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Effectiveness and efficiency of earthmoving in street construction at Espoo Public Works Department

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This thesis is the second research conducted in the topic of effectiveness and efficiency of earthmoving in street construction at Espoo Public Works Department. Earthmoving is an integral part of street construction and its effectiveness has a large impact on the overall result of the street construction unit. Among a total of approximately 35 earthmoving trucks in use at Espoo Public Works Department's street construction unit, any improvement in efficiency can yield significant cost benefit.

Earlier research conducted by Pasi Heiskanen in 2013 indicated that the efficiency of earthmoving in street construction at Espoo Public Works Department was below a satisfactory level. This was proven by quantitative research which revealed that the idling times of earthmoving trucks consisted of 49 % of the average workday in the year 2012.

On the basis of the first research, tools to improve efficiency were developed and put into use. However, the results of this thesis indicated that several of the problematic areas hindering efficiency have remained unchanged. Also the effects of the tools developed for improving earthmoving processes were underwhelming. Quantitative research of this thesis resulted in 57 % idling time for earthmoving trucks in 2014.

This thesis recommends Espoo Public Works Department to rethink its earthmoving demand fulfillment strategies. Enabling fluid cross-site truck usage is the most important aspect of reaching higher efficiency. As the primary recommendation of this thesis, the researcher suggests developing a smart device ordering and routing system for earthmoving trucks which addresses several key aspects currently hindering earthmoving efficiency.

Keywords	Earthmoving, Street construction, Municipal, Infrastructure,

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1 Introduction

This chapter introduces the thesis topic along with the research problem and methods. It also introduces the case company and its parent organization.

The commissioner of this thesis was Espoo city, Espoo Public Works Department. The mission statement of Espoo Public Works Department is as follows: "Espoo Public Works Department produces municipal construction, repairing and upkeep services in a cost efficient manner according to business principles" (Espoo kaupunkitekniikka - liikelaitoksen toimintaohje 2012: 1).

Street construction at Espoo Public Works Department is conducted by teams whose members are employed in-house. Large machinery which consists of excavators and earthmoving trucks including their operators are subcontracted from several different private sector companies. The earthmoving process can be roughly divided to 4 steps: Loading, unloading, driving and idling. Naturally when idling time increases, inefficiency increases as well.

Street construction and -upkeep are ongoing infrastructure services for Espoo city. On average, one standard 4-axle earthmoving truck in operation, subcontracted from a major service provider costs approximately 100.000 € per year. The annual need for Espoo Public Works Department's street construction is approximately 35 trucks, depending on the volume of operations. The issue has been under inspection in past research by Pasi Heiskanen at Espoo Public Works Department. The efficiency of the subcontracted earthmoving trucks was seen as below a satisfying level with an average idling time of 49 % of the workday. If these inefficiency problems could be properly addressed, considerable savings could be achieved (Heiskanen 2013: 25).

The research questions that this thesis intends to answer are:

-What is the current state of earthmoving efficiency Espoo Public Works Department?
-How can earthmoving efficiency be improved at Espoo Public Works Department?

This thesis will continue upon the past research of Pasi Heiskanen at Espoo Public

Works Department. Quantitative analysis was conducted to calculate idling times of earthmoving trucks at construction sites. Qualitative research was conducted in the form of interviews and targeted members of the street construction personnel. By creating a frame of reference to relevant literature and theory, an understanding of efficient earthmoving can be reached.

1.1 Espoo city

Espoo city services consist of Corporate Group Administration and four different sectors of service; Education and Cultural Services, Social and Health Services, Environment and Technical Services and Public Utilities Sector. Corporate Group Administration oversees the sectors and their sub departments including Espoo Public Works Department, which is a part of Public Utilities Services. In the departmental level, Espoo Public Works is divided into three service areas; upkeep, construction and environmental services (Organization 2012).

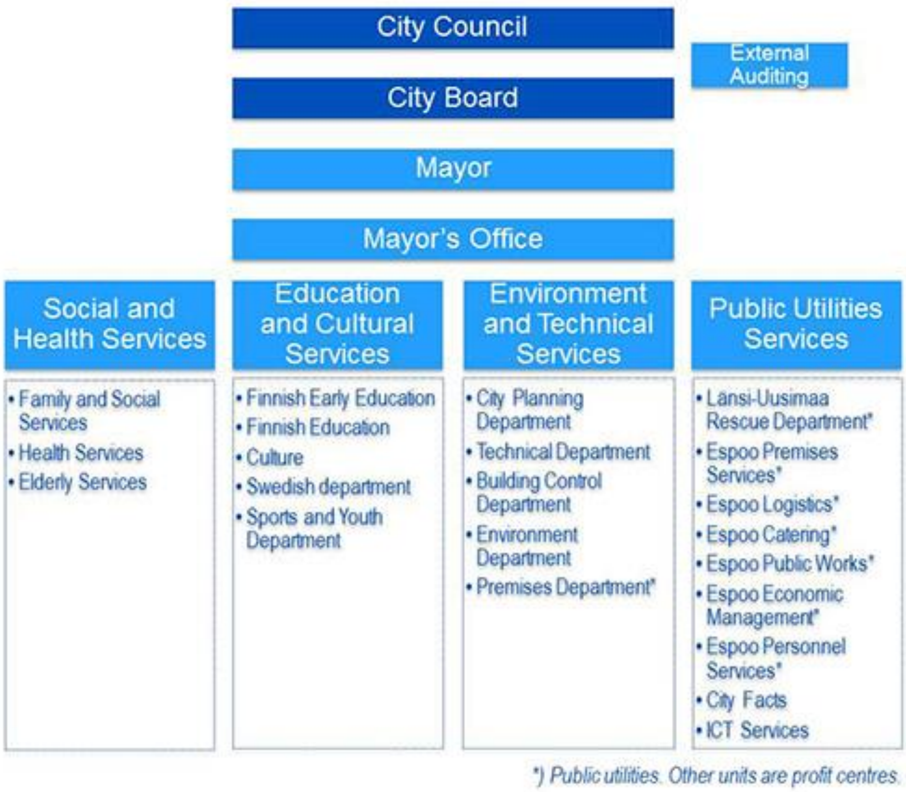

Figure 1. Espoo City organization chart

1.2 Espoo Public Works Department

Espoo Public Works Department is divided into three service units; upkeep, construction and environmental services. The construction service unit of Espoo Public Works Department is divided into 3 parts, northern and southern street construction districts and green space construction.

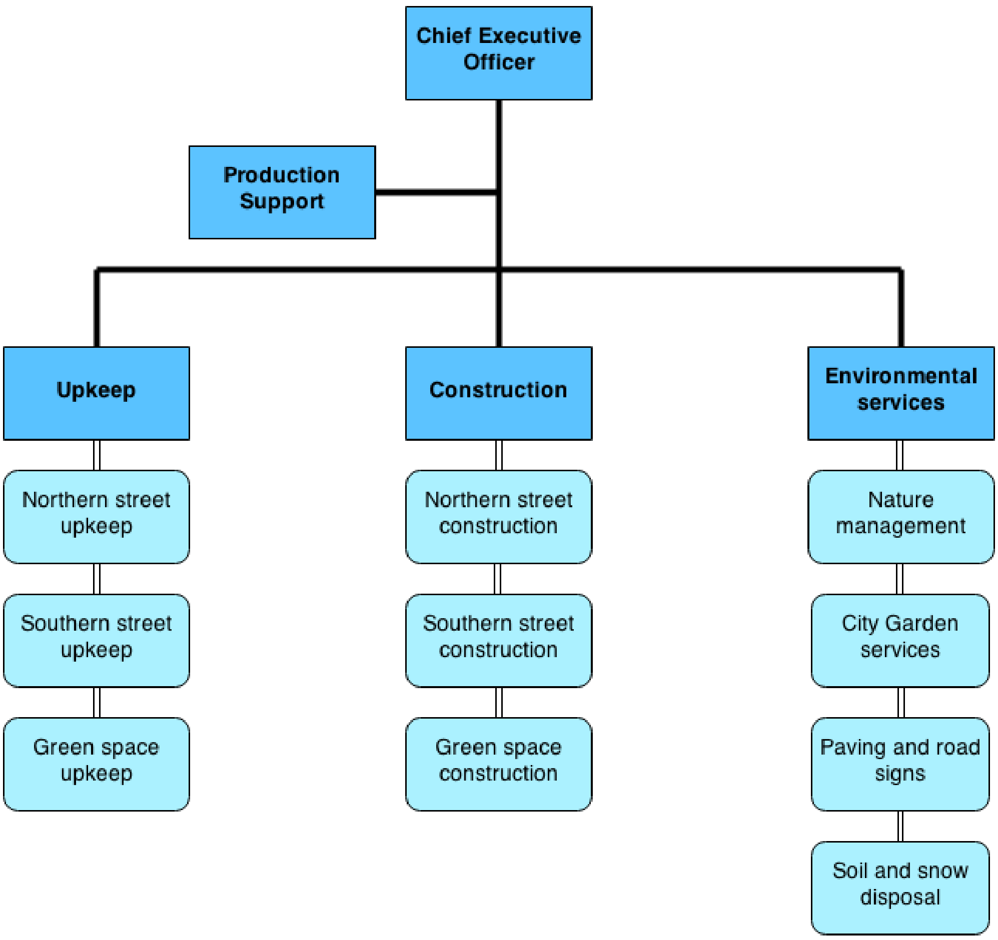

Figure 2. Espoo Public Works Department organization chart.

The business idea of Espoo Public Works Department is as follows; Espoo Public Works Department operates reliably and cost-efficiently in street construction, street and green space upkeep and upkeep of the city's forest property. Espoo Public Works Department looks after these aforementioned areas according to annual contracts and partnership contracts made with clients. Services are produced as subcontracted production and partially as own production (Vuoden 2014 talousarvio sekä taloussuunnitelma, 2013, 260). Approximately 20 % of all street construction projects are forwarded to Espoo Public Works Department and 80% of projects are tendered between private sector contractors (Heiskanen 2014: 10).

The services produced and provided by Espoo Public Works Department are based on contracts and orders. The biggest clients for Espoo Public Works Department are Espoo Technical Department and Espoo Premises Department, which means that the services are sold internally from department to another (Vuoden 2014 talousarvio sekä taloussuunnitelma, 2013: 258). Reorganization procedures for the current client-producer relationship and Espoo Public Works Department have been under contemplation in the past.

From a financial perspective, Espoo Public Works Department targets a positive bottom line in its operations and annual 5 % earnings on principal capital. The revenue for Espoo Public Works Department for 2014 was estimated at 54.6 million euros at the beginning of the year (Vuoden 2014 talousarvio sekä taloussuunnitelma, 2013: 258-260). The most recent forecast in the last quarter of the financial year estimates revenue at 46.080 million euros (Espoo Public Works Department 2014). The target of Espoo Public Works Department was to increase operational efficiency, flexibility and budget management. These targets were put into practice on a managerial level (Vuoden 2014 talousarvio sekä taloussuunnitelma, 2013: 258).

For the year 2014 the most important goals at Espoo Public Works Department were:

- Improving personnel and machinery efficiency by taking advantage of tools such as utilization rate measurements and working time arrangements.
- Reducing the average idling times of earthmoving trucks from 49 % to 44 %.
- Implementing a new infrastructure building information modeling (BIM) system for excavators which automates and aids in key aspects of excavation.
- Improving the construction unit's project monitoring capabilities by implementing a project tracking system and achieving a systematic control and tracking of workload and order backlogs.
- Introducing a uniform and easy-to-use ordering and tendering system to handle both customer side orders and service orders from subcontractors, including machinery, vehicle and construction subcontractors (Vuoden 2014 talousarvio sekä taloussuunnitelma 2013: 258).

2 Background

This chapter covers the fundamental aspects of street construction and earthmoving. Past research in their qualitative and quantitative forms is also inspected. These elements form the background for the thesis topics.

2.1 Characteristics of street construction

Public infrastructure projects in general are characterized by considerable risks in projects. These projects involve high complexity, involvement of many public and private stakeholders with conflicting interests and yield a high impact on the general public during project execution (Haponava and Al-Jibouri 2010: 854).

As in any construction process, the mutually conflicting elements of time, cost and quality are the most important determinants and indicators of success. The challenge of project management is to balance the trade-offs among these objectives (Fu 2011: 11). Positioning trade-offs are pervasive in competition and are essential to strategy (Porter 1996: 58).

The simple street construction unit at Espoo Public Works Department comprises of 3 tasks; earthmoving, excavation (including loading the trucks with earth and soil) and pipefitting (including all the manual work at the construction site). Excavators dictate the pace in which earthmoving can operate, while the pipefitters mostly dictate the pace in which the excavator can operate. In other terms, the street construction unit is as strong as its weakest contributor.

Street construction at Espoo city takes place in constructed areas. This means that the construction teams of Espoo Public Works Department have to take into consideration existing infrastructure on ground level and underground. Underground obstacles include electrical cables, optical fiber cables, water pipes, sewage pipes and drain pipes which must be taken into consideration in street construction. Soil type is also a factor that influences construction speed and required procedures. Ground level obstacles include cars, overhead power lines, street lights, trees, fences and other structures. The obstacles' existence and differing soil types can come as a surprise when documentation of construction sites are outdated or flawed (Heiskanen 2012: 3-4). Wintertime also has a negative effect on overall performance. The best time of the year for street construction is the summer (Street construction personnel interviews 2014). All of the aforementioned obstacles are factors that add difficulty to the planning processes and potentially hinder the progress of construction (Heiskanen 2012: 3-4).

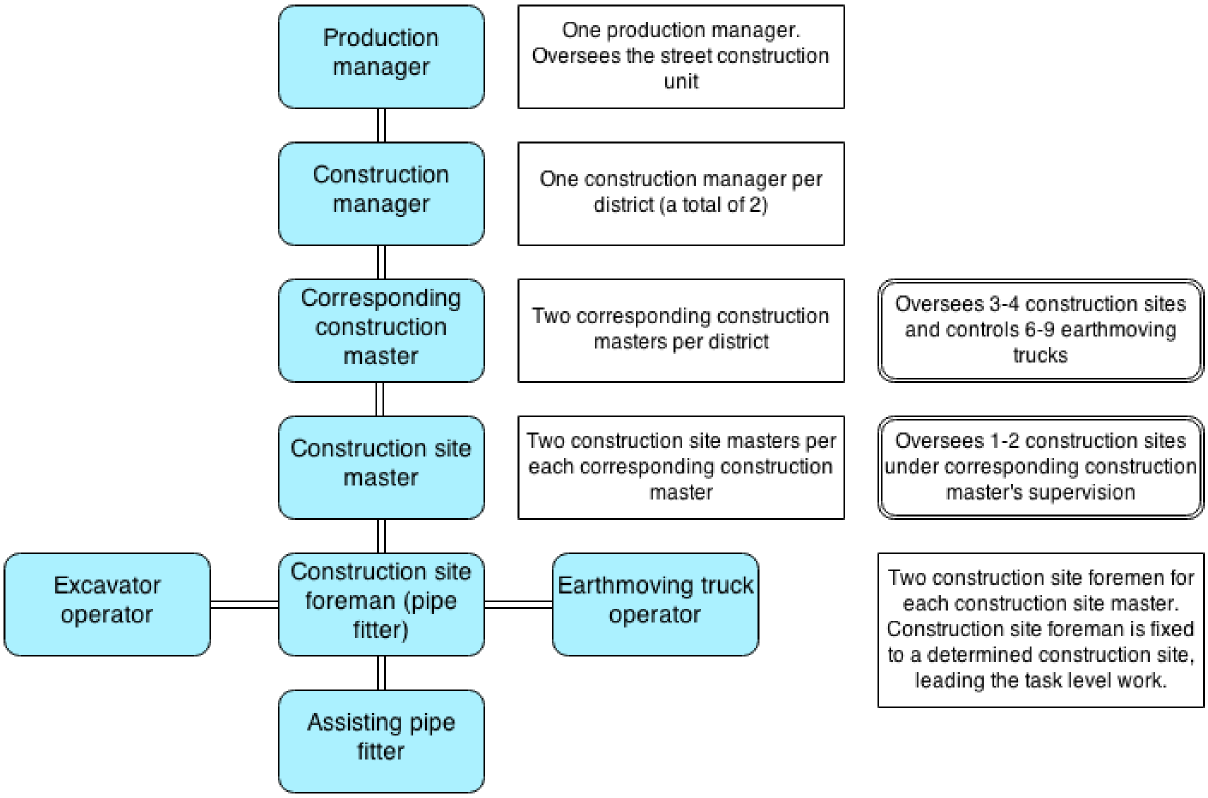

Figure 3. Street construction personnel hierarchy at Espoo Public Works Department.

2.2 Characteristics of earthmoving in street construction

Basic earthworks involve processes such as excavating, hauling, crushing, dumping and compacting (Fu 2010: 5).

A typical open pit (earthmoving) operation usually consists of four phases

1. The shovel (service; loading the trucks)
2. The loaded haulage road (service; travelling loaded)
3. The dump site (service; emptying the trucks)
4. The empty haulage road (service; travelling empty) (Ercelebi and Bascetin 2009: 434)

As an addition to these four basic steps, in many occasions for Espoo Public Works Department, the earthmoving truck is loaded with crushed aggregate at the dumpsite premises for the use of the serviced construction site.

For earthmoving to be successful, a high utilization rate for earthmoving trucks has to be maintained. This is especially true for hourly rate compensation models, where the truck is paid for, regardless of its utilization rate. The ability to serve excavators as their demand for earthmoving occurs is equally important. Naturally, while a construction site waits for earthmoving, the hourly fees for pipefitters and excavators are constant.

Figure 4. Standard 4-axle earthmoving truck being loaded under an excavator.

2.3 Earthmoving service

Currently, street construction at Espoo Public Works Department uses only subcontracted service for earthmoving operations. Subcontracted earthmoving trucks always include the driver. Espoo Public Works Department goes through public tendering in the private sector for earthmoving trucks to reach general agreement contracts.

The general agreement contracts specify the hourly prices for earthmoving service. The most usual price for standard 4-axle earthmoving truck service was 51.30 € per hour from Espoon KTK.

2.3.1 Contract agreements for outsourced earthmoving trucks

Various different companies take part in the tendering process but Espoon KTK which is the biggest subcontractor company for earthmoving trucks in the area gets the majority of service orders.

So far, the general agreement contracts have been valid for 2 years at a time, after which a new tendering process takes place. The general agreement contract specifies the terms of the service relationship between the contractor companies and Espoo Public Works Department. In order to get an earthmoving truck to the construction site, the corresponding construction site master must contact the subcontractor and make a service order. Fulfilled service orders are paid by the hour, whereas general agreement contracts determine the terms and conditions of the relationship but do not bind into any orders. The service order termination period is 2 workdays which means that an unneeded truck order is cancelled with a slight delay (Maansiirtokuljetuspalvelut 2014-2015; Sopimus 2013: 1, 4-5).

2.4 Past research

The topic of effectiveness and efficiency of earthmoving in street construction at Espoo Public Works Department has been researched before by Pasi Heiskanen in 2013. There is no research preceding Heiskanen's work. In his research, Heiskanen conducted both quantitative and qualitative research.

2.4.1 Quantitative research

In his research, Heiskanen conducted quantitative research to approximate the structure of the earthmoving truck's working day divided into 4 parts, loading, unloading, driving and idling. The quantitative research was based on 2012 data from the northern street construction district. The sample size was 3 two-week periods chosen at random, but always starting at the beginning of the two week billing period (odd week). The randomized two-week periods were weeks 5-6, 21-22 and 33-34. The research spanned over a total of 3148 paid working hours, 413 paid workdays (Heiskanen 2013: 3). Data for the research was collected from drivers work logs which are filled out after every workday and include data such as kilometers driven, hours in service, load material type, construction site and dump destination. After determining the average loading and unloading times along with average driving speed via discussions in interviews, the data set could be used to calculate average times for each of the 4 parts (Heiskanen 2013).

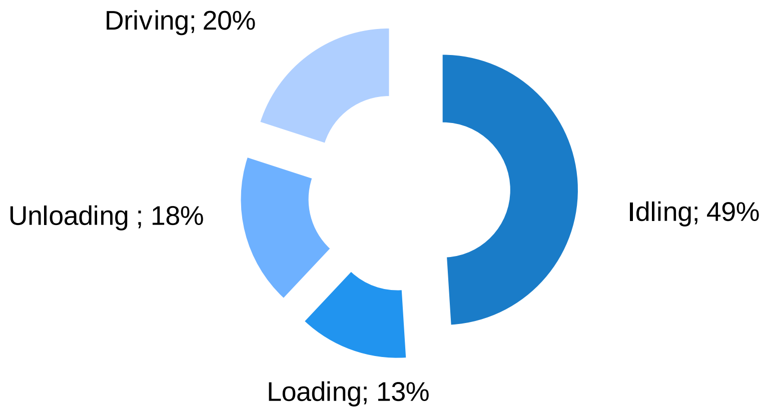

Figure 5. Structure of the average workday for an earthmoving truck at Espoo Public Works department in the year 2012.

2.4.2 Qualitative research

The qualitative research in Heiskanen's work was in the form of interviews. The interviews targeted 5 Espoo Public Works Department and 5 contractor side persons involved in street construction. The interviews consisted of 3 structured and 1 unstructured questions. In addition to the questions, discussion was held within the themes of the questions (Heiskanen 2013: 13).

Conclusions were possible to be drawn from these interviews: The ordering system and contract terms limited the flexibility to react to change. Corresponding construction masters hesitated to cancel earthmoving truck service orders because of perceived uncertainty in getting trucks back when needed. The optimal amount of trucks needed for a construction site was difficult to define. The coordination between construction sites was lacking and nonexistent between northern and southern street construction districts. Thus far, efficiency in earthmoving was not seen as of great importance or a critical factor of success (Heiskanen 2013: 16-17).

2.4.3 Research outcomes

The central finding of the research was that too many earthmoving trucks were being ordered compared to actual need. A seemingly cheap hourly fee was in effect, double the amount when calculating the actual effective working hour. As the first researcher of this issue, Heiskanen defined the optimal working day to have approximately 25% idling time of total paid working time, which was a far from the current situation. (Heiskanen 2013: 25)

General agreement contract terms were changed as a result of Heiskanen's research. Most important change was regarded the service order cancellation period. The previous service order cancellation periods were 2 weeks for long term orders (longer than 2 months) and 1 week for short term orders (shorter than 2 months). These periods were removed and replaced with a universal service order cancellation period of 2 days regardless of order length.

A major step in earthmoving operations improvement came in the form of an intranet fleet databank. This databank was established with Microsoft SharePoint. The databank contains information about all of the earthmoving trucks, excavators and other machinery. Contractor details, order status and order holder (corresponding construction site master) are also included in the data. This helps the corresponding construction site masters to see the bigger picture in Espoo Public Works Department's subcontracting status and also makes ordering and cancelling easier. An important feature in the fleet databank system was later developed for short term loans of earthmoving trucks between corresponding construction masters. The feature was designed to the improve utilization levels of earthmoving trucks and thus lower their idling times as well.

Driver assessment system was developed early 2014 to collect survey data about earthmoving truck and excavator drivers' qualities. Contract terms for earthmoving trucks and excavators state that a driver's working capabilities and qualities need to be at least at a good level. Dissatisfactory performance reviews are grounds for truck and excavator service order cancellation and replacement.

Further integration and data creation will come in the future along with the implementation of Microsoft Dynamics AX 2012 ERP-system although exact implementation and project details are yet to be decided.

All of the aforementioned reforms were made in order to improve the tools for active management of street construction operations at Espoo Public Works Department.

3 Research process

This chapter reviews the quantitative and qualitative research conducted for this thesis. The implications of the research results are also considered.

3.1 Quantitative research

The quantitative research for this thesis examined the idling times of earthmoving trucks in street construction. The research definitions in this thesis were the same as in Heiskanen’s (2013) research. The research was conducted to achieve continuity between previous research and current research in this thesis and provide evidence of potential efficiency change.

3.1.1 Quantitative research definitions

The data of this research is derived from work logs which are filled out by the truck drivers and include workday information and details. The work logs contain information such as construction site location, truck registration number, truck driver, amount of truckloads taken to the dumpsite and the destination of the dumpsite. The most usual truckload dump is Kulmakorpi for landmasses. Asphalt waste is taken to one of two asphalt dumpsites in Tuusula. In some cases, intermediate dump sites are used as their location is closer to the construction sites, but eventually need to be collected again and taken to the correct dump site. The research was limited to northern street construction district which operates within the same principles as southern street construction district.

In order to determine average idle times for a working day, some definitions had to be made. The estimations of average load time, unload time and driving speed were made from the basis of interviews conducted by Heiskanen. The estimated times were 15 minutes for load and 20 minutes for unload time.

Every truckload that is taken to the dumpsite naturally includes loading and unloading which adds up to 35 minutes. The last component is the driving time which comes from the distance from the construction site to the end destination and back to the construction site. Computer assisted route calculations were made to determine distances between sites. Average driving speed was estimated to be 60 kilometers per hour.

3.1.2 Research sample

The sample consisted of 3 two-week periods always starting at the beginning of the two week billing period (odd week). The periods were weeks 5-6, 21-22 and 33-34 in the year 2014.

The length of the workday from Monday to Thursday is 7:30-16:00. Fridays are shorter, 7:30-14:00. All workdays include a 30 minute lunch break (Maansiirtokuljetuspalvelut 2014-2015; Sopimus 2013: 6). Overtime and working on weekends are rare occurrences and didn’t occur during this research. All earthmoving trucks were priced at 51.30 € per hour for their service.

3.1.3 Quantitative research results

Weeks 5-6

The first two week period under inspection was the most efficient of all three. Among 13 earthmoving trucks in service, an average of 50 % of the working day was spent idling. The cost of the effective working hour was 102.60 € for this period.

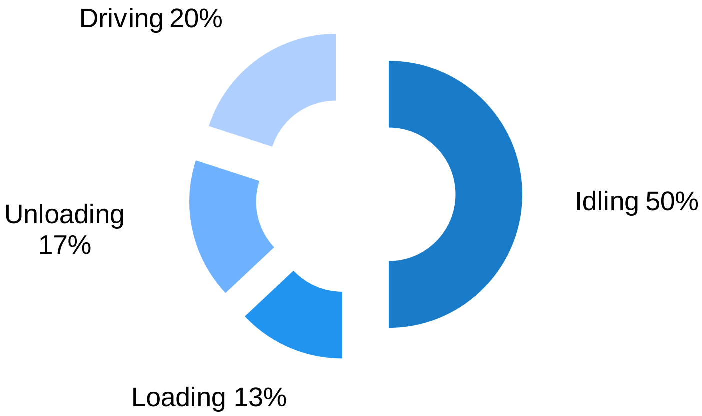

Figure 6. Average workday during weeks 5-6.

Weeks 21-22

The second two-week period resulted in 57 % idling time and 43 % effective working time among 13 earthmoving trucks. The cost of effective working hour was 119.30 € for this period.

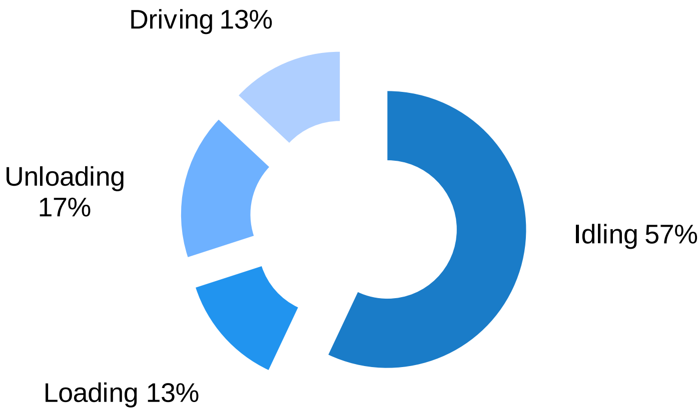

Figure 7. Average workday during weeks 21-22.

Weeks 33-34

The last two-week period was the least efficient with 63 % idling time and 37 % working time among 13 earthmoving trucks. The cost of the effective working hour was 138.65 € for the last period.

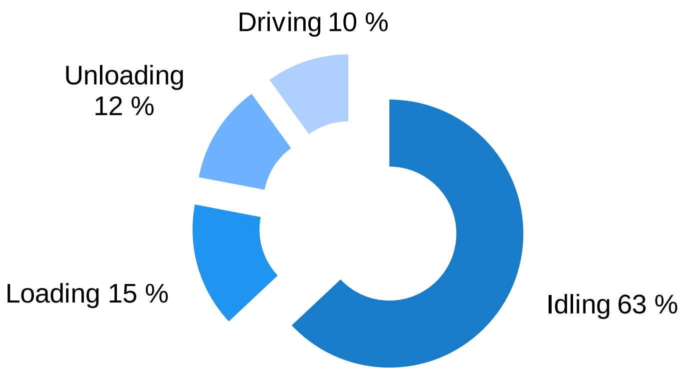

Figure 8. Average workday during weeks 33-34.

Research sample average

The final chart indicates the composition of an average working day in the research sample. The values are averaged from the three 2-week periods. The average cost of the effective hour was 119.30 €.

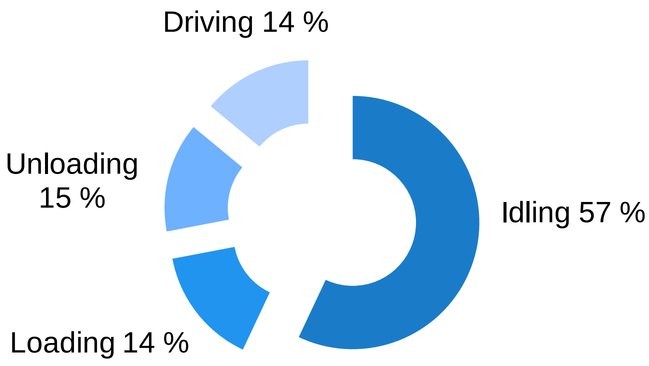

Figure 9. Average workday in the research sample.

3.1.4 Quantitative research conclusion

The quantitative research results indicated that idling time for earthmoving trucks at Espoo Public Works Department increased from 49 % to 57 % when compared to the year 2012. The quantitative research results reinforced the researcher's hypothesis that earthmoving efficiency at Espoo Public Works Department has not improved during the last two years.

The effects of newly appointed tools for efficiency improvement such as the machinery databank and changes in general agreement contracts for earthmoving trucks were, while useful on their own merits, nonetheless underwhelming. Furthermore, elements that were identified as harmful to efficiency such as the lack of earthmoving coordination between districts and the lack of performance oriented mindset have remained widely unchanged. The effective hour costs were not seen as controllable variables even in the presence of supporting functions, namely the tools developed to improve efficiency. A high amount of earthmoving trucks was required to maintain the *status quo*, an earthmoving system with average idling times of 57 % per day.

Future performance improvement measures that require active participation and leadership will require constant attention until their fluidity can be proven.

3.2 Qualitative research

The qualitative research in this thesis was in interview form. A total of five interviews were conducted in Finnish. Four interviews were granted permission to be recorded, one interviewee preferred not to be recorded. These in-depth interviews were conducted in person and their duration was between 30 minutes and 60 minutes. The interviewees were part of the street construction personnel in supervisory positions of different levels. The purpose of the qualitative research was to broaden the researchers understanding of the street construction unit's current situation within the themes of interview questions. Another goal was to create an understanding of attitudes towards the main topic of this thesis, furthering earthmoving efficiency and improvement initiatives. It is worth mentioning that the research and development team which works to improve street construction efficiency does not operate in the same premises as street construction. Also the district split affects the personnel's views of their street construction operations. The identities of the interviewees were kept confidential.

3.2.1 Interview structure

The interview consisted of 5 open ended questions regarding the current state of street construction, earthmoving and furthering its efficiency. The questions were broad in nature and resulted in wide variety of different conversations.

3.2.2 Interview analysis

Question 1

How would you act to fix the earthmoving efficiency problem?

Answer results

The interviewee responses to the first question were somewhat protective towards their own street construction operation. Three out of five respondents stated that the amount of earthmoving trucks could not be lowered in a reasonable way if the current amount of production is maintained. This response was given eventhough lowering the amount of earthmoving trucks was not mentioned. Two respondents mentioned that nearby construction sites have greater efficiency if their earthmoving operation is combined. The concept of advantage in larger scale operations in earthmoving was thus admitted, but the means to achieve it departmentwide in other ways was not clear to the two respondents. A difference within earthmoving drivers’ performance was also mentioned.

Question 2

What is your perception of the level of motivation in work teams at Espoo Public Works Department? What are the factors that lower motivation? What are the factors that raise motivation?

Answer results

The level of motivation at Espoo Public Works Department was seen differently among the interviewees. One respondent could not determine the level of motivation of work teams. Three respondents saw the level of motivation as good, however one of these respondents later admitted that the activeness of some workforce members was unsatisfactory. One respondent described the work teams to have alternating motivation between average and below average. A uniting topic was the “502” performance reward, which has been under several revisions during the last 5 years and lowered in amount. This performance reward was seen as an important aspect of maintaining workforce motivation. Decreasing the 502 reward was seen as a factor that limited motivation. Other aspects that were mentioned to raise workforce morale were simple praises for a job well done, workforce wellbeing activity days at sauna nights or ice hockey matches.

Question 3

What is the most important aspect in achieving efficiency in Espoo Public Works Department`s street construction?

Answer results

The third question resulted in two themes in which the respondents had similar views. Four out of five respondents said that good planning was crucial in achieving efficient street construction, two of whom stated that they had suffered from poor construction site planning which is an outsourced service. The second view was that capable, active and professional foremen and corresponding construction site masters were important in achieving efficiency. This requirement was stated by all five respondents in some form. Again the 502 performance reward and its increase were seen as important factors as well. Other issues mentioned were better timeliness, the usage of a written warnings to non-performers and the clumsiness and disconnection because of departmentalization, the buyer-producer relationship.

Question 4

By extending the responsibilities of the construction site foreman to include coordination of earthmoving need between different construction site foremen, better efficiency in earthmoving could reached (An appendix with information about the system was provided). What requirements or obstacles could such undertaking include at Espoo Public Works Department?

Answer results

Results for this question were mixed between responses stating that the construction site masters are responsible for this activity and descriptions of how the coordination of earthmoving is currently handled. When one respondent was describing the level of coordination of earthmoving trucks between different districts, the researcher could recognize that the statements were clearly exaggerated to a much more positive view than what the research had indicated. Only two respondents said that this kind of idea could be implemented in the current system. Two directly stated that this idea could not work in the current system because it interferes with the construction site masters' current responsibility areas. One respondent insisted that the idea was not implausible, but the current situation did not require implementation of the idea.

Question 5

Tablet guided work stage guidance, direct billing and truck tracking systems are getting more popular within the earthmoving industry. What requirements or obstacles could such undertaking include at Espoo Public Works Department?

Answer results

The last question was the most abstract to the interviewees. None of the respondents had experience with such a system. One respondent stated that a tablet operated infrastructure BIM (building information modeling) system for excavators had been a very positive experience and will surely be the future of excavation operations. One respondent stated that such systems could be beneficial in terms of efficiency and has thought about the usage of an information and notification applications for smart devices for general workforce communication purposes only and deemed such an application to be both usable and easily achievable. One respondent described the potential problems and cost implications if such a system would be implemented unsuccessfully.

3.2.3 Interview findings

Overall, the interview process was a success. The motives and opinions of the interviewees became clearer to the researcher while receiving valid concerns about the street construction process. The most important opinion that the interviews revealed was that the construction site foreman was generally not seen as a valid alternative to be in charge of earthmoving truck coordination. The significance in this opinion is that if real time or close to real time earthmoving coordination is desired, it cannot be achieved from other place than the construction site. Construction site masters are not fixed to a specific construction site at all times such as the construction site foremen, thus incomplete and untimely information limit the construction site masters’ capability of fulfilling the task. Eventhough the current responsibility area of earthmoving truck coordination is with the construction site master, with an implementation with the aforementioned requirements, the correct person for this task should go under close scrutiny.

4 Productivity and performance

This chapter reviews relevant theory and concepts regarding productivity and performance. Examples within the earthmoving theme strengthen the understanding of the concepts.

4.1 Determining productivity

Productivity is traditionally referred to the ratio of outputs to inputs. Beyond this abstract formula, there is no standard definition for productivity in construction. The most popular method of measuring productivity is with earned hours. This concept is based on a set of standard outputs or "norms". A unit of work per hour is determined and productivity can then be measured by the ratio of earned hours to actual worked hours (Shehata and El-Gohary 2011: 322). Productivity is defined in relation to an established base or norm, the need for appropriate and accurate benchmarks is apparent. A problem arises from the decision of how to obtain a baseline evaluation (Bernstein 2003: 51).

Example
An asphalt paving team of 2 persons has a set standard output of 50 m^2 *per hour. Incentivizing the workers' wages and rewarding an output greater than 50 m*^{2} *per hour could be effective, but only if a reliable norms could be established. In reality, asphalt paving, or any construction project, could be characteristic of high variance between daily or hourly outputs and thus be incompatible with standard output measurement.*

> "There is anecdotal evidence that great strides are being made in certain sectors of the industry, but… metrics and measurement represent one of the biggest challenges to be overcome in examining industry productivity, as there are few measures of success, no comprehensive baseline data, and few data on multifactor productivity, that is, productivity as influenced by a variety of factors" (Bernstein 2003: 47, 51).

4.2 Measuring productivity in earthmoving

For the application of earthmoving, measuring productivity faces same issues as the general construction industry, there is no standard determinant. In earlier research conducted on the effectiveness and efficiency of earthmoving in street construction for Espoo Public Works Department, Heiskanen had to create a measure of efficiency because such metric did not previously exist. Some estimations and generalizations were required to create the formula that could calculate the price of the effective working hour, the ratio of time in service and the time elapsed for an earthmoving truck during a workday.

For an earthmoving truck to be productive, it has to demonstrate high utility rate and readily service any appointed construction site. However, high utilization levels for earthmoving trucks could imply that too few trucks are in service. Similarly high service readiness could mean that idling times are high as well. Achieving the best results in earthmoving is a balancing act. When construction sites are variable in earthmoving requirements and earthmoving expenditure, accurately measuring productivity by cost is difficult as well.

As the asphalt paving example explained in chapter 4.1, the norm or standard output could be a specific objective number of truckloads or cubic meters transported, or kilometers traveled per day, but so far all of these aforementioned metrics have been seen to be unfit to describe effectiveness of earthmoving and unusable for potential efficiency incentives (Heiskanen and Franco 2014). Heiskanen (2014) also stated that the effective hour metric by itself is an incomplete determinant of earthmoving effectiveness and efficiency.

4.3 Measuring productivity in street construction

Efficient street construction is a multifactor process which strives in a state where all of the participants engage in effortless interplay. Cooperation and communication are important as is social fit among the working teams. Most importantly, thorough planning, competent foremen and management are necessary for efficiency and productivity (Street construction personnel interviews 2014).

The preferred outcome in the street construction unit is a situation where the participants are maximizing their contribution and utility in a situation where none of the participants can be made more efficient without compromising the efficiency of another participant.

An overarching metric that could describe the productivity and efficiency of a construction project has been sought after for some time at Espoo Public Works Department. Heiskanen suggests that the best metric could be the price of finished roadway square meter (Heiskanen 2014: 48). This metric could successfully capture the whole street construction process, all its cost factors and condense it to a figure of output. After longer term data collection across several projects has been conducted, standard outputs for street construction per euro amounts could finally be formed.

To maintain some measurability between construction projects and to develop norms or standard outputs, it could be beneficial to make a distinction between ordinary projects and "low efficiency projects", affected by clearly distinguishable factors. Similarly, delays caused by the customer, primarily Espoo Technical Department and Espoo Premises Department, could be billed from another budget grouping to determine the actual cost of operation while disregarding the cost of time delays unavoidable by the actions of Espoo Public Works Department (Heiskanen 2014: 47-48).

4.4 Performance rewards at Espoo Public Works Department

Rewarding efficient workers at Espoo Public Works Department was seen as an important aspect in maintaining good work morale and work output (Street construction personnel interviews 2014). These rewards are in the form of hourly bonuses to individuals, depending on their positive impact on the construction sites. Due to the absence of objective metrics such as standard outputs, the rewards are vulnerable to subjectivity. These rewards however, are not given to earthmoving truck drivers as they are a subcontracted service and not included in Espoo Public Works Department's internal payroll.

In the previous general agreement contract earthmoving trucks had a kilometer compensation for daily operation which exceeded 120 km between Monday to Thursday and 90 km on Fridays. However, previous research by Heiskanen (2013) lead to the cancellation of such contract clause. Although not an actual efficiency bonus, the kilometer compensation cancellation provoked speculation.

An easily understandable metric that is reliable and fair is called for, not only to measure efficiency and productivity but also to enable fair grounds for bonuses, also for subcontracted workforce.

4.5 Redundancy in earthmoving

A central challenge in risk management is to design a supply chain in a way that it can effectively respond to unforeseen events without significant cost increase. Careful analysis of supply chain cost trade-offs must be conducted in order to employ the correct amount of redundancy (Simchi-Levi 2010: 78).

Earthmoving is one of the three tasks required to conduct simple street construction. Unlike excavating and pipefitting which are static tasks, earthmoving is characteristic of higher uncertainty because variables such as traffic and movement between construction sites and dump site. A balanced amount of earthmoving, excavators and pipefitters have to be assigned to a construction site according to its requirements. Momentary slowdowns in street construction are prevalent and their constituents are always somewhat different. These factors increase the difficulty in subcontracting the correct amount of earthmoving trucks. To combat the uncertainty of earthmoving demand, some redundancy has to be employed, a safety stock of earthmoving.

Example

A construction site is in planning stages. The site in question will have slightly lower than average daily need for earthmoving. If one earthmoving truck satisfies a demand *of 1y tonnes per hour and the forecasted average demand for said construction site is 1.3y tonnes per hour, it will have no other choice than to hire 2 trucks and thus employ an average redundancy of 0.7y tonnes per hour. Because of the uncertainty of street construction in general, the momentary earthmoving need might deviate between 3y tonnes and 0,3y tonnes per hour. By employing 2 earthmoving trucks, the construction site assures that it can advance in site progress of an ordinary day, and still have some capacity to meet a busier day's demand. However during an average day the construction site will be 0.7y tonnes redundant and during an extraordinarily busy or slow day the static 2 truck standard will also perform poorly.*

Because this earthmoving problem is not an independent factor in street construction it can't be addressed without examining the effect it has on pipefitters and excavators and thus the overall advancement of the construction site. This means that an earthmoving truck that would reach 0 % idle time would only absorb its effectiveness from the other two street construction members which would carry the idle time that once was with the earthmoving truck.

In Espoo Public Works Department's street construction, the redundancy of earthmoving is not in a level of the redundancy example; corresponding construction masters control between 6 and 9 earthmoving trucks and are able to move the trucks according to earthmoving demand usually within a day's notice. However between different corresponding construction masters the interaction and collaboration reaction time is longer and between different regions which are northern and southern street construction units, earthmoving truck sharing does not occur at all (Street construction personnel interviews 2014).

In order to improve the efficiency of earthmoving at Espoo Public Works Department, the need for redundancy has to be lowered. As the redundancy example demonstrates, the larger amount of earthmoving trucks you can control with full flexibility to move to any construction site, the lower redundancy you have to employ. The ability to react to fluctuating earthmoving demand with means other than increasing redundancy has to be improved, which means significant overhauls to the current earthmoving process.

5 Fulfillment strategies

This chapter discusses the different strategies for customer demand fulfillment. In other words, it discusses the methods included in these strategies which make supply meet with demand. Examples and strategy identification within the earthmoving theme strengthen the understanding of the concepts.

5.1 Push, Pull and Push-Pull strategies

Push, pull and push-pull demand fulfillment strategies represent different means of reaching the satisfied customer (Simchi-Levi 2010: 35). In earthmoving, the customer is the construction site, more specifically the excavator. If the excavator isn't provided with an earthmoving truck, it cannot operate. In order to achieve efficient earthmoving, a proper fulfillment strategy needs to be implemented according to the limitations and requirements of Espoo Public Works Department's operations.

5.1.1 Push-based Supply Chain

Production decisions are based on long term forecasts in push strategies. Production correspondents base their decisions on available information of future demand. Push strategy shines in a supply chain which is predictable for long forecast periods. Economies of scale is a driver for a push-based strategy (Simchi-Levi 2010: 36-37). Economies of scale refers to cost advantage which occurs when production amount of a product or service is increased. Economies of scale is usually derived from spreading fixed cost between larger production thus lowering price per unit. In earthmoving operations, economies of scale is derived from lower variable cost by increasing synergy and operational efficiency over several server-client relationships.

Example
An earthmoving fleet of 3 trucks services 3 construction sites and meets demand at an acceptable level. When an earthmoving fleet of 4 trucks can service 5 similar

construction sites at the same level of service, economies of scale from lower variable costs is in use.

A push-based supply chain is usually slow to react to changing demand patterns. Determining production capacity is also problematic, as the determining factor can range from peak demand, average demand or something in between. Inefficient resource utilization can become an issue in a push-based supply chain as planning and managing are difficult. In the end, forecasts will always be wrong as you cannot perfectly match demand. As planning and forecasts extend further into the future, they become less accurate. Production capacity redundancy is normal in push systems. Push systems are most suitable to production and operations which can put overcapacity into good use (Simchi-Levi 2010: 36).

5.1.2 Pull-Based Supply Chain

Production is demand driven in a pull-based system. Production changes according to actual demand instead of forecasted estimates. The key enabler is efficient information flow about the actual demand along with point-of-service or point-of-sales data (Simchi-Levi 2010: 36-37).

In street construction, this point of service data refers to current construction site status and the need for less or more earthmoving. This need can be determined by a construction team member with the best available knowledge.

Pull systems have several benefits once successfully implemented:

-Decreased capacity redundancy required

-Improved ability to react to changing demand

-Improved ability to make production serve peak demand and minimize losses for low demand.

Pull systems are most beneficial in short supply chains where reacting to demand can be timely and effective. In long cycle time supply chains, pull systems are not as effective because reacting to demand would be impractical and rarely on time. Pull systems cannot take advantage of economies of scale by spreading fixed costs among larger production amount or capacity as production is constantly changed according to actual demand (Simchi-Levi 2010: 36-37). To take advantage of the positive sides of both supply chain strategies, a company must employ a combination of push and pull strategy.

5.1.3 Push-Pull Supply Chain

In a push-pull supply chain the initial stages are designed as push-systems. In this system, the initial stages of production are characteristic of low demand uncertainty, thus viable for push-based strategy. The later stages in a push-pull supply chain are considerably more variable in demand which encourages a specific turning point in strategy (Simchi-Levi 2010: 37-38).

Example
A baseline fleet of 1 earthmoving truck for a construction site has been defined. This single static earthmoving truck is employing a push strategy. In addition, the construction site has access to an additional truck via smart device ordering system. The push-pull boundary is met when the construction site orders the additional truck from the ordering system and thus employs a demand pull-based fulfillment strategy.

A push-pull system can react to changing demand most effectively only after the push-pull boundary has been reached. The push-pull boundary could be moved even further to the left (see figure 10) by tying 0 earthmoving trucks to a single site. This would mean that the static push strategy only determines the amount of earthmoving trucks in overall operation, none of which tied to a single construction site.

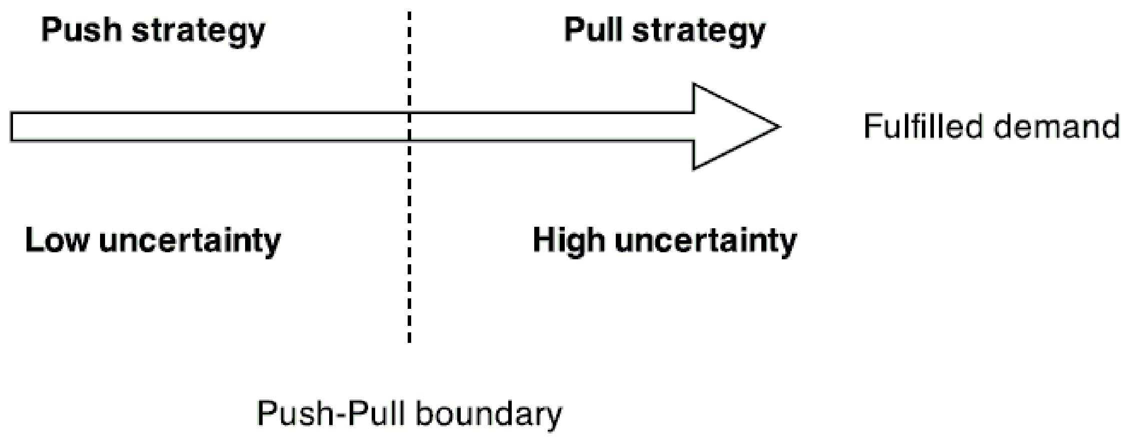

Figure 10. Push-Pull strategy visualization.

In reality, almost all supply chains are push-pull supply chains. The distinction of whether a supply chain is referred to be employing push or pull strategy comes from the location of the push-pull boundary. When the boundary moves further to the right, less and less reaction comes from current demand patterns and while going further to the left equates to more reaction earlier in the supply chain. Determining the most effective location for the push-pull boundary in operations is paramount for efficiency (Simchi-Levi 2010: 38).

5.2 Demand fulfillment strategy at Espoo Public Works Department

Demand uncertainty for earthmoving in street construction is relatively high. Daily demand variability degrades performance and results in high idle time. The current norm for the usage of earthmoving trucks is nearly a closed system. Most of the time earthmoving trucks are serving only one client, their dedicated construction site.

The “demand” fulfilment cycle times are low. The single cycle time of an earthmoving truck consists of driving to a construction site, loading cargo, driving to the dumpsite, unloading cargo and driving back to a construction site, which equates to less than 1.5

hours in almost all situations assuming no idle time at the construction site. Currently, the construction sites do not define their need for earthmoving demand in single cycles *i.e.,* as single truckloads, such as in a pull-based fulfilment strategy. Instead the current state is a static server-client relationship with little interference, a more push-based strategy.

Earthmoving truck sharing occurs mostly within construction sites under the control of one corresponding master. The biggest barriers are between corresponding masters and between northern and southern districts (Espoo Public Works Department street construction personnel interviews 2014). At the time of this research, a total of 35 earthmoving trucks were subcontracted for street construction. Economies of scale in this amount of earthmoving trucks exists, but the potential synergy of the whole earthmoving fleet working together is not utilized. By improving the synergy of earthmoving trucks with pull mechanisms, the need for high amounts of redundancy in earthmoving can be lowered.

A pull mechanism reacting to short timespan fluctuations such as a smart device ordering system is needed for Espoo Public Works Department. The main goal of this pull mechanism is to improve synergy between the whole fleet and improve ability to react to short term demand fluctuations. Another important factor is the enabling of cross-site and cross region truck sharing and truck allocation. A smart device ordering system could achieve better service levels with a same sized or even a smaller fleet of earthmoving trucks.

6 Solution discussion and suggestion

This chapter introduces and proposes solutions for earthmoving efficiency improvement. Both positive and negative aspects of the solution as well as other issues are evaluated.

6.1 Efficiency solution basis

Fleet management software and global positioning systems (GPS) in earthmoving trucks are becoming the norm also in the Finnish trucking industry. Finnish infrastructure service firms such as Stara and YIT Rakennus Oy Infrapalvelut have conducted research and development in order to improve their trucks' tracking systems and control elements (Luotamo 2010; Salonen 2013; Laitinen 2013). However, Simchi-Levi (2010) states that the business value of IT investments should be charecterized by goals such as reducing headcount, lowering operational costs, supporting growth, integrating business functions and increasing business speed, which are not the immediate goals that a tracking system or fleet management software would fulfill.

The problematic areas in street construction such as unpredictability, high redundancy, low synergy of earthmoving trucks *et cetera*, cannot be addressed with better control or tracking elements. Control elements are not useless however, but their value is diminished by the absence of a metric of productivity, a baseline value or a standard output which to draw comparison to or incentivize. Taking into consideration the problem areas to reaching efficient and productive earthmoving in street construction, the researcher developed a concept of a truck routing and ordering system.

6.2 Truck routing and ordering system

The routing and ordering system is a two way communication system. The earthmoving trucks will have a smart device in their cabin which serves the functions of accepting truckload order to construction site and route guidance to the correct construction site. In addition, the trucks can set their status on idle and their estimated time period for idling. All construction sites also have a smart device. Their device will perform order specifications, the amount of earthmoving trucks needed at specificied times. In other words, all construction sites would determine their earthmoving need for the time being and for the rest of the working day.

6.2.1 Benefits of the truck routing and ordering system

In this system, the earthmoving trucks are not in a static single server-client relationship but are always directed to a construction site with a demand for earthmoving, regardless of construction district or past co-operation issues between corresponding masters. This system will allocate all of Espoo Public Works' earthmoving trucks into a single functional pool which can be much more effective. The unpredictability of street construction and the constantly deviating demand for earthmoving can be met more easily from a larger whole.

As a larger whole, the economies of scale from lower variable costs can be achieved through higher synergy and cooperation. Construction sites with a need for more earthmoving trucks will have its demand met while another construction site with a need for less earthmoving will not have to keep trucks idling. The need for redudancy to ensure a certain service level will be significantly lower as the amount of trucks able to service any construction site is higher while at the same time trucks will not be bound to a single construction site.

Higher utilization rates can be achieved when the earthmoving demand is met between all operations, not just a single construction site or a handful of construction sites. Earthmoving trucks' working hours can be effectively filled with productive work throughout the day, guiding the trucks between construction sites with a need for earthmoving, which is not a possibility in the current system.
In a system where earthmoving truck service is paid by the hourly fee, the ability to make earthmoving trucks active throughout the day will force the service payment model to work in the favor of Espoo Public Works Department, not the service provider.

Depending on implementation possibilities, earthmoving demand fulfillment could be changed into a considerably more pull oriented strategy with single cycle fulfillment.

This would mean that every truckload is given from the routing and ordering system. In single cycle fulfillment, the earthmoving fleet would be in its most effective state.

6.2.2 Obstacles of the truck routing and ordering system

As mentioned in chapter 3.1.6, the implementation of various tools in the past have yielded underwhelming results. A guiding principle for earthmoving needs to be established in order to make any advancement in efficiency:

High costs and low utilization levels of earthmoving trucks are not acceptable.

This is a fundamental guideline which is not fully followed at Espoo Public Works Department. In effect, currently no one is held responsible for high costs and low efficiency in earthmoving. Without appropriate leadership and motivation towards the right direction, the tools that enable efficiency will remain unused and efficiency targets unreached.

The recommendation that this thesis suggests is based upon the assumption that high earthmoving costs and low utilization causes the responsible parties to take action in order to reduce and eventually minimize their presence. It is only after Espoo Public Works Department can realistically assume that all tools that improve efficiency are used to their potential, that system implementation should be taken further.

In the current situation, if construction sites and corresponding construction masters are given freedom to advocate their own interest in earthmoving, a situation might occur where almost no one is coordinating their earthmoving trucks between construction sites and prefer to employ high redundancy and higher costs.

Assuming a successful implementation of the truck routing and ordering system, an issue may arise from increased diesel consumption from lower idling times of earthmoving trucks. Earthmoving trucks’ diesel consumption is around 50 liters per 100 km, a considerable sum in operating expenses. To offset this change, earthmoving contractors might object the new system implementation or its usage. This issue would fix itself after the next tendering period where contractors would be familiarized with the system where less idling exists and adjusted service prices accordingly. A more direct tool for Espoo Public Works Department to enforce the change and the system implementation is termination of service for lack of co-operation and compliance to development initiatives, a clause in earthmoving truck general contracts (Maansiirtokuljetuspalvelut; Sopimus 2014-2015 2013: 10-11).

6.3 Earthmoving truck service order ownership issues

In the current system, corresponding construction site masters control the amount of earthmoving trucks under their service and pay for the service accordingly. These considerations are noticably different when earthmoving changes from an always-on single server-single client relationship to a more demand pull-based multiple client system.

In the current system, expenditures from earthmoving services are covered by the same corresponding construction site master. Earthmoving expenditure allocation becomes significantly more complicated when earthmoving trucks are not fixed to one construction site, corresponding master, or even to the same construction district. To achieve successful expenditure allocation, a unit of work has to be established. Whether on the basis of transported truckloads, cubic meters, time in service or another definition, the measurement of choice needs to be billable and a good representation of tangible earthmoving service.

The second consideration is decisionmaking regarding the actual amount of trucks in service. In this more demand pull-based system, the earthmoving trucks are shared between all members in the pool. The amount of earthmoving trucks in service needs to be relative to the current street construction operation, not solely to the need of a single corresponding construction master. The desired earthmoving service level along with the required amount of earthmoving trucks (elements, which are positively affected by a successful implementation and usage of a truck routing and ordering system) must be established with the knowledge of the ongoing street construction operations.

In order to adress these issues, the researcher suggests following a set of distinct definitions.

6.3.1 Earthmoving truck service order ownership issue solutions

The service provided by earthmoving trucks in street construction should be based on the presumption, that it concentrates solely on transporting landmasses between dumpsites and construction sites. This presumption ensures that all other ambiguous activities listed as general service truckloads (huoltoajo in Finnish) are performed appropriately by their dedicated service trucks.

The amount of earthmoving trucks can be determined with a simple definition, a "parking lot" system, which avoids ambiguity in the decisionmaking process. In this system, all earthmoving trucks start their workday at a figurative parking lot. When service orders are placed at the construction sites, earthmoving trucks dispatch to fulfill the workday's demands. If no service orders are made, the earthmoving truck returns to the parking lot. If there are no earthmoving service orders for an earthmoving truck in one complete day, the earthmoving truck order is cancelled.

When service orders are defined by truckloads, the costs can be appointed and quantified between their users. The final cost of the earthmoving service will be divided between service users according to the amount of truckloads transported for each user.

Example

$$\frac{Your\ truckloads\ transported}{Total\ truckloads\ transported} = Your\ service\ cost\ responsibility$$

and

*Total cost of service * Service cost responsibility = Your service cost*

For example

$$\frac{2\ of\ your\ truckloads\ transported}{10\ truckloads\ tranported\ in\ total} = 0{,}2\ or\ 20\ \%\ service\ cost\ responsibility$$

and

*Total cost of 100 € * Service cost responsibility of 0,20 = Your service cost of 20 €*

With the help of these definitions, expenditure allocation and decisionmaking in earthmoving truck amounts becomes systematic and objective. Once again, it is worth noting that the ability of this set of definitions to increase efficiency is based upon the assumption that high earthmoving costs and low utilization causes the all responsible parties to take action in reducing and eventually minimizing their presence.

6.4 Outsourced demand fulfillment service

In terms of furthering efficiency in earthmoving, a consideration that has not yet been fully explored is a completely outsourced demand fulfillment service. To explore this possibility further, the researcher contacted three major earthmoving service providers, Espoon KTK, Helsingin KTK and Konerinki by telephone call and discussed the prospect of entering a demand fulfillment based service relationship.

Demand fulfillment based service relationship means that Espoo Public Works Department enters a service contract with a single earthmoving service provider. This service provider then assumes responsibility for all earthmoving demand fulfillment. Before entering a contract, demand fulfillment service level will be specified in terms such as cubic transported cubic meters of landmass per day or as service availability (determined in time for demand fulfillment to arrive). The significance in this arrangement is that the service provider offers a certain service level and then addresses the optimization and efficiency problems by itself. If the service provider is particularly effective in resolving the problem faced by Espoo Public Works Department, it also gains all the cost benefit from it. All three of the aforementioned companies indicated willingness to submit a tender offer and listed additional companies likely to be interested in submitting an offer as well.

A completely outsourced demand fulfillment service can improve earthmoving efficiency by moving all responsibility of efficiency improvement to the service provider. From Espoo Public Works Department’s point of view, actual cost reduction is only as high as the new contractual service cost. Most likely all of the risk and reward in earthmoving service research and development would be moved to the service provider’s side, contrary to Espoo Public Works Department’s interest.

Effective supply contracts help firms to achieve global optimization by allowing buyers and suppliers to share risk and potential benefits (Simchi-Levi 2010: 66).

The researcher suggests entering a demand fulfillment service relationship only in the following situations:

-It is seen that earthmoving efficiency improvement coming from inside of the organization is not as a realistic scenario.

-It is realistic to assume that new tools developed to improve earthmoving efficiency will be left unused to their potential.

- A mutually beneficial solution and service contract can be achieved (Including the optimal use of research and development and know-how of both parties).

7 Synthesis and discussion

The last chapter views the thesis as a whole.

7.1 Reliability and validity

Reliability refers to the research's ability to give non-random results (Hirsjärvi, Remes and Sajavaara 1997; 226-227). Yin (2009: 45) suggests that a case study is reliable when an auditor could repeat the procedures of a thesis and arrive at the same results. Detailed descriptions of past research increase reliability, as does the conscious attempt to minimize errors and biases. These aforementioned methods were used to increase the reliability of this thesis.

Validity refers to the research method's ability to measure what is supposed to be measured. The employed research methods do not always measure what is hoped for, the validity of a research can vary according to the researchers subjectivity (Hirsjärvi, Remes and Sajavaara 1997; 226-227). Yin (2003: 41) categorizes validity into 3 different categories.

Construct validity aims to achieve the operational set of measures for the concepts that are being studied. Construct validity can be improved with 3 methods; Using multiple sources of evidence, establishing a chain of evidence and by having the case study draft reviewed by key informants. This thesis utilized all three aspects. This thesis also utilized triangulation, a combination of research methods, both qualitative and quantitative (Yin 2003: 41-42, 3). In addition to interviews, the researcher participated in informal conversations with numerous different members of Espoo Public Works Department's personnel. The chain of evidence method was used in qualitative research by recording interviews and writing notes of statements and conversations of interest. This case study was reviewed by the key informant of street construction research and development, Pasi Heiskanen, in several occasions.

Internal validity refers to the causal relationships of phenomena. If a researcher concludes that event A leads to event B, when in fact the causal relationship was between event A and a formerly unknown event C, the research suffers from low internal validity. Internal validity is furthered by explanation building and thorough causality mapping which is achieved by thorough research of all explinations and possibilities. This thesis and its researcher aimed to achieve as holistic of a view of earthmoving and street construction as possible and the researcher was able to achieve good internal validity with reasonable confidence (Yin 2003: 42-43).

External validity determines whether or not a study's findings are generalizable beyond the immediate case study Yin (2003: 43-44). suggests that theory can be used in order to reinforce external validity in single-case studies. The external validity of this thesis is at a good level within the limitations and specific problem which areas are inspected. This holds true to especially the theory and concepts used in this thesis. However due to the specifications of earthmoving at Espoo Public Works Department, the collection of methods to achieve more efficient earthmoving elsewhere could be somewhat dissimilar.

7.2 Conclusion

The curret state of earthmoving efficiency for street construction at Espoo Public Works Department is still at an unsatisfactory level. An average idling time of 57 % of the average workday for an earthmoving truck was calculated in the quantitative research part of this thesis. Despite earlier research and development, efforts taken in earthmoving improvement by the street construction personnel have been scarce.

The general opinion within the street construction workforce was that any meaningful efficiency improvement in earthmoving cannot be achieved. High costs and low utilization of earthmoving trucks were seen as a part of the norm.

Defining efficiency in the construction industry has always been a difficult task. There are no universally accepted standards for efficiency. The most usable measurement of efficiency for earthmoving trucks in street construction has been the idling time measurement, which has its own merits and weaknesses.

Employing a suitable strategy for demand fulfillment is key for efficiency improvement. Given the right circumstances, a truck routing and ordering system could implement the appropriate strategies and significantly improve efficiency. Beyond the primary recommendation of this thesis, some efficiency improvement could be attained from an outsourced earthmoving demand fulfillment service from a single service provider.

7.3 Recommendations

The primary recommendation of this thesis is to develop and implement a truck routing and ordering system in order to improve earthmoving efficiency. Before pursuing this solution, it is essential to ensure that implementation and usage does not fall into the same pitfalls as previous efficiency improvement tools. If street construction personnel does not share the same goals with the research and development team, reaching any meaningful efficiency goal will be difficult.

The secondary recommendation of this thesis is to explore the single earthmoving service provider model further. If it is seen, that earthmoving efficiency improvement cannot be achieved internally, outsourcing demand fulfillment service can achieve at least some efficiency benefit.

In order to gain favourable results among the street construction workforce at Espoo Public Works Department, leadership and motivation will need to be reshaped and aligned with a performance and change oriented mindset.

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Nokkamiehen vastuualueen laajentaminen

Nokkamiehen toimenkuvaan on kaavailtu mahdollista muutosta. Nokkamiehen vastuulle lisättäisiin maansiirtoautojen tarpeen kartoittaminen omalla työmaalla sekä yhteydenpito aluksi muutaman muun työmaan välillä. Vastaisuudessa nokkamies olisi siis yhteydessä myös muihin nokkamiehiin ja heidän maansiirtotarpeisiinsa. Puhelimella tapahtuva yhteydenpito laajentaisi maansiirtoautojen yhteiskäyttöä.

Päätöksentekomahdollisuus kuorma-autojen siirroista olisi vastaisuudessa myös nokkamiehellä vastaavan mestarin ja työmaarakennusmestarin lisäksi.

Oleellinen kehitystavoite nokkamiesten ringin muodostamisessa olisi maansiirtoautojen yhteiskäytön saavuttaminen tehokkaasti myös eri vastaavien mestareiden ja lopulta pohjoinen/etelä alueiden välillä.

Tämä yhteistyön tehostamishanke olisi ensiaskel kohti sujuvampaa, mahdollisesti tabletilla toimivaa ajojärjestelyä kohti. Järjestelmä ohjaisi maansiirtoautoja niitä tarvitseville työmaille vähentäen odotusaikoja toisaalla ja tehostaen kaivamista toisaalla. Nokkamiesten työpanos tässä vaiheessa olisi yhä maansiirron tarpeen määrittäminen, mutta ringin sijasta suoraan sähköiseen järjestelmään, joka ohjaisi koko maansiirtotoimintaa.

Motivaattorina työryhmille ja nokkamiehille toimisivat tehostuksen perusteella jaettavat kannustepalkkiot. Hyvitys ja korvauskäytännöt kuorma-autojen yhteiskäytöstä luotaisiin hyödyttämään kuorma-auton lainaajaa ja lainaksiottajaa, hyödyt näkyisivät lopulta aina kannustepalkkiossa. Tehostamisen myötä kuorma-autojen polttoainekulutus saattaa kasvaa, jonka vuoksi kuorma-autoja varten tulisi myös miettiä suoritteisiin perustuvia korvausrakenteita.