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School of Business

Single visit model in Finnish municipal dental care
A more efficient service model for low-complexity patients

MSc program in Information and Service Management

Master's thesis

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2015

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Abstract of master's thesis

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Title of thesis SINGLE VISIT MODEL IN FINNISH MUNICIPAL DENTAL CARE	
Degree Master of Science in Economics and Business Administration	
Degree programme Information and Service Management	
Thesis advisor(s) Katariina Kemppainen, Tomi Malmström	
Year of approval 2015	**Number of pages** 95 **Language** English

Abstract

For several years, the public dental care system of Finland has been facing difficulties concerning long waiting times and resource sufficiency. The demand for public dental services is likely to increase in coming years due to ageing population. The high demand and scarce resources of public dental services are building pressure on adopting new service models to ensure the availability and effectiveness of Finland's public dental services in the future.

Previous studies in the field of healthcare have shown that service delivery efficiency can be improved by designing the service production to match the actual needs of the patients. However, the highly variant needs of public sector patients make tailoring the service delivery challenging. By recognizing more homogeneous patient groups, the service delivery could be better designed to match supply and demand. For example, Lean techniques such as flexible, just-in-time (JIT) scheduling and open-ended appointments could be utilized to reduce slack and to improve the productivity of staff. This type of approach has become more common, especially in emergency clinics, aspiring to improve the flow of low-complexity patients. However, in dentistry, Lean thinking is still in its infancy.

This thesis poses a setting where the Finnish public dental care could assume two different operating modes: the traditional mode currently used by municipalities and a single visit (SV) mode. The SV mode would act as a fast-track for low-complexity patients who only require a reduced set of basic procedures by providing all necessary treatment during a single visit. To understand both of the modes, the operations of two municipalities - Jyväskylä and Espoo - and a private SV clinic – Megaklinikka - were analyzed. By mining data on staff, visits and performed procedures, the differences between the two modes in terms of operating model, patient & case mix and operational efficiency were examined. The operation of an additional SV service line in one dental care unit of Jyväskylä was also simulated.

Unlike the traditional model, the SV model allows dentists and hygienists to switch rooms and utilizes open-ended appointments and an ERP system to synchronize a JIT-flow of patients. Due to these features and a more homogenous patient and case mix, the SV model is able to produce ~90% more procedures and treat ~68% more patients annually than the traditional model in relation to the amount of clinical staff. Per one dentist, the SV model requires 20% less nurses and 120% more hygienists than the traditional model. The SV model results to 44% less visits, as 80% more procedures can be performed during a single visit. Roughly 40% of all patients and 70% of adult patients in municipalities could be classified as basic patients, meaning that for the majority of adult patients, the SV model could be applied. The simulation suggested that a SV service line would increase the annual procedure output of a municipal dental care unit by 7% without any additional staff. To harness this approach on a larger scale, the proportion of hygienists should be roughly doubled in municipalities. The results of this thesis show that the SV service model could offer a way to treat the majority of adult patients more efficiently in Finnish municipal dental care.

Keywords Dental care, efficiency, process improvement

Tiivistelmä

Suomen julkinen hammashoito on useiden vuosien ajan paininut resurssien riittävyyden ja pitkien hoidon odotusaikojen kanssa. Tulevina vuosina Suomen ikääntyvä väestö tulee lisäämään aikuisten hammashoitopalveluiden kysyntää entisestään. Julkisen terveydenhuollon korkea kysyntä ja niukat resurssit luovat painetta omaksua uusia toimintatapoja palveluiden saatavuuden ja vaikuttavuuden turvaamiseksi.

Aiemmat tutkimukset terveydenhuollon saralla ovat osoittaneet, että palveluiden toimittamisen tehokkuutta voidaan parantaa suunnittelemalla palvelutuotanto vastaamaan potilaiden tarpeita. Julkisen sektorin potilaiden vaihtelevat hoidontarpeet tekevät kuitenkin palvelutuotannon räätälöinnistä haasteellista. Tunnistamalla samankaltaiset tarpeet omaavia potilasryhmiä, palveluntarjonta voitaisiin suunnitella paremmin vastaamaan aitoa kysyntää. Esimerkiksi Lean-menetelmiä, kuten juuri oikeaan tarpeeseen (JOT)- aikataulutusta ja kestoltaan joustavia vastaanottoaikoja voitaisiin hyödyntää resurssien tyhjäkäynnin vähentämiseen ja henkilöstön tuottavuuden parantamiseen. Tämän kaltaiset ratkaisut ovat yleistyneet varsinkin ensiapupoleilla, tarkoituksenaan nopeuttaa peruspotilaiden virtaa. Hammashoidossa Lean-lähestymistavat ovat kuitenkin vielä lapsenkengissään.

Tämä tutkielma tarkastelee asetelmaa, jossa Suomen julkisessa hammashoidossa olisi kaksi erilaista toimintamallia: perinteinen, kuntien nykyisin käyttämä malli, sekä yhden käynnin malli. Yhden käynnin toimintamalli toimisi nopeana kaistana peruspotilaille tarjoamalla kaiken tarvittavan hoidon yhden käynnin aikana. Näiden kahden eri toimintatavan ymmärtämiseksi, tämä tutkielma paneutuu kahden kunnan – Jyväskylän ja Espoon – hammashoidon sekä yksityisen yhden käynnin klinikan – Megaklinikan – toimintaan. Tutkimalla dataa henkilökunnasta, potilaskäynneistä ja tehdyistä toimenpiteistä pyritään selvittämään eroja näiden kolmen toimijan toimintamalleissa, potilaissa, toimenpiteissä ja tuotannon tehokkuudessa. Dataa käytettiin myös simuloimaan yhden käynnin mallin toimintaa yhdessä Jyväskylän hammashoitoloista. Analyysiä täydentävät hammashoidon ammattilaisten haastattelut, joilla tulosten todenmukaisuutta ja laskentatapoja pyrittiin parantamaan.

Perinteisestä toimintamallista poiketen, yhden käynnin mallissa suuhygienistit ja hammaslääkärit voivat siirtyä toimenpidehuoneesta toiseen. Yhden käynnin malli hyödyntää myös joustavan mittaisia vastaanottoaikoja ja toiminnanohjausjärjestelmän ylläpitämää JOT-potilasvirtaa. Standardoitu potilas- ja toimenpidekanta pelkkine perustoimenpiteineen mahdollistavat edellä mainittujen tekniikoiden hyödyntämisen. Tuloksena yhden käynnin mallilla pystytään tuottamaan ~90% enemmän toimenpiteitä ja hoitamaan ~68% enemmän potilaita vuodessa, kuin kuntien perinteisellä mallilla suhteutettuna kliinisen henkilöstön määrään. Yhden käynnin mallissa yhtä hammaslääkäriä kohden on 20% vähemmän hoitajia ja 120% enemmän suuhygienistejä, kuin perinteisessä mallissa. Yhden käynnin mallissa potilailla on 44% vähemmän käyntejä potilasta kohden, sillä mallissa tehdään 80% enemmän toimenpiteitä käyntiä kohden. Noin 40% kaikista, ja 70% aikuisikäisistä kuntien potilaista voitiin luokitella peruspotilaiksi. Voidaan siis sanoa, että valtaosan kuntien aikuispotilaista voisi hoitaa myös yhden käynnin mallilla. Simulaatiomalli osoitti, että yhden käynnin malli pienessä mittakaavassa eräässä hammashoitolassa nostaisi vuotuista toimenpiteiden tuotantoa 7% ilman muutoksia henkilöstöresursseihin. Mikäli yhden käynnin mallia haluttaisiin kuitenkin hyödyntää isommassa mittakaavassa julkisessa hammashoidossa, tulisi suuhygienistien määrä karkeasti tuplata. Kaiken kaikkiaan tulokset viittaavat siihen, että yhden käynnin malli voisi tarjota tehokkaamman toimintatavan valtaosalle julkisen sektorin aikuispotilaista.

Avainsanat Hammashoito, tehokkuus, prosessien tehostaminen

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1 INTRODUCTION

Finnish public dental care system is currently in need for improvement. According to the Ministry of Employment and Economy (Hjelt et al., 2011) the Finnish public dental care system requires a large-scale service innovation. During the years 2001 and 2002, Finland's national healthcare policy was renewed and age restrictions in public healthcare were removed. Prior to this public dental care was targeted only for underage citizens. Modifications in dental care legislation (L1219/2000, 1202,/2000) made public dental care available for all Finnish nationals regardless of age and enabled receiving welfare support for private dental care. The political goal was to increase national oral health, equality and dental care service availability and to remove financial obstacles for seeking treatment. (Suominen-Taipale and Widström, 2006). This resulted in a peak in demand for dental care services, especially in the public sector (Widström et al. 2004; Widström et al. 2005; Kiiskinen et al. 2005). The private dental services were also struggling to meet rapidly increasing demand (Widström and Pietilä, 2003) resulting in rising trend in queue length and frequency, both in public and private dental services (Widström and Nihtilä, 2004). To control the expanding waiting times, Finnish government declared a statutory care guarantee in March 2005 setting the target waiting time for non-acute patients as three months and the maximum to be six months in public dental care (1326/2010).

1.1 Challenges in Finnish Dental Care

According to WHO (2012), the oral hygiene level of Finland does not compare well against international measurement. 25% of Finnish population (>30 years old) have caries and the amount of gum diseases is nearly 64% within the same population (Koskinen et al., 2012). In comparison with other Nordic countries, the overall dental health of Finnish adults is poor and treatment intervals are longer (Ministry of Finance, 2014). Based on a study conducted by the National Institute of Health and Welfare (Koskinen et al., 2012), 73% of adults over 30 were clinically proven to be in need for dental treatment. The socioeconomic factors strongly affect the need and usage of treatment. Age and low education level correlate positively with poor dental health and need for treatment. The aging population of Finland is likely to increase the amount of total adult patients in the coming years as the proportional size of the largest group in need for dental care, 50 to 70 year-olds will grow in the next 15 years (Koskinen et al., 2012).

Currently, the public dental services are not able to uphold regular callbacks to adult patients due to insufficient resources (Ministry of Finance, 2014). The municipalities are struggling to meet legislative waiting time limits as is. Based on monitoring by the Institute for National Health and Welfare (Nordblad et al., 2013), the waiting times are somewhat in control by legislative measurements. Ninety percent of Finnish population was based in a residential area, where waiting time for non-acute treatment was under six months. The amount of patients with post-six-month waiting time has steadily decreased since 2011. However, the amount of patients with waiting time of 3 to 6 months has not been decreasing. Thus, the problem of long queues seems to prevail in public dental care, albeit the decrease in violations of the legal maximum.

The costs of dental care have grown during the 20th century at an average annual rate of 3.3%. This figure is slightly higher than the respective one for general health services. (Nordblad et al., 2013). More alarmingly, the cost per treated patient is increasing in both private and public dental services. At the same time, productivity is decreasing as fewer patients can be treated with similar resources than in 2010. (Ministry of Finance, 2014)

Private dental care is an option for adult patients and it is supported by the government up to a certain point. However, the multi-channel public financing of dental care in Finland creates problems. The queues in municipal dental care stay in control as patients are passively forced to seek private treatment in hope for a shorter waiting time (Ministry of Finance, 2014). Thus the availability of dental care is still very much dependent on person's income level, which is against the official goals of Ministry of Social Affairs and Health. The problem with the financial threshold for seeking dental care is further enforced by the fact that adult patients that don't seek care from the private sector due to financial reasons, belong to the problem group that is specifically in demand for shorter, more regular treatment intervals. Studies by Ministry of Finance (2014) and Ministry of Social Affairs and Health (Koskinen et al., 2012) have clearly shown the positive correlation of age, low education level and low income level with poor dental health in Finland. It has also been speculated, that public sector dentists fall behind on know-how in adult treatment due to the emphasis public sector used to have on underage patients (Ministry of Finance, 2014). The frequency of adults with gum diseases in public dental care suggests that adult patients should more often be directed to hygienists instead of straining dentist resources. Overall, the division of work between hygienists, dentists and nurses should be revised to help improve the flow of patients to unload the long queues (Ministry of Finance, 2014).

These issues are not new to decision-makers. Yet, the same problems seem to exist in public dental care from one year to another and radical changes are conspicuous by their absence. This raises questions about the management and development of the public dental services. The Ministry of Finance (2014) listed lack of efficient management and inability to adopt new ways of working as major concerns in public dental care. According to the report, the lack of leadership-mentality is materialized in stiff organizational culture, negativity towards management positions and inability to adjust the delivery of services to match the needs of patients. As an example, the report highlights the opening hours of public dental service providers, which have been found out of date already for some time and yet remained unchanged. The compensation logic in public dental care is further contributing negatively to the issues in leadership. Chief positions in public dentistry do not bring enough additional income to substitute for the lost procedure bonuses caused by additional administrative work. Most of the chief of dentistry appointments are assigned without the dentist's personal interest and application to the position. Majority of personnel in public dental care management also feel that they are forced to work independently without proper organizational support.

1.2 Legislation and Usage of Dental Services in Finland

In addition to setting the maximum waiting time at six months (1326/2010), the Finnish legislation obligates municipalities to arrange basic and special dental care services for all inhabitants (66/1972; 1062/1989). There are several ways to fulfill this setting. According to law (733/1992) municipalities are allowed to arrange the services by themselves, via contracts with other municipalities, by participation in municipal federation, by purchasing services from public or private operators or by funding the end user of the service with service coupons. Finnish law 1326/2010 determines the coverage of public healthcare services. The law states that municipalities must offer healthcare services in such way that the wellbeing, patient security, social security and condition of inhabitants is ensured when estimated by general, dental and scientific health measurements (10 §). Preventive dental care for children is regulated by the Government degree: children must be examined regularly until completion of comprehensive school (Valtioneuvoston asetus 338/2011, 10 §). For adults, the examination intervals are not regulated by law and they are free to seek care from either the municipal dental services or private dental services.

During 2010, public dental services of Finland were consumed by 1.9 million people of whom 1 227 000 were adults. Over one million adults and roughly 15 000 people under 19 also sought dental care from the private sector in 2010. A long term study (Ministry of Finance, 2014) shows that over a longer period of time, roughly half of the adult population consumes public healthcare services whereas approximately one third of adults uses private services. The public service users have more irregular visit intervals because only private service providers use regular call-backs for adult patients. In the public sector, regular call-backs are only used for underage population. The amount of visits in public dental services in 2010 was roughly 4.9 million (Nordblad et al., 2013). The amount of visits has remained stable over the past years but the proportion of dentist appointments has decreased whereas the proportion of hygienist and nurse appointments has increased. The Finnish Dentist Union reported Finland to have 4325 union dentists and roughly 250 non-union dentists in 2012 (Ministry of Finance, 2014). The public sector employed 2081 full-time dentists whereas the respective number for private sector was 1842. Inhabitants per employed dentists- ratio was approximately 1330, the highest in the Nordic countries (Nordblad et al., 2013).

1.3 Approach to the Challenges in Finnish dental care

Under the reign of Finland's current government, the emphasis on dental health has grown, but the vortex of decreasing efficiency and increasing costs per patient has often been blamed on lack of resources in public discussion (Ministry of Finance, 2014). Recently though, the focus has switched towards considering new approaches to arranging the services to improve the service delivery efficiency. Finland's Ministry of Social Affairs and Health (MSAH) analyzed the current situation and launched a series of suggestions for future improvements in their report: Suun terveyttä koko väestölle (2013). The improvement of service models in municipal dental health services was recognized as one of the focus points. According to MSAH, the need for use of best practices, public-private collaboration and efficiency improvements in operations is imminent. The goals are to ensure sufficient healthcare for all citizens and to shorten the waiting time for getting treatment.

Efficiency focus is not a novel approach in healthcare industry and the pursuit of efficiency has established a firm position as a popular tool for healthcare decision-making (Jacobs et. al, 2006). Some analyses of Finnish municipal dental care efficiency have been conducted in previous years (e.g. Hynninen, 2012; Linna, 2003; Nordblad et al., 1996). The findings suggest that public dental care providers have struggled to adjust their service delivery to match patient's needs, especially in the low-risk patient group, as good oral health of patients has been recognized as a major factor for inefficiency. Previous studies in healthcare field have found that different patient types and operating environments function best with differing appointment system designs (e.g. Ho and Lau, 1992, 1999; Lahtrop, 1993). The problem with service design in public dental care is the high variability of patient needs and the obligation to provide all types of treatment for all patients. If the patients could be divided into more homogeneous groups, the service delivery efficiency could be designed in a more efficient manner. A different demand and supply- based mode of operation could be selected for each group (Lillrank et al., 2010). This would help the predictability of treatment lengths, which is the key to achieving a more unified flow of patients and could in turn increase the productivity of the dental care services (Bahri, 2009).

The above-mentioned point of view to dental care service design reveals a gap in current research. Although the need for new, more efficient service models for Finnish public dental care has been recognized, the current literature lacks a comprehensive analysis of the municipal service model and comparisons with alternative approaches to dental care service delivery. To further estimate the possibilities of improving the long-prevailed issues in Finland's public dental care, a more dynamic approach and analysis of dental care efficiency than just an efficiency analysis of different providers is needed (Hynninen, 2012).

1.4 Objectives and Research Questions

This thesis was created as a part of the Social and Healtcare Innovation Program by the Finnish Funding Agency for Innovation (TEKES), specifically in its sub-project called the Jyvä Initiative. The goals of the Jyvä Initiative are to help spread effective innovation throughout Finnish healthcare systems, to increase collaboration between public and private health services and to create new service innovations for acute problems in Finnish social and healthcare industry. The Jyvä- initiative operates under the institution of Healthcare Engineering, Management and Architecture at Aalto University.

The goal of this thesis is to elaborate, whether the productivity of public dental care in Finland could be improved with a new service model for low-complexity patients by analyzing two different service dental care models. The two approaches in question are the traditional service model used in majority of Finland's public dental care centers and a single visit model designed to treat only low-complexity patients with as little amount of visits as possible, used by a private sector dental care provider. The fundamental research question is:

Could the single visit operating model improve the productivity of Finnish municipal dental care?

On a more concrete level, the objective of this thesis is to analyze the two different approaches to arranging dental care and to illustrate the differences between them in terms of patient and procedure mixes, appointment system designs and operational efficiencies. Moreover, the possible effects of the single visit model in a municipal dental care unit are analyzed through simulation. The objectives thus are:

1. Illustrate the differences between the traditional public dental care service model and the single visit service model in terms of:

- *appointment system design*
- *patient types*
- *procedure types*
- *staff resources used*
- *efficiency?*

2. Determine the proportion of low-complexity municipal patients

3. Estimate the effects a single-visit service line could have in a municipal dental care unit in terms of productivity

1.5 Methodology and Structure

To achieve these objectives, this thesis features an empirical analysis of the operation of two municipalities, Jyväskylä and Espoo, and a private, single visit dental clinic, Megaklinikka. As the operating environments of the service providers analyzed in this thesis differ (public vs. selective private service) a more comprehensive approach than a pure productivity comparison is needed. The main methodology of this thesis is best described as process mining. Process mining utilizes data recorded by information systems (event logs) to understand the function of business processes (Van Der Aalst, 2011) providing insight on their actual operation (Rebuge and Ferreira, 2012). In this thesis, the event logs consist of patient visits, performed procedures and clinical staff information from the two municipalities and Megaklinikka in year 2013. To improve the accuracy and relevance of the analysis, input from multiple dental care professionals from all three service providers was utilized when constructing this thesis. Assumptions, estimations, adjustments and findings were assembled and validated with all of these stakeholders on a continuous basis. Relevant literature was also utilized to familiarize the reader with healthcare related operations management aspects and to yield frameworks for mining the data and measuring efficiency of dental care service delivery. This thesis also features a simulation model based on discrete probability distributions yielded from the data.

The model is used to estimate the effects and applicability of a single visit service line in a municipal dental care unit.

The rest of this thesis assumes the following structure. In section 2, relevant literature on e.g. appointment systems, processes, service production and efficiency is reviewed to introduce the reader to these operations management areas in healthcare context. Section 3 presents the theoretical framework for this thesis. The framework is twofold. The conceptual framework describes the offset of municipalities having both the single visit and the traditional operating models. The efficiency and data framework then describes the metrics used in the data analysis and how the event logs are mined to extract the results. Section 4 presents the manipulation, validation and adjusting measures performed to make the datasets valid and comparable for the data analysis. The validity of the data is also discussed. Section 5 contains the results in three parts. First, the service models and appointment system designs are explained on a process level. The second part of results is the data analysis. The third part of results contains a simulation model of a single municipal dental care unit with two service lines: one operating according to the traditional model and other utilizing the single-visit model. Section 6 discusses the results through the objectives and theoretical framework of this thesis. Section 7 concludes the findings and managerial implications of this thesis and summarizes the answer for the research question. Some suggestions for future research topics are also presented.

1.6 Terminology

AMQ = Appointment making queue or the waiting list. Represents the queue between booking an appointment and next available appointment (Creemers and Lambrecht, 2009)

Changeover time = Time used to prepare the room for the next patient. Includes cleaning and change of equipment

DMU = Decision making unit. In the data analysis there are three DMUs: Jyväskylä, Espoo and Megaklinikka

Full time equivalent (FTE) = Staff amount scaled to represent full time employees. Full annual working time for dentists is 1924 hours and 1989 hours for hygienists and nurses

Just-in-Time (JIT) = A system of production that makes and delivers just what is needed, just when it is needed, and just in the amount needed (Lean Lexicon, 2014)

Lead time = The time required for a product to move all the way through a process from start to finish. (Lean Lexicon, 2014)

Lean production = A production strategy that aims for less human effort, less space, less capital, less material, and less time to make products with fewer defects to precise customer desires, compared with the previous system of mass production (Lean Lexicon, 2014)

M1 = Municipality 1, Jyväskylä

M2 = Municipality 2, Espoo

Operating mode = Selecting a service model based on patient demand and supply capability (Lillrank et al. 2011)

SFQ = Service facility queue. Represents the queue of patients in the clinic waiting for their treatment to start (Creemers and Lambrecht, 2009)

Single visit (SV) model = A service model designed to provide all treatment a patient requires during a single visit to the clinic

SV Clinic = Megaklinikka

Takt time = Available production time divided by demand (Lean Lexicon, 2014)

Theoretical working time = Full staff working time. Estimated at 1780 hours a year (Based on collective agreement between Finland's Dentist's Employer Union and Union of Health and Social Care Professionals, 2014)

Traditional model = The service model currently used in Finnish public dental care

Treatment time = The time patient spends in the treatment room. Includes patient examinations and procedures

Visit time = Total time of the patient visit. Includes treatment time and changeover time

2 LITERATURE REVIEW

This section briefly introduces the literature areas relevant for this thesis. First, the key aspects of appointment system and scheduling design are elaborated. Second, a short overview of the role of ERP- systems in healthcare is conducted. The focus then moves to describing the nature of healthcare processes and service production. In section 2.5 the application of Lean production methods in dental care is examined. Section 2.6 presents approaches to defining efficiency in healthcare. In section 2.6., efficiency estimation methods and previous research on efficiency of Finnish dental care are assessed. Finally, relevant literature on process mining approach in healthcare is briefly introduced.

2.1 Appointment Systems and Scheduling

Interest in appointment system scheduling was first initiated by Bailey (1952). In 1954, Bailey presented the idea of a threshold capacity in outpatient clinics where service supply equals demand. By Bailey's concept, an infinite queue is eventually formed when demand exceeds service supply. Since then, appointment systems and scheduling problems have initiated a great number of studies (see e.g. Tang et al., 2014; Fomundam and Herrman, 2007; Cayirli, and Veral, 2003 for a comprehensive review). A common finding in previous research in this area is that effective outpatient scheduling can result in reduced costs and increased care quality (Cayirli, and Veral, 2003; Gupta and Denton, 2008). The prevailing idea behind outpatient appointment scheduling often is to reduce several time-based measures in the healthcare delivery system such as doctor idle time, patient waiting time and overtime (Qu et al., 2013).

Creemers and Lambrecht (2009) see that appointment systems include two distinctive queuing systems: appointment making- queueing system (AMQ) and service facility- queueing system (SFQ). They refer to AMQ also as "the waiting list" and state it to represent a complex vacation model with origins in studies by Doshi (1986), Takagi (1988) and Tian and Zhang (2006). The authors note that generally, the term appointment systems in scientific literature refers to modelling specifically the SFQ. According to the authors, SFQ problems relate to scheduling patients to optimize some measure of performance, e.g. customer waiting time in the clinic, doctor idle time or staff overtime. In their extensive research, Gupta and Denton (2008) studied several opportunities and challenges in healthcare appointment scheduling. They too emphasized a clear distinction between direct and indirect waiting time experienced by patients. By their definition, direct waiting time is the time patient experiences while waiting in the clinic whereas indirect waiting time is the time sequence between appointment booking and receiving treatment, thus reflecting more the availability of the health service. Gupta's and Denton's (2008) distinction between direct and indirect waiting time can be seen as similar to the SFQ – AMQ division by Creemers and Lambrecht (2009). Both studies found that literature on appointment systems often considers only the SFQ or the direct waiting time aspect. The complexity of modelling indirect waiting time or AMQ was seen as the biggest contributor to this phenomenon in both studies.

According to Tsai and Teng (2014), appointment systems consist of three components: appointment rules, patient classification and an adjustment policy. Appointment rules, or appointment scheduling rules (ASR) are determined by the initial block design, appointment block sizes, and appointment intervals (Cayirili and Veral, 2003). In block appointment rules, the sessions are divided to blocks where a certain amount of patients are scheduled to arrive at the beginning of each block. If the block design is nonexistent, the ASR is considered as an individual block system or individual appointment system, where patients are scheduled individual appointments by specific intervals (Tsai and Teng, 2014). Studies by Bailey (1952, 1954) and Welch (1964) were the forerunners in individual appointment rule studies suggesting appointment intervals based on average service times of patients. Since then, multiple studies have applied different methods for creating ASRs for different healthcare environments. Ho and Lau (1992) evaluated 50 popular ASRs in scientific literature and found that no single rule prevails as dominant in all environments. The "environment" in their case was formed by probability of no-shows, variance in service times and number of patients in a clinical session. The same authors further analyzed operation condition's effect on ASRs (1999) and concluded on the absence of universally dominant ASR in all operation environments. However, ASRs that aimed to reduce customer waiting time had the most constant performance across all operation environments tested. Vice versa, ASRs that scheduled multiple customers to arrive at the beginning of a session generally resulted in long waiting times. The authors also see that a good understanding of the three operating environment elements helps find the appropriate ASR design. Other authors have also shared this view. Tsai and Teng (2014) note that patient classification can contribute to achieving more accurate ruling for appointment scheduling. The classification can be based on e.g. acuity levels (Tsai and Teng, 2014), new/return patients, variability in service times and type of procedure (Cayirli and Veral, 2003). Fomundam and Herrman (2007) found that majority of appointment system related research assumes static and abundant demand. However, in reality, variable demand, no-show patients and walk-ins can occur in outpatient clinics. Adjustment policies in appointment systems are approaches to account for this variance (Tsai and Teng, 2014). These approaches include e.g. overbooking (Kim and Giachetti, 2006), shortening of appointment intervals (Vissers, 1979) and sequential call-in process (Muthuraman and Lawley, 2008).

Murray and Berwick (2003), classified appointment systems into three categories based on the access design of the service: traditional, carve-out and advanced access. In traditional model, all of the appointments are booked in advance. The carve-out model allocates certain amount of appointments to possible urgent patients, while the rest of the appointments are booked in advance for non-urgent patients. The advanced access (also referred to as open access or same-day access), aims to eliminate appointment delay entirely (Murray and Berwick, 2003). This method relies on matching service capacity with demand on a daily basis and is quite vulnerable to the variations in patient needs and imbalances between demand and supply (Liu et al., 2010; Robinson & Chen, 2010). A relatively new approach to appointment systems is the split-patient flow approach, commonly referred to as fast-tracking (Cochran and Roche, 2009), which can be seen as a combination of traditional and open-access appointment systems. Cochran and Roche (2009) explain fast-tracking in appointment systems as a bypass lane for lower complexity patients. La and Jewkes (2013) describe fast-tracking as a mean to decrease waiting times in appointment systems. Edwards et al. (2012) see fast-tracking as an application of Lean ideology in healthcare. They studied different applications of lean methodology in healthcare and found that Lean techniques, such as just-in-time scheduling, can be successfully implemented to healthcare environments. However, they state, that Lean methodology sets certain demands for the operating environment in terms of e.g. standardized activities and processes, which means that only certain types of healthcare environments offer stable enough ground for Lean applications. The majority of fast-tracking research to date focuses on emergency departments. Already in 1995, Garcia et al. concluded that improving care access for fast-track patients does not affect negatively to the service availability of regular patients. Al Darrab et al. (2006) and Walley (2003) reported similar results in their studies. Wiler et al. (2010) found that fast-tracking increases the amount of low-complexity patients treated and contributes positively to the overall effectiveness of emergency clinics.

Another aspect in appointment scheduling is the management of resources to match the demand of services, often referred to as capacity management. Studies have identified matching demand with current and available resources as one of the most significant challenges in service management (Heskett et al. 1990; Jack et al. 2006; Klassen and Rohleder 2001; Lovelock, 1984). These types of challenges are increasing especially in healthcare service delivery creating the need for effective capacity management strategies (Adenso-Diaz et al., 2002; Li and Benton 1996). Smith-Daniels et al. (1988) describe capacity management in healthcare context as decisions and activities related to planning the allocation of key resources: facilities, equipment and workforce. Klassen and Rohleder (2002) presented examples of capacity management options to be e.g. scheduling employees, allowing customer waiting and changing allocation of resources. Jack and Powers (2009) conducted an extensive literature review on capacity and demand management research within healthcare industry. By synthesizing findings from similar literature review by Smith-Daniels et al. (1988), they recognized the focus areas of healthcare capacity management to be capacity management strategies, workforce management, utilization, subcontracting and information technology. Their overall findings suggest that significant improvements in healthcare delivery systems can be achieved through new operating models and advancements in computerized optimization.

2.2 Healthcare ERP

Enterprise resource planning- systems (ERP) are primarily designed to solve the fragmentation of information in large organizations (Davenport, 1998). Typical healthcare ERP applications are designed to assist with profitability improvement, process streamlining and improvement of patient satisfaction (Bose, 2003). Information systems are also used for improving clinical care (Anderson, 1997; McDonald et al., 1998). As ERP systems became more common in recent decades, healthcare organizations were also influenced although the first attempts to integrate clinical and business management were not successful in the 1980s (Stefanou & Revanoglou, 2006). In the 1990s, healthcare organizations kept seeking care quality and efficiency improvements from new information technologies in increasing amount (Raghupathi & Tan, 1999) and the same trend seems to be continuing today (Bose, 2003). According to multiple studies, ERP systems in healthcare are harnessed to help in decision-making tasks through information retrieval, data analysis and procedure management and have had a transforming effect in healthcare in the last decades (see e.g. Bose, 2003 for a comprehensive review).

Although the popularity and benefits of ERP systems in healthcare context have been recognized, it must be noted, that ERP is merely an information system or combination of those. ERP enables distribution of timely information across organizations, but the information must also be implemented efficiently and harnessed to support healthcare-specific decision-making (Elmuti and Topaloglu, 2013). Torres and Guo, (2004) emphasized the need to first recognize and measure key processes to improve patient satisfaction in healthcare service. (Kohlbacher et al. 2008) also highlighted the need for process recognition. They state that ERP systems can be used to optimize the use of resources in healthcare organizations, but the prerequisite of this is recognizing the key processes and performance indicators. Some studies suggest that ERPs are not flexible enough to adapt to complex healthcare processes (Boonstra and Govers, 2009; Davenport, 1998; Markus et al., 2000). To help the process complexity issue, some healthcare organizations are switching towards greater integration through more homogeneous offering (Van Merode et al., 2004). According to Boostra and Govers (2009), this type of shift is often driven by the need to control costs and need for better organizational procedures and standardized processes.

2.3 Healthcare Processes

A precondition for many service improvement initiatives is the recognition of the service in a process form. According to Davenport (1993), a process orientation can be applied successfully to different industries, not just traditional process industries. Vera and Kuntz (2007) presented empirical evidence of a clear positive correlation between high process orientation and efficiency in hospitals. Gemmel et al. (2008) summarized previous studies on process orientation to indicate two ways for process orientation can present in the hospital industry. The first is an apporach where horizontal processes are planted on top of existing vertical structures without changing the functional organization. The second way is to design the processes based on the needs of the patients. Gemmel et al. (2008) state that in the latter approach, the healthcare service lines are optimally organized to match the real needs of patients. This patient oriented approach concerns mainly the service production in healthcare and is thus discussed in more detail in the next sub-section. On a higher level, Lenz and Reichert (2007) classify healthcare processes into two categories: medical treatment processes and generic organizational processes. Medical treatment processes are directly linked to the patient and consist of observation, reasoning and action whereas organizational processes are generic patterns designed to support and coordinate treatment (Rebuge and Ferreira, 2012). Lillrank and Liukko (2004) presented a classification of healthcare processes that can be seen to acknowledge both the medical treatment and the organizational view. The authors divided healthcare processes into three categories: standard, routine and non-routine. By their definition, the standard processes have identical repetition and the treatment is based on compliance and certain procedures. Routine processes have similar, yet not identical repetition and the care is based on selection between certain clinical guidelines. Non-routine processes do not show a repetitive pattern and the selection of treatment lies heavily on the healthcare professional's intuition and interpretation. In a more recent study, Lillrank et al. (2011) state that in healthcare, the identification of a process requires reasonable stability and repetition volume. The authors also see that to be a meaningful unit of analysis, a process should have at least the following characteristics: a set of productive resources that transform inputs to outputs and a predetermined flow with a beginning and an end enabling pre-production planning based on expected end results.

To understand processes in healthcare, previous studies have found multiple approaches, like process mapping, measurement and analysis techniques (e.g. Vissers and Beech, 2005; Ronen and Pliskin, 2006). When mapping healthcare operations into a process flow, the approach is often from the point of view of only the service producer (Lillrank et al. 2011) despite the fact that the importance of a patient-oriented approach in healthcare system design has been widely recognized (Tarte and Bogiages, 1992; Vissers, 1998; Lillrank et al., 2003; Kujala,et al., 2006). Womack and Jones (2005) stated that in the process mapping for any service, the producer activities should be separated from those of the customer. The service blueprint approach by Fliess and Kleinaltenkamp, (2004) recognizes customer as part of the service process on some level. Lillrank et al. (2011) translated this into healthcare context by stating that in healthcare context, process mapping should comprise the flow of a patient case through the healthcare production system. This view was materialized in the episode-event conceptualization concept.

The episode-event conceptualization was originated in HEMA, Aalto University School of Science through various case studies involving health service organizations and aiming to apply industrial management methods to healthcare organizations. The basic idea is to complete traditional process analysis with episodes and events to integrate patients in healthcare production systems on a conceptual level (Lillrank et al. 2011). The terms in episode-event conceptualization can be interpreted based on Lillrank et al. (2011) as follows: An episode describes the time-sequence the patient is subject to health-related activity. Service events are points where the healthcare process meets the episodes. They are performed by one producer or a team of producers in interaction with the patient, with a schedule and with an expected end result.

The patient-in-process concept by Lillrank et al. (2003) encouraged researchers to focus on applying certain best practices from manufacturing industry to healthcare. The authors divided process throughput time into productive and unproductive time and saw that reductions in productive time would essentially mean faster working pace whereas non-productive time could be interpreted as slack in the process, which could be managed by resource allocation and scheduling. The results of using the episode-event conceptualization have been bipartite. In some cases industrial management methods fit well into healthcare context and help yield improvement supporting analyses (Peltokorpi et al. 2008; Torkki et al., 2006; Peltokorpi et al., 2006; Peltokorpi and Kujala, 2005; Torkki et al., 2005). However, in some cases, manufacturing methodologies fail to offer further insight to healthcare processes. The latter type includes typically healthcare processes that lack some of the characteristics required from a process to be a meaningful unit of analysis and contain more exceptions than regularities (Lillrank et al. 2011).

2.4 Healthcare Service Production

This sub-section focuses the service production in healthcare process: the part where the actual treatment is delivered. Service production in healthcare can be seen as more complex than in other industries. Lawrence and Lorsch (1967) saw the major dilemmas of service production to be integration, coordination and control (Lawrence and Lorsch, 1967). In addition to these, in healthcare services patients must be treated based on their individual needs (Berry and Benapudi, 2007) while providing standardized service with limited resources (Lillrank et al. 2010). The strong effect of varying patient needs can create problems when designing healthcare service production and delivery systems. One example of the challenges is achieving the managerial homogeneity (Lillrank et al., 2010). Henderson and Clark (1990) posed the underlying assumption that tasks with similar operational requirements should be performed in similarly organized systems. In healthcare context, failure to achieve managerial homogeneity can present as e.g. using common resources for acute and non-acute patients and often results in inefficiencies in capacity utilization and waiting times (Joustra et al. 2010). Multiple studies have contributed to recognizing managerial homogeneity as an essential precondition for efficiency in healthcare service production (e.g. Glouberman and Mintzberg, 2001; Christensen et al. 2009, Bohmer, 2009; Bohmer and Lawrence, 2009, Lillrank et al. 2010). The pursuit of managerial homogeneity is the driving force behind the patient-oriented view in healthcare service design, which was referred to briefly in the previous section. Lathrop (1993) presented the concept of patient-focused hospital where the underlying assumption is that the operating structure of the healthcare production needs to be redesigned around the patient and his actual need for treatment. According to the author this would essentially mean creating more autonomous departments treating more homogeneous patient groups.

A crucial precondition for patient-focused service design and achieving managerial homogeneity is the classification of patients. One example of patient classification is the case mix methodology, where patients are divided into segments based on the treatment types they undergo (Lillrank et al., 2010). The most well-known case mix method is the diagnostic-related group- method (DRG). According to Lillrank et al. (2010) the literature on demand based patient classification methods outside DRG is quite limited. They also point out, that due to information asymmetry between patients and providers (Neuman and Neuman 2007; Robinson and Thomson 2001), demand alone is not a sufficient basis for complete grouping factor. Lillrank et al. (2010) instead present a demand and supply- based classification of patient cases: seven different operating modes. Operating mode is described as a set of integration, coordination and control principles (Lillrank et al. 2010). This model creates an algorithm to help identify the suitable approach for the patient case on provider's side. Figure 2-1 illustrates the operating modes in a flowchart.

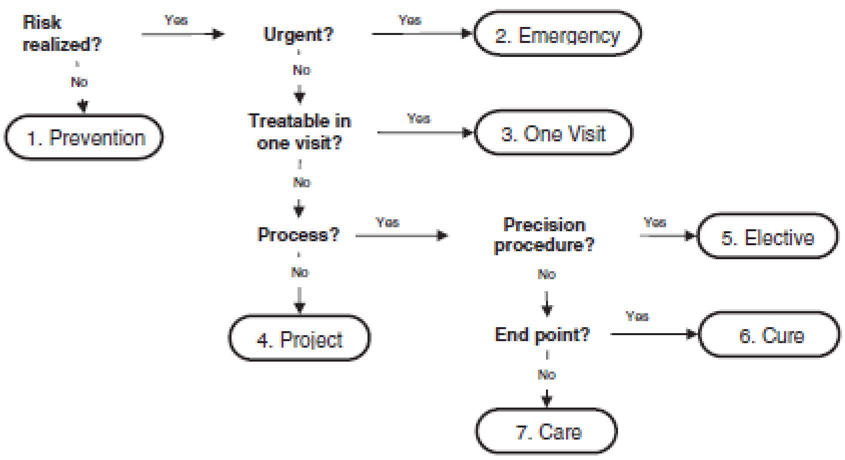


Figure 2-1 - Operating mode flowchart (from Lillrank et al., 2010)

In essence, the operating mode- concept suggests that as the patient needs are predictable, the service provider could select the most appropriate mode of operation. Each mode could be seen as a different service line with different coordination and control principles.

2.5 Lean in Dental Care

The concept of Lean production was first coined in 1988 via introduction of the Toyota Production System (Ohno, 1988), and was made popular by the book: The machine that changed the world (Womack et al., 1990). Since then it has generated numerous applications and studies across industries (see e.g. Jasti and Kodali, 2015 for a comprehensive review). The Lean ideology can be summed up as using less of everything to produce more products in less time with ever increasing quality (Womack et al., 1990). As discussed earlier, Lean has been successfully implemented in healthcare as well (Edwards et al., 2012). However, Lean approach in dental care can be seen relatively new and not many researchers have approached this particular topic. The most comprehensive assessment of Lean in dental care can be found in the book: Follow the Learner by Bahri (2009). In this book, Bahri discusses the fundamentals of Lean in dental care context and elaborates the development of his own dental practice which is considered as the first Lean application in dentistry.

Bahri found that Lean in dental care is formed by three key elements: leveling, one-piece patient flow and synchronization. The first element, leveling, is explained as balancing the amount of work with capacity and distributing procedures throughout the schedule. In dentistry this means arranging the performance of procedures based on the takt time (the production time available to fulfil demand). The second element, one-piece patient flow, requires the redefinition of piece and lot. Bahri considers a tooth as one piece and a mouth as one lot. In Lean production, the aim is to minimize lead time - the time between process initiation and execution - for production of lots (Ohno, 1988). In dental care this translates to providing all necessary treatment to whole mouth during a single-visit (Bahri, 2009). To implement the one-piece flow, Bahri recognized three key measures: grouping, flow scheduling and crossing functional boundaries. Grouping essentially means patient classification based on complexity and predictability. These groups are then scheduled to match provider capacity and the assessed need for treatment. Crossing of functional boundaries is needed to provide both hygienist and dentist treatment during the same visit as traditionally, they require separate appointments (Bahri, 2009). The final element, synchronization, focuses on fulfilling the just-in-time aspect of Lean (Womack et al. 1990). Bahri explains synchronization as coordinating patients to be where they are needed at exactly the right time. For this purpose, Bahri's clinic appointed a patient flow manager for steering the patient flows and employees to eliminate idle time of staff and waiting time of patients. According to Bahri (2009) the Lean approach has helped his practice to reduce lead times and number of visits while increasing staff productivity and patient satisfaction.

2.6 Defining Efficiency in Healthcare

According to Agnieszka et al. (2014) the most popular definition of efficiency in healthcare is the traditional input-output orientation. They explain this view as efforts to maximize outputs with fixed inputs or minimizing inputs with fixed outputs. Burgess (2012) notes that this approach assumes that the quality of the delivered service is not lowered as the production of outputs increases. Nojszewska (2011) parallels healthcare efficiency to economic cost effectiveness and value for money concepts by defining it as the relation of the stated objectives to the resources used. Agniezka (2014) states, that these types of definitions can somewhat be grouped under technical efficiency. Technical efficiency is defined as producing the maximum amount of output for a given amount of input or producing a given output with minimum quantities of input (Farrell and Royal, 1957; Hollingsworth et al., 1999). This can be translated to measuring efficiency through the function of health production (Ogloblin, 2011).

Eklund (2008) studied resource constraints in healthcare in his doctoral dissertation. In addition to technical efficiency, he added allocative efficiency and economic efficiency to his mix of metrics. The results of his study suggest that resource constraints occur in both healthcare production process and patient flow due to the interdependency of resource capacity. He states that efforts should be directed at improvements in technical or allocative efficiency on production process and patient flow level to achieve better economic efficiency.

Peltokorpi (2010) states that to estimate the performance of healthcare processes, it is necessary to consider the value chain as described by Porter (1985). According to previous research, the value chain approach can also be used for assessing healthcare system performance (Burns 2001; Lillrank et al. 2004; Eklund 2008; Peltokorpi 2008). Figure 2-2 illustrates Peltokorpi’s view of healthcare value chain.

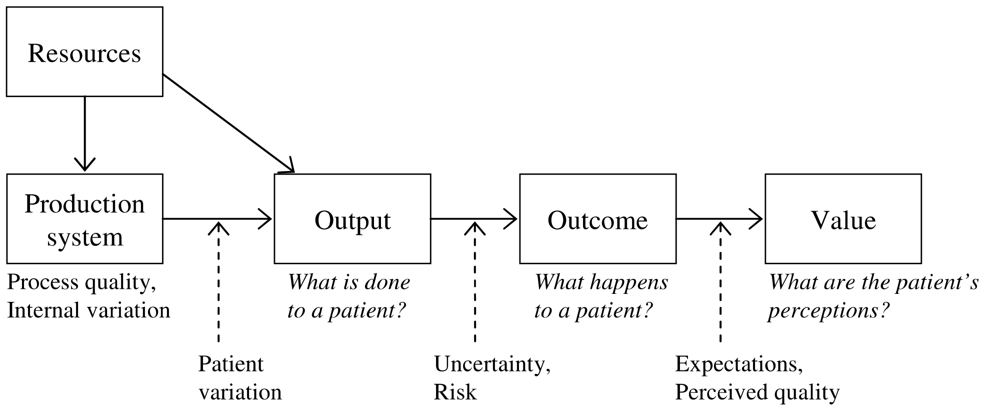


Figure 2-2 - The value chain of healthcare (from Peltokorpi, 2010)

Peltokorpi (2010) also expands the efficiency types earlier presented by Eklund (2008). He utilized a study by Lillrank et al. (2004) to yield a representation of efficiency in healthcare production. Figure 2-3 represents this model.

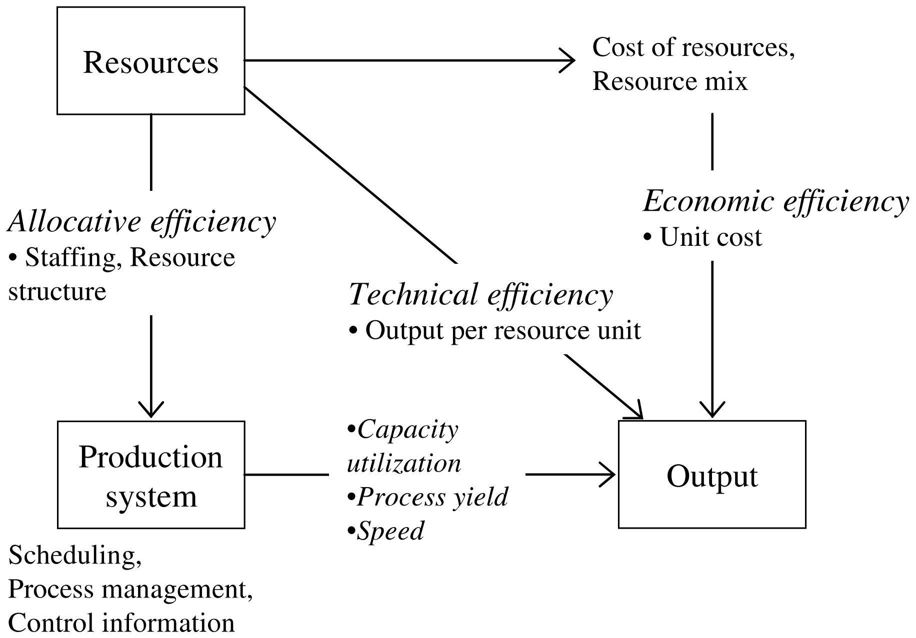


Figure 2-3 - Efficiency in healthcare production (from Peltokorpi, 2010)

This model illustrates the efficiency metrics for the beginning of the value chain. However, the fundamental idea of healthcare systems is to contribute positively on patients' health (Peltokorpi, 2010). The health outcome and patient perceptions on e.g. quality and access to care together form the perceived value of the healthcare service (Peltokorpi, 2010). Nevertheless, the service characteristics of healthcare result to very subjective patient perceptions and make quantifying total value of the service extremely complex (Petronela and Adrian, 2014). Finding universally valid standards for measuring customer's perceived value in service delivery process is almost impossible (Plaias et al. 2012). The estimation of the outcome in the healthcare value chain can be equally challenging. Health measurement has an evaluative and subjective nature and there is a lack of standardized measures for measuring outcomes and effectiveness of healthcare services (Fuchs, 1993; European Research Group on Health Outcomes, 1994). Due to, inter alia, the above-mentioned reasons, efficiency analysis in healthcare often focuses on estimating the performance of resource allocation and production system, since that part of the healthcare value chain is easier to quantify and will give more objective results (Jacobs et al. 2006). Even though healthcare efficiency analyses often focus on the operational efficiency, some studies suggest that the outcome and value dimensions can still be partly included. Ahmed and Amagoh (2014) saw that efficiency in healthcare service delivery also creates value for patients. Wang (1994) found that the increase in the efficiency of healthcare service delivery does not jeopardize the quality of the service. Furthermore, Varsio et al. (2008) found that there is a strong correlation between the operational efficiency and actual effectiveness in healthcare services. Effectiveness in this case has a similar meaning as the outcome in healthcare value chain, describing the actual effects on patients.

2.7 Efficiency Estimation Methods and Dental Care Efficiency in Finland

In healthcare efficiency analytics, the data envelopment analysis (DEA) has established a dominant position as the most frequently used approach to estimate the performance of healthcare operating units (Hollingsworth, 2003). DEA is a nonparametric methodology for evaluating the production process of operational units usually referred to as decision-making units (DMU) (Cheng and Zervopoulos, 2014). A DMU is an organization or a part of an organization forming an independent entity with the ability to affect its own operations through decision- making activities (Hynninen, 2012). Charnes et al. (1978) defined the scope of DEA to be the comparative efficiency assessment of DMUs focusing on either maximum outputs or minimum inputs. Some studies have argued that the outputs in DEA analysis should be divided further into desirable and undesirable outputs and have developed methods for asymmetric approach for these two different outputs (Chung et al., 1997; Färe et al., 1989, Scheel, 2001, Seiford and Zhu, 2002 and Tone, 2004). Moreover, some researchers have argued that the omission of undesirable outputs could yield misleading results in DEA analyses (Färe et al., 1989; Lozano and Gutierrez; 2011; Yang and Pollitt; 2009;Yu et al., 2008). The role of undesirable outputs can be better understood through Jacobs et al.'s (2006) definitions of the terms productivity and efficiency. Productivity was defined as the simple relationship between inputs and outputs. Efficiency then, describes productivity with the quality aspect included. By their definition, a service can be highly productive but inefficient at the same time, if part of the produced outputs is undesirable. They conclude efficiency analysis to be a valid tool for healthcare industry as long as the nature of the outputs and the output's contribution to health outcomes are known.

The largest dental care development project in Finland has since 1999 been the Challenges in Dental Care- initiative (CDC) conducted by the National Institute for Health and Welfare (Varsio et al. 2008). The CDC is a network-approach to developing practices and management of municipal dental care (National Institute of Health and Welfare). The Balanced Scorecard methodology, self-assessment and peer assessment have been used to collect data for indicators measuring fulfillment of strategic objectives and critical success factors (Hynninen, 2012). The main operational efficiency measurement methodology in CDC has been the DEA approach with added variations to the original model (Hynninen, 2012). Operative efficiency has been measured by using the amount of weighted procedures performed as outputs and the amount of staff members as inputs (Varsio et al. 2008). Cost efficiency has been measured by comparing the number of treated patients with operating expenses (Hynninen, 2012).

Nordblad et al. (1996) analyzed the cost efficiencies of public dental services in Finland. The findings suggested significant differences in cost efficiency between different health centers. Linna et al. (2003) saw that the substantial differences in this study may have been caused by an omitted variable bias, as major sources of inefficiency can depend on some unobserved environmental characteristics (e.g. financial incentives). In this more recent study, Linna et al. (2003) investigated both technical and cost efficiency of public dental care providers in Finland and the key factors causing these differences. The selected methodologies were different DEA models and econometric analysis. The selected outputs were the number of treated patients and the number of visits. The inputs were respectively total costs (operating costs + equipment) and full time equivalents (FTE) of personnel. The difference in efficiencies was substantial but also largely dependent on the selected output measures. The greatest factor explaining efficiency was the dental health of the respective municipal population of the health care center when using visits as the output of the service production. According to Linna et al. (2003), this correlation could indicate that municipalities have failed in resource reallocation as the dental health of population has improved. The authors state another possible implication to be that the number of visits is overestimated for patients with poor dental health.

Hynninen (2012) conducted another efficiency comparison in Finnish municipal dental care. He extended a DEA model to a Ratio-Based Efficiency Analysis- model (REA) which focuses on pairwise comparison of the DMUs. Selected inputs were the staff time spent on treatment and number of visits. Selected output was number of procedures. In his study the procedures were given weights based on the difficulty level of the procedure. This allowed the inclusion of case-mix in the analysis. Hynninen (2012) too found significant differences in municipal dental care efficiencies. The most efficient municipality was on average 13% more efficient than the rest of the municipalities. His analysis contained two distinct approaches to efficiency. First approach was the relation of time spent in operations and the produced amount of weighted procedures. This ratio indicates both the speed of production and the utilization of the allocated time. The second approach is the relation of weighted procedures per visits. Hynninen (2012) assumed that it is in the patients interest to get treatment with as little visits as possible, thus more procedures per visit indicated more efficient service delivery.

Although Finnish dental care efficiency has been previously assessed in scientific literature, a few limitations in these studies can be identified. First, the DEA-based approaches do not recognize the possible noise in the data, but the measurements are always assumed to reflect reality accurately. This can decrease the validity of the results as the incompleteness and noise in healthcare data have been recognized as frequent challenges (e.g. Rebuge and Ferreira, 2012; Gupta, 2007; Mans et al., 2008a; Lang et al., 2008). The second limitation is the way the efficient frontier is comprised, dating back to definitions by Farrell (1957). Essentially the previous approaches to Finland's dental care efficiency assume that the efficient frontier can be found within the compared DMUs. In reality, the efficient DMUs in the analysis are not necessarily efficient when compared to a larger selection of service providers leading to faulty indicators for efficiency for all DMUs. Also, the effects of different service models to efficiency are not revealed. To complement these issues, a more dynamic approach to dental care efficiency analysis is needed (Hynninen, 2012).

2.8 Process Mining in Healthcare

Jans et al. (2014) describe process mining as systematic analysis of data recorded by information systems (event logs), to understand the operation of complex business processes. According to Van Der Aalst (2011), process mining enables a fact-based recognition of problems in business processes and allows comparisons between designed and actual processes. Rebuge and Ferreira (2012) state, that process mining offers a valid tool for analyzing especially healthcare processes. They see that as healthcare processes are considered highly dynamic, complex and ad-hoc, the event log based knowledge of processes is extremely valuable for gaining insight on actual operation of the process. Van Der Aalst et al. (2007) presented four approaches to analyzing event data in process mining: the control-flow perspective, the organizational perspective, the data perspective and the performance perspective. The control-flow perspective focuses on the activities in the process and their order of execution. The organizational perspective is concerned with the relationships between the users who perform the activities. The performance perspective tries to reveal bottlenecks and help calculate performance indicators. The data perspective aims to classify the data objects as inputs and outputs in the process.

Several studies have applied process mining techniques to healthcare industry. Mans et al. (2008a) utilized process mining to compare the treatment paths of stroke patients in different hospitals. In another study, Mans et al. (2008b) studied the careflow of gynecological oncology patients in the AMC hospital, Amsterdam. Lang et al. (2008) conducted an analysis of the radiology workflows in the Erlagen University Clinic, Germany. All of these studies investigated specific healthcare workflows or careflows with selected approaches by Van Der Aalst et al. (2007). According to Rebuge and Ferreira (2012), a common feature in process mining approaches in healthcare context is the need for intensive preprocessing of data. The authors state that as the analysis is based on data recorded by ERP systems, an extensive validation and construction of the event logs is often needed to prepare the data to act as a meaningful source for the analysis.

3 THEORETICAL FRAMEWORK

This section describes the theoretical lens for understanding the setting of this thesis. Fundamentally, this thesis analyses two different approaches to dental care delivery, both of which have their own characteristics regarding the appointment system design, scheduling, capacity management and service production. Moreover, the dental care delivery models currently operate under different environments. Thus, the term operating logic is used to describe the comprehensive approach to dental care service provision. The theoretical framework can be divided into two parts: conceptual framework and framework for efficiency and data mining. The conceptual level describes offsets of two different operating logics in light of reviewed literature. The data level sets the framework for studying the operating logics based on the data provided.

3.1 Conceptual Framework

First, the nature of the dental care services is assessed to justify the feasibility of this type of research. Healthcare is often referred to as a complex and multi-disciplined industry, where applying operations management techniques may be difficult. Lillrank et al. (2011) found that complex healthcare processes that contain more exceptions than regularities tend to react poorly to industrial management based process improvement techniques. However, it could be argued that the dental care processes usually fulfil Lillrank's and Liukko's (2004) definition of a routine process. The repetitions in dental care are not identical for each patient but are often quite similar, and the case mix can be seen to be quite restricted compared to e.g. a general ER clinic, while the operations remain between predefined clinical guidelines. Thus, dental care should provide a static enough ground for applying industrial management techniques for process improvement. That being said, it must be noted that the processes in the two different operating logics are not equally "routine". The single-visit logic can be seen as a Lean approach to dental care, where by standardizing the patient and case mix, the delivery process has been designed to treat low-complexity patients with high efficiency. Through standardization, it is easier to match the service capacity with the demand enabling an open access design as described by Murray and Berwick (2003). Moreover, the standardized patient mix helps fulfill the key elements in Lean dental care defined by Bahri (2009): leveling, one-piece flow and synchronization. The municipalities then, offer a more comprehensive dental service with more legislative requirements and variance in patient types and cases resulting in a more complex delivery process. The access design can be seen as a carve-out model, where non-acute patients are assigned individual appointments in advance. Treating all types of patients with a similar operating logic builds the risk of inefficient service delivery for some patient types.

The literature suggested that fast-tracking has increased the amount of low-complexity patients treated in ER units without damaging the flow of other patients (Garcia et al., 1995; Al Darrab et al., 2006; Walley, 2003; Wiler et al., 2010). In addition, Bahri (2009) reported positive results after applying Lean methodologies to his dental practice. The results from these studies support the idea that fast-tracking could be applied to public dental care in Finland to help improve the flow of patients and productivity of staff. Lathrop's (1993) patient-focused hospital concept posed the idea of redesigning the healthcare production to better match the actual patient needs. By classifying the patients into more homogeneous groups, treatment could be provided in a more efficient manner. The patient-focused hospital concept can be seen to relate closely to the operating modes concept by Lillrank et al. (2011). This concept described a demand and supply based patient classification structure, where based on patient classification, the most suitable operating mode would be selected. The overall suggestion of reviewed literature is that different patient types require different approaches to appointment system design to provide care in the best possible manner. Figure 3-1 illustrates this ideology and conceptual theoretical framework of this thesis on a high level.

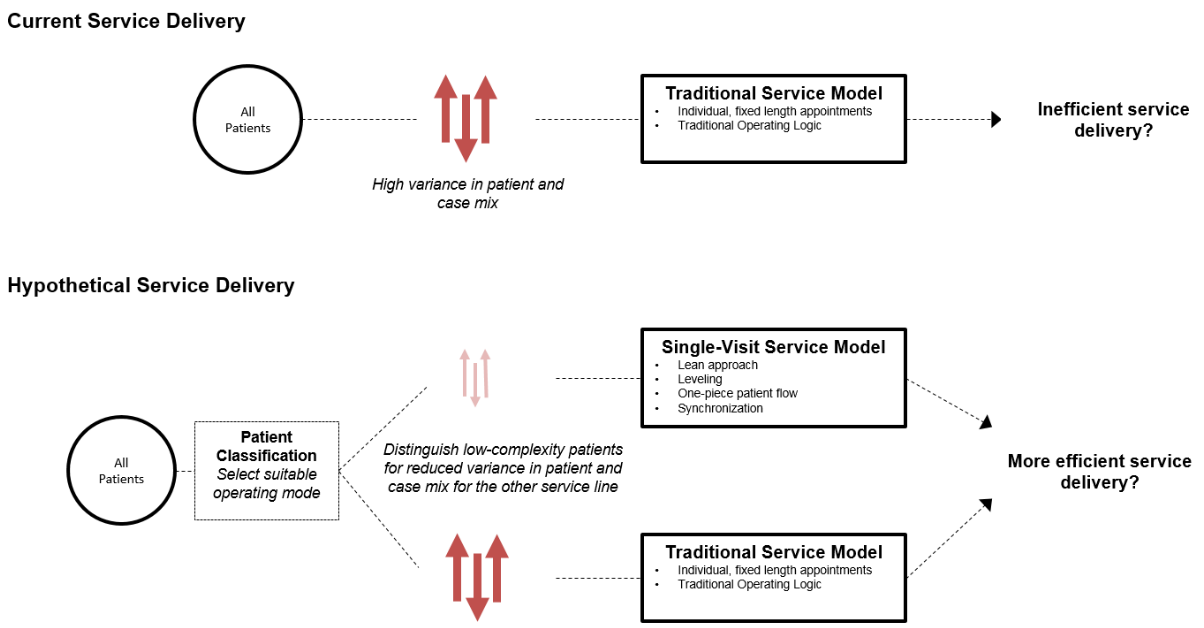


Figure 3-1 - Conceptual theoretical framework

To assess the feasibility and possible benefits of fast-tracking and Lean in Finnish public dental care, the operating logics of the municipal dental care and the single-visit clinic need to be analyzed. Through process mining, efficiency analysis and specialist interviews, the results of this thesis portray the current arrangement, function, patient mix and efficiency of dental services in the two municipalities and compare it with the single-visit clinic. The framework for addressing these factors is described in the next section.

3.2 Framework for Determining Efficiency and Data Mining

In this thesis, a process mining approach combined with some elements from DEA analysis is used to describe the different dental care providers in terms of resources, patients, procedures, visits and efficiencies. Out of the four approaches on event data analysis presented by Van Der Aalst et al. (2007), the emphasis is on the performance and organizational perspective. As Rebuge and Ferreira (2012) noted, event log-based process mining often requires intensive preprocessing of data. This thesis is no exception to that rule. The goal of the preprocessing is to make the event logs comparable, reliable and valid and to remove the unnecessary noise in the data. The process mining approach helps diminish the earlier mentioned limitation of a pure DEA- approach, as data is not considered valid from the beginning. Also, as the data is not used to form a universal efficient frontier for all service providers. This enables the comparison of service providers with differing operating environments and service models.

The approach to efficiency in this thesis follows the traditional input – output orientation. The focus is on determining how much production is performed in relation to available resources and how the service is divided within the patient episodes. The input used in this thesis is the working time of clinical staff scaled as FTEs. The outputs are performed procedures, visits and treated patients. The analysis does not include the outcome and value of the healthcare value chain as defined by Peltokorpi (2010). For the reasons discussed in sub-section 2.5 and lack of data on e.g. patient preferences, the quantified estimation of these factors would require lot of assumptions and could possibly decrease the objectivity of the results. Although direct measurement of health outcomes and customer value is not included, the reviewed literature suggested that the operational efficiency often has a positive correlation with these dimensions as well. In this case it is assumed, that more dental procedures equal better health outcomes and effectiveness of care. Similar reasoning was used by e.g. Hynninen (2012).

In addition to evaluating the differences in procedure outputs in relation to resources, the efficiency analysis in this thesis focuses on revealing slack or non-productive time (as described by Lillrank et al., 2003) in the process, which can be managed by resource allocation and scheduling. The productive time (or working phase) in different service models is assumed to be somewhat identical. In essence, the speed of performing the actions during the appointments is not assumed to vary. As the working pace is assumed to remain constant, the hypothesis of non-decreasing quality of produced outputs by Burgess (2012) is assumed to prevail meaning that the increase in the amount of outputs will not affect the quality of outputs as the productivity increase is seen to stem from management of the unproductive time.

To define the efficiency metrics used in the data analysis, a dimensional approach with implications from Peltokorpi (2010) and Eklund (2008) was selected. The DMUs in this case are the SV clinic and the two municipalities. Peltokorpi's illustration of efficiency in healthcare production is customized to yield a dental care- specific structure for measuring efficiency presented in Figure 3-2.

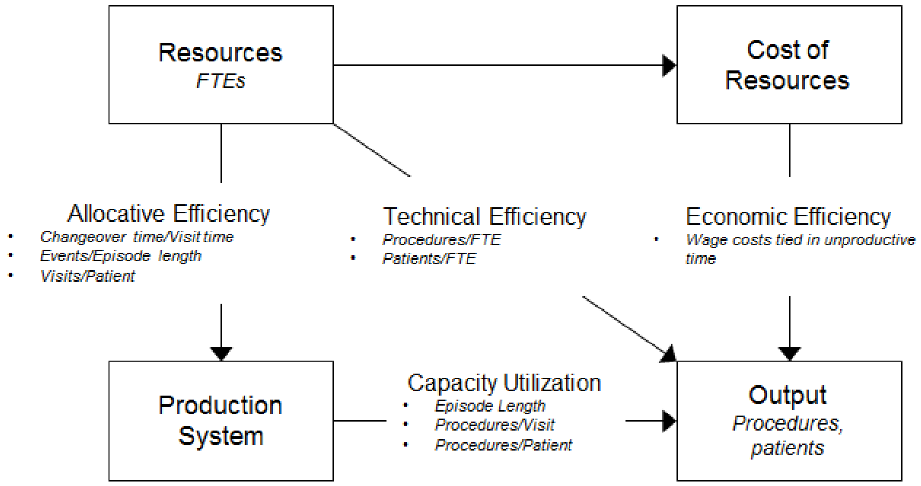


Figure 3-2 - Efficiency in dental care delivery (modified from Peltokorpi, 2010;Eklund, 2008)

As presented in sub-section 2.7 the traditional DEA approaches to efficiency have received criticism for often dismissing the possibility for undesirable outputs (Färe et al., 1989, Lozano and Gutierrez, 2011, Yang and Pollitt, 2009 and Yu et al., 2008). In this thesis, the number of visits per patients can be seen as an undesirable output. The approach to this metric is quite similar as Hynninen's (2012). The assumption is that the patient will benefit if minimum amount of visits is used to deliver the treatment. Thus, visits per patient can be seen to reflect the allocative efficiency of the resources. Additionally, allocative efficiency can be analyzed by utilizing Lillrank et al.'s (2003) concept of productive and non-productive time in the healthcare process. This relationship is analyzed by comparing the time used for treatment (*visit time*) with the time used in other activities such as changing equipment and cleaning the operating rooms (*changeover time*). The episode lengths can be seen to relate to both allocative efficiency and capacity utilization. The episode-event conceptualization forms a theoretical ground for studying patient episodes and events. In this thesis, the episode is defined as the time sequence patient undergoes dental treatment. If the treatment requires multiple appointments, the episode length would be the gap between first and last treatment. Service events can be interpreted as the visits to the dental care service provider, as in service events, the patient episode meets the healthcare service process (Lillrank et al., 2011). Figure 3-3 illustrates the episode-event approach in this thesis. Naturally, there must be some constraint for the episode length. Otherwise all treatment a patient undergoes during his life could be interpreted as one long episode. However, as the waiting times in municipal dental care are measured in months, an episode requiring several visits could theoretically last for a full year. Thus, the episode length constraint should be left relatively loose when assessing dental care episodes and events. In this case, as the data is available for a full year, the episodes are not constrained below this time cap.

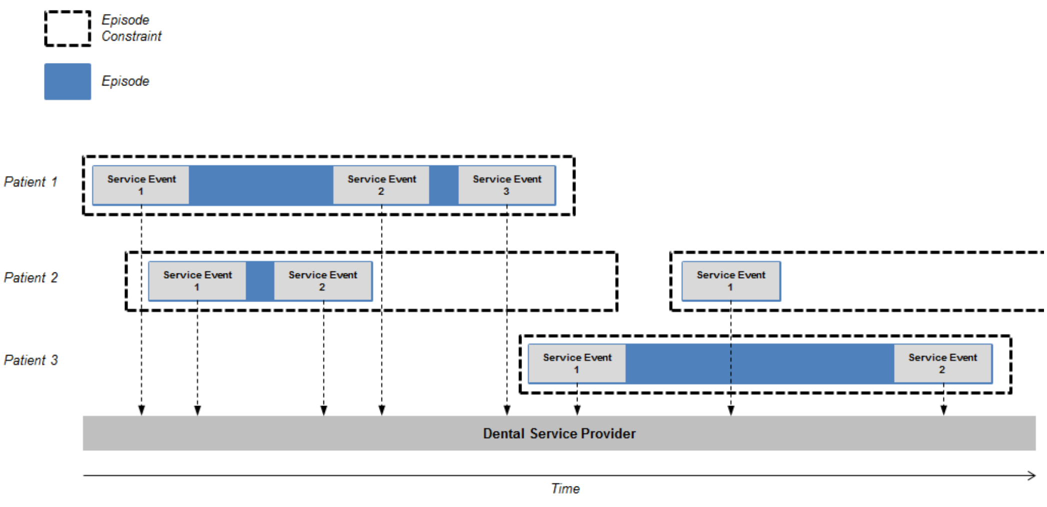


Figure 3-3 - Episode-event approach

The recognition of patient episodes is crucial for embedding indirect waiting time in the analysis. As Gupta and Denton (2008) and Creemers and Lambrecht (2009) noted, indirect waiting time is hard to model due to number of reasons. By recognizing the service events as occurrences within a patient episode and not analyzing patient waiting within the service event, the lens of tracking the patient in the treatment process can be expanded and some representation of the indirect waiting is provided. For correct assessment of the full length of a patient episode, the concept should include also the booking of the first appointment. However, considering the data available for this thesis, expanding the patient episode prior to the first service event would require too many assumptions and estimations to provide any reliable or feasible results. In addition to episode lengths, capacity utilization can be analyzed by measuring the amount of procedures performed in each visit and procedures performed for each patient. Due to lack of financial data, the economic efficiency is of low emphasis in this thesis. However, the wage costs of staff can be estimated based on dental industry salary reports to give some indication of personnel costs tied to the unproductive time.

Although previous literature has found sufficient metrics to measure the efficiency of dental care service delivery, a pure head-to-head comparison based on the presented metrics might not be that informative, since the operational environments of the dental care providers evaluated in this thesis are different. Instead, this thesis takes a process mining approach to clarify the operating logics of different dental care providers both on a conceptual and data level. The the following structure is used to analyze the different DMUs and the differences in terms of resources, patients, procedures, visits and efficiencies, described in Figure 3-4.

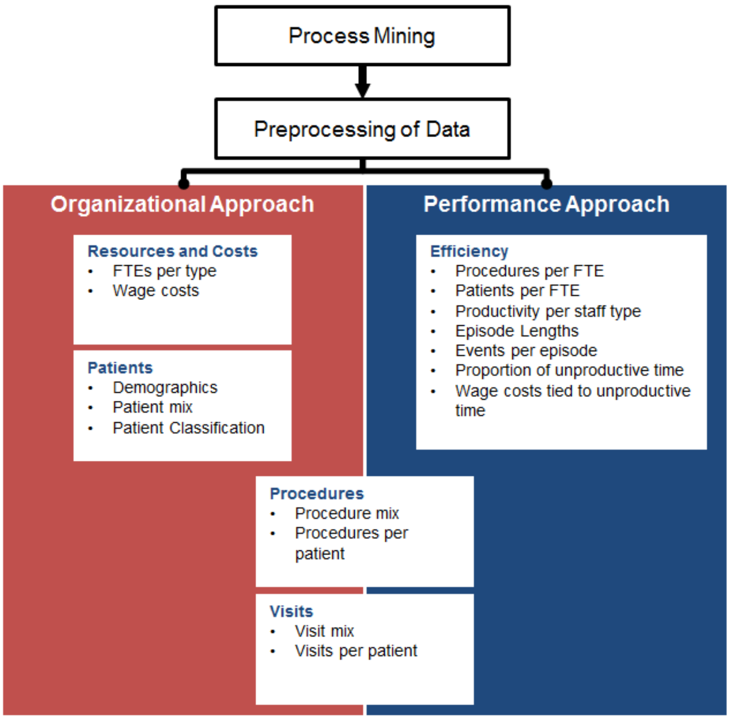


Figure 3-4 - Framework for data analysis

The aforementioned efficiency metrics are embedded into the process mining blocks. It is important to understand, that some of the metrics are not purely indicators of efficiency but also portrayals of the patient needs, production capabilities and the overall logic of arranging the service. With this technique, the DEA- based comparison of DMUs with similar operations can be extended to consider DMUs with different operating models. To achieve this, the data are mined from both performance and organizational point of view. The organizational approach describes the relationships between resources (e.g. workforce allocation) as well as the operation environment through patient and procedure mixes and the arrangement of appointments. The performance view is used to extract the efficiency indicators determined earlier from the data.

4 PREPARING THE DATA FOR ANALYSIS

This section describes the nature of the data used in the analysis and the preprocessing actions to make the datasets comparable and meaningful sources for metrics. The data were provided by three dental care DMUs: Jyväskylä, Espoo and Megaklinikka. Each party delivered datasets of patient visits, performed procedures and staff levels for year 2013. Next, the visit, procedure and staff data are individually described and the necessary modifications, corrective actions and data enrichment activities are presented. This section also explains the patient classification logic for the municipal patients used in the results section of this thesis. Lastly, the validity of the data is discussed.

4.1 Visits

The visit data covers all patient visits in the two municipalities and Megaklinikka in 2013. In municipalities, the structure of the data is somewhat identical. Unique key for visit data is the time stamp of the visit. The municipal visit data also includes patient age, sex, home municipality, encrypted social security number, location of the visit, duration of the visit (in minutes), type of contact and information on the staff member the visit was booked for (staff id, role).

At Megaklinikka, the data structure for visits is slightly different. The unique key is the treatment ID: a different serial number given for each visit. The visit data also includes patient ID, age and sex as in the municipal data. The major difference comes from how the duration of the visit is logged. Megaklinikka uses several time stamps between patient entering the Clinic and leaving it. Another difference is that at Megaklinikka, the visits aren't booked for a certain member of the staff so there's no information on staff members in the visit- dataset.

The changeover times for visits were provided by representatives of the different dental care providers and were based on observations and experience. The changeover time for a pair of dentist and a hygienist was set at 7 minutes, the changeover for hygienist at 10 minutes, respectively. The changeovers at the Megaklinikka were estimated to be 9 minutes on average.

In municipal dental care, the visit data includes 13 different contact types. The amounts and proportions of total visits are listed in Table 4-1 for both municipalities.

Table 4-1 - Visit types in municipalities

		M1		M2	
Visit type	*Code*	*Visits*	*%*	*Visits*	*%*
Visit	1	131488	87 %	193457	82 %
Workplace-visit	2	28	0 %	1	0 %
Phone contact	3	2	0 %	8	0 %
Assistment	4	509	0 %	1978	1 %
Group event	5	269	0 %	73	0 %
Inpatient visit	7	160	0 %	71	0 %
No-show	8	7212	5 %	7277	3 %
Other	9	11863	8 %	7025	3 %
E-service	9a	2	0 %	3	0 %
Email	9b	2	0 %	3	0 %
Letter	9c	44	0 %	512	0 %
Consultation	9d	11	0 %	794	0 %
Document log without document	9e	226	0 %	23605	10 %
Total		**151816**		**234807**	

Since the focus in this thesis is on outpatient visits, only visits with code 1 or 8 were included in the forthcoming analyses. Based on consultations with the municipal representatives, visits with other codes are exceptions and their inclusion would make the analysis less comparable to the single-visit logic, since they are not regular outpatient visits. No-show visits are included for two reasons. Firstly, the time is allocated for the visit beforehand and the appointment time is used whether the patient shows up or not. Secondly, the data included several no-show appointments that included procedures. This may be due to late arrivals or human or data errors. Nevertheless, the no-show visits must be included to avoid leaving out performed procedures and occupied visit time. The single visit clinic only has basic outpatient visits, comparable to the municipal classification *1, visits*. According to Megaklinikka's representatives, the amount of no-shows is basically nonexistent and it is not definable from the data available for this thesis.

4.2 Procedures

The procedure data for municipalities includes the time stamp, patient encrypted social security number, procedure code and the tooth the procedure was performed on. It must be noted that although each procedure has a time stamp, it is not a unique key. In the procedure dataset the treatment id merely connects the procedures to a certain visit. Thus, the time stamp is identical for all procedures performed on the same visit and does not enable time tracking of procedures within the treatment.

At Megaklinikka, the procedure data includes the treatment ID, procedure code, performer of the procedure (staff id, role) and duration of the procedure (i.e. how long the performance of the procedure took). The treatment id acts similarly in this dataset as the time stamp does in municipal procedure data: it connects procedures to a certain visit.

As mentioned previously, the whole operating model differs rather significantly between the single-visit clinic and municipal dental care. Municipalities are required by legislation to provide all types of treatment to all types of patients. This naturally results to having a more substantial case mix. There are other differences in the procedure data than just the vastness of the case mix. Generally, Megaklinikka only logs clinical procedures such as fillings and tartar removals as procedures. Municipalities however may have descriptive indicators such as payment types and visit types logged as procedure codes. As the amount of procedures is one of the key indicators in the data analysis, the procedures first had to be filtered to include only clinical procedures from all parties. This was done via multiple meetings/interviews where representatives from each party evaluated which procedure codes to include and which to exclude. The goal was to achieve a selection of procedure codes that would represent the actual clinical output of the staff. The list of included and removed procedure codes is presented in Appendix A.

Since dental care procedures can differ significantly from one another, it is necessary to assign weights for different procedures based on difficulty and duration. Otherwise the effects of having different case mixes would not be revealed. The weights of the procedures carry a lot of emphasis in the data analysis and especially in the simulation model. They affect both the productivity figures and the assessment of patient’s need for procedures. Moreover, it was assumed that the differences in procedure mixes are embedded in the weights of the procedures. Thus, possible errors in procedure weights could have a significant impact on the results. To mitigate the risk of faulty procedure weights, three different sets of procedure weights were studied (see section 4.3.) to ensure the best possible selection of weights. The basic assumption in procedure weighting is that a single surface filling (coded SFA10) is considered as the base case and assigned a weight of 1,00. Other procedures are given weights based on scaling against SFA10. Until today there has not been unanimously approved approach to weighing the procedures among the dental care industry. The Finnish dentist’s union has provided one weighting recommendation. The union weights have received some criticism from dental care professionals of being inaccurate and leaving too many procedures without weights altogether. Unhappiness with the union weights has led to other, customized approaches. Three Finnish municipalities (Espoo, Helsinki and Vantaa) used a stopwatch to record the duration of all procedures during one control week. Duration of SFA10 was again used as the base case. By taking the average from all three municipalities, Espoo formed their own set of procedure weightings. The most recent attempt to achieve consensus on procedure weights has been by the CDC- initiative (briefly presented in sub-section 2.7). Several professionals have contributed to developing these weights by monitoring and discussions. The CDC- initiative also extended the previous weight sets to achieve a more comprehensive cover for all possible procedure codes.

These three weighting protocols were all embedded in the data to evaluate the effects of the weights on procedure amounts. It was determined by the dental care professionals associated with this thesis, that the latter weight set provided the best procedure cover and accuracy. Thus, the weights generated in the CDC initiative were selected to be used in the data analysis. This weight set was further customized for the data in this thesis to assure a 100% cover for the all procedure codes (i.e. all procedures have a weight). Henceforth, they are referred to simply as *weights* or *weighted procedures.* These weights are listed in Appendix A.

4.3 Staff

To estimate the inputs in the service production systems, all dental service providers were asked to provide data of their employed clinical staff in 2013. The clinical staff in this context means dentists, hygienists and dental nurses. To take on account part-time employees, outsourcing and absences, the staff amount was given as full time equivalents (FTE). The annual theoretical full working time was determined as 1924 hours for dentists and 1989 hours for hygienists and nurses, respectively. The calculation of FTEs included actual working time and paid leaves. Non-clinical work, such as service desk and equipment management, was excluded from FTE calculations. In municipalities, specialized dentists are included in the dentist FTE. The FTE scaling allows a direct comparison between the different dental service providers regardless of the nature of the contracts of the employees.

4.4 Low-Complexity Patients

As discussed in section 3, the patient-oriented approach to service design requires classification of patients into homogeneous groups. For this thesis, patient classification was made based on procedure codes patients underwent during 2013. The municipal patients were classified into two groups: basic (B) patients and complex (C) patients. B patients are adults that had only had procedure codes included in the case mix of Megaklinikka. C patients are either underage or had one or more procedure codes outside Megaklinikka’s case mix. Due to differing procedure logging protocols, some customizations were made to find representative procedure codes from municipalities' and Megaklinikka's data. The customized procedure mix to determine the B patients was reviewed and validated by dental care professionals associated with this thesis. The list is presented as a whole in Appendix A.

4.5 Data Validity

Overall, the data was quite consistent. Some errors occurred in form of faulty time stamps, duplicates and missing values. Most of these issues were corrected with manual validation. The biggest validity issue concerns data presence in municipal visit data. Both municipalities had several thousands of visits with missing duration. The missing durations were replaced with average visit lengths. Although use of averages should be avoided, in this case, it can be justified for two reasons. First, according to the dental care professionals associated with this thesis, the appointment lengths do not vary much in municipalities and majority of the visits are scheduled at 30 minutes. The data also showed that the average probability of lengths other than 30 minutes was roughly 0.1%. Thus, the use of averages should not skew the overall results significantly. Second, the visit durations do not affect majority of the results as they are not used in calculating other metrics than the productive time of staff in the process. However, the results that are based on visit durations should still be reviewed more as approximates than other sections of the analysis.

5 RESULTS

This section presents the results of this thesis and is divided into three sub-sections. First, the operating models and appointment system designs of municipalities and the single-visit clinic are described on a conceptual and process level. The results of the first sub-section are largely based on interviews with the dental care professionals associated with this thesis (see: references – interviews). Second, the event log data is analyzed based on the framework presented in sub-section 3.2. Third, the operation of a municipal dental care unit with a single-visit service line is simulated using discrete probability distributions extracted from the data.

5.1 Comparison of Service Models

This sub-section illustrates the differences in the fundamental operating model and service delivery process between the municipalities and the SV clinic. As discussed, municipal dental care operates under many legislative regulations compared to private dental care. Municipalities are regulated by legislation to offer basic, special, acute and non-acute dental services to all citizens. Besides dentists, hygienists and dental nurses they also employ specialized dentists and dental technicians. Some of the specialized dental care is also outsourced. Municipal dental care in Jyväskylä and Espoo covers multiple service units with slightly varying services. For underage patients, municipal dental care conducts regular check-up intervals. Jyväskylä had roughly 135.000 inhabitants in the beginning of 2014 (Finnish population register, 2014) and by year 2030 the amount is estimated to grow to 150.000 (jyväskylä.fi). Respectively, Espoo had 261.000 inhabitants in 2014 (Finnish population register) and by 2024 the amount estimated to grow to 302.000 (espoo.fi). These parties are henceforth referred to as M1 (Jyväskylä – Municipality 1), M2 (Espoo – Municipality 2). Since the service models in both Jyväskylä and Espoo are similar, they are in some cases also commonly referred to as “municipalities”.

Megaklinikka is a private dental clinic in Helsinki with a restricted offering, homogeneous case-mix and constrained patient intake depending on age and current oral health. The core concept of Megaklinikka is to perform all necessary procedures to patients during a single visit. Treatment is offered to persons over 15 years old with a Finnish social security number. Available services include basic dental care by dentists and hygienists, such as fillings and tartar removal. Megaklinikka does not employ any specialized dentists or dental technicians, thus particularly demanding operations like difficult tooth removals or challenging root treatments are not available. If a patient is diagnosed with a condition requiring special dental care, he is directed to seek help from specialized dental services. Since Megaklinikka uses the single visit operating model, it is referred to as the “SV clinic”.

5.1.1 Appointment Booking

In both M1 and M2 the appointment booking is done by phone. In M1, appointment booking is divided into four areas, each with its own service units and phone numbers for reservation. In M2 the appointment booking for all units is centralized under a single phone line. However, during peaks in call frequency, the appointment booking lines become centralized also in M1. A predetermined time window each day is reserved to book acute cases only. During the appointment booking, the preliminary assessment of need for treatment is conducted by a healthcare professional. Based on the discussion with the patient and the patient’s description of the condition, the operator performs a phone consultation, directs the patient to an ER visit or schedules an appointment for either a hygienist or a dentist. For non-acute cases, the need for special treatment is determined only after the examination during the first appointment. All non-acute cases are treated as basic cases by default. Typically, all patients should have an assigned dentist and hygienist in the closest service unit of their residential area. Times are scheduled primarily only for the assigned healthcare professionals of the patients, although some exceptions may occur. The length of the appointment is determined during the oral health assessment over the phone. Appointments are scheduled with 15-minute increases and appointments over 60 minutes are very rarely booked. The most typical length for an appointment is 30 minutes. Even if the phone assessment suggests need for both a hygienist and a dentist, only one appointment is booked at a time for either one.

In The SV Clinic, the appointment booking is usually done via an online booking system on The SV Clinic’s homepage. Patients select a time slot of one hour for the starting time of their treatment. An SMS- notification is sent to patient’s mobile phone half an hour before the exact treatment starting time. For example, patient selects a time slot between 11:00 and 12:00. At 10:45 the patient gets an SMS- notification stating the treatment time to be 11:15. There are some exceptions to the general time slot booking. Some slots can only be booked by phone, in some slots, not all treatments are available and in the last slots of the day, long treatments will not be finished during a single visit. Available times and exceptions can be seen from the online booking system. The clinical staff does not have personal time reservation books but treatments are allocated to the next available staff member. In the booking process the patient is asked to describe the reason for seeking treatment. The options are ache, piercing pain, filling, split, tooth removal, check-up, check-up and oral health assessment, hygienist (tartar removal) and occlusion rail and root treatment.

As described above, the patients in municipal dental care always book the appointment for a specific healthcare professional. The clinical staff has their own reservation books and appointment lengths are determined beforehand. The staff is allowed to personally allocate available reception time and breaks in their schedule. The scheduling lists are printed and approved by managers. The recommendation is 30 hours of clinical work per week. In municipalities, the appointment reservation is not connected to any ERP system. It is only used to track the working hours of the staff.

In the SV Clinic, the appointment booking is directly connected to the ERP controlling both scheduling and workforce allocation. The patients book a time slot without any dependencies to personal schedules of the staff. All open time slots are available for booking equally. The clinical staff is allocated to patients on a next available- basis by the ERP- system. The ERP is connected to the patient database and based on historical patient data and selected reason for appointment, forecasts the required length for treatment. The flexible queuing model means that patients may experience some direct waiting time within their time slot but at the same time, it enables open-ended appointments and open-access appointment system design. Figure 5-1 describes the appointment booking logics of the dental service providers.

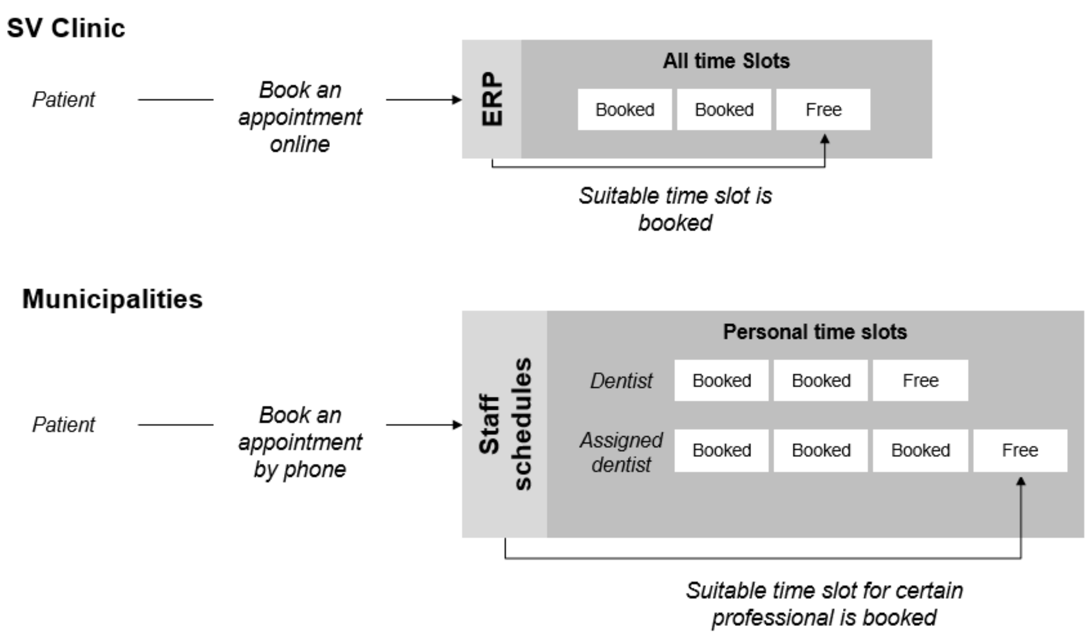


Figure 5-1 - Appointment booking logics

5.1.2 Service Delivery

In municipal dental care the patient fills an anamnesis form upon arrival further clarifying the reason for seeking dental treatment. When patient enters the room, the reason for seeking treatment is first discussed with the patient based on the information given during appointment booking and in the anamnesis form. The patient is examined and a treatment plan is conducted. If a patient is already undergoing a treatment plan, the patient is nevertheless examined and treatment is adjusted if necessary or continued based on the original plan. Typically, treatment is planned for multiple appointments. Depending on the type of the appointment, a dentist or a hygienist then performs necessary procedures. Often the scheduled time does not allow to perform all necessary procedures during the first visit. In this case either the treating staff member books the next appointment for the patient or instructs the patient to book the next appointment in reception. Patient arriving for a hygienist appointment may also have a need for dentist treatment and vice versa. Hygienist and dentist treatments always require separate appointments in municipal dental care. This, again, results in booking a new appointment.

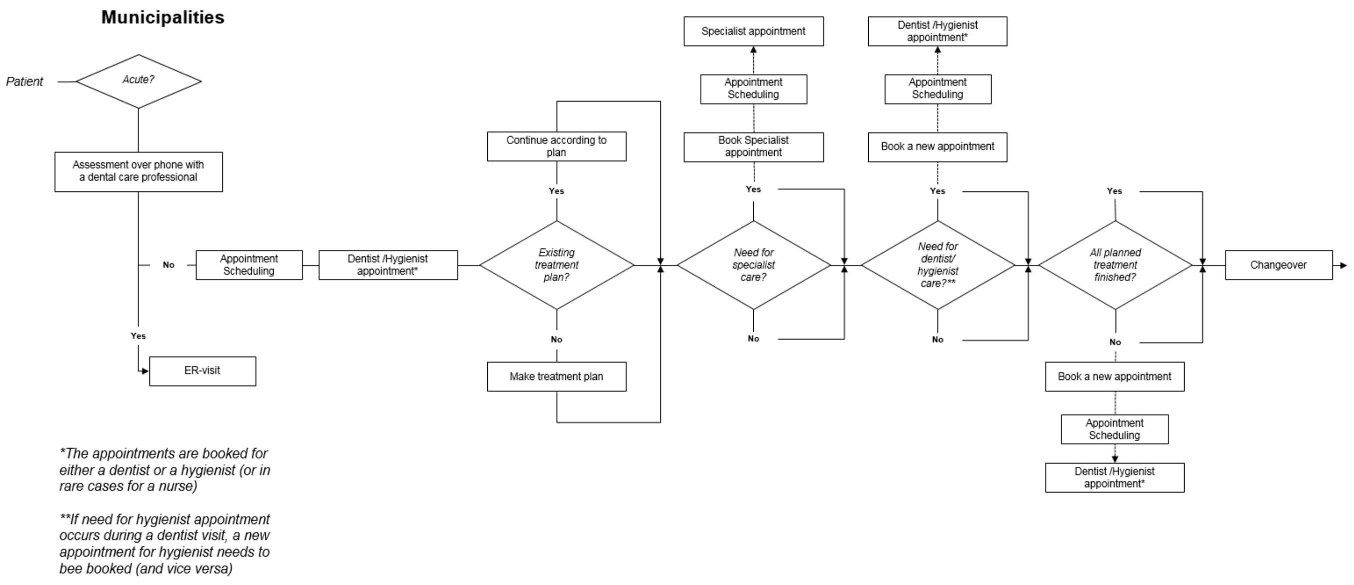


Figure 5-2 - Municipal service delivery

In the SV Clinic, a dental nurse will be receiving the patient with either a dentist or a hygienist. Patient’s selection for the reason for treatment during the booking determines the receiving staff members. In rare cases, patients may already be undergoing a treatment plan. This information is usually given when submitting the slot reservation and the staff members required for the next phase will be present. The hygienist or the dentist checks the patient and prepares him for the procedures while the nurse handles the necessary entries and logs. If the check-up is done by a hygienist and the patient does not have a doctor's referral for hygienist treatment, a dentist is always called to confirm the diagnosis and health assessment. After the diagnosis, the dentist or hygienist logs the estimated time to complete the treatment into the ERP system, which in turn estimates the starting time of next treatment the room. If the patient does not require any specialized dental care, all necessary treatment is given. A hygienist or a dentist can be called into the room to perform procedures on an ad hoc- basis. The ERP system is used to signal, where different staff members are needed at a certain point of time. After the procedures are done, they are logged by the performer (dentist or hygienist). If a patient requires treatment from both hygienist and dentist, the dentist may leave after performing and logging his procedures and vice versa. The goal is to perform all necessary treatment during a single visit. There's no fixed time for the appointment and the length is adjusted to the treatment. However, for the last time slots of the day, long treatments are not finished during the same visit. Figure 5 -3 illustrates the service delivery processes of the SV clinic.

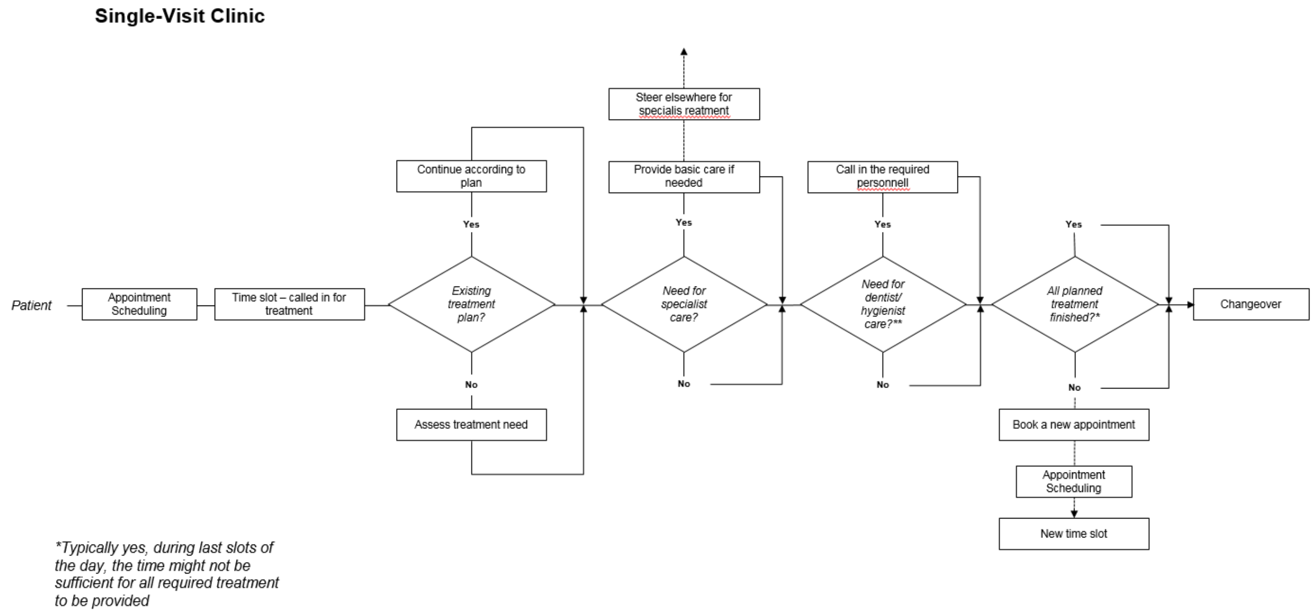


Figure 5-3 – Single visit service delivery

5.1.3 Workforce management

In addition to the differences in appointment booking protocols and service delivery models, municipal dental care and The SV Clinic have different approaches to workforce management in the Clinic. The workforce allocation logic of different dental service providers is illustrated on a high level in Figure 5-4.

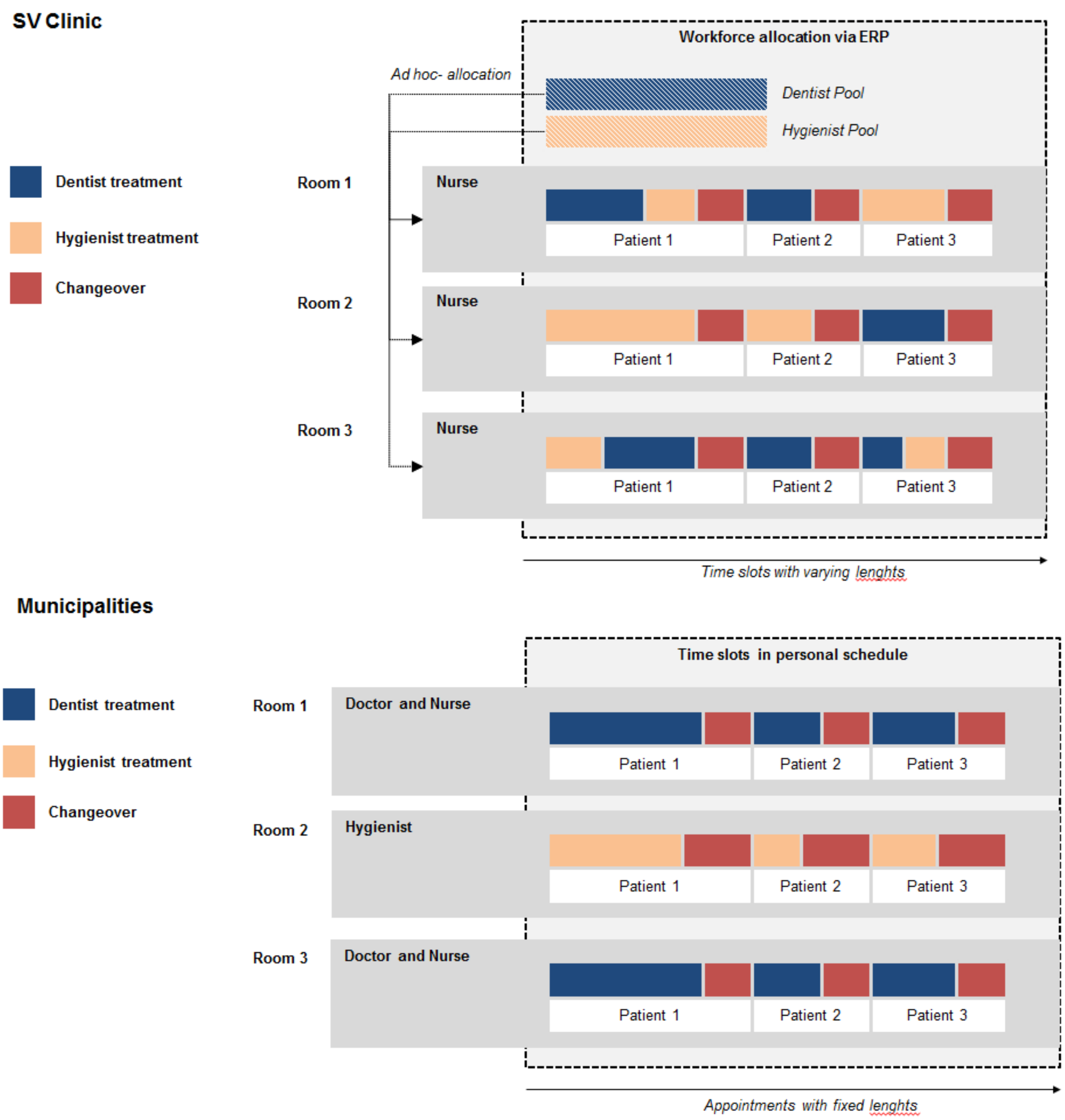


Figure 5-4 - Workforce allocation logics

In municipalities, clinical staff members work in the same room during their whole shift. Dentists and nurses work as pair while hygienists operate alone. After the treatment is performed, the procedures must be logged, instruments changed and the operating facilities cleaned. As appointments are usually scheduled to start back-to-back, a changeover time at the end of each appointment must be reserved to perform the before-mentioned tasks. The usual changeover time reserved for a pair of a dentist and a nurse is seven minutes. As hygienists work alone, the changeover time for hygienist appointments is approximately ten minutes. In The SV Clinic, dentists and hygienists do not have assigned rooms but are paged to different rooms on ad-hoc basis. The appointment booking is synchronized with the workforce allocation in the ERP system. As appointment lengths are not fixed, the staff works on an independent schedule. They move from one room to another, perform necessary treatment, log their procedures and move on to the next patient. This enables hygienists and dentists to use their time mainly for performing procedures while dental nurses handle the changeovers.

5.2 Data Analysis

This sub-section presents the results from the data analysis. The data described in section 4 are analyzed based on the framework in sub-section 3.2. In addition to the metrics described in the process mining framework, some illustrative results are also presented to increase the depth of the analysis and to form a better picture of the operation through the event logs. The three dental care providers, M1, M2 and SV, are also occasionally referred to as decision-making units (DMUs) in later sections.

5.2.1 Resources

Resources in the context of this thesis mean the full time equivalents of clinical staff. The actual amount of staff is higher in all DMUs. All non-clinical work, such as service desk or administrative duties, was excluded when determining the FTEs. Thus, the FTEs presented in Table 5-1 represent the resources available for treating patients in different DMUs in 2013. Specialized dentists are included in the dentist FTEs in municipalities.

Table 5-1- FTEs

	SV	*M1*	*M2*
Dental Nurses	12,0	68,6	113,4
Dentists	10,1	44,1	74,1
Hygienists	13,6	27,1	33,3
Total	**35,7**	**139,8**	**220,8**

The FTE values reveal a notable difference in relative staff type proportions between the DMUs. In the SV Clinic, hygienists are the largest group whereas in municipalities, the majority of FTEs consist of dental nurses, hygienists being the smallest group. The differences are more comparable in Table 5-2, which shows the FTEs of each staff type in relation to dentist FTEs. In essence, the table shows how many full time nurses and hygienists were employed per dentist in 2013.

Table 5-2 - FTEs in relation to the amount of dentists

	SV	*M1*	*M2*
Dental Nurses	1,20	1,56	1,53
Dentists	1,00	1,00	1,00
Hygienists	1,35	0,62	0,45

As can be seen, the relation of different staff types varies depending on the operating model. In the SV clinic, hygienists are the largest group with 1.35 hygienists per one dentist. The corresponding level is 0.45 to 0.62 in municipalities. Vice versa, both municipalities have more nurses per dentist than the SV clinic does. The proportions of staff types are one factor affecting the productivity of the service model as nurses do not essentially perform procedures. When comparing the produced procedures to FTEs, nurses have a decreasing effect on the efficiency.

The wage cost of each resource type is estimated based on the average salaries reported in the dental job market research by the Finnish Dentist's union (2014). Since The SV Clinic is not a publicly funded company, private sector wages are applied. To yield the actual cost to the employer per resource type, the annual wages were multiplied by 1,4 and by the respective FTE figure. The coefficient 1,4 represents the legislative payments each employee inflicts to the employer, which are roughly 40% of the employee's salary in Finland. Table 5-3 shows these estimated wage costs.

Table 5-3- Estimated wage costs

displayed in millions

	SV	*M1*	*M2*
Dental Nurses	0,5 €	2,5 €	4,0 €
Dentists	1,1 €	4,7 €	7,9 €
Hygienists	0,6 €	1,0 €	1,3 €
Total	**2,2 €**	**8,2 €**	**13,2 €**

5.2.2 Patients

The number of *patients* in each DMU was defined as number of different patient IDs in 2013. *Treated patients* represents the number of different patient ids that had procedures. The difference between these figures can be interpreted as actual no-shows for municipalities. For the SV Clinic, the difference represents patients that required treatment that was not available in the SV model. Table 5-4 summarizes the amount of patients and basic demographics for each DMU and Figure 5-5 illustrates the age distributions, respectively.

Table 5-4 - Basic demographics

	SV	*M1*	*M2*
Patients	21976	55476	78767
Treated patients	21839	53709	76074
Male	42 %	46 %	45 %
Female	58 %	54 %	55 %
Max age	113	101	102
Min age	16	0	0
Average age	39	32	30
Median age	36	28	24
Under 18	0 %	38 %	43 %
18+	100 %	62 %	57 %

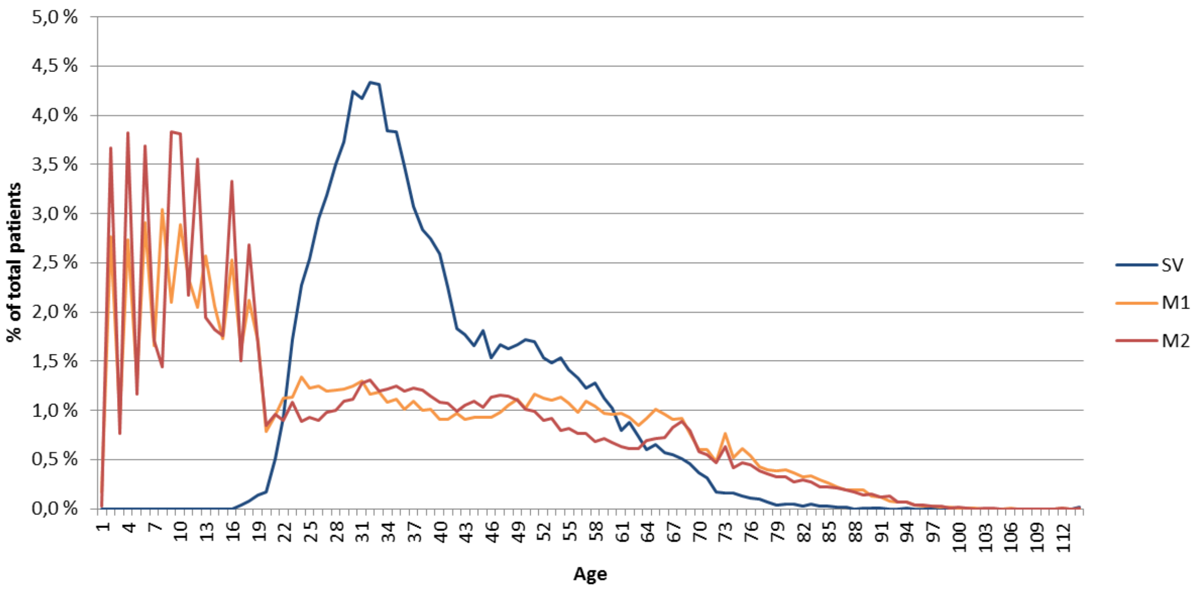


Figure 5-5 - Age distributions

The difference in patient mix in terms of age is clearly visible. The legislative responsibility to provide regular treatment for underage patients is shown as high peaks in ages under 18 in both municipalities covering roughly 40% of the total annual patients. For adult patients, the age distribution is somewhat flat. For the single visit Clinic, majority of patients seem to be 25 to 40 years old. This seems logical, as they target patients with only basic procedure needs. Statistically, this age group has better oral health than older age groups (Koskinen et al., 2012), which would make them a better fit for the single visit logic.

As described in section 4, the municipal patients were further classified into two groups: basic (B) and complex (C). B patients represent the group of adult patients that had only procedure codes that were included in the SV Clinic’s case mix in 2013. C patients are either underage or had at least one procedure that was not included in the SV clinic’s case mix. Table 5-5 and Figure 5-6 illustrate the proportion of B patients in both municipalities.

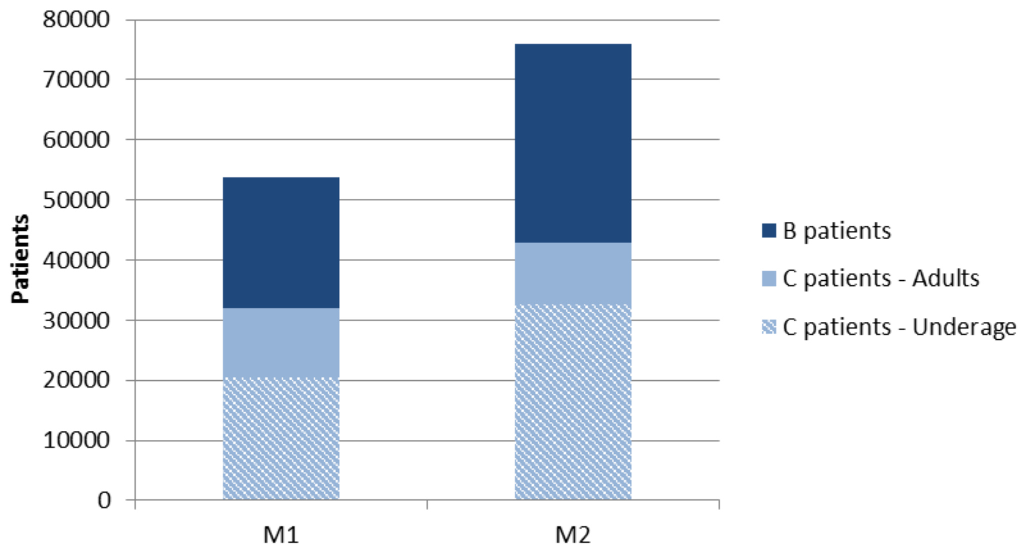


Figure 5-6 - B and C patients in municipalities

Table 5-5 - Proportion of B patients in municipalities

	M1	*M2*
B patients	21630	33188
% of total	40 %	44 %
% of adults	65 %	77 %

The offset presented in the conceptual framework was to utilize two different service models in municipal dental care based on the patient needs. The second objective of this thesis was to examine, what proportion of municipal patients could be treated with the SV model. Thus, these results are especially of interest. The patient classification shows that 40%-44% of all patients in the two municipalities studied can be classified as B patients. Moreover, the clear majority of adult patients (65%-77%) are B patients. This supports the idea that by treating low-complexity patients with a more efficient service model, the productivity of the whole dental care system could improve, as this patient group covers a sizeable proportion of patients, especially adults.

5.2.3 Procedures

After certain modifications (described in section 4) the amount of performed procedures in 2013 for each DMU was extracted from the data. Table 5-6 illustrates the number of different procedure codes performed and the gross amount of procedures performed in each DMU, both weighted and unweighted. Group B- patients is shown separately for both municipalities.

Table 5-6 – Procedures and weight effects

	SV	*M1*	*M1 - B*	*M2*	*M2 - B*
Different procedure codes	86	237	93	250	93
Unweighted	95034	250738	99134	343129	137904
Weighted	101658	216101	86949	311019	123230
Weight effect	7 %	-14 %	-12 %	-9 %	-11 %
Average weight	1,15	1,91	1,3	1,87	1,32
* Average weight	1,07	0,86	0,88	0,91	0,89

The appliance of weights changes the procedure amounts by 7%-14%. The *Average weight* of procedures is clearly higher in municipalities than in the SV Clinic. This can is a signal of a more challenging case mix. The municipal case mix is roughly three times larger than in the SV Clinic in terms of different procedure codes. For B-patients, the average weight decreases to approximately 1.3 as the case mixes are restricted to 93 basic procedures. However, in municipalities the weighted amount of procedures is 9 to 14 percent lower than the unweigthed amount whereas the SV clinic's procedures increase by 7% after applying the weights. This phenomenon is captured by the figure **Average Weight*, which is the average weight of procedures weighted by the procedure amounts.

The **Average weight* is less than 1 in municipalities resulting in decrease in procedure amounts after applying the weights. This indicates that even though municipalities have more complex procedures in their case mix, the majority of procedures are easier procedures with a weight under 1. Even though the case mix of the SV clinic is restricted to 86 basic procedures, the emphasis is on procedures with weight higher than one. The weight effect is further illustrated in Appendix A, where comparisons of 15 most common procedure codes and their respective weighted amounts in each DMU is presented.

In addition to weights, the case mixes in different DMUs can be further analyzed by dividing the procedures into treatment categories determined by the Finnish Dentist's union. Table 5-7 presents the treatment categories and the distributions of unweighted procedures by treatment categories. Figures 5-7 and 5-8 compare B-patient's case mix with the respective municipality's overall case mix and the SV Clinic's case mix.

Table 5-7- Treatment category distributions of procedures

		% of all procedures				
Code	Explanation	SV	M1	M1 - B	M2	M2 - B
SA	Examinations	0,18	0,25	0,22	0,20	0,17
SB	Supplementary examinations	0,00	0,01	0,00	0,01	0,00
SC	Preventive care	0,04	0,09	0,02	0,10	0,04
SD	Parodontium care	0,15	0,07	0,08	0,08	0,10
SF	Fillings	0,34	0,18	0,26	0,19	0,27
SG	Root treatment	0,01	0,04	0,06	0,04	0,06
SH	Occlusion treatment	0,01	0,01	0,01	0,01	0,01
SJ	Orthodontics	0,00	0,07	0,00	0,09	0,00
E	Surgical procedures	0,08	0,13	0,17	0,14	0,17
T	Minor procedures	0,00	0,00	0,00	0,00	0,00
WX	Anaesthesia	0,17	0,13	0,17	0,13	0,17
WY	Treatment type	0,00	0,00	0,00	0,00	0,00
WZ	Medical certificates, prescriptions	0,02	0,01	0,00	0,00	0,00
SP	Dental Prosthetics	0,00	0,00	0,00	0,01	0,00
Other	Other	0,00	0,00	0,00	0,01	0,00

The municipal case mixes seem to be somewhat identical with each other. The average difference in the treatment category distribution between M1 and M2 is under 1% This suggests that both municipalities offer similar treatment types in similar proportions. The case mix of the SV Clinic deviates from the municipal case mix most distinctively in the proportion of preventive care, parodontium care, orthodontics and surgical procedures. The SV Clinic produces relatively more fillings and periodontium care and less surgical procedures than the municipalities. The share of orthodontics treatment is close to non-existent (0.03%).

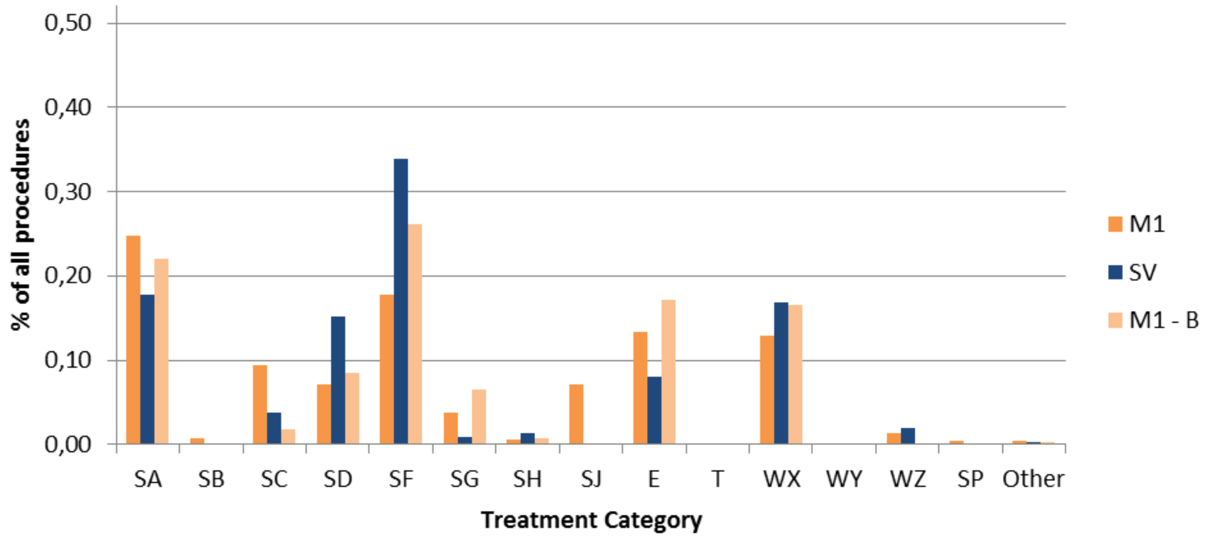


Figure 5-7 - Procedure mixes - SV clinic vs. M1

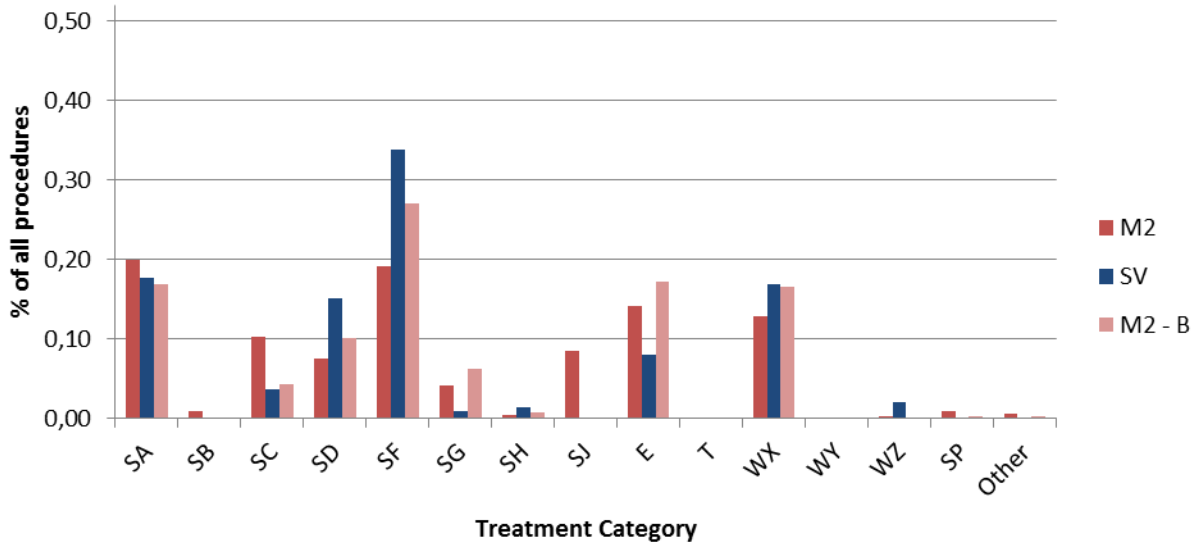


Figure 5-8 - Procedure mixes - SV clinic vs. M2

The treatment category distributions of B- patients resemble slightly more the case mix of the SV Clinic. The relative proportion of fillings grows and the proportion of preventive care and orthodontics decreases. However, the difference in root treatment and surgical procedures expands even wider. The data shows that even though the B-patients have only similar procedure codes as the SV Clinic, the treatment category distributions are not identical. The SV Clinic's case mix has emphasis on fillings and parodontium care whereas the municipal B patients seem to undergo more root treatment and surgical procedures.

To evaluate the need for procedures on the patient level, the data was used to determine the amount of procedures performed for each patient in 2013. From these amounts, a distribution of procedures per patient can be formed for each DMU. Weighted procedure amounts were used to include the variation in procedure types. The use of weights often result in non-integer procedure amounts. For this reason, procedures were measured with 0.5 intervals. The procedures per patient distributions for all DMUs are displayed in Figure 5-9. The graph is restricted to 20 procedures to make the illustration more feasible. Thus, the last value on x-axis indicates "20 procedures or more".

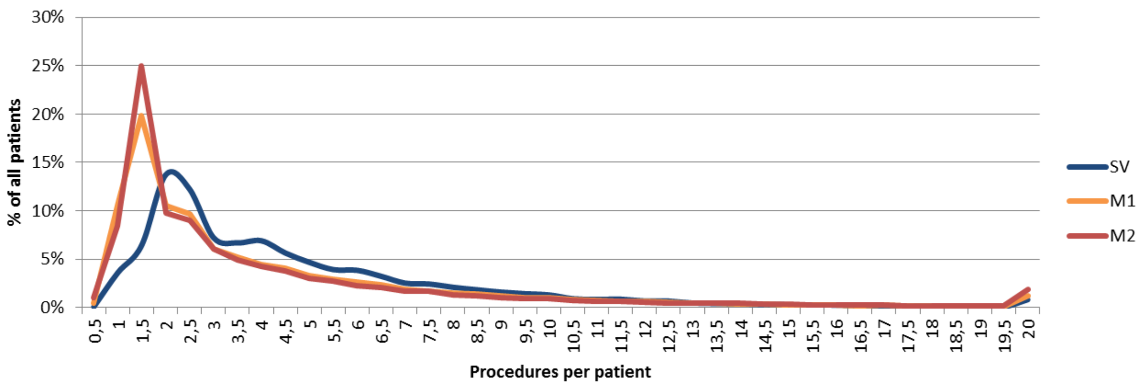


Figure 5-9 - Procedures per patient- distributions

On a larger perspective, the distributions have a similar shape with a long tail to the right. However, the municipal distributions show a higher positive skew than the SV Clinic's distribution. This indicates that the municipal patients had less procedures per patient on average than the SV patients. As described earlier, the patients can be further classified into B and C patients. Figure 5-13 illustrates the procedures per patient distributions for SV and municipal patients and also separately for B and C patients. The view is restricted to five procedures per patient to illustrate the differences on the left side of the distribution more clearly.

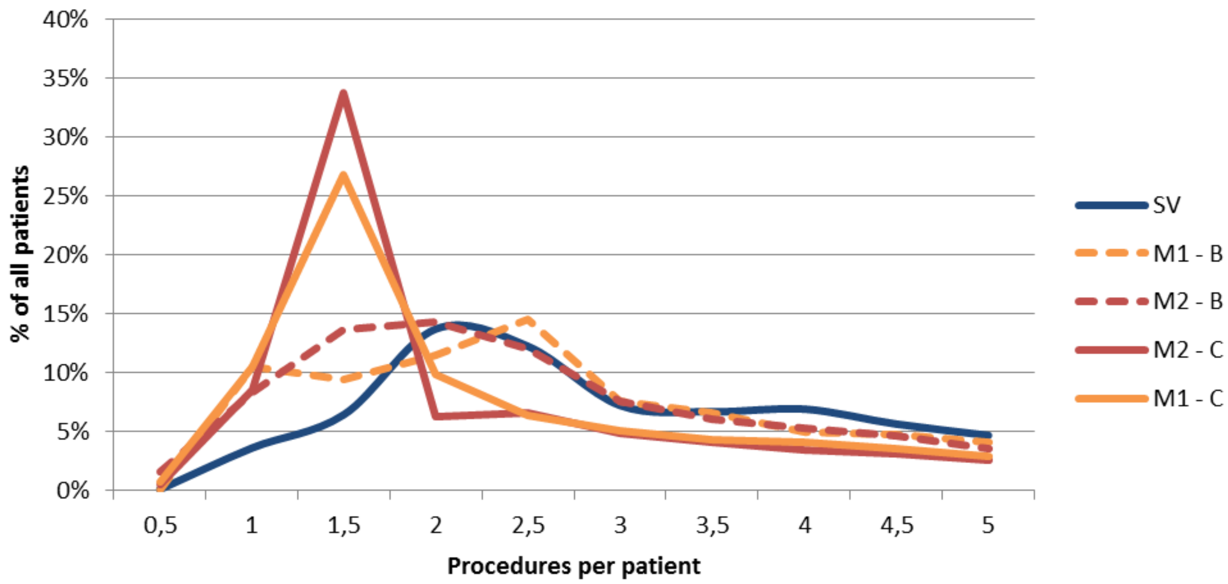


Figure 5-10 - Procedures per patient- distributions2

Now it can be seen, that B patients' distribution has slightly lower skew than the C patient's distribution. It is still not identical to the SV Clinic's distribution, but the resemblance is a lot higher than in the distribution for all municipal patients. To assess the distributions numerically, selected statistical indicators were calculated. The results are shown in Table 5-8.

Table 5-8 - Procedures per patient - selected statistics

	SV	*M1*	*M1 - B*	*M1 - C*	*M2*	*M2 - B*	*M2 - C*
Wgtd average procedures per patient	4,9	4,2	4,3	4,2	4,2	3,9	4,4
Max	56,2	161,2	56,2	161,2	91,2	44,9	91,2
Min	0,3	0,3	0,3	0,3	0,3	0,3	0,3
Median	0,5	2,5	2,8	2,1	2,3	2,5	2
Stdev	3,8	4,4	3,6	4,9	4,8	3,4	5,6
Var	14,3	19,4	12,9	23,8	23,0	11,6	31,7

The results in Figure 5-10 and Table 5-8 illustrate the difference in patient procedure needs between the DMUs. The SV patients actually required slightly more weighted procedures on average than the municipal patients. Nevertheless, the amounts for all types of patients are roughly between four and five weighted procedures. Noteworthy is that B and C patients do not differ much in procedure amounts per patient, but the variance for the procedure need per patient is clearly lower for B patients. Actually, the B patient's figures in Table 5-8 resemble those of the SV patient's quite a lot signaling that that the municipal B patients have similar procedure needs as the SV patients. Thus, the classification into B and C patients does indeed help decrease the variation in procedure needs for the B patient group. In terms of considering the applicability of the single visit model for municipal B patients, these results are promising.

To further study the patient mixes in terms of differing procedure needs, the treatment categories (shown earlier in this section) can be used to see the proportions of patients that had certain procedures types in different patient groups. Table 5-9 illustrates, what proportion of patients had procedures in each treatment category. The results are shown separately for municipal B patients. Figures 5-11 and 5-12 illustrate graphically the differences in these proportions between the SV clinic, municipal patients and municipal B patients.

Table 5-9 - Patient mixes based on treatment categories

Code	*Explanation*	*SV*	*M1*	*M1 - B*	*M2*	*M2 - B*
SA	Examinations	72 %	83 %	76 %	73 %	56 %
SB	Supplementary examinations	0 %	3 %	0 %	4 %	0 %
SC	Preventive care	15 %	33 %	8 %	39 %	14 %
SD	Parodontium care	59 %	28 %	33 %	30 %	40 %
SF	Fillings	61 %	40 %	59 %	40 %	58 %
SG	Root treatment	3 %	9 %	16 %	8 %	12 %
SH	Occlusion treatment	6 %	2 %	3 %	2 %	3 %
SJ	Orthodontics	0 %	8 %	0 %	7 %	0 %
E	Surgical procedures	27 %	34 %	47 %	37 %	46 %
T	Minor procedures	0 %	1 %	0 %	1 %	0 %
WX	Anaesthesia	42 %	33 %	47 %	30 %	40 %
WY	Treatment type	0 %	0 %	0 %	0 %	0 %
WZ	Medical certificates, prescriptions	8 %	6 %	1 %	1 %	0 %
SP	Dental Prosthetics	0 %	1 %	1 %	2 %	1 %
Other	Other	1 %	2 %	1 %	2 %	2 %

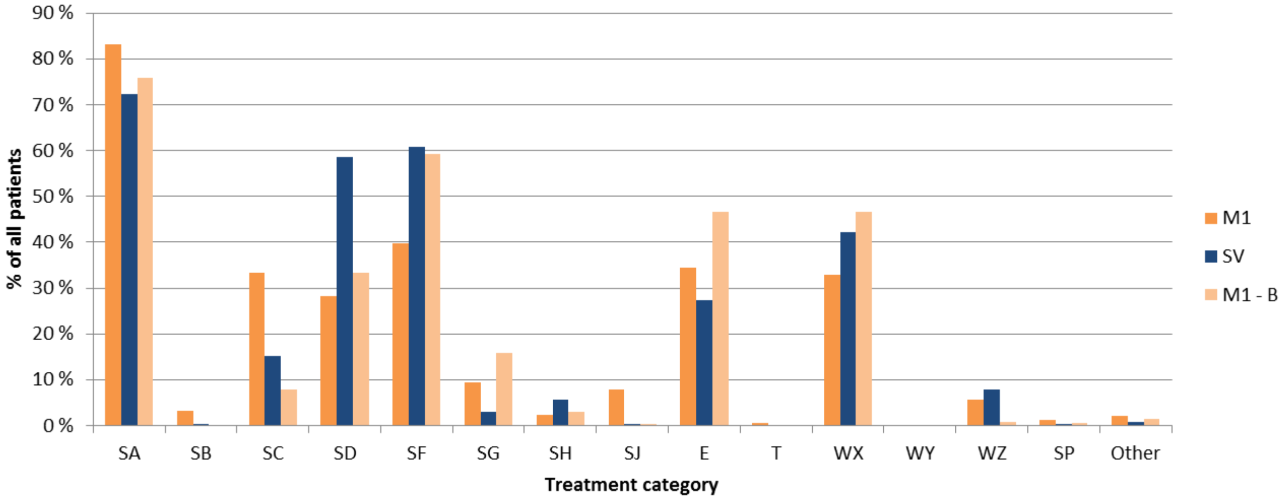


Figure 5-11 - Patient mixes - SV clinic vs M1

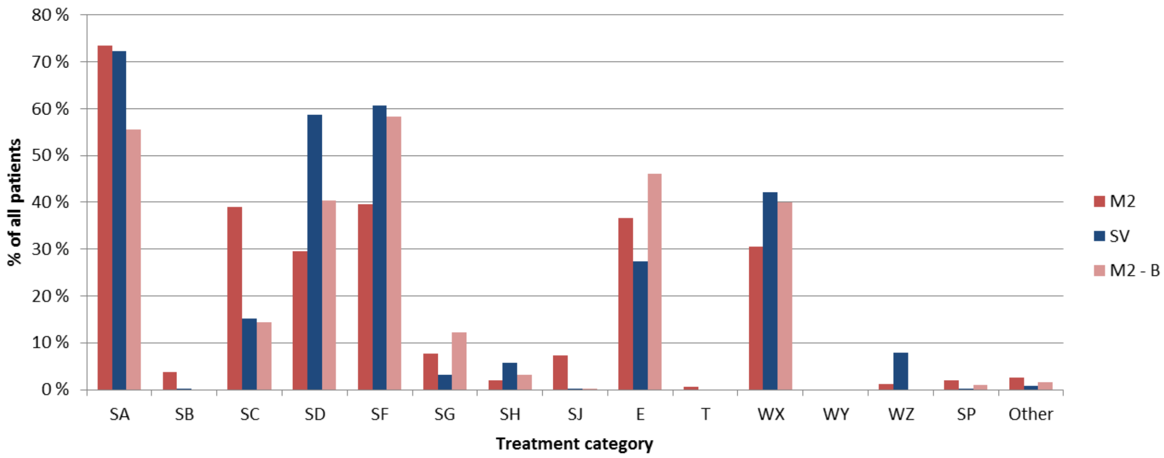


Figure 5-12 - Patient mixes - SV clinic vs M2

As can be seen, in terms of treatment categories, the B patient mix has a greater resemblance with the SV clinic's patient mix than the overall municipal patient mix has. However, similar differences in the proportion of parodontium care, root treatment and surgical procedures can be seen as earlier when assessing the procedure distributions between the treatment categories. Again, a distinctive feature is how the proportion of fillings (SF) grows in the B patient group. In dental care, fillings represent one of the most standardized treatment category, as the production of these types of procedures is pretty much identical for all patients. Thus, Lean production methods fit well to these kinds of procedures.

5.2.4 Visits

As described, in municipalities the visits are always assigned to a certain staff member. Thus, the visits can be further classified to different types based on the contact person's role. In the SV logic, there is a possibility to receive treatment from both hygienists and dentists during the same visit. Table 5-10 illustrates the total amount of visits in different DMUs and the proportion of visits to different staff members. For the SV logic, the percentages for *dentist* and *hygienist* represent visits that only included the respective staff member, *dentist + hygienist* are visits that included both staff types.

Table 5-10 - Staff type distributions of visits

	SV	*M1*	*M2*
Total visits	30548	137168	196459
Dental Nurse	-	6 %	3 %
Dentist	58 %	64 %	75 %
Hygienist	10 %	30 %	21 %
Dentist + Hygienist	32 %	-	-

The results show that majority of the visits in all DMUs were for a dentist. In the SV Clinic 90% of all visits required dentist treatment. Also, 32% of visits included both hygienist and a dentist. In municipalities, these types of visits would be split into separate appointments. Thus, the use of different staff types is better elaborated by studying the proportions of patients that had visits to different staff members. Table 5-11 and Figure 5-13 illustrate these results. B-patients are shown separately for both municipalities.

Table 5-11- Visits to different staff types as % of patients

	SV	M1	M1 - B	M2	M2 - B
Dental Nurse	0 %	13 %	0 %	7 %	1 %
Dentist	94 %	76 %	92 %	83 %	96 %
Hygienist	52 %	50 %	29 %	43 %	32 %
Dentist and Hygienist	46 %	30 %	19 %	25 %	23 %

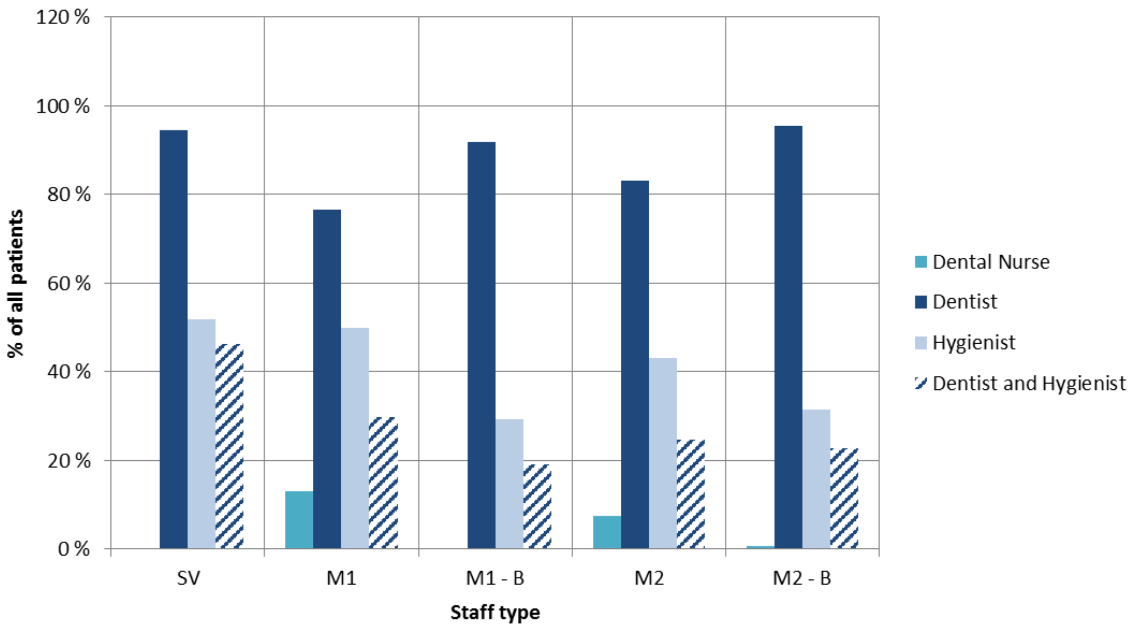


Figure 5-13 - Visits to different staff types as % of patients

Table 5-11 shows that patients that required both a hygienist and a dentist accounted for 25 to 30 percent of patients in M1 and M2. For B patients this figure drops to roughly 20%. The proportion of B patients with hygienist appointments is 10 to 20 percent lower than in municipalities in general and the proportion of patients with dentist appointments grows to over 90%. In the SV Clinic, 94% of patients required a dentist whereas a hygienist was required by 52% of patients. Out of all SV clinic's patients. 46% received treatment from both hygienist and a dentist.

Previously, the data was used to yield distributions for procedures per patient. Similar distribution can be conducted for visits per patients. Figure 5-14 illustrates the visits per patient distributions for all DMUs. The dotted lines represent the cumulative distributions.

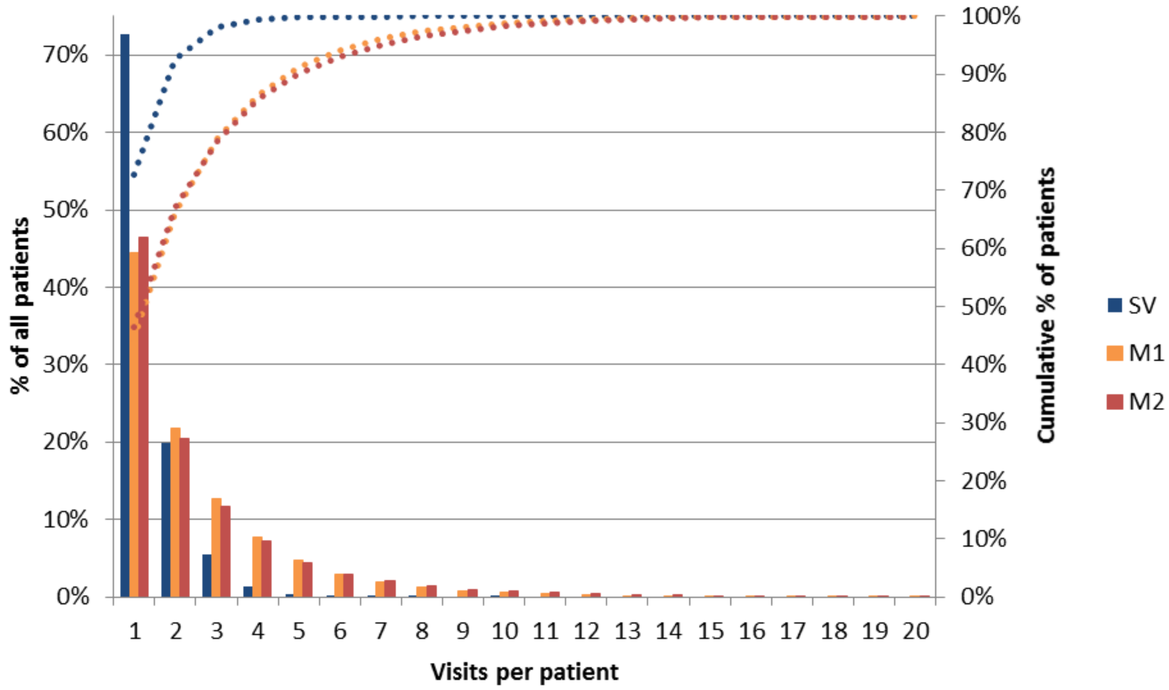


Figure 5-14 - Visits per patient- distributions

The distributions show that municipal patients had more visits on average than the SV-patients did. The cumulative distribution indicates that in the SV Clinic, two visits were enough to treat over 90% of patients. The 90% threshold is broken at four visits in M1 and in five visits in M2. The graph only shows the overall municipal values, since values for B and C patients were so alike that the difference would not be visible in the figure. However, some differences occur between the patient groups when looking at the weighted averages for visits per patient. Table 5-12 shows these results.

Table 5-12 - Visits per patient - selected statistics

	SV	*M1*	*M1 - B*	*M1 - C*	*M2*	*M2 - B*	*M2 - C*
Wgtd average visits per patient	1,4	2,5	2,3	2,7	2,5	2,3	2,9
Max	10	79	21	79	26	21	26
Min	1	1	1	1	1	1	1
Median	1	2	2	2	2	2	2

The weighted average amount of visits per patient was 1.4 in the SV Clinic. In municipalities, the patients had roughly one visit more during the year. For B patients, the figure was 2.3 in both municipalities while C patients had closer to three visits. These figures indicate that the individual appointment system in municipal dental care results in several appointments for most of the patients. As the typical length is 30 minutes, it is often insufficient to provide all planned treatment. Moreover, it was shown that 25-30% of municipal patients required both hygienist and dentist treatment. With the traditional service model, this automatically results to at least two appointments.

5.2.5 Efficiency

The efficiency of the DMUs is determined as produced procedures and treated patients per FTE. To include the variation of case mixes, weighted procedures were used. Results are presented in Table 5-13.

Table 5-13- Efficiency

	SV	*M1*	*M2*
FTE	35,7	139,8	220,8
HD FTE	23,7	71,2	107,4
Procedures	101658	216101	311019
Treated patients	21839	53709	76074
Procedures/FTE	2847	1546	1409
Patients/FTE	612	384	345
Procedures/HD FTE	4295	3036	2896
Patients/HD FTE	923	755	708

The data shows that in 2013, the SV Clinic produced 1.8 - 2 times more procedures, and treated 1.5 – 1.7 times more patients per one FTE than the municipalities. Comparing produced procedures to overall FTE levels gives an indication of the efficiency of the whole clinical staff as a unit. However, in sub-section 5.2.1 it was shown that the proportions of different staff members varied between the municipalities and the SV clinic. The proportions of staff types are one factor affecting the efficiency of the service model as nurses do not perform procedures. When comparing the produced procedures to FTEs, nurses have a decreasing effect on the efficiency. Thus, the figure HD FTE is used to illustrate the amount of only dentist and hygienist FTEs. When compared to only HD FTE levels, the SV clinic produces roughly 1.4 - 1.5 times more procedures and treats 1.2 – 1.3 times more patients than the municipalities do.

Next, the productivity of dentists and hygienists can be examined separately. The efficiency can be drilled down to staff type level by looking at the amount of weighted procedures by hygienists and dentists on each day of operation in different DMUs. These amounts were then divided by the respective staff type FTE- figures to construct probability distributions for different quantities of produced procedures per FTE for each day of operation, separately for hygienists and dentists. The distributions for dentists are illustrated in Figure 5-15 and for hygienists in Figure 5-16. Table 5-14 summarizes the weighted average daily procedures per dentist FTE in each DMU.

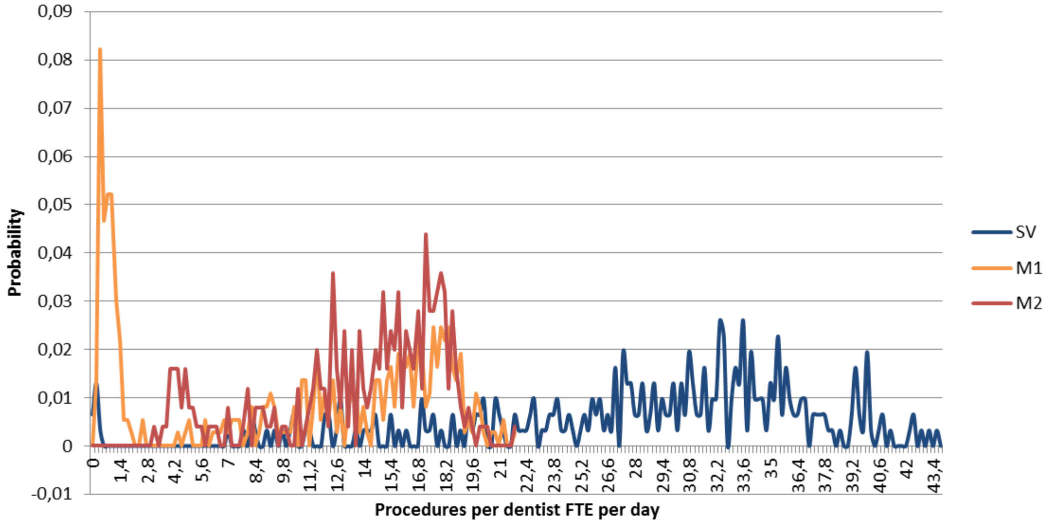


Figure 5-15 - Procedures per FTE- distributions - Dentists

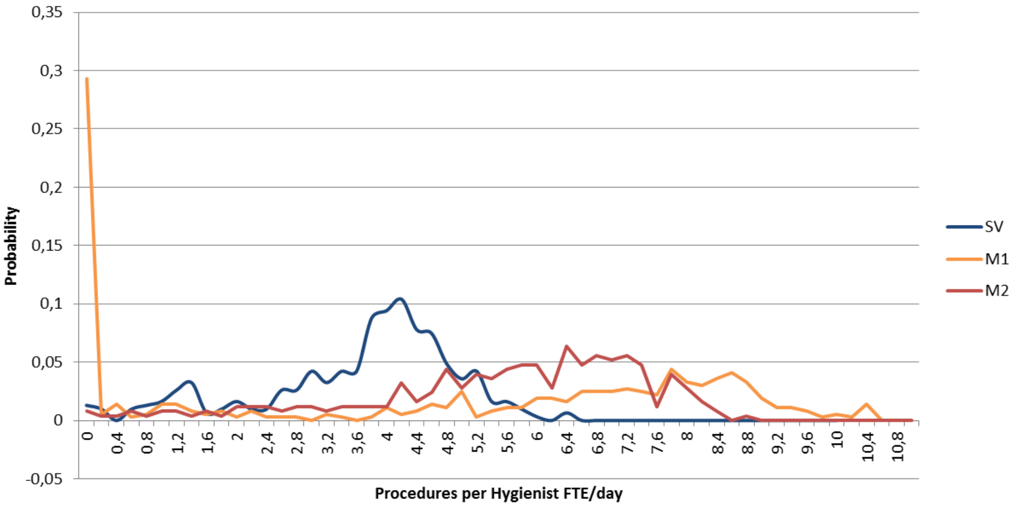


Figure 5-16 - Procedures per FTE- distributions - Hygienists

Table 5-14 - Procedures per FTE per day

	wgtd avg procedures/FTE/day		
	SV	*M1*	*M2*
Hygienist	28,1	10,3	13,8
Dentist	3,6	4,6	5,4

These illustrations show that in the SV Clinic, one dentist FTE can produce more weighted procedures daily than in municipalities. However, for hygienists the situation is reversed, as the municipal hygienists seem to be more productive than the SV Clinic's hygienists are. One reason for this phenomenon is that in the SV Clinic, hygienists often assist dentists and perform treatment and preparations that are not logged as procedures. Thus some hygienist work remains undetected in the data. Earlier it was shown that the hygienists were the largest staff type in the SV Clinic with 1.35 hygienist FTEs per a single dentist FTE. The efficiency analysis indicates that hygienists are largely used to assist dentists making the dentist's efficiency high in the SV Clinic at the expense of hygienist efficiency. Larger relative amount of hygienists is needed to compensate for the lower efficiency of the hygienists in terms of hygienist procedures. However, these decisions with staff allocation seem to yield better overall efficiency for the SV Clinic. Another noteworthy factor is that the SV clinic employs less nurses per dentist than municipalities. This contributes to the higher productivity to staff FTE-ratio as nurses do not perform procedures. One explanation for the lower amount of nurses in the SV clinic is again the wider job description of the hygienists. As hygienists can assume more nurse-like role assisting the dentists at times, less nurses are required in the roster.

From the patients' point of view, efficiency of the service production can be experienced through the patient episodes. The episode lengths were measured in days between the first and last visit per patient from the visit data of different DMUs in 2013. From these results, the episode length distributions were constructed. The distribution shows the amount of patients with different episode lengths as percentages of all patients. Episodes with length of 1 are treated as an own entity, since they illustrate patients that only have had one visit during 2013. Other episode lengths are presented as intervals to make the illustration more feasible. Table 5-15 presents the episode length distributions, average episode lengths and Visits/episode (V/E)-ratios for all DMUs. The V/E ratio was calculated for each patient as number of visits per episode length in days. Figure 5-17 illustrates the episode length- distributions graphically.

Table 5-15- Episode length- distributions

Episode length	% of patients SV	M1	M1 -B	M2	M2 - B	Cumulative SV	M1	M1 -B	M2	M2 - B
1	73 %	49 %	49 %	47 %	44 %	0,7	0,5	0,5	0,5	0,4
2-30	10 %	7 %	8 %	7 %	9 %	0,8	0,6	0,6	0,5	0,5
31-60	4 %	6 %	6 %	8 %	9 %	0,9	0,6	0,6	0,6	0,6
61 - 90	2 %	5 %	6 %	6 %	8 %	0,9	0,7	0,7	0,7	0,7
91-121	2 %	5 %	6 %	5 %	6 %	0,9	0,7	0,7	0,7	0,8
121-150	2 %	4 %	5 %	4 %	4 %	0,9	0,8	0,8	0,8	0,8
151-180	2 %	4 %	4 %	3 %	4 %	0,9	0,8	0,8	0,8	0,8
181-210	2 %	4 %	4 %	4 %	4 %	1,0	0,8	0,9	0,8	0,9
211-240	1 %	4 %	4 %	4 %	4 %	1,0	0,9	0,9	0,9	0,9
241-270	1 %	4 %	3 %	3 %	3 %	1,0	0,9	0,9	0,9	0,9
271-300	1 %	4 %	3 %	4 %	3 %	1,0	1,0	1,0	1,0	1,0
301-330	1 %	3 %	2 %	3 %	3 %	1,0	1,0	1,0	1,0	1,0
331-365	0 %	1 %	1 %	1 %	1 %	1,0	1,0	1,0	1,0	1,0
Average episode length	27	79	71	76	73					
V/E	0,8	0,6	0,6	0,5	0,5					

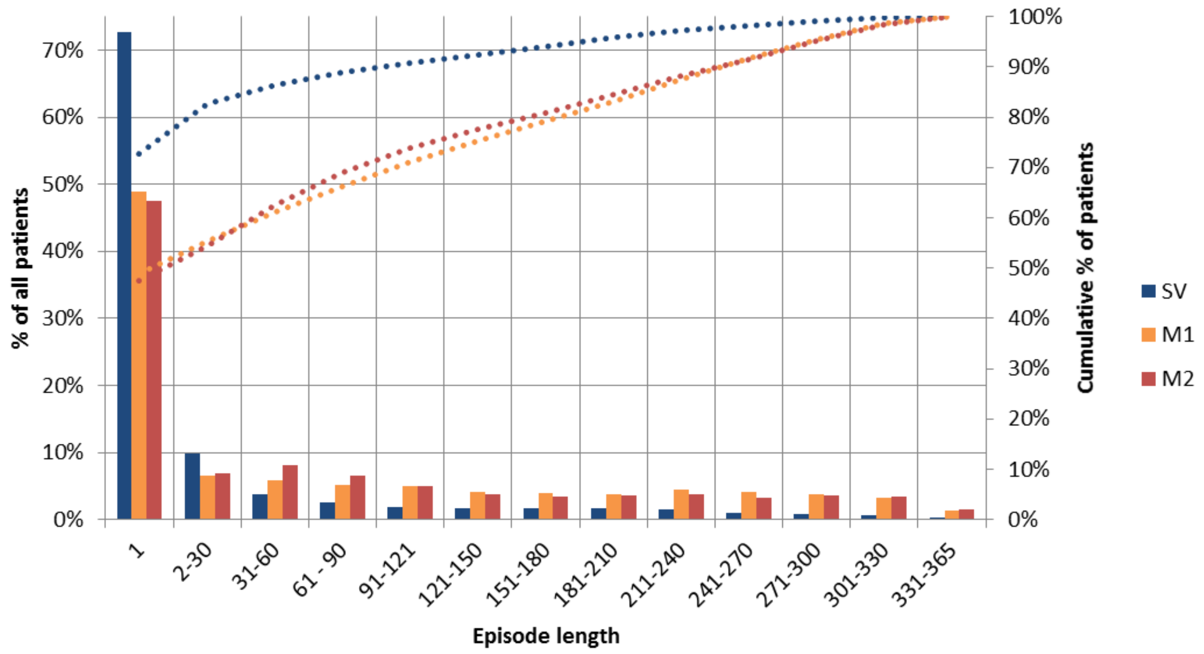


Figure 5-17 - Episode length- distributions

Again, both municipalities have somewhat similar results. The average episode lengths are 70-80 days and average V/E-ratios are between 0.5 and 0.6. The results are very much alike for B- patients. This is as such, unsurprising, since all non-acute patients are treated with similar process. However, the data confirms that the case mix of the patient has little effect on episode lengths in municipal dental care as regardless of procedure complexity, the episodes tend to extend over several months. In both municipalities, roughly 50% of patients had only one visit in 2013 resulting in an episode of 1. In the SV Clinic, the corresponding figure was 73%. Even though 27% of SV patients had episodes over 1 day, the cumulative distribution (represented by the dotted lines) reveals that 90% of patients were treated in episodes of fewer than two months. The 90% cumulative value is reached in municipalities only in the 6-to-8 month area. The average V/E-ratios illustrate, how much the average patient receives treatment within his episode. The V/E-ratio is 0.2-0.3 units higher in the SV Clinic than in the municipalities due to the higher relative amount of patients with short episodes.

Since the results suggest quite significant differences in productivity, it is worthwhile to study the time allocation of the staff to clarify, what components in the process contribute to the efficiency. A key factor in any process efficiency improvement is the minimization of slack. In the context of this thesis, slack time can be seen as the time that is not used to produce the outputs. In essence, all time that is not used to actual patient treatment is unwanted slack and thus should be minimized. Majority of slack in the dental care process consists of the changeover time. Changeover time means the time used to prepare the operating room for the next patient. By comparing the time sunk in changeovers to the total visit time, we can assess the efficiency of resource allocation. In addition, these times can be further mapped against the theoretical full working time of the staff to evaluate the proportion of actual treatment time in the process. Table 5-17 summarizes the average time allocation indicators for all DMUs in 2013.

Table 5-16 - Proportion of changeover time

	SV	M1	M2
Changeover/Treatment time	0,19	0,28	0,36
Changeover/Visit time	0,16	0,22	0,26
Visit time/Theor. Work. Time	0,44	0,33	0,25

In the SV Clinic, the proportion of changeover time of the total visit time is six to ten percentage units lower than in municipalities. One explanation behind the difference is the lower amount of visits per patient in the SV Clinic. Earlier it was shown, that the procedure requirement per patient per year was between four and five procedures in all DMUs. However, the visits per patient distributions showed that the municipal patients needed roughly one visit more than the SV patients to have these procedures performed. Theoretically, the efficiency of the service delivery would improve if similar care was provided with least amount of visits possible. If a patient undergoes four procedures during a single visit, this creates a single changeover. If the patient has two visits for this treatment, two changeovers are created. As the SV Clinic had fewer visits per patient and even slightly more procedures per patient than the municipalities in 2013, logically this would mean more procedures per visit as well. To study the amount of treatment provided during visits in different DMUs, procedures per visits distributions were created from the data for all DMUs. Weighted procedures were used to capture the effects of differing case mixes. Figure 5-18 represents the distributions for all DMUs. The dashed lines indicate the cumulative distributions, respectively

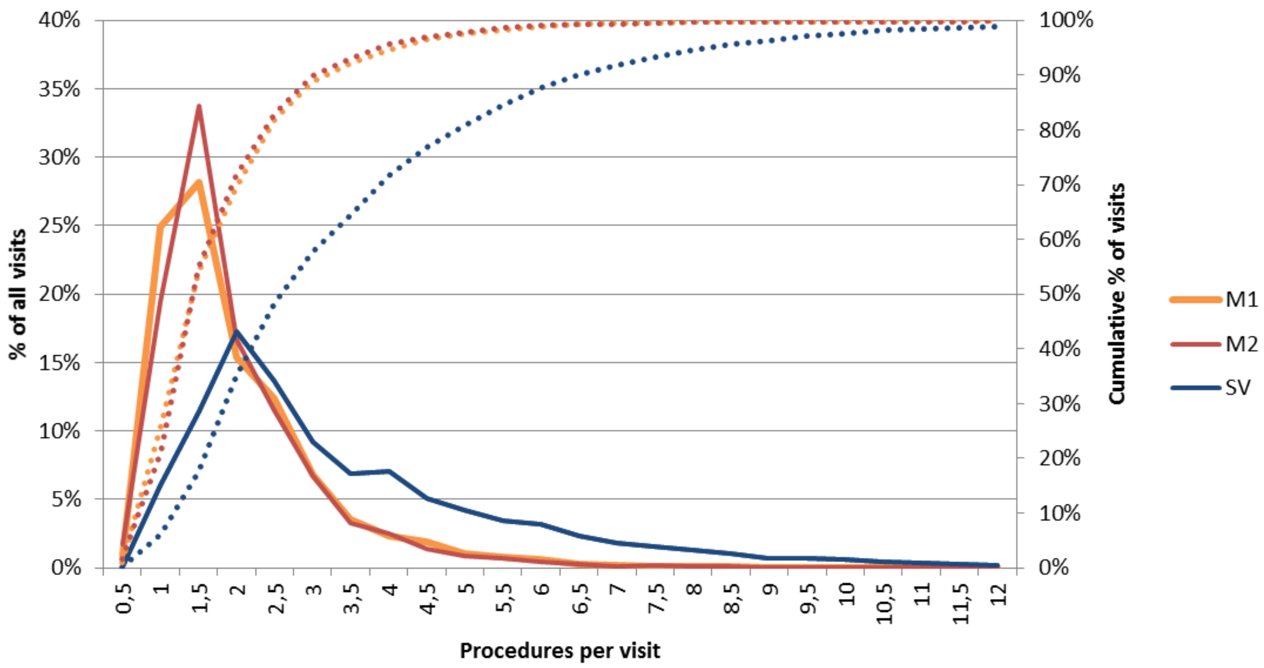


Figure 5-18 - Procedures per visit- distributions

The procedures per visit distributions are in line with the previous findings from the data, as the SV Clinic's distribution has less positive skew than the municipalities indicating more procedures per visit on average. The municipal distributions are again close to identical. The cumulative distributions show that 90% of visits in municipalities include less than 3.5 weighted procedures. The respective figure for the SV Clinic is 6.5 weighted procedures. When classifying the visits further to B and C patient level, the B patients seem to have slightly more procedures per visit on average. However, the difference is not major, especially in M2. Table 5-17 illustrates the weighted averages and basic statistics for procedures per visits in each DMU and for B and C patients.

Table 5-17 - Procedures per visits - selected statistics

	SV	*M1*	*M1 - B*	*M1 - C*	*M2*	*M2 - B*	*M2 - C*
Wgtd average procedures per visit	3,6	2,0	2,2	1,9	2,0	2,0	2,0
Max	32,3	120,7	23,3	120,7	72,2	29,1	72,2
Min	0,3	0,2	0,2	0,3	0,3	0,3	0,3
Median	2,6	1,4	1,8	1,3	1,4	1,5	1,3

The SV Clinic performs on average 1.6 procedures more during visits than the municipalities. The patient classification provides some variation within municipalities, especially in M1. B patient visits include more procedures than the visits of C patients. This effect was visible also in visits per patient distributions shown earlier, as B patients had a slightly lower visits per patient averages than the C patients or municipalities in general. Comparing the changeover time to total visit times showed that the SV logic seems to help reduce the proportion of changeover time in the service delivery process, as patients are treated with less visits.

The importance of minimizing changeover time in the process can be better understood by estimating the cost of changeover time in terms of staff wages. The cost of changeovers is not only affected by the amount of changeover time but also by the division of work. As described in sub-section 5.1 the approaches in work division differ between the DMUs. In municipalities the changeover time falls upon the clinical staff members in the room, which means either a pair of a dentist and a nurse, or a hygienist. In the SV Clinic, the changeovers are always done by nurses. Since the municipal visits are always assigned to a certain staff member, the wage cost of changeovers can be estimated by using hourly wages of different roles presented in sub-section 5.2.1. All dentist visits are assumed to include also a dental nurse. In the SV Clinic, all changeovers are calculated based on the hourly cost of a dental nurse. The estimation of average changeover unit costs and total changeover costs for different DMUs in 2013 are presented in Table 5-18.

Table 5-18 - Estimation of changeover wage costs

**as k€*

	SV	*M1*	*M2*
Changeover minute cost	0,32 €	0,83 €	0,94 €
Average changeover (min)	9	7,9	7,6
Average changeover cost	2,88 €	6,56 €	7,19 €
*Total Changeover Costs**			
Dental Nurse	100 €	203 €	330 €
Dentist		567 €	971 €
Hygienist		139 €	143 €
Total	100 €	909 €	1 444 €

As can be seen, the estimated average cost of a changeover is 56%-60% less in the SV clinic than in municipalities. The biggest factor contributing to low changeover costs in the SV Clinic is the exclusion of dentists and hygienists of this task. In addition to reducing the changeover costs, the work division in the SV Clinic contributes to the productivity of the service delivery by allowing dentists and hygienists to move to the next patient after performing the required procedures resulting in more treated patients. In table 5-20, the total visit times for hygienists and dentists in 2013 are compared to the theoretical annual working time (1782 hours*FTE). Since the SV Clinic does not have assigned visits to dentists or hygienists separately, the *actual visit time*s for each group include the duration of all visits that included at least one procedure performed by the respective role.

Table 5-19- Time allocation of dentists and hygienists

	SV	*M1*	*M2*
Actual visit time (hours)			
Dentist	21537	50517	66416
Hygienist	13328	27815	27709
Theoretical working time (hours)			
Dentist	17915	78536	132052
Hygienist	24262	48303	59343
Actual/Theoretical (%)			
Dentist	120 %	64 %	50 %
Hygienist	55 %	58 %	47 %

The figures in Table 5-20 reveal how dentists at the SV Clinic are able to attend more visits than their theoretical annual working time is. This is possible due to the fact that the dentists are in the room only when necessary, in essence to perform examinations and procedures. Despite the clear difference in dentist time allocations, the hygienist working time- ratios are within a close range of each other in all DMUs. The “invisible work” of hygienists in the SV Clinic was present in previous results as well. As mentioned, In the SV clinic hygienists often assist dentists and perform treatment and preparations that are not logged as procedures. Since the method of extracting the actual visit time required a procedure during a specific visit by the corresponding staff type, some hygienist work might remain undetected in the data.

5.3 Simulation of SV Model’s Effects in a Municipal Dental Care Unit

So far, the results of this thesis indicate that the single-visit logic results in fewer visits per patient and higher productivity than the traditional model. The data also suggests that a noteworthy amount of municipal patients can be classified as B patients. However, the different operating logics seem to require a different combination of nurses, dentists and hygienists. In previous sections, the municipalities M1 and M2 have been treated as units. In reality, they consist of multiple, smaller dental care units. This section uses a simulation model to test the hypothetical effects of an additional service line operating with a single-visit logic in a specific service unit of M1. This unit is henceforth referred to as original unit (O unit). During spring 2015, a pilot project was launched in M1 to test the use of the single visit operating logic in municipal dental care. For this project, nine new appointment rooms were set up in O unit to act as a parallel service line with the traditional operating logic. These service lines are referred to as single visit (SV) line and traditional (T) line. Together, they form a new, combined dental care unit (C unit).

The simulation model is used to test two scenarios. The first scenario models the new C unit with additional resources as described above. The resources are allocated between the two lines based on the proportions used in the pilot. In the second scenario, the resources of the O unit are static, meaning no new staff members or operating rooms. Staff resources that are allocated to the SV line are subtracted from the T line resources. The second scenario essentially tests, whether the new service model would fit into a typical municipal dental care unit without changing the underlying staff resources and simulates the operation with a smaller staff composition.

Table 5-21 presents the original staff resources in the O unit, the total resources of the C unit with additional resources and the resource division between the two service lines.

Table 5-20 - FTEs in the O and C units

	O unit	*C unit*	*SV line*	*T line*
Explanation	Original operating unit	New, combined unit consisting of the SV line and T line	Service line with the single visit operating logic	Service line with the traditional operating logic
Dental nurses	9,6	9,8	4,0	5,8
Dentists	6,0	10,4	6,0	4,4
Hygienists	2,0	5,6	5,0	0,6
Total	**17,6**	**25,8**	**15,0**	**10,8**

As can be seen, the C unit not only has more resources but also a different composition of nurses, dentists and hygienists. The amount of nurses stays almost the same in the C unit whereas 3.6 additional hygienists and 4.4 dentists are brought in (FTEs).

5.3.1 Structure of the Model

The simulation model utilizes discrete probability distributions to estimate the production capacity and need for treatment in terms of weighted procedures. The procedures are further classified to dentist and hygienist procedures to include the effects of differing ratios of staff types in O and C units. Nurses were regarded only as assistants, as the proportion of procedures by nurses was close to 0% in this particular unit. The amount of visits is estimated based on the expected amount of visits given the total amount of procedures for each patient. Figure 5-19 presents the high level logic of the simulation model.

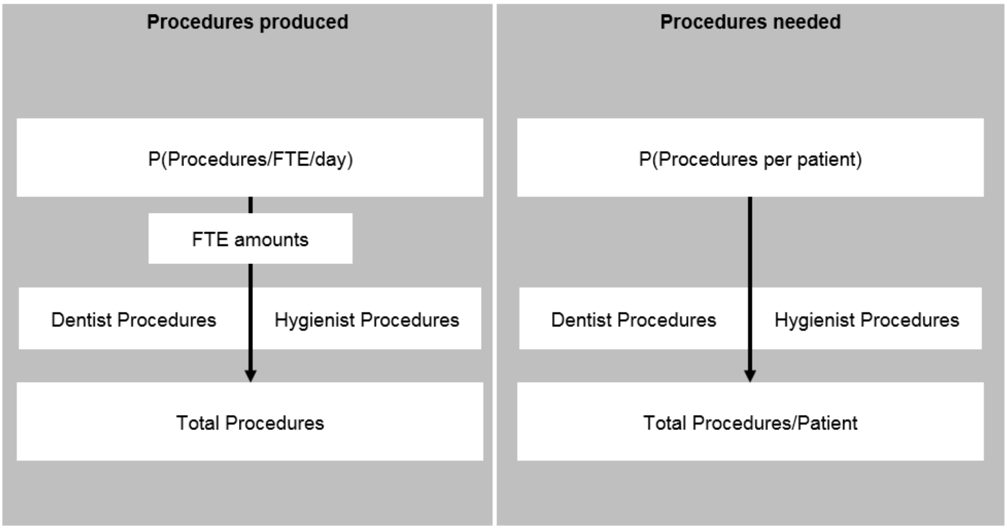


Figure 5-19 - Structure of the simulation model

The model consists of two main elements: production capacity and procedure. The production capacities were estimated by looking at the daily amount of procedures per dentist and hygienist FTEs. This yielded a discrete probability distribution of procedures per FTE per day, for dentists and hygienists, respectively. These distributions were then used to simulate 10 years of activity with 251 days of operation/year (O unit had 251 days of operation in 2013). To estimate the need for procedures, probability distributions for procedures per patient were extracted from the data (similarly as in sub-section 5.2.3. but with 0.2 accuracy), separately for hygienist and dentist procedures. These distributions were used to simulate patients with distinctive procedure needs.

Since the service lines had different operating logics, different sources for the above mentioned distributions were used to construct the model of C unit. The procedure needs for all lines and units were based on the patient data of the O unit in 2013. However, for the SV and T lines, the distributions were divided to concern only B patients or C patients. In essence, the procedure need for the SV line comes from the procedures per patient distribution of B patients in O unit and the respective need for T line comes from C patients. Also, for the SV line, the production capacity is estimated based on the SV clinic's data, since that line represents the SV operating logic. For T line, the production capacity is based on O unit's performance in 2013. Before simulating the scenarios, the model was tested by simulating the operation of the year 2013 in the SV Clinic and the O unit and comparing the results with actual data from 2013. The results and errors are shown in Table 5-21.

Table 5-21 - Model test results

	SV Clinique			*O unit*		
	Actual	*Simulated*	*Error*	*Actual*	*Simulated*	*Error*
Patients Treated	21839	21636	-1 %	8724	8661	-1 %
Procedures performed	101658	103015	1 %	28489	28724	1 %
Hygienist	14870	15372	3 %	4018	4036	0 %
Dentist	86788	87642	1 %	24471	24688	1 %

The test showed that the model quite accurately describes the behavior of the SV Clinic and the O unit as all errors are under 4%. The average error was 0.78%.

5.3.2 Scenario 1 – New resources

In scenario 1, the C unit has a total of 25.8 FTEs and nine new operating rooms. The resources are first allocated as described in Table 5-20. The simulation was run for 10 years and the average values of these years were used in the summarized results. Figure 5-20 first shows the increase in produced procedures for hygienists and dentists separately.

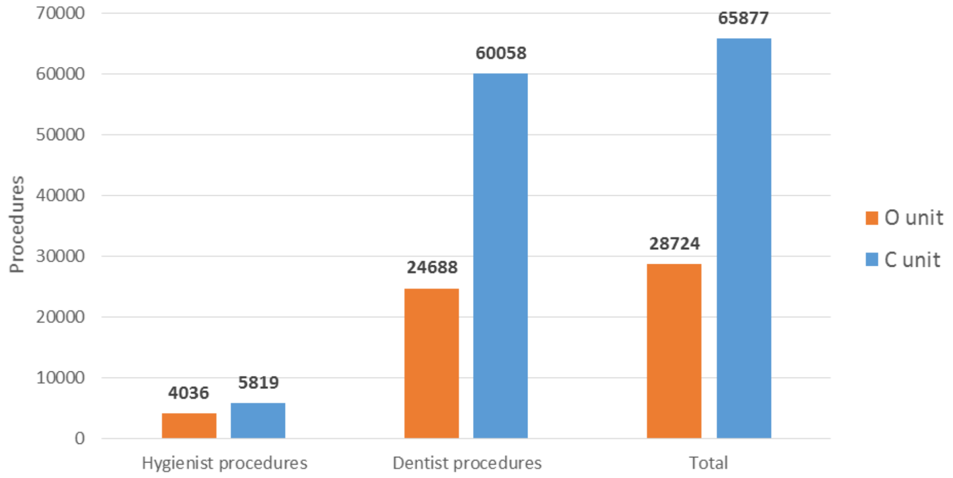


Figure 5-20 – Scenario 1 outputs

The hygienist procedures increase by 44% while the increase in dentist procedures is 143%. As it was shown earlier, the SV clinic's hygienists are not more productive than municipal hygienists in terms of procedure output. The majority of the C unit's hygienist resources (5 out of 5.6 FTEs) are placed in the SV line, the relative productivity increase in hygienist procedures is quite low. The efficiency increase is instead more visible in the dentist's output level.

Figure 5-21 illustrates the increase in treated patients. As the production was divided to hygienist and dentist procedures, the amount of treated patients can also be viewed in two parts. The leftmost columns (Patients – Hygienists) signals how many patients the unit is able to treat in terms of hygienist procedures. Vice versa, the columns on the right illustrate how many patients' dentist procedure need could be provided.

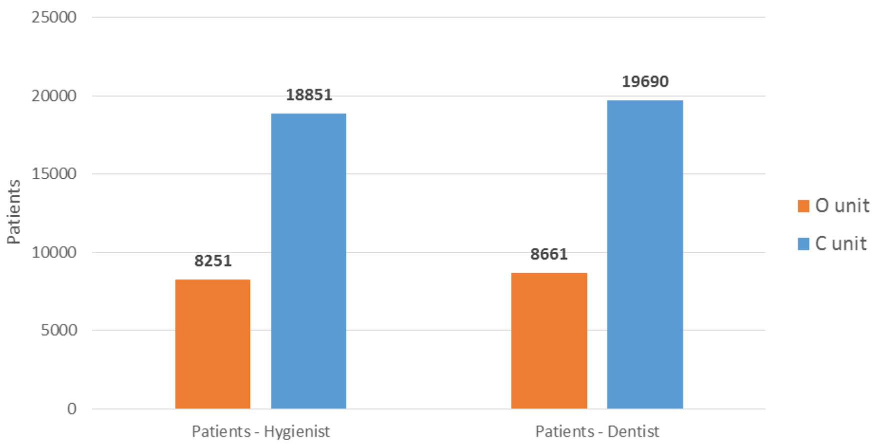


Figure 5-21 – Scenario 1 patients treated

The results show that the amount of treated patients increases by roughly 127% in the C unit as the new maximum amount of patients treated is 19690. Out of this amount, 840 patients are estimated to still have need for hygienist treatment. Thus, for 18851 patients, all necessary hygienist and dentist treatment could be provided in the C unit compared to the O unit's 8251 patients.

As the units have different amount of resources, the productivity is viewed in relation to resources. Figure 5-22 shows the produced procedures and treated patients in relation to the total FTE amount of different units. It must be noted though, that the SV line is not the only factor contributing to this increase. The C unit has proportionally less nurses in its staff composition. As nurses do not perform procedures, all nurse FTEs have a decreasing effect to productivity. Thus Figure 5-28 also shows the procedures and patients in relation to only dentist and hygienist FTEs (HD FTE).

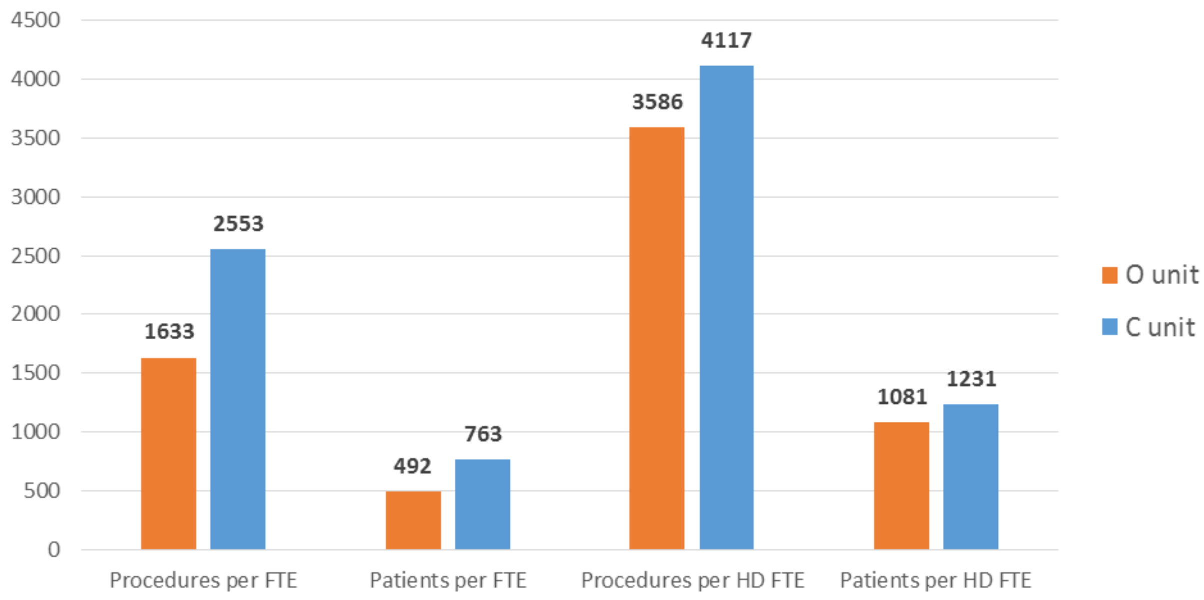


Figure 5-22 – Scenario 1 productivity

Despite being more productive in gross amounts, the C unit also has improved performance related to its resources. Compared to all FTEs, the ratios are roughly 55% higher in the C unit. When using only dentist and hygienist FTEs as the baseline, the increase in the C unit's ratios is around 15%.

5.3.3 Scenario 2 – No additional resources

In scenario 2, the effects of the SV service line are estimated without changes in underlying resources. This means that in terms of FTEs, there are 9.6 nurses, 6.0 dentists and 2.0 hygienists available. Like in the first scenario, the resources are first divided to the service lines in the same proportion as in the pilot project. Since the amount of resources is low, the first scenario allocates 1 dentist to the SV line which translates to 0.83 hygienists and 0.67 nurses. The rest of the FTEs remain in the T line. The simulation was again run for 10 years and the average values of these years were used in the results.

Similarly as in scenario 1, the production capability of the units is first illustrated in Figure 5-23.

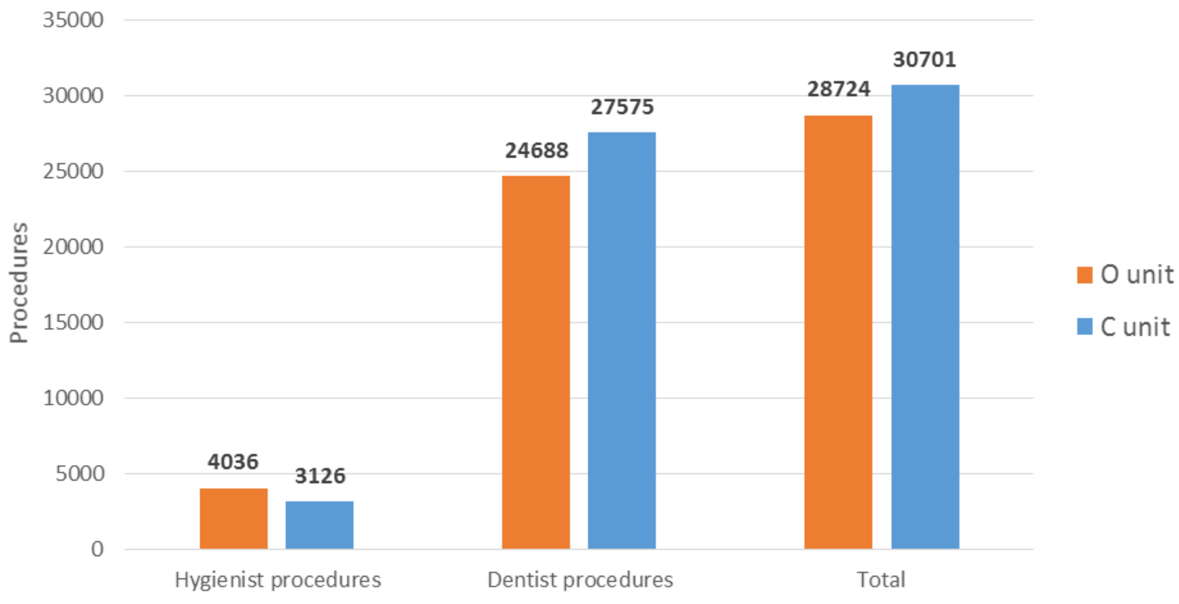


Figure 5-23 - Scenario 2 outputs

Now we can see, that even though the total procedure output grows, the amount of hygienist procedures decreases. This is due to the fact that one hygienist FTE in the SV line produces less procedures than one hygienist FTE in the T line. However, the higher dentist productivity in the SV line takes the C unit's total procedure output up by 7%.

Figure 5-24 shows how the increase in procedures translates into treated patients.

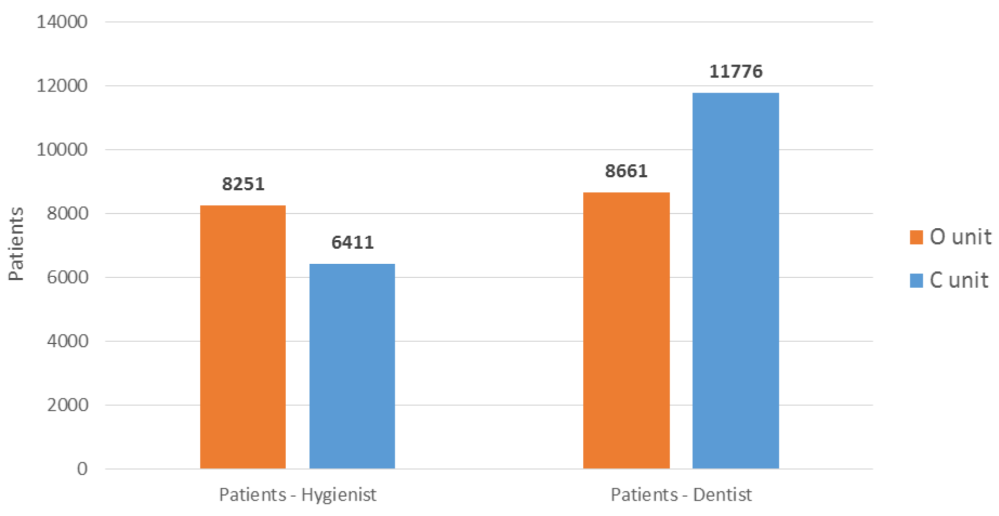


Figure 5-24 - Scenario 2 patients treated

Due to the lower amount of hygienist procedures in the C unit, the amount of patients to whom all hygienist treatment can be provided decreases by 22%. However, the dentist treatment now covers 36% more patients. The total amount of patients treated increases by

3115 patients but over 5000 patients are estimated to have hygienist procedure needs that cannot be provided. In terms of overall productivity, the C unit still manages to show improvements compared to the O unit despite the lower level of hygienist procedures. Figure 5-25 displays similar efficiency metrics as in scenario 1.

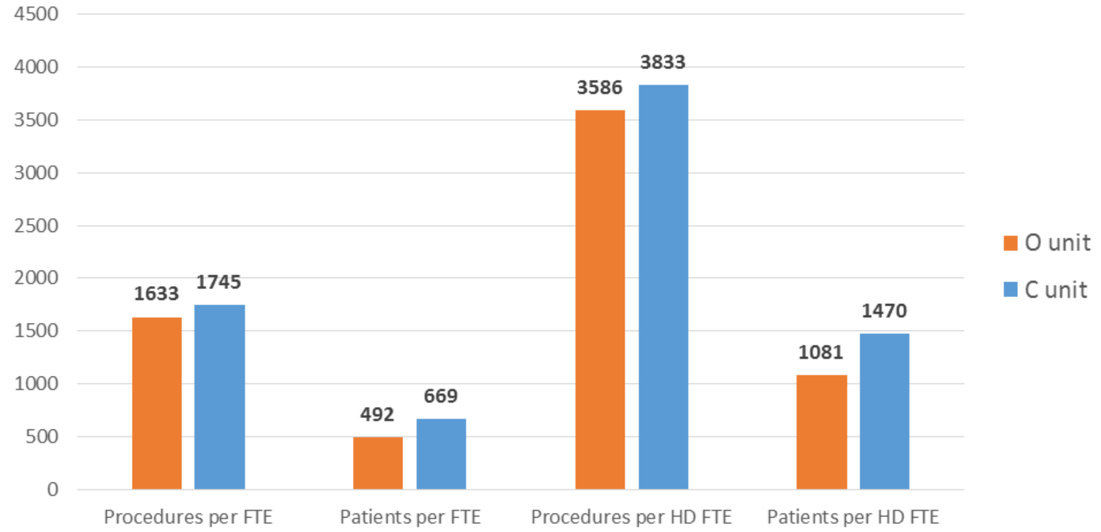


Figure 5-25 - Scenario 2 productivity

In this case, the increases in the ratios do not change with the baseline, as both units have the same staff resources. The procedures per FTE ratio goes up by 7% which is about half of the respective procedures per HD FTE figure in scenario 1. However, the increase in patients per FTE is 36% which is about 20 percentage-units higher than in scenario 1 with HD FTEs as a baseline. These results indicate that the SV service model could increase the patient flow in municipal units even with small staff compositions. However, to provide patients with a comprehensive dental service in terms of also hygienist treatment, increases in hygienist resources are necessary as the SV model requires more hygienists than the traditional model.

Even though both scenarios suggest the C unit to be able to treat more patients in a year than the O unit, there are a couple of factors to consider. First, the model assumes that the appointment booking can classify patients into B and C patients effectively. Patients falsely classified as B patients may have to revisit the Clinic as C patients in the T line, causing disturbances in patient intake and scheduling. However, the number of these kinds of occurrences can be assumed to be quite low. Earlier it was shown (sub-section 5.2.2.), that under 1% of visits in the SV Clinic resulted in no treatment. As dental care professionals operate the appointment booking in municipalities, the false classification errors should be reduced close to non-existent. Second, it should be noted that the queue of patients is assumed to be infinite. In essence, there are both B and C patients requiring care as much as the unit is able to offer it. This assumption is justified by the fact that one of the main problems in public dental care is the long waiting lists. Thus, running out of patients would be an unlikely outcome. Third, to avoid making the model too complex, queuing theory, estimations of patient's tardiness and fluctuating demand were excluded. Should accurate data on these factors be available, the model could be extended to cover these elements as well.

6 DISCUSSION

The objectives of this thesis were to illustrate the differences between the traditional service model and the SV model, to determine the proportion of low-complexity patients in municipalities and to estimate the productivity effects of the SV model in a municipal dental care unit. These objectives were fulfilled by reviewing relevant literature on e.g. appointment systems, healthcare processes and efficiency measurement and by thorough process mining of event logs provided by two municipalities and one private SV clinic. The results fulfilling these objectives are summarized in Table 6-1.

Table 6-1 - Objectives revisited

		Single Visit Model	Traditional Model
Objective 1	**Appointment system design**	Restricted case mix enables open ended appointments, leveling, one piece patient flow and synchronization. As little visits as possible. Adjustment by allowing customers to wait within time slots.	Individual appointments, typically 30 minutes, treatment spread over several visits if necessary. Adjustment by overbooking = waiting list.
	Patients	Only basic, adult patients, avg 4.9 procedures per patient	All patients, avg 4.2 procedures per patient
	Procedures	~90 different procedures, emphasis on fillings and parodontium care	~250 different procedures, emphasis on examinations, preventive care and surgical procedures
	Resources	1.4 hygienists, 1.2 nurses per dentist	0.5 - 0.6 hygienists, 1.5 nurses per dentist
	Efficiency	1 Dentist FTE = 28 procedures per day, hygienist = 3.6 procedures per day	1 Dentist FTE = 10 - 14 procedures per day, hygienist = 4.5 - 5.4 procedures per day
		610 patients/FTE	350 - 380 patients/FTE
		Avg episode 27 days	Avg episode 80 days
Objective 2	**Proportion of Basic patients**	100 %	40% - 45% of all patients, 65% - 77% of adult patients
Objective 3	**Effects with additional resources**	55% more procedures and patients per FTE, 15% more per HD FTE	
	Effects without additional resources	7% more procedures and patients per FTE, 23% Less hygienist procedures	

The municipal operating model represents a traditional individual appointment system. The access design can be seen as a carve-out model, where some of the resources are reserved for ER-visits and all non-acute patients are scheduled an individual appointment. The most typical appointment length is very close to the average length of appointments as 30 minutes is the usual appointment length in both municipalities and the average length from data was roughly 35 minutes. This selected ASR has characteristics from studies by Bailey (1952, 1954) and Welch (1964) (individual block design, average length appointments for all patients). Tsai and Teng (2014) saw that in addition to the ASR, appointment system design also consists of patient classification and adjustment policy. In municipalities, the patient classification is somewhat nonexistent. Only acute cases are directed to ER whereas all non-acute patients are reserved individual appointments similarly. Specialist treatment need is determined only after the first regular appointment. The problem with the municipal appointment system is the coping – or lack thereof – with high demand. The threshold capacity definition by Bailey (1952) stated that an infinite queue is eventually formed when demand exceeds capacity in outpatient clinics. Hence, the third element of appointment systems, adjustment policy, becomes relevant. Currently, the municipal adjustment policy is overbooking as patients are steered to waiting list. This results in expanded AMQ- systems and long waiting times between appointment booking and treatment. Moreover, as the 30 minute- appointment is seldom enough to provide all necessary treatment, patients are returned to the AMQ further straining the waiting list and extending the patient episodes.

In the SV clinic the operating model can be seen as a Lean approach to dental care. On the background of Bahri's Lean practice was the idea of minimizing the lead time for treating the whole mouth of a patient. This is the core idea in the SV clinic as well as all necessary treatment is provided during the first visit. Like in municipalities, the ASR is also based on individual appointments but the patient classification component and the adjustment policy enable the use of flexible, open-ended appointments. The patient classification component translates to the standardized offering and patient selection. As all patients are known to require only a certain set of basic procedures, the treatment times are more predictable. This enables an open access design where patients book a time slot for start of treatment instead of a fixed length appointment. The adjustment policy is to allow customers to wait within their time slots and calling them in for treatment exactly at the right time. Hence, the JIT- flow of patients is achieved. In terms of queuing systems this means that the SV clinic uses the SFQ instead of AMQ to level capacity and demand resulting in short (or nonexistent) waiting lists, which is the key idea of open access clinics. It was noted by Liu et al. (2010) and Robinson & Chen (2010) that this approach is highly vulnerable to variances in patient needs. However, as the patient mix is restricted to only low-complexity patients, high variances in treatment needs are unlikely to occur. Bahri (2009) saw leveling, one-piece patient flow and synchronization as the cornerstones of Lean production in dental care. The aforementioned elements help achieve the one-piece patient flow and level the capacity of staff throughout the schedule with minimum doctor idle time and slack between transitions. The last element, synchronization, relies on the ERP system of the SV clinic, which assumes the roles of appointment scheduler, workforce manager and patient flow coordinator. The ERP helps achieve a JIT- flow not only for the patients but also for the staff, as hygienists and dentists are directed to treatment rooms on an ad-hoc basis. The functional barrier of separate hygienist and dentist appointments in the traditional model is also overcome by allowing the staff members to switch rooms.

Due to these factors, the SV Clinic is able to treat more patients and perform more procedures in relation to clinical staff. When studying the efficiency of hygienists, it was found that in the SV clinic, hygienist efficiency is actually lower than in municipalities when measured in performed procedures. Vice versa, the dentist efficiency was significantly (100%-170%) higher in the SV Clinic than in municipalities in terms of procedures. This signals a difference in division of work between the two service models. In the SV model, a major part of hygienist's role consists of assisting work for the dentists. This work is not visible in the data as procedures performed by hygienists but instead presents as high dentist efficiency resulting in high overall efficiency in relation to full time clinical employees. Another factor contributing to the SV model's better efficiency is the lower relative amount of nurses. As larger proportion of staff are productive (hygienists or dentists), the procedure output is higher in relation to all clinical staff. Thus, the efficiency was measured also in relation to only hygienist and dentist FTEs. Even after restricting nurse FTEs out of the comparison, the SV model showed 40%-50% higher procedure output and 20%-30% more treated patients per FTE than the traditional model.

The municipal dental care has to cope with variable patient and case mixes. The municipal patient mix consists of patients of all age and condition (partly due to legislative requirements) whereas the SV Clinic's patient mix consists only of adult patients with low-complexity procedure needs. Nevertheless, over 60% of adult patients in both municipalities could be classified as low-complexity patients with similar procedure needs as the SV patients. By studying weighted procedures performed per patient, it was determined, that the annual average treatment need is actually lower for the municipal patients than for the SV clinic's patients. The variance in these needs is somewhat similar for municipal B patients and the SV clinic's patients. Thus it can be concluded that a patient group applicable for the SV model could be recognized from the municipal patients and that this group covers the majority of adult patients.

7 CONCLUSIONS

The long waiting times and capacity-exceeding demand are ailing the public dental care system of Finland. The ageing population and scarce public resources are putting pressure on decision-makers to find ways to cope with the increasing amount of adult patients. The issues in Finnish dental care have been known for quite a while, yet the public sector dentistry has still followed the same protocols for years. The need for new, more efficient service models has been recognized on a national level.

This thesis was set out to study, whether the low-complexity patients could be treated with a different, more efficient service model. The proposed idea was to have two operating modes in public dental care. The low-complexity patients would be treated with a single visit model utilizing Lean production methods like JIT scheduling and minimized lead time accounting for all required treatment with as few visits as possible. Patients with more variant treatment needs would be treated with the traditional service model. This approach required thoroughly analyzing both of these service models. How do they differ? What types of procedures and patients can the models handle? What is the difference in efficiency? What kinds of productivity improvements could be expected from this approach? These aspects were summarized into the research question:

Could the single visit operating model improve the productivity of Finnish municipal dental care?

7.1 Main Findings

The main finding is that the SV model could indeed help municipal dental care to improve its productivity. The difference in productivity in relation to staff was evident, as the SV clinic produced nearly twice as many procedures and treated 50%-70% more patients per staff FTE than the municipalities. Another important finding was that majority (over 60%) of the municipalities' adult patients could be classified as low-complexity patients. This means that if this patient group was treated with better efficiency, the contribution to the overall efficiency of municipal dental care would be sizeable. In fact, through simulation, the productivity improvement was estimated to be over 50% in one dental care unit of Jyväskylä, when treating all low-complexity patients with the SV model. However, this sizeable improvement required some additional hygienist and dentist resources, which leads us to the third main finding: the difference in clinical staff proportions. Roughly 50% of municipal staff are nurses and the percentage of hygienists was under 20%. The SV clinic's clinical staff consists of roughly one third of each staff type: dentists, hygienists and nurses.

7.2 Managerial Implications

This thesis provides two main implications for decision-makers. First is the role and amount of hygienists in public dental care. The need to revise the remit of hygienists and to direct more patients to hygienists instead of dentists has already been discussed on a national level (Ministry of Finance, 2014). The results of this thesis further encourage to consider the effective use of different staff types. A practical example is that in the traditional model, part of dentists' and hygienists' working time is wasted in changeovers. The simulation model showed that the use of SV model requires some additional hygienist resources compared to the current level to function properly. Hygienists also assume a more assisting role in the SV model improving the fluency of dentists' work and decreasing the need for nurses. Moreover, as large proportion of municipal clinical staff is unproductive (nurses do not perform procedures) the overall efficiency of the dental care system suffers. One possibility could be to transfer some of the nurse resources to hygienists through training, since the amount of nurses is relatively high in relation to other staff types in municipalities.

The second implication is improving the culture in public dental care towards a more efficiency-oriented and change-favorable one. As it was mentioned, reluctance to change ways of working and negativity towards management positions were common issues in public dental care. This thesis provides numerical evidence of the operations of different service models and a set of metrics to evaluate the dental care service delivery. However, the implementation of a new service model requires decision-makers to reconsider e.g. the incentive systems of staff, functional barriers such as personal dentists and the development of data and information systems to cope with new methods, systems and ways of working.

As the main contributions of this thesis have been presented, the limitations should also be addressed. This thesis utilized data from two municipalities to describe the traditional service model and elements of public dental care. This approach is suitable in terms of the service model, as the dental care professionals associated with this thesis saw that similar model is used in the public sector nationwide. The data analysis showed that the two municipalities had also quite similar patient, procedure and performance profiles. Nevertheless, this might not be the case for all municipalities, which decreases the generalizability of some of the results. For example, the amount of low-complexity patients might vary in different municipalities. The lack of quantified quality measures can be seen as another limitation. The productivity differences were seen to stem from appointment system design and workforce management instead of faster pace in actual clinical work. Hence the quality of care was assumed to be similar in both service models.

7.3 Future Research

This thesis did not have any direct predecessors. Hence, it opens up several possibilities to extend the research and to tackle the aforementioned limitations. First, the quality of the outputs produced in different service models could be studied by e.g. measuring the amount of recurring fillings during relatively short time horizons. This would require procedure data that shows the exact teeth and side the procedure was performed on. Second, a more comprehensive dataset could also be utilized to expand the time horizons beyond one year and to include more municipalities in the analysis. Third, future research could focus on determining the economic benefits and implementation costs of the SV model. Megaklinikka is currently productizing their operating model and ERP system. The cost of this procurement could be compared to the monetary benefits of increased productivity in municipal dental care (e.g. increased fee income, decreased outsourcing and lower unit costs). In addition to financial perspective, the feasibility of this type of implementation could be studied from behavioral perspective and consider the change management requirements, patient and staff preferences and different incentive systems. Still, perhaps the most interesting future research topic is monitoring the pilot project in Jyväskylä. This pilot should provide actual data on the single visit model's performance in a municipal dental care unit. By using similar metrics as in this thesis, the unit's performance can be compared to previous years in terms of e.g. performed procedures and treated patients. Moreover, surveys can be utilized to measure the patient and staff attitudes towards the new model. The length of the unit's waiting list should also be monitored to see, whether the performance of the unit has an effect on appointment making queue length on the long term.

Appendix A: Procedures

Table A1:Procedure weights (CDC-initiative)

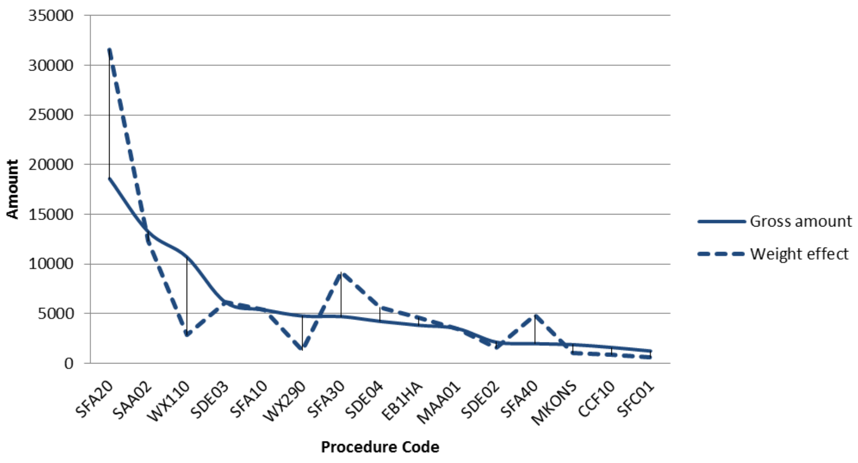
CCF05	0,55	eba15a	2,54	EEA10	0,93	SAA04e	2,09	SDA10	2,05	SFC00	2,10	SHA03	1,34	SPC30	5,50	WX110a	0,27
CCF10	0,55	eba15e	2,54	efa40	2,54	SAALT1	1,34	SDA10	2,05	SFC01	0,52	SHA04	2,09	SPC35	5,60	WX110b	0,27
CCS10	0,27	EBA15f	2,54	EFA50	3,74	SAALT2	1,34	SDA11	2,84	SFC01	0,52	SHA04	2,09	SPC40	3,74	WX290	0,27
Cpost	0,52	EBA20	2,14	efb10	2,84	SAAPAR	0,52	SDA11	2,84	SFC92	0,92	SHB00	2,85	SPC50	2,14	wx290a	0,27
EAA00	1,00	EBA20	2,14	EG1AA	1,20	SAB01	0,57	SDC10	1,50	SFC92	0,92	SHB00	2,85	spc60	0,52	WX290b	0,27
EAA10	1,60	EBA30	1,00	EGC00	9,32	SAB02	0,74	SDC10	1,50	SFCVA	0,55	SHG20	0,55	SPD00	5,70	WZC00	0,57
EAB00	0,74	EBA30	1,00	EHA10	0,93	SAC01	1,20	SDC20	1,84	SGA01	0,80	SHGPI	0,74	SPD05	6,89	wzc05	1,00
EAB10a	1,60	EBA40	2,60	EHB00	3,74	sac01b	1,20	SDC30	1,95	SGA01	0,80	sjb00	1,18	SPD10	6,89	WZC05e	2,09
EAB10b	1,60	EBA45	3,75	EJA10	0,93	SAC01o	1,20	SDC40	2,44	SGA02	1,00	SJB10	2,09	SPD20	6,89	WZC10a	2,09
EB1AA	0,47	EBA99	1,00	EJB00	0,93	SAC01y	1,20	SDC50	5,06	SGA02	1,00	SJB30	0,53	SPE00	7,15	WZC10b	2,09
EB1AA	0,47	EBB00	3,75	EJB10	2,84	SAC02	1,80	SDD01	0,74	SGA02e	1,00	SJB60a	1,09	SPE05	9,32	WZC10c	2,09
EB1Ad	3,28	EBB05	1,60	EJC00	0,93	SAC02o	1,80	SDD01	0,74	SGA03	1,40	SJB60b	1,09	SPE90	5,70	WZC10e	2,09
EB1AI	3,08	ebb10	5,05	EJC20a	1,60	sac03	2,40	SDD02	1,47	SGA03	1,40	SJC01	0,53	SPF00	1,30	ZX198	1,00
EB1Bd	3,58	ebb11	3,74	EJC20b	1,60	SAC03o	2,40	SDD02	1,47	SGA03e	1,40	sjc01	0,53	SPF00	1,30		
EB1BI	3,28	EBB15	1,95	EKA00	0,74	SAD01	0,37	SDD03	2,06	SGA04	2,14	sjc02	1,63	SPF00e	1,30		
EB1CA	0,22	EBU00	1,00	EKA10	0,93	SAD02	0,47	SDD03	2,06	SGA04	2,14	SJC03	3,74	SPF10	1,80		
EB1CA	0,22	eca00	1,96	EKB00	1,60	SBA00	0,78	SDD10	2,84	SGA04e	2,14	SJC10	0,75	SPF20	1,30		
EB1CI	3,58	ECA10	0,74	EKC00	0,74	SBA10	0,39	SDE02	0,74	SGA05	2,85	SJC20	0,53	SPF30	2,14		
EB1FA	1,20	ECA10	0,74	ELA20	2,54	SBA20	0,39	SDE02	0,74	sga05	2,85	SJC40	0,92	SPF40	1,45		
EB1HA	1,20	ECA10e	0,74	ELA30	3,74	sbb00	0,78	SDE03	1,00	SGA05e	2,85	SJC50	1,63	SPF40	1,45		
eb1ha	1,20	ECA20	0,93	ELB10	2,84	sbb10	0,78	sde03	1,00	SGA06	2,09	sjd00	1,18	SPF50	2,14		
EB1MA	1,20	ECA30	1,60	EWA00	0,74	SBB10a	0,78	SDE04	1,34	SGA07	2,84	sjd10	1,36	SPF50	2,14		
EB1SA	0,55	ECA35b	2,84	EWA00	0,74	sbb10b	0,78	sde04	1,34	SGB00	1,00	SJD20	1,63	SPF50v	2,14		
EB1SA	0,55	ECA35c	2,84	EWE00	0,93	SBB201	0,47	SFA00	0,74	SGB00a	1,00	sjd30	2,47	SPF60	2,00		
EBA00	1,10	ECA40	2,85	HKoru	0,74	SBB203	0,47	sfa00	0,74	SGB00b	1,00	sjd40	1,36	SPG10a	1,00		
EBA00a	1,10	ECA40	2,85	IA000	0,52	SCA01	0,55	SFA10	1,00	SGB10	1,00	SJD50	1,63	SXA10	0,40		
EBA00b	1,10	ECA50	3,74	IA100	0,78	SCA01	0,55	sfa10	1,00	SGB10	1,00	SJE90	1,70	SXA20	0,27		
EBA00c	1,10	ECA55	6,89	IA200	1,00	sca02	1,10	sfa10k	1,00	SGB20	1,40	SJF01	0,50	SXA20	0,27		
EBA00d	1,10	ECA60	0,74	IA300	1,00	SCA02B	1,10	SFA20	1,70	sgb20	1,40	SJX00	1,63	SXB00	0,52		
EBA00e	1,10	ECA60	0,74	MAA01	1,00	SCA02K	1,10	SFA20a	1,70	SGB30	2,14	SJX00	1,63	SXB00	0,52		
EBA00f	1,10	ECA60e	0,74	MKONS	0,57	SCA03	1,20	SFA20b	1,70	SGB30	2,14	SJX10	0,53	SXB10	1,00		
EBA00g	1,10	ECA70	6,89	Paro1	0,57	SCE00	0,74	sfa20k	1,70	SGC00	0,80	SJX10b	0,53	SXB10	1,00		
EBA00h	1,10	ECA99	3,74	Paro2	0,57	SCF01	0,57	SFA30	1,95	SGC00	0,80	SJX20	1,00	SXC02	0,74		
EBA05	2,14	ECB00	0,74	Paro3	0,57	scf02	0,74	SFA30a	1,95	SGC00e	0,80	SPA00	1,00	SXC03	1,47		
EBA05a	2,14	ECB00	0,74	SAA01	0,52	SCF03	0,93	SFA30b	1,95	SGC10	0,80	SPA00b	1,00	SXC04	2,05		
EBA05d	2,14	ECB00e	0,74	SAA01e	0,52	SDA01	0,57	SFA40	2,44	SGC10	0,80	spa05	2,15	TEA00	0,93		
EBA05e	2,14	ECB05	1,60	SAA02	0,93	SDA01	0,57	SFA40a	2,44	SGC20	2,14	SPA10	3,74	TEN00	1,00		
EBA05f	2,14	ECB10	1,60	SAA02o	0,93	SDA02	0,75	SFA40b	2,44	SGC30	2,85	SPA20	0,74	TEW99	1,00		
EBA05g	2,14	ecb15	2,84	saa02p	0,93	sda02	0,75	SFB10	1,72	SGC40	2,14	SPB00	0,52	Valky	0,74		
EBA05h	2,14	ECB20	1,60	SAA03a	1,34	SDA03	1,47	SFB20a	2,87	SGC40	2,14	SPB10	1,34	VValk	1,34		
EBA10	3,75	ecb40	5,05	saa03e	1,34	sda03	1,47	SFB20b	2,87	SHA01	0,52	SPB20	0,55	WX002a	1,10		
EBA10a	3,75	ecb50	1,95	SAA03p	1,34	SDA04	2,06	SFB30a	5,10	SHA01	0,52	SPB30	3,00	WX002b	1,10		
EBA10b	3,75	ECB99	5,05	SAA04a	2,09	SDA04	2,06	SFB30b	5,10	SHA02	0,93	SPC10	5,50	WX105	0,27		
EBA12	6,90	eda00	1,34	SAA04c	2,09	SDA05	2,85	SFB40	1,00	SHA02	0,93	SPC20	5,50	WX105	0,27		
eba15	2,54	EEA00	1,34	SAA04d	2,09	SDA05	2,85	SFC00	2,10	SHA03	1,34	SPC25	5,50	WX110	0,27		

Table A2: Excluded procedure codes

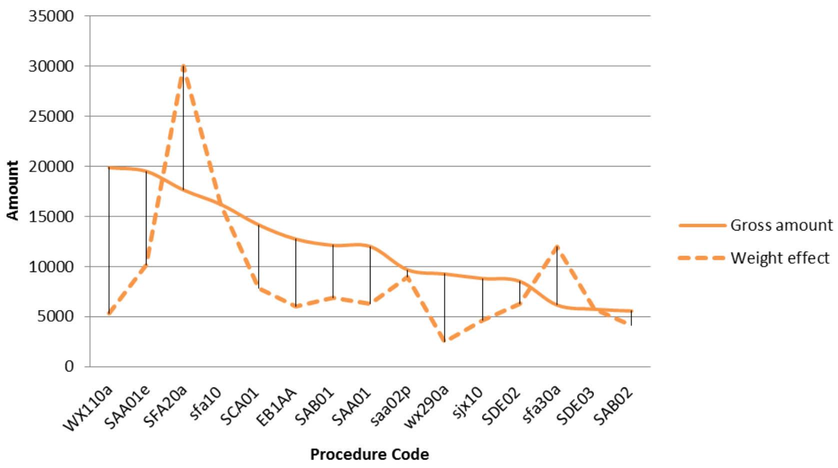
SV	*M1*				*M2*	
CAA10	900	oikkes	sch01	WZA90e	900	WYA05
CCK10	auk00	oiks	SOH	WZA90h	§A1	wya10
CCK20	bih00	oikval	sok0	WZB00a	§A5	wya20a
CCL10	DIAB	omah0	sok1	WZB00c	§E00	WYA20b
CCM10	emak	omah1	sok2	väliv	§E07	WYA30a
CCM6	hanke	omah2	SPA00	Ä10HML	§E20	WYA30b
CCM8	hkoulu	OSH	SPA00b	Ä10SHG	3riski	WYA30c
CCP01	hmak	ostop	TLOKE1	Ä20HML	ANESTK	WYA40
Lahet	hmat	OÄ	TLOKE2		EAV	wya50
LKNas	hopisk	pad-n	TLOKE3		emak	WZA00
SHG_A	hukkhf	PAK21	TLOPKE		hmak	WZA90a
WZA00	hukkop	pin01	tp000		htekn	WZA90b
WZA90	itseh	plak0	tpa00		IMPLAN	WZA90c
WZAPK	jono	plak1	tpa01		jono	WZA90d
WZB00	khväl	plak2	tpa02		kmak	WZA90e
WZC00	kip00	plak3	Ttkou		LASKU	WZA90h
	kip01	poli	Ttkäy		OD	WZB00a
	kmak	PYS	Ttmuu		OIKAL	WZB00c
	kor00	qh000	TUPEI		oikint	wzc05e
	kors1	qh002	TUPEI1		oikjat	WZC10a
	KUH	qh004	TUPEI2		OIKKES	WZC10b
	labra	ret00	TUPEI3		OIKOST	WZC10c
	lau00	ret01	TUPSAT		oikret	WZC10e
	LHTA1	ret02	valmis		oiksii	väliv
	LHTA2	ret03	WYA00		OIKTAR	
	lin00	ret04	WYA05		oikval	
	lin01	ret05	WYA10		osto	
	lin02	ret06	wya20a		PKS	
	M-	ret10	WYA20b		poli	
	M+	retal	WYA30a		S0000	
	MO	reth	WYA30b		saa03u	
	moi	retval	WYA40		Ttkou	
	nop00	s0000	WYA45		Ttkäy	
	oi	saa03u	WYA50		Ttmuu	
	oikalo	SAC01	WZA00		TUPEI	
	oikh	sac02	WZA90a		tupky	
	oikint	sac03	WZA90b		valmis	
	oikk	sbb00	wza90d		WYA00	

Table A3:B Patient procedures

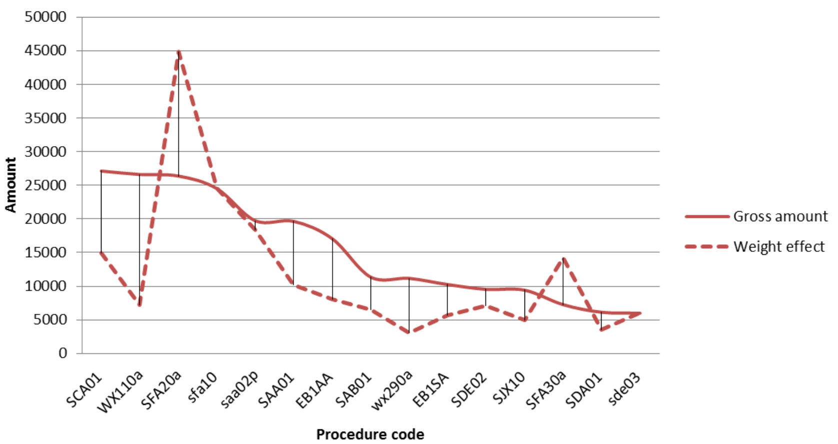
EB1AA	SFA20a	WZC00
EB1CA	SFA20b	WZC05e
eb1ha	sfa20k	WZC10e
EB1SA	sfa30a	
EBA00a	SFA30b	
EBA00b	SFA40a	
EBA00c	SFA40b	
eba00d	sfc00	
EBA00e	SFC01	
eba00f	SFC92	
EBA00g	SGA01	
EBA00h	SGA02	
EBA05a	SGA02e	
eba05d	SGA03	
EBA05e	SGA03e	
EBA05f	SGA04	
eba05g	SGA04e	
EBA05h	SGA05	
EBA20	SGA05e	
EBA30	SGB00a	
ECA10	SGB00b	
ECA40	SGB10	
ECA60	SGB20	
ECB00	SGB30	
SAA01	SGC00	
SAA01e	SGC10	
SAA02o	SGC40	
saa02p	SHA01	
SCA01	SHA02	
SCA02B	SHA03	
SCA02K	SHA04	
SDA01	SHB00	
SDA02	sjc01	
SDA03	SPF00	
SDA04	SPF40	
SDA05	SPF50	
SDA10	SPF50v	
SDC10	SXA20	
SDD01	SXB00	
SDE02	SXB10	
SDE03	WX105	
SDE04	WX110a	
SFA00	WX110b	
sfa10	wx290a	
sfa10k	WX290b	



Megaklinikka



Jyväskylä



Espoo

Figure A1 – Weight effect on procedures

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