading to resource underutilization. As discussed earlier, the new occurring tasks inside a scheduled period which are reacted fast, cause deviations to schedules and are involved in causing the difficulties in scheduling. Thus, these intersecting conceptions presented above form the first conflict of this CRD. Even though the UDE *fast response to CM works* was not recognized as a core problem in CRT, it stands as the base of the CRD due to the recognized conflict. The first part of this CRD is illustrated in Figure 20.

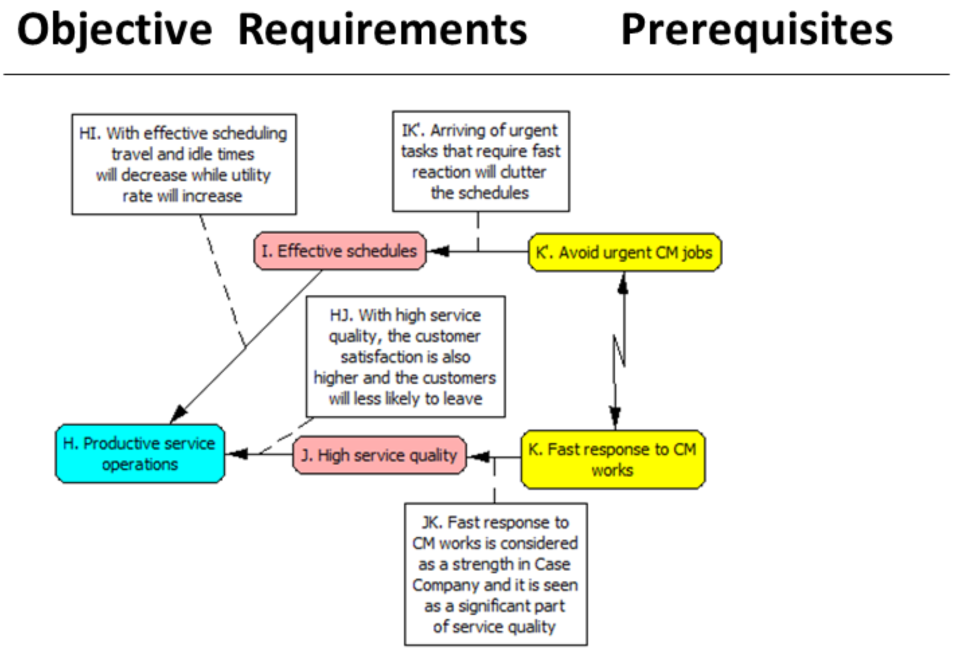

Figure 20. Conflict #1 of the prioritization CRD.

The CRD reads: in order to *keep service operations productive* (H), Case Co. must have effective schedules (I). The assumption is that *effective scheduling decreases travel and idle time of technicians and, thus, the utility rate of the resources will increase* (HI). One prerequisite for effective scheduling is to *avoid urgent CM works* (K'), as the urgent works will clutter the schedules and permit the execution of those (IK'). Another requirement for *productive service operations* (H) is that

Case Co. must keep *the level of service quality high* (J). *With high service quality, the customers are more satisfied and they tend to continue the cooperation with Case Co.* (HJ). One prerequisite for high service quality is considered to be fast reaction to customers' needs, occurring in Case Co.'s operations as fast response to CM works (K). The fast response is seen as a key strength in Case Co. and as a significant part of service quality (JK). This is creates a conflict between the needs to avoid urgency and react fast with CM works (K'K).

The weak assumption of this CRD was discovered to be *fast responses imply better service quality* (JK). As mentioned earlier in the literature review, Haugen & Hill (1999) argue that the customer often appreciates more if he gets informed of the intended maintenance time, than that the actual maintenance operation is executed quickly. In addition, according to Groop (2012) the timecritical and non-timecritical needs of customer should be clearly distinguished in field services, and only the timecritical works treated as urgent. Moreover, Apte et al. (2007) present that especially with non-timecritical maintenance customers prefer execution times they can choose over fast responses. However, as the core problem *no common guidelines for prioritizing* reveals, parameters for timecriticality are not explicitly conducted in Case Co.'s current service process. Therefore, the aspiration for fast responses doesn't result in better service quality if the task is not timecritical for customer, which makes the assumption JK weak.

Prioritization of tasks, conflict #2

Another conflict were also discovered beyond the first one, which includes the core problem revealed in the CRT part five, *no response times, which leads to that all priorities are equally priced*. An observation was made during the research that the common mentality in Case Co. was to evade response times for CM works. The response times were considered to be expensive to the company due to the potential contractual penalties and, therefore, those were attempted avoid as much as possible. That mentality reflected also to the contract contents: in company-wide contracts, response times were told to be included with only a few customers. However, no actual inspection of contracts was made during this research.

The lack of response times has an effect on the prioritizing issue. It causes that the different priorities will be equally priced: if no response times exist, the payment for customer doesn't change whether the work will be executed fast or not. Therefore, it will be among the customer's interest to get the work done rather sooner than later. As discovered in CRT part five, *no common guidelines for prioritizing (5-4)* exist, and the current *prioritizing is influenced largely by the customer requests*

(UDE#6). This contributes to increasing the fast responses to CM works (F), while charging extra for urgencies would have the opposite effect (F'). This confrontation forms the second conflict of the CRD, which is presented as a whole in in Figure 21.

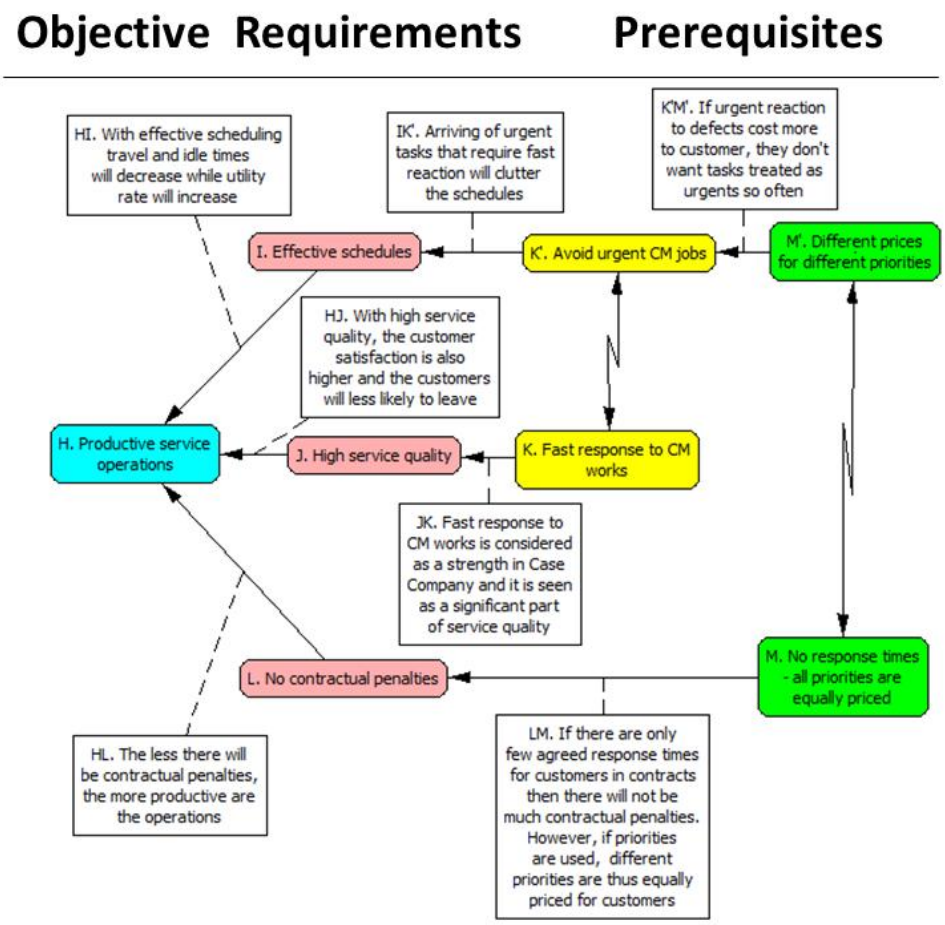

Figure 21. The prioritization CRD as a whole, conflict #2 as outer

The CRD expand from the prerequisite K', *avoid urgent CM works,* which has an own prerequisite: *different prices for different priorities* (M'). The assumption is that *if urgent reactions to CM works cost more, the customers themselves don't want the CM works performed so fast so often* (K'M'). Starting over from the objective, *productive service operations* (H), third requirement discovered was to *avoid contractual penalties* (L). The assumption holds that *the less there will be contractual penalties, the more productive are the operations* (HL). A prerequisite for avoiding contractual penalties designated in Case Co. is to *avoid response times*, which includes that *all priorities are equally priced* (M). The assumption is that *if there are only few agreed response times for customers in contracts then there will not be much contractual penalties. However, if priorities are used, different priorities are, thus, equally priced for customers* (LM). This reveals the second conflict of this CRD: the intentions to price priorities equally and charge extra for urgent priorities (MM’). As the Figure 21 reveals, the second conflict is strengthening the first conflict.

An unambiguous weak assumption considering the second conflict was not found. However, minimizing the amount of response times doesn’t necessarily lead to more productive services, as supposed in assumption LM. Even though the response times would cause some contractual penalties they may also significantly contribute improving the scheduling process as illustrated in the CRD (M’->K’->I->H), which would, again, increase the productivity. Therefore, the leverage of the conflicting interests should be analyzed and discussed.

7 Interventions and Solution Suggestions

This chapter describes the interventions and solutions designed to break the identified constraints that are preventing the scheduling to take place. The interventions are related to the policies of the company that are causing the conflicts behind the core problems, while the solutions are addressed to core problems were no actual conflicts were found. This chapter provides first the straightforward solution suggestions from every part of the CRT. Then, the intervention propositions for solving the conflicts by eliminating the weak and false assumptions identified in the CRDs are represented.

7.1 Straightforward Solutions

In first section of solutions, no conflicting interests were observed to exist, and solving the problems is merely to create alternative processes and tools rather than make fundamental changes. For each CRT areas presented here, apparent solutions can be addressed and the execution is mainly

CRT part one – PPM in master data

The first part of the CRT contained discussion of PPM. The issue of importing contract data to ERP will be discussed later with the conflict interventions in section 7.2, but for the core problem relating to scheduling tool, MRS, no conflicts were revealed. As mentioned earlier, MRS is not dynamic and does not provide automated scheduling. As a solution, the tool needs to be updated. More dynamic tool is required with the possibility for automated schedule creation. However, the purchasing and implementing of a scheduling tool is a significant operation requiring careful preparation. The required functionalities should be examined and listed, and multiple tools should be benchmarked to find the most suitable solution for Case Co. The findings of this study should be considered during the process of purchasing the new scheduling tool.

CRT part two – Online allocation

The CRT part two concerned issues with online allocation. The analysis revealed that online allocation solution are currently not made in optimal basis due to the unawareness of the location of the technicians, and the unawareness of the status of the ongoing work. In other words, no common awareness exists of where technicians are and what they are doing. CRT revealed that there would be available methods to maintain that awareness through updating the work statuses with mobile platforms and tracking the service cars with GPS. Those methods are, however, currently not utilized: the internal policy doesn’t require real-time reporting and the use of own cars doesn’t allow every car to be equipped with a GPS tracker. Practically, for attain the awareness of location of the technicians it would be sufficient to solve only one of those two issues. The problems constraining the use of those two ways to gain awareness were not considered as core problems.

With the mobile reporting, pivotal is to increase the encouraging and monitoring of the reporting. The actual implementation procedure and methods should be investigated more, and the details how to conduct the real-time reporting should be discussed. At simplest, it could consist of reporting start and finish times of the works, in which case, the status of the technician could be provided for online allocation. The usability of the mobile platform software should be developed considering the needs of the technicians. In addition, needs for double reporting (customer systems, separate payroll reporting) should be eliminated so that technicians could handle all their reporting with the mobile platform, which increases the motivation to use the mobile device. Also creating interfaces between the IT systems of customers and Case Co. could be worth of consideration so that all works to would be included in Case Co.’s SAP.

The most essential issue with GPS tracking is to have every service car tracked. Therefore, a suggestion is that all technicians should use service cars of Case Co., if the legal issues with tracking personal cars cannot be solved.

CRT part three – Service team composition

The third CRT part concerned service-team composition and allocation principles. Currently resources are not levelled between service teams and tasks for each service teams are allocated separately. Two core problems were found: lacking documentation of installed base data, and internal policies that prevent sharing the technicians between service teams. For the latter, a conflict was found and it is discussed more in next section, but for the earlier, straightforward solution is suggested next.

The installed base data of maintained equipment, that is required for executing the work, is not currently documented in most Case Co. units, and, thus, exist only as a tacit knowledge among the technicians who have experience over the particular site. Therefore, the technicians from other teams who don’t possess that information cannot execute the task. As mentioned in chapter 1, Ala-Risku (2009) argues that a field service technician needs information of equipment locations, access constraints, equipment characteristics, service histories and customer contracts to perform the maintenance work efficiently. Therefore, a process to collect and document that data to ERP should be launched to get the tacit knowledge off the field. Even though, in those units where the installed base data was observed to be documented, the technicians didn't have access to it. Therefore, an interface should be created to mobile platforms enabling the access to the installed base data.

CRT part four – Inadequate task information

The CRT part four considered the inadequate information of a task that is gathered from the customer and should be available in the scheduling process. As reviewed in the literature part in section 3.2, effective scheduling requires rich input data (Voudouris et al., 2008) including estimated duration, task description and the installed base data discussed earlier. In addition, it is critical to make that data available for a technician in the execution phase. The observations revealed that the quality and form of that input data varies a lot in Case Co.'s scheduling process.

The process of gathering information from customer needs to be reconsidered. The problem with the incompetent customers is difficult to overcome due to the enormous number of end-customers. However, if clear guidelines are provided for what to inquire from the customer in different situations, more information could be received, even though neither the customer nor the help desk workers are technical specialist. The possibility to use scripts to support the inquiry should be considered.

In addition, strict definitions, of what information has to be included in the service orders, need to be created. Thus, all gathered information should be available for all parties involved in the service process. However, in case of urgency, a service order should be created with deficient information, but the parameters for the urgency have to be clearly defined, which is discussed more in intervention related to prioritization (section 7.2). Moreover, the amount of different channels for incoming works should be discussed. During the observations, most positive feedback was reported on those units where all incoming defect announcements had to be directly to help desk where the routine and experience for receiving tasks were in high level.

The history data is not utilized as much as it could because the level of reporting is often insufficient. The details in the reports of what have been done are not described accurately. As discussed in chapter 3, Voudouris et al. (2008) propose that the task duration estimations can best be made based on history data. Thus, the level of reporting should be enhanced and structured to enable the exploitation of history data. Another reason the estimation of task durations is not currently made, was that the estimations are not exploited: because no scheduling is made (UDE#1), the estimated duration reported to ERP holds no significance for any role involved in the service process. When scheduling process, where exact times for each works are defined, will commence, also the need for creating task duration estimations will emerge.

7.2 Conflict Interventions

In addition to the straightforward suggestions, some core problems were observed to be caused by conflicts case organization's in internal policies. Those conflicts emerge in three branches of CRT, and CRDs were created in section 6.2.3 to reveal them and identify the weak assumptions leading to the conflicts. Following the CRD, potential problem solving interventions are suggested.

Intervention to CRD#1 - PPM in master data

The CRT part one concerned PPM works and a conflict were revealed concerning the import of contract details to master data and whether creating PPM works manually or automated. A false assumption was discovered in the CRD which was identified to create a conflict behind the core problem: *if PM works will be created manually, there is no need for importing contract information to ERP.* As mentioned in section 7.2, if contract data will be made available in ERP, it will benefit also the work execution phase. To eliminate the weak assumptions it is necessary to communicate the importance and all benefits of contract details existing in master data. As an intervention, the contract data should be imported to master data in all Case Co. units.

Moreover, once the information has been imported, all PPM works should be generated in SAP in order to reduce the needless work and ensure that all PPM works will be visible for scheduling. As discussed earlier, importing all contracts to master data requires resources. Therefore, for the initiation of the intervention, resources must be directed for establishing the importing process. In addition to the importing, it is also necessary to keep the data updated whenever changes occur or new contracts are concluded.

As discussed earlier, in some of Case Co.'s divisions, the PPM works are already generated in ERP. Those units possess experience over the process which should be exploited while the process will be implemented in other divisions.

Intervention to CRD#2 - Limitations to allocation set by the service team boundaries

The second CRD exposed a conflict between maximizing the efficiency of a single service team and optimal allocation solutions. It derived from the CRT part three and caused sub-optimization in allocation. A weak assumption in the CRD was found to be *maximizing the productivity of every service team will lead to better overall productivity*.

For eliminating the weak assumption, the internal mobility of the technicians should be enhanced. Mindset, where every service team is individual entity, should be eliminated. Instead, service team boundaries should be undermined and cooperation should be encouraged. Using technicians from other teams in order to level the demand should be made more attractive. This thesis does not provide a concrete intervention, because more investigation is recommended for finding the solution. However, two solutions represented in the literature review, a global allocation process suggested by Ursu (2003) or excess capacity buffer suggested by Groop (2012), would be possible premises for the intervention.

Intervention to CRD#3 - Prioritization

The prioritization CRD revealed two conflicts: first one is response fast to CM works and avoid fast responses, while the second one, strengthening the first one, whether the customer should be charge extra for urgent tasks. A weak assumption causing the first conflict, were identified to be c*ustomers appreciate fast response and it is seen as a significant part of customer service*, while the weak assumptions behind the second conflict, though an ambiguous ones, were revealed to be both *if there are only few agreed response time for customers in contracts then there will not be much contractual penalties* and *the less there will be contractual penalties, the more productive are the operations*.

To eliminate the first weak assumption, c*ustomers appreciate fast response and it is seen as a significant part of customer service*, it is necessary to distinguish the timecritical and non-timecritical tasks, as recommended by Groop (2012), and do not treat the non-timecritical with fast responses. In order to do it, the prerequisites for different priorities need to be defined, which also solves the core problem concerning lacking prioritizing guidelines. As mentioned in chapter 3, according to Lin & Jun (2009), the prioritizing based mostly on common sense, which take place currently in Case Co., often lead to increased downtime and wasted resources. Thus, Lin & Jun (2009) suggest analytical creating of priorities involving all relevant character values included. While creating the priorities, the objective should be to avoid changes in technicians' schedules during a work day in order to eliminate the weak assumption. As Petrakis et al. (2012) argued, changes emerging during the day induce deviations from the planned schedule causing unnecessary travelling and task delays. One way to avoid changes is to avoid executing a tasks during the day of arrival as long as possible If, however, the need for urgent tasks is discovered to be significant, then excessive capacity for urgent tasks should be held during the day, as suggested by Groop (2012).

As the latter two weak assumptions couldn't be unambiguously proven weak, they should not necessarily be even eliminated. As discussed in section 7.2 when the CRD was presented, the effects that increasing the number of response times would cause to the total productivity, have to be studied more before applying more response times. The second conflict causes only an indirect negative effect to scheduling: it strengthens the first conflict. Therefore, it may not be valid if the inner conflict can be settled. Should it so happen, it might not be necessary to solve the second conflict at all. However, the issue must not be ignored but rather investigated more before any actions should be taken.

Method for possible intervention, meaning how to involve customers to prioritization, could be to differentiate the prices and define response times for different priorities. Challenging for this intervention would be to figure out how those definitions could be included to existing contracts.

IV DISCUSSION

8 Responses to Research Questions and Conclusions

This chapter provides summarized responses to three research questions of this study, and it presents the conclusions of the results. First, the research questions are discussed one per one, followed by the conclusions.

8.1 RQ1 What are the elements of an effective field service scheduling system and how does scheduling affect service quality?

The first research question focused on exploring previous research made on the field service scheduling and it set the guidelines for the literature review. The literature review was presented in chapters 2 and 3, and now, brief summary of findings are provided in order to respond to the RQ1.

The context of this thesis, maintenance field services, refers to a service which is provided in spatially distributed locations with mobile workforce in order to deliver maintenance services for customers' equipment. Essential characteristic for field services is that the field service technician operates in different customers' properties. Therefore, the work of a field service technician contains much travelling, which poses challenges concerning scheduling.

Workforce scheduling, in turn, consist of assigning tasks to personnel in order to deliver the promised service to customers. Scheduling is limited by constraints related to resources, tasks and operating environment and it is guided by scheduling objectives. Dynamic environment, which is typical for field services, forms an additional challenge with constant changes and need of rescheduling. Overall, scheduling is balancing between the constraints and objectives in order to find optimal solutions.

The input data, on which the schedules are based, stands in a critical position considering successful scheduling. According to Voudouris et al. (2008) and supplemented with Ala-Risku (2009), that particular data consist of following elements:

- Amount of resources (technicians, equipment, material)
- Properties of the resources (skills, experience and location of technicians; location of materials and tools)
- Demand (confirmed and forecasted)

- Details of the tasks (descriptions, required skills and materials, location, travel and work duration, access constraints)
- Details of the maintained equipment (criticality, service history, contract agreements)

Voudouris et al. (2008) suggest that the input data should be standardized, accurate, easily available, and its quality should be high in order to enable effective schedules. However, for example in field services, accurate task estimations may not be possible to make. In those cases, there should be systematic methods to at least create sufficiently accurate estimations.

Organizing the scheduling process was discussed in the sections 3.5 and 3.6. Manual dispatching suits for small scheduling environments where constant changes occur, but when the scale of the scheduled problem grows, automated computational scheduling systems are needed to follow scheduling rules and reach the objectives. For field service environment, metaheuristic computational scheduling approach are recommended due to the fast computation time and possibility to reach solutions that are optimal enough (Voudouris et al. 2008; Punchinger & Raidl, 2005). The rescheduling period in field services depends on the level of dynamism. Voudouris et al. (2013) recommend a scheduling process with three components: scheduling, real-time allocating and schedule revision component. Original schedules are created in scheduling component based on confirmed demand and forecasts. The real-time allocation component allocates the tasks to technicians based on the schedules and new tasks occurred after the original scheduling. The revision component in turn, observes the difference between the original and current schedules, and when those differ enough, rescheduling will take place.

The second part of the literature review concerned the service quality and productivity, and especially how scheduling affects those. Methods for measuring and analyzing service quality varies in literature, but common for most methods is the comparison between the customer’s expectations and perceptions of the service event (Seth et al., 2005). The effects of service quality to productivity were also discussed. According Oliva & Sterman (2001), poor service quality often leads to slower growth, lost sales and lower profit.

Most widely applied service quality model developed by Parasuraman, SERVQUAL, was presented in this study. Service quality aspects in field service were examined through SERVQUAL, which contains five quality dimensions: tangibles, reliability, responsiveness, assurance and empathy. The effects of scheduling to SERVQUAL dimensions was investigated based on the findings on scheduling literature. Based on that investigation, scheduling was identified to have effects in three quality dimensions. Good scheduling affects reliability by providing reliable schedules and decreasing lateness of the technicians. The fast response times enabled by optimal schedules are part of responsiveness dimension. Assurance includes the communication aspect, and it is improved by good scheduling by enabling that the customer can be informed of the planned execution times.

More traditional service quality measures relating to field services were also examined. According to Haugen & Hill (1999), measures like response times, promise times and tardiness are appropriate for defining service quality in field service environments where emergent tasks occur. They continue that all those measures are substantially affected by scheduling. Apte et al. (2007) suggest that when dealing with non-emergent tasks, it is more important to notify the customer's wishes and expectations than attempt to deliver services fast.

Scheduling was observed to hold also direct implications to productivity. According to Voudouris et al. (2008), effective scheduling decrease idle-times and travel costs, as well as increase capacity utilization.

8.2 RQ2 Why scheduling is currently not effective in the case organization?

The second research question concerned the current state of the scheduling system in the case organization. It seeks reasons why scheduling is not currently effective. This thesis started to build the response to the second research question with empirical data gathering targeted to different roles involved in scheduling process. The analysis of the data presented in chapter 6 was then conducted with TOC TP tools, including CRT and CRD. The CRT that was created based on the empirical data (section 6.2.2) provides explanation why the scheduling is not currently optimal. The found problems are presented in section 6.2.2 and summarized in Table 4.

Table 4. Key findings from the Current Reality Tree (CRT).

CRT area	Symptom	Problems
PPM in master data	All tasks are not visible for scheduling	1) PPM works are not generated in ERP, because information from contracts not imported there 2) Scheduling tool MRS is not dynamic 3) Some PPM works exist only in customers' systems
Online allocation of new emerging tasks	No awareness of where the technicians are and what they are doing	4) Real-time mobile reporting not monitored and encouraged enough 5) GPS trackers not equipped in every technician's car because own cars in used where GPS cannot be installed
Service team composition	Allocation of tasks is pre-limited to small service teams and, thus, is sub optimized	6) Installed base data not available for field technicians 7) Due to policy constraints, service managers don't want to release technicians to other teams, which prevents levelling demand between service teams
Inadequate task information	Lacking information of tasks (including descriptions, duration estimations, required competences) is complicating their planning and scheduling	8) No support for receiving tasks (during customers' phone calls) 9) All available information (control room data, history data, installed base data) not provided or exploited in task receiving
Inadequate task information	Dispatchers have limited awareness of the competences of technicians	10) Technician skills not listed in ERP
Inadequate task information	No proper estimations made of the task durations	11) No clear system support for creating task duration estimations 12) No need for estimations because no realistic target times and schedules created
Prioritization	CM works are responded fast, but urgent tasks clutter the schedule of technician	13) Prioritizing of CM tasks currently based on common sense and experience of the dispatcher, as well as customer requests - no defined guidelines for prioritizing in use 14) Fast responses considered as strength of Case Co. 15) All priorities equally priced for most customers – they tend to want fast responses

Totally 15 problems were found and identified as constraints that are preventing the scheduling to take place. When the problems are observed, a notable unifying factor for several problems (1, 3, 6, 9, and 10) is that they are related to master data. Either the data is not documented (1, 10), not exploited (9) or not available when required (3, 6, 9). As discussed earlier, effective scheduling is based on the input data (Voudouris et al., 2008), and currently in Case Co., there seems to be significant difficulties with that data. Second emerging characteristic among the problems seems to be lack of common guidelines and supporting procedures among the different areas of scheduling process (4, 8, 11, and 13).

8.3 RQ3 What changes should be made to enhance the scheduling system and, thus, service quality in the case organization?

Last research question concerned the renewal of the scheduling process and called for means to overcome the observed constraints. As a response, solutions for the revealed problems are presented. The TP logic stands that often the core problems found in the CRT are caused by conflicting actions ensued by attempting to attain mutual objective (Dettmer, 2007). Thus, the core problems revealed in this study were examined in order to find those conflicts. For most of the problems, no internal conflicts were discovered and rather straightforward solution suggestions were found. Those straightforward solution suggestions were presented in section 7.1 and a summary can be found in Table 5.

Table 5. Straightforward solution suggestions.

Problem	Straightforward solution suggestion
Real-time mobile reporting not monitored and encouraged enough	Better monitoring of the real-time mobile reporting. Share the understanding of benefits, in order to motivate the technicians to report real-time.
Scheduling tool, MRS, not dynamic and doesn´t enable automated scheduling	Update of the tool
GPS trackers not equipped in every technician's car because own cars in used where GPS cannot be installed	Use only service cars of Case Co.
Installed base data not available for field technicians	Access to installed base data from mobile devices. Enhance and accurate the installed base data in master data.
No support for receiving tasks (during customers' phone calls)	Scripts and clear guidelines for receiving tasks
All available information (control room data, history data, installed base data) not provided for task receiving	Information concerning the task available task for receiving
Technician skills not listed in ERP	Import technicians skills to ERP
No clear system support for creating task duration estimations	History data should be exploited for task duration estimations
No need for estimations because no realistic target times and schedules created	Once scheduling will be started, need for estimations will emerge
Prioritizing of CM tasks currently based on common sense and experience of the dispatcher, as well as customer requests - no defined guidelines for prioritizing in use	Define rules for prioritizing

In addition to the problems where straightforward solutions could be addressed, four problems caused by conflicts were discovered. One conflict concerns importing contract data to master data, one concerns isolation of service teams and last two conflicts concern prioritizing. CRD's were created to illustrate those conflicts and to prove the weak assumptions that are causing the conflicts. Ways to eliminate those weak assumptions and interventions for solving the conflicts were also suggested. Summary of the conflicts and the design propositions for those are presented in Table 6.

Table 6, Revealed conflicts and their solutions.

Problem	Conflict	Weak assumption and its elimination	Proposed intervention
PPM works are not generated in ERP, because information from contracts not imported there	Importing all PPM to ERP is laborious Vs. Opening every task manually is laborious	**Weak assumption**: If PPM works will be created manually, there is no need for importing contract information to ERP. **Elimination**: Importing contract data brings also other benefits besides scheduling – e.g. for the execution of the work	Import contract data to ERP and create PPM work automatically
Policy constraints in internal invoicing prevents levelling demand between service teams	Efficiency of a single service team Vs. More optimal task allocation	**Weak assumption:** Maximizing the productivity of every service team will lead to better overall productivity. **Elimination**: Optimizing the performance of a local team doesn't necessary lead to global optimality	Technician exchange between teams should be facilitated. For example, by global allocation procedure when unleveled demand exists.
Fast responses considered as a strength of Case Co.	Fast reactions for new occurring CM tasks. Vs. Reliable schedules for technicians	**Weak assumption**: Customers appreciate fast response and it is seen as a significant part of customer service. **Elimination**: Customer often appreciate more the communication of expected maintenance time	Avoid executing CM tasks during the day they occur unless they are defined urgent
All priorities equally priced for most customers – they tend to want fast responses	Charge extra for urgencies vs. No response times – all priorities equally priced	**Weak assumption**: Excluding response times will eliminate contractual penalties which leads to improved productivity **Elimination**: Response times will involve customers in prioritizing, which facilitates scheduling. Effective schedules may improve productivity more than eliminating response times	Discuss the possibility to involve customers in prioritizing by charging extra from urgencies or giving discount of non-urgencies

8.4 Conclusions

This thesis studied the service and scheduling process of Case Co. It revealed multiple problems that are complicating the scheduling process and causing the current non-existence of the scheduling in the case organization. In addition, several positive elements in service process were discovered in the current-state analysis of this study (section 6.1). Now, the congruence between the problems and scheduling literature including discussion on master data, automated scheduling and prioritizing is analyzed followed by the representation of the few most important strengths found in Case Co.'s service processes related to scheduling.

Master data as scheduling prerequisite

As mentioned in the previous section, several problems found in the empirical study are related to inadequate level of master data. In the literature review, several type of prerequisite information, or input data, for effective scheduling were enumerated by Voudouris et al. (2008) and Ala-Risku (2009) that need to be available in the field service operations and in the scheduling process. That data, in many respects, is represented in the different problem areas found in this study. The summary of how the different problems related to master data are related to the required scheduling inputs can be found in Table 7.

Table 7. Required input data for scheduling and how the data is lacking in Case Co.

Required input data	How the data is lacking in Case Co.
Resource related information – Technician competences and experience – Location of a technician	– Technician competences and experiences not imported to ERP – No awareness of where the technicians are and what they are doing
Task related information – Task descriptions – Required competences and materials in a task – Task duration – Amount of tasks	– Task descriptions, duration estimations, required competences for tasks are often inadequate or lacking – No support for task receiving – Lacking details with manually opened PPM works – Some PPM works exist only in customers' systems
Site/customer related information – Access constraints – Criticality and service history of the maintained equipment – Contract agreements	– All available information (control room data, history data, installed base data) not provided or exploited in task receiving – Installed base data not available for field technicians – PPM works are not generated in ERP, because information from contracts not imported there
Resource related – Amount of technicians – Amount of materials Task related – Forecast and confirmed demand – Location of a task	– No deficiencies observed

As can be seen on the Table 7 above, inadequate information pose serious limits for the scheduling process: deficiencies exist in almost all information areas that are required as input data for scheduling. Thus, the observations and findings made in this study are supported by the findings from scheduling literature: the factors that were observed to prevent scheduling in case organization are defined as key perquisites for scheduling in literature.

Automated scheduling

In literature review, automated scheduling was recommended for large scheduling environments (Voudouris et al., 2008). Because the total amount of maintenance field service technicians in the case organization exceeds 10 000, an automated scheduling would be required to allow optimal work allocation. However, the problems discovered during this research are complicating the possibility transfer to automated scheduling and, thus, need to be solved. Even though all those problems virtually complicate the scheduling for some level, few issues identified to constrain the transfer to automated scheduling more than others.

As mentioned in Chapter 3, most essential advantage of automated scheduling is the possibility to reach optimal allocation solutions (Puchinger & Raidl, 2005). That is perceived by handling large amount of resources and tasks, which would be impossible to do manually. However, as the problem in CRT part 3 addressed, the task allocation problem of Case Co. is currently divided to small service teams leading to sub optimization. As pointed out in literature review, Ursu et al. (2005) emphasize that, in addition to local work allocation, global allocation of excess resources and unallocated tasks should be executed to avoid simultaneous demand peaks and resource shortages. In addition, Groop (2012) suggests in his research of field services that skill group buffers should be maintained in a common resource pool to react according the actual demand in local units. Those solutions should be considered in Case Co. when redefining of the scheduling system is conducted in order to transfer to the automated scheduling.

In addition to the process constraints, there are also technical limitations concerning the transition to automated scheduling. The issues discussed earlier concerning the master data has to be solved. Automated scheduling cannot be performed unless all necessary information mentioned in Table 7 is available for the scheduling system. In addition, the current scheduling tool, MRS does not provide the possibility for automated scheduling, and therefore, updating the scheduling tool will also be necessary before transferring to automated scheduling.

Prioritization

In addition, support for the prioritization issue can be found from the literature. As Lin & Jun (2009) stated, prioritizing of tasks based on common sense derived from experience lead often to increased downtime and wasted resources. This study revealed that prioritization decisions in Case Co. based mostly to common sense. The analysis then revealed that the prioritization decisions are not leading to most optimal resource utilization and rather cause fragmentation to the work of technicians. Therefore, this thesis provides support for the findings of Li & Jun (2009).

Positive elements in the current process

Despite the revealed debilities in this study, there are several elements in the service processes of Case Co. that also support scheduling. The basis for effective service operations are the process definitions. In Case Co., the different service processes are well defined: clear roles exist with well-defined tasks and responsibilities. As revealed in the study, the actual operation do not entirely correspond the process definitions, but all different elements were still found. Especially the role of a dispatcher was recognized to exist in every observed unit, and the tasks of the dispatcher responded the common definitions for the most part. Even though differences exist between definitions and current processes, improving the process is more facile when awareness of how things should be done exists.

Second strength concerns the mobile platforms of the technicians. The implementation of mobile platforms is ongoing throughout the whole Case Co. organization. As mentioned in section 3.7, the mobile platforms provide significant possibilities for reacting dynamic changes and improving communication between the dispatch and the technicians. Therefore, the mobile platforms will create significant benefit for optimal allocation in Case Co. as soon as the procedures related to their use will be stabilized.

The last strength of Case Co. that is mentioned here is the possibility to create PPM tasks automatically. One of the most pivotal problems found in this study is that, in most units, the PPM works are not generated automatically. However, in those units, where the PPM works are created automatically, the practices were observed to be very effective. Thus, the knowledge and competence do exist, and the upcoming task is to share that knowledge throughout the organization.

9 Implications and Limitations

The last chapter of this thesis provides practical and theoretical implications of this research, as well as the discussion of the limitations and future research. It begins by presenting the implications followed by the discussion of limitations and, finally, it provides suggestions for future research.

9.1 Implications

9.1.1 Managerial Implications

This section discusses the managerial recommendations for enhancing scheduling in maintenance field service environment. This study presents several suggestions for tackling the observed constraints, which form the body of managerial implications. Those interventions and solution suggestions were summarized in the previous section. Now the most pivotal interventions are compressed as two design propositions following the CIMO logic of design science methodology. The first one related to PPM is following:

> *In the context of maintenance field service, import all contract data related to maintained equipment and PPM to ERP (intervention) for creating PPM works automatically (mechanism), in order to ensure that all tasks and their details are known for scheduling (outcome).*

The second overarching design proposition concerns prioritizing as follows:

> *In the context of maintenance field service, define prerequisites for urgent tasks (intervention#1), and if those prerequisites not met, avoid allocating tasks to technicians during the day the tasks occur (intervention#2), in order to avoid the cluttering of the technicians' schedules (mechanism), which enables creating schedules for technicians (outcome).*

For the first design proposition, it is necessary to define the information that is required for scheduling. Then, it has to be ensured that all that information is collected from the customer and documented, while creating new maintenance contracts. For the second proposition, essential is to discuss what the prerequisites for urgencies should be. As Lin & Jun (2009) suggest, quantitative analysis of different priority parameters and their preference over each other's would be necessary to attain optimal priority prerequisites.

Those two design propositions are emphasized due to the conflicts that cause the problems behind symptoms that those propositions are trying to solve. As TOC principles suggest, the problems caused by underlying conflicts are usually pivotal and causing multiple other problems (Dettmer, 2007). This thesis suggests that solving those conflicts will be essential for enabling the scheduling. However, the other problems cannot be neglected.

The design proposition and the straightforward solutions found in this thesis cannot be generalized due to the strong relationship to the studied context. However, they will act as general guidelines for managerial problems resembling the studied one, while the details of the core problems need to be studied separately in every organization.

9.1.2 Theoretical Implications

The theoretical objective of this thesis was to provide knowledge how the observed constraints in the maintenance field service organization affects service quality. As presented in the literature review, workforce scheduling has been studied widely, and also in context of field services. Most of the research focuses on the optimization of different scheduling algorithms and the efficiency of different scheduling procedures, and case studies have been conducted on those topics. Ernst et al. (2004) reports that the recent [by the time of the article’s publication] scheduling literature consist of wide range of studies concerning the suitability of different scheduling models and algorithms for different application areas. Moreover, according to Van Den Bergh et al. (2013), many aspects and variables relevant in real-life environments, like dynamism, are not sufficiently taken account in the current workforce scheduling literature.

However, case study research on how to apply and implement scheduling procedures and automated scheduling systems in maintenance field service environment with high degree of dynamism were not found. This research will contribute filling that particular gap on the scheduling research. It has studied the maintenance field service process of a case organization and has attempted to provide reasons why scheduling doesn´t exist in the case organization, and what are the constraints that need to be overcome in order to be able to commence the scheduling process.

This thesis contributes also in the field of TOC TP applicability for field services. Groop (2012) suggest that the TP tools provide suitable methods to solve unstructured problems in field services. The premises of this study are suitable to the definition of Groop: maintenance field service operations organization facing a problem related to scheduling without exact knowledge of the causes of the problem. Also the results of this study follow the suggestion of Groop: with TP analysis, the root causes for the unstructured problem were revealed and it was possible to illustrate the context of the problem in more organized way.

9.2 Limitations and Future Research

The analysis of the empirical data was conducted by TOC TP analysis, and two TP tools, CRT and CRD were availed. The CRT and CRD diagrams were examined against the CLR rules (section 4.3.2) and no logical inadequacies were found. However, some differences with the use of TP tools in this study to TP principles were recognized. The two CRDs of this thesis, first and third CRD, are not completely congruent with the TP principles: both diagrams includes two conflicts instead of one, while usually only one conflict is represented in one diagram. However, those conflicts were observed to be interrelated, and thus, illustrating two conflicts in mutual diagram was essential to capture the characteristics of the conflicts.

In addition, the amount of problems found is not entirely compatible with TOC philosophy. The fundamental objective of TOC is that most of the problems experienced by an organization are actually caused by one or very few core problems (Dettmer, 2007). In this study, several constraints were identified preventing the scheduling process to take place, and no evidence were related that only one of those could be defined as a problem that causes the others. The reason for the large amount of core problems found might lie in the nature of those problems. Many problems found were not identified to be caused by any conflicts. As Dettmer (2007) asserts, in well-developed systems problems usually don’t exist, unless there are underlying conflicts that prevent a straightforward solution. However, due to the relatively short period of way of working in Case Co., all evident problems haven´t been able to be solved yet. Therefore, there are currently several core problems preventing the scheduling process.

Only one maintenance field service organization was studied in this thesis, which causes limitations to the transferability of this study. More case example should be studied in order to investigate whether the same core problems occur more widely. However, discussion conducted with other maintenance field service organizations prove that especially the difficulties with master data and prioritization appear also outside the case organization.

This thesis provided propositions for how to enhance service process of a field service organization in order to enable scheduling. Those propositions are based on the empirical data and TP analysis, but no practical implementation of the propositions is conducted. An important future research target would be, thus, to provide practical validation of the findings. In other words, the suggested propositions should be implemented, and examine whether the desired and expected outcome would be reached.

Part of this research was to examine the effects of the scheduling to service quality and productivity. The examination was conducted by reflecting the empirical scheduling constraints to the findings on literature review. Due to the lack of implementation, neither these effects were validated and no evidence were received of the effects of the design propositions to service quality and productivity are provided. Practical implementation would be required to confirm also these effects.

As the design proposition consist of multiple distinct factors, it is important to focus on the implementation methods. Because this study didn’t include the implementation of the propositions, no attention was paid either on the implementation practices. Before executing the implementation as suggested earlier, the implementation methods should be also focused on.

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List of Appendices

Appendix 1, Original Undesirable Effects (UDEs)

Undesirable Effects

- The information of orders/tasks filed to SAP is often inadequate
- No realistic estimations given of the duration of the tasks
- Dispatchers have no methods for defining the duration of the task and they neither get any feedback of how accurate have their estimations been
- Dispatchers don´t have realistic information neither the workload nor the location of the technicians
- Lots of tacit knowledge throughout the system: e.g. service tasks: when customer orders a job directly from Service manager or technician, no accurate reporting to the system; creates possible difficulties for invoicing.
- Ten (listed) different routes how the customer orders are received, some very informal
- No clear processes how to receive the customer orders, i.e. know how to answer the right questions.
- Dispatcher do not know how to prioritize works
- MRS tool isn´t good for scheduling works
- Technician skills not listed to SAP
- Phone calls to dispatchers incoming from two sources: own cellphones and common dispatch *telephone line.* Sometimes two phone calls may emerge simultaneously and therefore some assistants are not attending to the dispatch line
- GPS tracking: no currently available to every car, makes the whole system useless
- Informing the customer on unfinished jobs: no clear processes
- Separate tool for planning outside SAP: shared excel file – have to deal with multiple tools
- Multiple users in excel-file cause difficulties: saving issues
- Only two timeslots for tasks: before and after lunch
- All jobs are shown as 4 hours in dispatching excel (the actual estimations of the durations [ServiFlex jobs] not exploited)
- All disciplines does not use the planning tool (e.g. electricity)
- All salespersons don´t use the calculation tool for job duration estimations in contract creation
- Creating a work order in SAP is complicated and require multiple steps
- MRS doesn’t show the actual status of ongoing works
- Urgent works: difficult to reach technicians by phone
- Coordinators have no tool to exact daily scheduling: MRS is only used to put new jobs to technicians
- MRS is slow and not communicating well with CS (i.e. when changing something in CS, takes time to update manually to MRS)
- Problems with sick absences and MRS: urgent jobs should be easier transferred to another technician
- Postponed works – when materials arrive, the technicians don’t necessary go immediately do the work
- Staff turnover in help desk is considered high
- Technician makes constant planning: while executing current job the decision where to go next is made

- Big amount of AdHoc jobs doesn’t support planning for the technician
- Customer’s service book difficult to use with mobile device
- Double reporting for hours: mobile and paper reports
- A conflict between the actual work hours and the ones reported to mobile: minimum Ad Hoc job duration that can be reported is one hour
- Difficult to define the urgency of a AdHoc job, based only on common sense and the definition of the fault given by Help Desk
- Mobile device is not usable for searching job history: no calendar view and no order number search
- Customer’s service book works consists of small fragments - difficult to handle what to do and when
- Many orders remain unsolved after first visit
- No time to do repairs – always in hurry
- Area responsible technician is specialized in electricity but every order in certain area goes to him
- Dispatchers don’t get any feedback of how accurate have their duration estimations been
- Planned maintenance work resourcing is partly based on technician requests, how to control that all works will get gone?
- Scheduling of PPM works are on technicians responsibility, sometimes some works have finished late
- Work resourced to technicians partly by two agents (dispatch: PM and service manager: Ad Hoc) so the control of the workload is difficult

Appendix 2, Channels for incoming works

Channel	Who order?	Cons	Pros
Call to Dispatch	Technicians, Service Managers (*customers*)	SO details remain often inadequate: service managers and technicians know the details already and they don't necessary report those. Dispatcher don't want to ask too much	Fast opening of a SO
Call to Help Desk	Customers	Customer and HD-worker are neither technical specialists – all essential information may not be documented	Direct contact to customers for further questions
Call to the personal phone of a dispatcher	Technicians, Service Managers (*customers*)	Dispatcher has to be able to answer to two phones	Customer reaches just the person he wants
Email to the personal address of a dispatcher or Help Desk worker	Technicians, Service Managers (*customers*)	No interaction. The mails may get stuck to the personal mailboxes in case of absence	Customer reaches just the person he wants
Email to Helpdesk	Customer	No interaction. Information may be inadequate because no guidance for customer of the required information	Emails are visible for all. Helps for prioritizing and employee who has information over the particular case can handle it.
Email to Dispatch	Technicians, Service Managers (*customers*)	No interaction. Information may be inadequate because no guidance for customer of the required information	Emails are visible for all. Helps for prioritizing and employee who has information over the particular case can handle it.
Form in the web-site, which generates email to Help Desk	Customer	No interaction.	The required information can be defined.
PPM works from ERP	End-customers (generated in ERP)	Importing and updating the data related to PPM to SAP is laborious	If all necessary information have been imported to SAP, every task has good details
Service books of the customers	Customer	Has to be handled separately outside own SAP	Customer provides all required information
Face-to-face	Customer	Inaccurate, dependent on the person	Immediate

Appendix 3, Current Reality Tree (CRT)