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Ilkka Lehtinen

MATERIAL HANDLING OPTIMIZATION IN A CLEANING COMPANY

– A LEAN SIX SIGMA APPROACH

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MATERIAL HANDLING OPTIMIZATION IN A CLEANING COMPANY

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The purpose of this thesis is to provide a general view of two of the most popular quality thinking systems, Lean and Six Sigma, which can be either separated or, as is the case in today's quality work, utilized simultaneously. The origins of the words are described and a short history presentation leading to the current status of the systems is given. Purpose was to open up the ideas at a general level so that the most common philosophical basis, methodologies and concepts become known. Because two systems utilize a lot of similar way of operation it is explained why in today's world the two are presented as one concept named Lean Six Sigma. Because of the huge amount of content in both two concepts, the presentation in this thesis is limited. This thesis is meant to be as a basis of the most common issues connected with two systems and using the thesis it is possible to find more information in literature and articles published in the internet. The thesis also presents an exemplary research project based on Lean Six Sigma thinking which is on purpose selected in an untypical way to broaden the view where the concepts can be used. The research concentrates on material management of a company and the result is that it is essential to do material forecasting to minimize the stress of the employees and enabling them to concentrate on their actual work. As a summary the Lean and Six Sigma current status in general, importance and the role in general management are estimated.

KEYWORDS:

Lean, Six Sigma, kaizen, flow, pull system, DMAIC, data driven problem solving

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Ilkka Lehtinen

MATERIAALIN HALLINTA SIIVOUSPALVELUYRITYKSESSÄ

- LEAN SIX SIGMA -LÄHESTYMISTAPA

Tämän työn tavoite on luoda katsaus kahteen maailmanlaajuisesti ylivoimaiseen, erillisinä järjestelminä pidettäviin laatuajattelumalleihin, Leaniin ja Six Sigmaan. Työssä kerrotaan molempien metodien ja niiden nimityksien alkuperä sekä perehdytään niille ominaisiin toimintamalleihin, ja annetaan selventävä kuva niistä niin, että ajattelumallit kokonaisuutena tulevat yleisellä tasolla selviksi. Kumpaankin ajattelumalliin liittyvien yleisimpien käsitteiden sisältö avataan. Työssä valaistaan Leanin ja Six Sigman eroja ja yhtäläisyyksiä, mistä johtuen käsitteet tätä työtä kirjoitettaessa on yhdistetty Lean Six Sigmaksi. Leanin ja Six Sigman laajuuden vuoksi työn esitystapa on rajallinen, mutta työtä apuna käyttäen on mahdollista löytää kirjallisuudesta ja internetiä apuna käyttäen valtavasti lisätietoa niiden toteuttamiseksi. Työssä esitetään Lean Six Sigma -metodiin perustuva tutkimusnäyte, joka on tarkoituksellisesti epätyypillinen materiaalinhallinnan lähestymistapa, jotta käsitys ajattelumallien monikäyttöisyydestä voi laajentua. Tutkimuksessa on tutkittu erään yrityksen materiaalinhallintaa sen tehostamisen näkökulmasta, ja tutkimuksen tuloksena todetaan materiaalinhallinnan olevan tärkeä tekijä operatiivisen sujuvuuden ja ennustettavuuden varmistamiseksi. Materiaalinhallintaa esitetyllä tavalla muuttamalla suunnitellummaksi voidaan yrityksen työntekijöiden tehokkuutta kasvattaa, sillä operatiivisen henkilöstön osuus materiaalin hankinnasta pienenee, ja heidän työpanostaan voidaan tehokkaammin käyttää varsinaiseen päätyöhön. Tutkimuksen tuloksena korostetaan työntekijöiden stressin vähenemistä minimoimalla heille turhaa materiaalinhallinnasta huolehtimista. Yhteenvetona työssä pohditaan mainittujen laatuajattelumallien tilaa, tärkeyttä ja osuutta johtamisessa yleensä.

ASIASANAT:

Lean, Six Sigma, kaizen, flow, pull system, DMAIC, data driven problem solving

CONTENT

APPENDICES

LIST OF ABBREVIATIONS (OR) SYMBOLS

λ	Average amount of time for an item to arrive into the queue (Little's law)
σ	Greek letter sigma used in statistical theory for standard deviation
C	Amount of units in one box (Kanban calculations)
D	Need in the workplace (Kanban calculations)
DPMO	Defects Per Million Opportunities
L	Average amount of units in queue (Little's law)
N	Kanban quantity (Kanban calculations)
n_{all}	Amount of all units produced (OEE calculations)
n	Amount of units produced (OEE calculations)
n_D	Number of defected performances (OEE calculations)
n_{ok}	Amount of good quality units (OEE calculations)
n_{Opp}	Total number of opportunities (OEE calculations)
OEE	Overall Equipment Effectiveness
P	P value is probability that we are wrong in saying that something is different. Statistical analysis term. Also known as Producer's risk.
r	Correllation factor
S	Safety stock (Kanban calculations)
T	Fulfill time (throughput time) (Kanban calculations)
$t_{d,unplanned}$	Unplanned disturbance time (OEE calculations)
$t_{ct,standard}$	Standard cycle time (OEE calculations)
$t_{int,planned}$	Time spent for planned interruptions (OEE calculations)
W	Average queuing time (Little's law)

X	Argument in a Six Sigma project. Possible causes affecting the response variable.
Y	Response variable in a Six Sigma project. The issue that needs improvement.
5S	A name of the method to organize working place. An acronym of Japanese words seiri, seiton, seiso, seiketsu, and shitsuke, and translated into English (for example) "sort", "set in order", "shine", "standardize", and "sustain".
ANOVA	Analysis of Variance, a statistical model to analyze differences in mean values and their procedures, a basic concept of Six Sigma
ASQ	American Society for Quality
CE matrix	Cause and Effects matrix. A method to assess the importance of customer requirements.
DMAIC	Define, Measure, Analyze, Improve, Control (Six Sigma project structure)
DOE	Design of Experiment. Result prediction method based on previous results.
FGI	Finished Goods Inventory
FMEA	Failure Mode and Effect Analysis. A risk assessment and correction method.
LSL	Lower Specification Limit
MSA	Measurement System Analysis. A test method to assess the confidence into a measurement system or device.
NUMMI	New United Motor Manufacturing, Incorporated
PSS	Policy Safety Stock
QFD	Quality Functional Deployment
RPN	Risk Priority Number (FMEA process)
SKU	Stock Keeping Units (another name for normal stock)

TPS	Toyota Production System
USL	Upper Specification Limit
VOC	Voice of Customer

1 INTRODUCTION

Purpose of this thesis is to first familiarize reader with the two of the by far most popular quality philosophies, Lean and Six Sigma, and also present the details of research part which is a case study of material logistics improvement in a cleaning company due to inefficiencies. The background of the research is the inefficiency in material logistics and planning system noted by author and that it can be easily improved by just establishing a system of planning the material needs.

The thesis includes comprehensive presentation of history and methods included in Lean and Six Sigma because it is considered the best way to understand the research structure if the basics of the two philosophies are known.

The triangulation research study theory is based on Six Sigma theory which is a collection of tools, methods and philosophies including statistical analysis theory and some basic ideas of quality management philosophies. Using the company internal information and the history data of delivered materials the purpose is to increase efficiency of the employees by minimizing unnecessary visits to material supplier due to bad planning. This way the employees can concentrate on what they are best in: customer service and leadership of cleaning staff. Qualitative methods are used in obtaining the material needed for the research and quantitative methods are used in handling the material.

The reseach problem is constructed by setting the question that how much can the material consumption be planned in order to avoid the unnecessary trips to supplier to fetch some material because it does not exist in the stock. The result is not any collection of detailed instruction for material management departmet but an example to make the material manager understand the true need for material planning instead of giving up without calculating anything nor using any historical data.

The presentation of background and the systems of Lean and Six Sigma are mostly collected using material from several sources to which the author of this thesis has added descriptive parts in order for the reader to understand better the subject handled. The research study is completely coined by the author and the only external sources of information are the delivery history records from the material supplier and some information gained by personal studies in the company and interviewing certain employees. All figures and calculations in the research part are made by the author either using common office programs but especially a statistical software used by Six Sigma professionals.

1.1 EARLIER VIEWS IN THE AREA OF THE RESEARCH PROBLEM

Supply chain problems are one type of problems perfecty optimizable using Six Sigma methods, since problems in the efficiencies of supply chain management cause billions of dollars of excess cost. In a report written by James W. Martin [1] the general idea of Six Sigma implementation in supply chain optimization is presented. He lists two major reasons for supply chain problems:

1) complicated processes with numerous rework loops and a lot of insignificant, professionally non-value-adding operations and unprofessional scheduling
2) poor management practices in defining the optimal inventory sizes causing excess and obsolete inventory which is directly added to the costs of the company.

Martin notes the Six Sigma solving method of DMAIC (Define, Measure, Analyze, Improve, Control) and finding the problem response variable (*Y*) and the arguments possibly affecting it (*X*'s) is an effective method in opti-mizing the supply chain problems. He does not go into details but notes that the prob-lems are identified, countermeasures to eliminate the problems are found, and imple-menting the improving actions that are to be rooted in the company operations for an efficient operation in the future. Using Six Sigma methods is not complicated and the good results can be reached by actually only taking a Six Sigma type point of view into the problems and easily large sums of money are saved by efficient planning, finding the relationships between affecting arguments into the problem and just rooting the results into the company philosophy.

In another optimization study published in the Journal of the Korean Institute of Industrial Engineers in 2005 [2] the Xerox company total costs for different stock values and transportation methods were optimized. The normal stock is called in the report by term SKU (Stock Keeping Units). The variables affecting the total value of the stock included safety stock value, normal shipment cost and outbound premium shipment cost which is the more expensive way to ship products due to customer requirements. A simulation model was generated in order to balance the optimal policy safety stock (PSS) and general

SKU and the simulation model was based on functions deploying the design of experiment (DOE) methodology. In DOE methodology, the optimization is done setting expected values of for SKU and the minimum stock out percentage and adjusting these while calculating the optimal level for total cost. The resulting figure is an optimization for safety stock and the different priced shipment cost, where savings were found just by optimizing the quantities of each of the group. The methodology in this kind of optimization is included in Six Sigma methodology.

In his thesis work Algassem [3] researched, among others, Lean Six Sigma methods' capabilities to overcome the challenges in supply chain operations. In the study it was found out that independent of company size the information management and control the material flow can be very complicated but that by managing the information in an efficient way it is possible to significantly avoid bottlenecks, waste, manage the cost level and stabilize the service level and organizational quality. All these factors unavoidably increase customer satisfaction by disturbing the customer's own activity as little as possible. Problems are of similar nature in both larger and smaller firms which is an important notice in quality development. By implementing Lean Six Sigma tools such as Kanban inventory system, quality assurance, 5S, 7 Wastes, space optimization in addition to efficient information management the lead times became more accurate and the decision-making easier as problems were surfaced using these methods.

2 LEAN CULTURE

In order to understand what "lean" means, we need to take a short look at the history and there are some clearly visible personalities that have developed the efficient production or service process to what is nowadays called in the western world as lean. It is important to understand that lean is not a set of tools and principles but that it is a culture. Before getting into the historical view and the details of the concept the word itself and its origins are considered.

2.1 ETYMOLOGICAL ORIGIN OF THE WORD

As a word, it is useful to open the literal meaning of the word as "lean" is explained in a dictionary (as suitable in this quality related context) as:

"adjective, leaner, leanest.

1. (of persons or animals) without much flesh or fat; not plump or fat; thin: lean cattle.
2. (of edible meat) containing little or no fat.
3. lacking in richness, fullness, quantity, etc.; poor: a lean diet; lean years.
4. spare; economical: a lean prose style." [1]

The word "lean" in production system structure is a concept first coined by American John Krafcik (born 1961). Originally, Krafcik had been working as a quality and manufacturing engineer in New United Motor Manufacturing, Incorporated, that is more familiar among automobile industry and quality professionals by its acronym NUMMI. The factory was jointly owned by Toyota and General Motors and is the place from where the lean manufacturing principles spread into the western world. [5], [6]

Krafcik learned the manufacturing principles of what is to be later called lean in NUMMI from his Japanese, Toyota backgrounded colleagues. They were using Japanese words that were to be translated into English as "fragile" and "robust" due to the manufacturing plant arrangement systems containing only what is absolutely necessary but still containing all items for the production to always run smoothly. But as he used in his early academic work [8], [9] these direct translations of the manufacturing system and discussed the arrangements with his American managers, the concept "fragile (but robust) manufacturing” created negative reactions as it did not sound a sellable concept name and thus re-branding was necessary. Krafcik knew the Japanese idea very well and chose the word “lean” as it in his opinion was a better translation even though not a direct one. [7]

The first time he publicly used the word lean to describe a certain manufacturing system was in his Massachusetts Institute of Technology’s Sloan Management Review article named “Triumph of the Lean Production System” [7], [10], which is known worldwide as the birth of the westernization of Toyota Production System. Lean culture was born in the west and it was born both worldwide and in the west in the automobile industry, which is today the leading reference and origin to practically all quality tools, quality standards and quality management systems worldwide.

2.2 HISTORY OF LEAN AND DEFINITION

Although it is possible to find numerous small similarities to current day process thinking throughout the history only certain names that have been recognized to have a significant influence on the issue are introduced. It is out of the scope of this thesis to make detailed introduction into all fragments that might be considered having affected the development of the standardized way of manufacturing and thus certainly some people will not be mentioned in this chapter.

Eli Whitney (1765-1825)

Eli Whitney was an American inventor who first got involved into business by improving new techniques in cotton manufacturing. He invented a machine that is called a cotton gin (where the word “gin” is an abbreviation from the word “engine”). Cotton gin raised the efficiency of cotton production by speeding the separation of seeds from the cotton fiber and thus was significant improvement in cotton production in the latter part of the 18th century. [11]

Cotton gin was a great improvement for the cotton production as it significantly increased the one worker’s daily cleaning of cotton fiber of cotton seeds from one pound (≈ 0.454 kg [12]) to about 50 pounds (≈ 22.7 kg [12]) but due to patent infringements Whitney lost a lot of money and did not gain significant financial benefit from it. The patent system had many loopholes at the time and it was easy for the cotton farmers to manufacture machines of their own that were similar but different in some tiny little - in Whitney's opinion, insignificant - way to Whitney's cotton gin. Thus they did not need to pay royalties to Whitney. [11]

Partially because of the reputation he received with the cotton gin he was able to secure a manufacturing contract with the United States government in 1798 to build muskets (a predecessor of a rifle) in a relatively short period. The idea Whitney got at the end of the 18th century was about improving the manufacturing process by concentrating on the continuance: he understood that it is very cost-efficient to use parts in machinery that can be used in any machine and that they are not manufactured by professional smiths and craftsmen creating not similar parts but that the parts would be interchangeable to any machine. This would significantly quicken both the assembly and the repair process of the muskets. [11]

The interchangeability of parts is a significant step towards efficient manufacturing and clearly a starting point towards organized quality manufacturing. By reputation Whitney gained from cotton gin and the musket manufacturing, he is today credited as a pioneer of developing an efficient mass-production in the United States of America. [11]

Henry Ford (1863-1947)

Henry Ford is best known for his T model Ford that changed an automobile from a luxury product into one that can be afforded by workers. To reach this Ford made arrangements in production lines that had not been seen previously, and these lead to significant cost savings that enabled him to pay huge salaries to the workers and still be profitable. The basic ideas he had can be summarized in the following general level quote from him:

"

1. To make an ever increasingly large quantity of goods of the best possible quality, to make them in the best and most economical fashion, and to force them out onto the market.
2. To strive always for higher quality and lower prices as well as lower costs.
3. To raise wages gradually but continuously and never to cut them.
4. To get the goods to the consumer in the most economical manner so that the benefits of low cost production may reach him.

" [13]

More complete understanding of Ford’s ideas about manufacturing are detailed in his book My Life and Work which was originally published in January 1, 1922 [14]. The ideas he describes are very familiar to anyone who nowadays, 100 years later, is familiar with lean production system principles: Ford understood that all extra movement is always waste and slows down the manufacturing process. Even one extra step is too much if it can be avoided. Ford describes that whatever amount can be saved or gained is always missed if the action is not taken to make the save or gain reality. The book contains very clear numerical examples to make the idea clearly understood: if a gain of *X* per cent can be gained the owner of the business is always ready to pay *X/2* per cent in order to get the gain. If a building is built, it takes the same amount of ground area to build thirty stories high a building as it takes to build five stories high a building, by which Ford means that after a process is started it can be used to extend the usage with the same starting costs to gain more. [15]

If the amount of workers at all the factories is twelve thousand and you save ten steps from each of the worker a day by just rationalizing the production arrangement you have saved fifty miles of wasted movement and energy from your employees and – what is important to notice – the gain or the production process outcome is exactly the same. [15]

In the book Ford also gives three exact principles where to base the arrangements and decisions of making the production efficient:

1. **Optimal sequence.** All the employees and the tools and parts they need for their part of the assembly process must be placed in the optimal sequence in order to avoid any extra movement of the assembly part and the employee itself. This unnecessary extra movement includes even stooping over to reach a tool or part to assemble or move the assembled part to the next step in the assembly process.
2. **Exactly same process.** The place to where the employee moves the part he/she assembled must be always the same. Gravity should be used as much as possible to carry the assembled part forward, and to reach this there should be work slides in use which is the way the employee stresses his/her muscles as little as possible.
3. **Use of assembly lines.** Since it is not possible always to move the assembled part to a lower level by using only gravity to do the work, there must be assembly lines that move the part forward using a machine to do the transfer process. It is

to be avoided at all costs that the employee needs to move the part by physically moving to another location.

[15]

The new part in a manufacturing industry that was first applied in Ford's automobile factories are the result of the principle number three: on April 1, 1913 the first experiment of an assembly line was completed. The assembly line worked on the power generated by a flywheel magneto, which at least Ford presumes to be the first moving line ever installed. The important part of the description of the new assembly line is that it is pressed to have been very carefully tested before taking into use: no new production method was taken into use before it was clearly measured to be better than the old way. [15] Here the press is on the word "measured" since *nothing is an improvement before it can be showed to be one on a paper using data and calculations.*

In addition to the three principles above leading to the movement reduction to minimum, I would like to point out two additional ideas from the Ford's book that are significant in developing fluent manufacturing organization:

1. **The employees do not need to be experts**. The majority of the tasks or work steps can be devided into so simple steps that anyone can learn to do in very short periods.

This leads to extremely easy human resources management where time does not have to be spent in training new employees but that absence or resign of an employee is very easy to be corrected by hiring a new employee and training him/her in a short period of time to completely replace the absent or resigned employee. Another point is the negative side of a person calling himself/herself an expert: Ford points out that any employee who truly knows his/her job never calls himself/herself an expert. The instant someone becomes an expert in his/her own opinion makes many things immediately impossible because the open-mindedness suffers significantly of "I am an expert" thinking.

2. **Constantly adjusting the process.** The optimal speed of assembly, that is, how much time the employee is given to do the job, is always monitored and corrected if there are extra seconds or steps that waste time. Also the division of manufacturing process into optimal sized departments needs to be found.

[15]

The optimal amount of employees handling a certain job phase can be a multiplication of the current amount and still the result of the manufacturing process cost per manufactured part or product reaches a lower level than it does with smaller amount of workers. Also, when it comes to automated assembly lines, the moving speed needs to be optimized in order to find the most fluent speed of operation of the employees. To current day lean manufacturing professionals this fluency reflects directly to the other point of view which is to reduce waste time or movement. Fluency and reducing waste are two sides of the same coin and are the heart of current understanding of lean manufacturing even though, as explained in detail in next subchapter, are far from complete definition of lean.

Taiichi Ohno (1912-1990), Eiji Toyoda (1913-2013) and definition of lean

In order to strictly standardize the way to develop further the ideas presented by Henry Ford the Toyota Production System (TPS) development was started in Toyota automobile factories in Japan after the Second World War. The Japanese strict hierarchy and the shame of war loss, where Japan was forced to demilitarize the country and thus not being able to spend resources into military development, were the two great motivators for the automobile factory to find solutions to become leading country in technology development.

Taiichi Onho was a Japanese industrial engineer and later a businessman to whom the TPS is credited [16]. He developed it with cooperation of Eiji Toyoda, another Japanese industrialist [17]. What Onho and Toyoda found out is that Ford’s system was not flexible in giving the variety the customers need. Ford’s manufacturing system was extremely cost efficient when the result was measured as cost per machine [18]. To present the ideas completely but in a condensed format, I refer here the excellent book by Jeffery Liker [18]. I personally think the ideas of TPS cannot be presented more clearly or significantly better than what Liker does.

In a nutshell, according to Liker, in TPS there are fourteen separate steps that need to be followed in order to reach all the benefits of the system that is the true basis of the Lean Manufacturing Process. <u>The following fourteen-point list equals to what is today understood as Lean Manufacturing Process.</u>

First, the **philosophy must be created** inside the company that covers long-term gain even if the short-term financial success is negatively affected by it [18]. It is vital to draw outside lines before developing the company short-term decision making process and to make these outlines superceding the conflicting short-term decisions. Responsibility of the whole organization and value-generation for everyone including not only customers but also society and economy in general is essential for a company to be successful long-term.

Second, the **processes** inside the company **must be continuous** since only by that way it is possible to see the problems inside generating problems. All idle times for a prod-uct or an employee are problems and do not generate value-added flow. [18] This sec-ond principle is the reason for people considering lean being equal to flow processing, which is not exactly true due to being incomplete description.

Third, overproduction should be avoided at all times using so called **"pull" system** which means the material is used only when it is needed, that is, when next step in production process "pulls" material as the next step requires it in order not to stay idle and **keep up the "flow"** [18]. At this point it must be understood that this does not mean zero stocks anywhere but it means stocks that have a need in the planned future. It is often thought that all stocks are waste but this definitely is not true since it is not possible to keep up the "flow" with zero stocks all the time. If the production is seriously large mass production as automobile factories today are, then it is possible to require the suppliers to deliver only what is needed and when it is needed. This strategy is not possible in smaller companies which the majority of all businesses actually are.

Fourth, the **workload** at each step **should be levelled** or at least a serious thought should be used in order to strive for it. It is very important to avoid overburdening employees. This levelling is called *heijunka* in Japanese. [18] Heijunka is often forgotten in companies.

Fifth, there must be resources in operations to allow **slowing down or even stopping the process** in case quality problems are found, and the problems are found by having clear visual systems to identify them immediately as they happen. This way of thinking is called ***getting quality right the first time***. [18] These clear visual systems can tell the problem to anyone inside the company immediately telling that something is not right. Ideal situation is that a process cannot continue without any employee (independent of level) even noticing the problem. There is a numerous amount of different methods in this but going into them is out of the scope of this presentation (in next chapter some of them are listed).

Sixth, all tasks and operations must be based on **stabile, repeatable and standardized way of operation**. [18] *This is the basis for all modern quality thinking that includes the process of continuous improvement and getting the employees involved and motivated in it.* Without the known process flows step by step, timing of each step and known input and output of the process it is not possible to operate following the “pull” and “flow” principles. Without a standardized way of operation there will always be unnecessary uncertainty that is waste and generates stress for employees. When the processes and its steps are known there is immediately possibility for anyone – especially the employee doing the tasks in the process – to find improvements and thus make the process in whole more efficient.

Seventh, the visual indicators to unhide the problems as talked in fifth step [18]. But to extend that it is to be pressed that the **indicators must be simple** since otherwise they will not work in the long run. These visual systems support also the “pull” and “flow” but to add what is previously mentioned, the simplicity must reach all documentation: if there are **no reports longer than one page and no material, steps, in-line stocks, machinery have been left unmarked**, this seventh step has been fulfilled.

Eighth, only **tested, reliable technology is good enough** for you to use in your operations [18]. If technology is slowing the process because of creating instability, unreliability or unpredictability, it must be immediately removed. Use only reliable, thoroughly tested technology that serves your people and processes, and never forget that technology is only supporting people: it should not replace people.

Ninth, company should always **grow and upkeep leadership** that not only understands the work but **that lives the company philosophy and is capable of teaching it to others** [18]. Because it takes time to fully understand a philosophy a company is operating with it is often more productive to promote people from within the organization than relying on turnkey solutions in buying a leader from outside.

Tenth, the exceptional **team cooperation according to company philosophy** is the only way for the company to reach the common goals [18]. A very hard and consistent work towards team cooperation both inside the team and cross-functionally will pay back in the long run. Difficult problems will be solved with cooperation and when the employees are fa-miliar with company tools and methodology. Training must be always present since it must be remembered that exceptional teamwork has to be learned separately in each company and that teamwork is based on training on all occasions.

Eleventh, always **respect your network** that consists of people outside your organization in addition to only the customers, that is suppliers and partners, by challenging them and helping them to improve as widely as you can [18]. No business can work without supporting organizations and people and this is sadly often forgotten that respect for suppliers is necessary for you to get a service from them you need. Ignoring and a negative attitude does not develop your own business which is the reason your company exists in the business. Partners and suppliers need to be helped and challenged to reach the targets you set in order to perform the way that is optimal to your business.

Twelveth, the processes and operations can only be understood by managers of any level – yes, even the top management – and leaders by **seeing the problems by themselves**. This attitude is in Japanese called *genchi genbutsu*. [18] The management based on reports only never gives a good enough picture of what really is happening but the management should verify the problem reported by themselves. This does not mean they should thoroughly understand all the details of every operation but the understanding can drastically improve by actually seeing the connection between the report and the real life situation.

Thirteenth, the decisions should never be made without a **careful consideration of all options that lead to consensus**, which as a process is in Japanese called *nemawashi* [18]. After a careful *nemawashi* the implementation of the solution or management decision happens much quicker than in a situation where people are not sure about the solution because a thorough consideration has not been done and though consensus has not been reached. It must always be remembered that there might be another point of view to any problem, so even after making the decisions the implementation should be done carefully. **Rapid implementation** after consensus is reached is also vital follow-up part of nemawashi.

Fourteenth, all organizations should become learning organizations, and that state is reached only by constantly **evaluating the results and effects of actions**, which in Japanese is called *hansei*, and **continuous improvement**, *kaizen* [18]. Processes must be described and they have to match with actual operations in the company. Relentless work must be done in order to make these processes stabile, but as these processes always contain inefficiencies in the beginning they must be made more efficient by continuous im-provement. This is not possible without being aware of the numerous continuous im-provement tools (that will be discussed in Chapter 3 of this thesis) that make counter-measure actions possible to be implemented efficiently. The requirement of as low inventory both on production lines and in the stocks is there because of this learning requirement of lean thinking: a low inventory reveals problems. These problems must always be thoroughly discussed in order to everyone to understand the problem and thus being capable of avoiding them in the future. It is utterly inefficient to find new, your own solutions to the problems but it is necessary to be familiar with the best practices that have been verified to be working in the problem situation. It must be noted that this instruction does not work without stable personnel who is familiar with company philosophy and willing to develop it and teach it to others. Internal promotion must be slow but present.

3 SIX SIGMA

There is not an absolute consensus about what is the exact definition of Six Sigma philosophy. Before discussing the alternatives and definition in depth, I am going to establish a picture of where the name itself has originated from even though the practical connection to actual quality enhancement work *is not relevant*. Six Sigma quality enhancement in practical work does not use the content of the etymological content of the term Six Sigma nor talk about "Sigma levels" but uses a wide variety of tools and philosophical attitude and thinking to enhance the operational performance of an entity. A proof of this is that explanation of the etymological concept or calculation of sigma levels is not possible using the over 600 page Lean Six Sigma Black Belt handbook [20]. However, I find presenting the origin of the concept important in this thesis because it describes the accuracy and level of improvement well as a starting point into the subject for people not familiar with it.

3.1 ETYMOLOGICAL ORIGIN OF THE CONCEPT

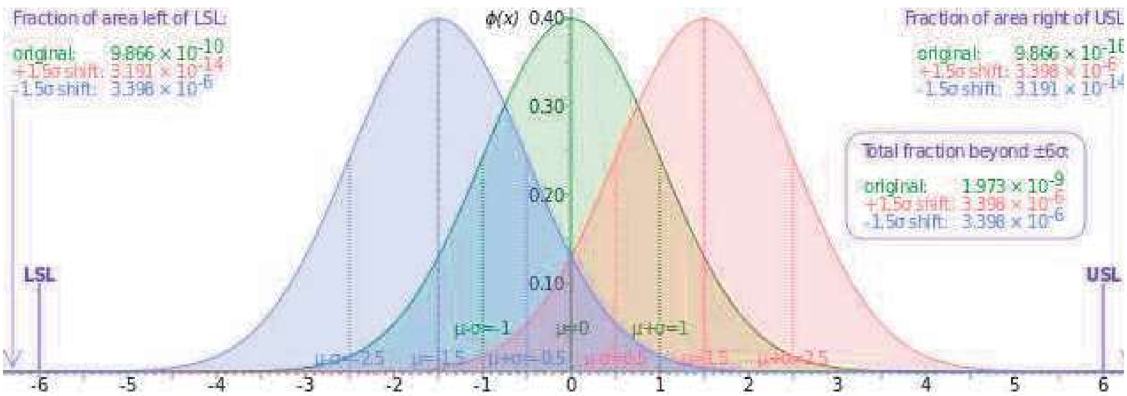

Figure 3.1 Graph of the normal distribution that is the statistical basis of the Six Sigma model (source: Wikiwand.com).

Figure 3.1 presents the origin of the term Six Sigma. It is based on normally distributed data which is a requirement for a data to have an average that is usable when doing statistical analysis of which I will talk later in this chapter. In order to understand the presentation of **Figure 3.1** it is necessary to understand following concepts:

a) Lower specification limit (LSL) which is the lowest value allowed for a measurement result to yield an acceptable result

b) Upper specification limit (USL) which is the largest value allowed for a measurement result to yield an acceptable result
c) Mean or average value of the measurements
d) Standard deviation: square root of average of squares of individual measurement result distances from average = square root of variance, presented in equation form as

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(X_i - \bar{X})^2}{n-1}}.$$

It is not possible to explain the etymological concept of Six Sigma without mentioning all of the concepts a) – d) above. The idea is based on a set of measurement results of anything that is measurable. The results can be anything where acceptability can be defined as a result compared with the acceptability limits. It is not possible to create nor present a complete list of possible variables to be measured in order to improve the performance by a Six Sigma project but, to give some kind of an idea, for example, the results in question can be

1) The measured length of anything or part of it.
2) The measured weight of anything or part of it.
3) Any measurable property of a device, machine, service, process or part of a process like the temperature, current consumption, distance from a point, the melting point of a plastic, drying time of a paint or varnish, amount of defects on a surface, distance travelled during the manufacturing or service process, and so on.
4) Time used to complete a process or part of a process.
5) Time wasted to wait for a process to be able to continue or doing additional, corrective actions.
6) The amount of money spent on anything, including a process, material or part of either one.
7) Price of a part, material, or substance used.
8) The amount of material or ingredient used in producing a product or service.

Figure 3.1 has the horizontal axis representing the value of a current measurement results and the units are the quantity of standard deviations as a distance from the average value, to both positive and negative directions. The figure has three normally distributed sets of measurement results where the middle one is the current process. The empirical experience has shown, anyway, that the measurement results vary for the following reasons by natural process deviation:

1) The average of the measurement results even in a stabile process deviates during time,
2) the measurement results vary so that the long-term standard deviation of the measurement results will be larger than the short-term standard deviation or
3) both.

This variation in even a well controlled process has been shown in empirical experiments to be ±1.5 standard deviations, and thus the process that has been measured to be a six sigma process will decrease to be only 4.5 sigma process.

Opportunities is a concept used for all measured performances or units of anything listed in the incomplete example list previously. The success of a process is defined by concept *defects per million opportunities (DPMO)*, which equals a figure of defected performances if the quantity of all opportunities is one million. *DPMO* is defined as

$$DPMO = \frac{n_D}{n_{Opp}} \times 10^6$$

Where n_D is number of defected performances and n_{Opp} is total number of opportunities. The theory behind this calculation as to what is the *DPMO* in normally distributed data is the value of the *cumulative distribution function*

$$F(x) = \int_{-\infty}^{x} f(t)\,dt,$$

where *f(t)* is the normal distribution function, where average is zero and standard deviation is 1. The result is the area from the sigma level to the negative infinity that for x value 4.5 gives an approximate result of 3.4×10^{-6} meaning there are 3.4 defects in million opportunities for a process that is a six sigma process. As I said earlier, Six Sigma professionals do not calculate these figures but they improve the processes using methods described later.

3.2 ORIGINS OF SIX SIGMA

The foundations of Six Sigma lie in the developments of continuous improvement ideas developed by automobile industries previously described in Ford and Toyota companies.

Essential to Six Sigma is that the process developments are *always based on measurable data*. Without data there is no Six Sigma but Six Sigma is also a quality philosophy that needs utter dedication in work to be done. Several persons have been credited in developing the tools nowadays inside the Six Sigma toolbox and it is useful to mention a few of them and their groundbreaking ideas before the toolbox ever was called as Six Sigma.

Walter A. Shewhart (1891-1967)

Shewhart was an American physicist and engineer who is considered to have a great impact on certain quality tools, especially statistical quality control in general and use of control charts in quality control. Shewhart was said to be self-taught in statistics which he used for the first time to install train station track-switching systems. He is the first honourary member of American Society for Quality (ASQ). [20], [21]

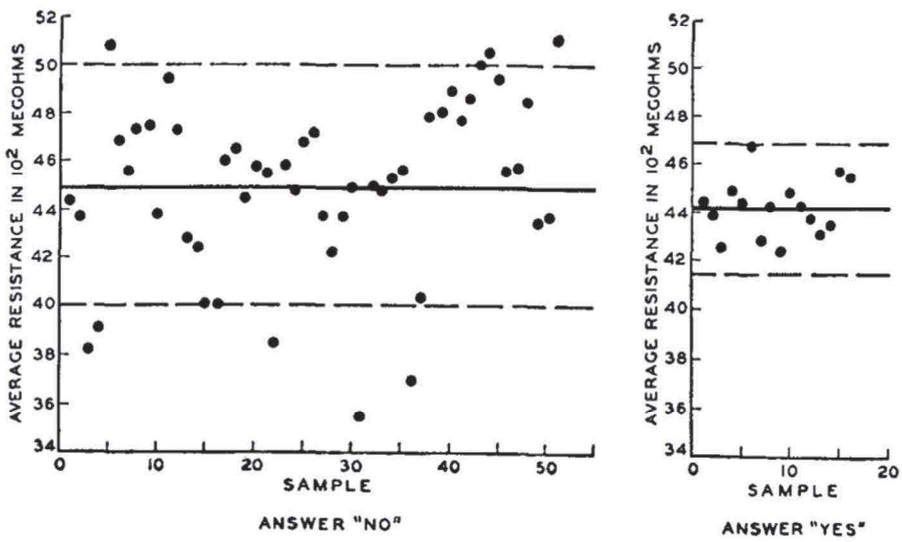

FIG. 7.—SHOULD THESE VARIATIONS BE LEFT TO CHANCE?

Figure 3.2 Early examples of control charts [22]

In order to control variation in the process Shewhart was first person to use statistical quality control methods in order to improve manufacturing processes. In his book *Economic Control of Quality of Manufactured Product* published in 1931 he explains an example of insulation resistance measurement where he questions whether variation is to be left to chance or not. **Figure 3.2** (on page 25) shows the measurement results where each dot is an average of four consecutive resistance measurements. The dotted lines in both of the two graphs are the limits that experience has shown the measurement result should fall into. In the left side of the picture there are measurement results of measurements where causes of variability has been completely left to chance. In the right side, after research the some causes of variability were found and eliminated and the measurement result got significantly more accurate. Further research is not feasible since the accuracy of the measurement is high enough for the production to continue in way more economical way. [22]

What has been done in the example above is the variability minimization process using control charts. *Minimizing variability in a process is the main reason why Six Sigma methods are used in quality work today.*

W. Edwards Deming (1900-1993)

William Deming was an American engineer and professor famous for his statistic methods and management consultant career. He was a supporter of ideas of Walter Shewhart when it comes to quality control using statistical process or quality control and Shewhart Cycle, where the original Plan - Do - Study - Act tool that Deming viewed as misunderstood view into Shewhart's work. Deming was one of the consultants that helped Japanese industry to evolve from the losses suffered in the Second World War. The most important legacy of Deming are the fourteen points [20] that describe what should and should not be done in an organization in order for it to succeed *in long-term*. The fourteen points are intertwined into one another and must be handled as an entity instead of separate advices since the fourteen points represent a philosophy. Next I am going to present those fourteen points and shortly explain each of them and thus giving better understanding of the key part of the point.

1) Product or service must be explained in a way that a constant meaning into its improvement is found at all points. The work should never be understood to be only a source of salary since it will not create quality of life. Work is what people do most of their valued time and the work should be done with respect which is only possible by making the meaning of improvement clearly understood.
2) Without a change in a company philosophy there is no change let alone improvement in the actions of a company.

3) Inspection is a sign of bad processes leading to bad quality products. Finding what's wrong is not an improvement in the process: it is very important to understand the difference between putting out fires or plugging leaks and improvement of processes.
4) The cost of a product or service can be minimized if the amount of suppliers is minimized, possibly to even one. The bad side of having too many suppliers is that it can easily be understood to be a competition of prices and delivery times and thus leading to short-term gain only. Valuable suppliers can be forced out of the business due to inadequate rating system that does not support long term gain of the both the customer and the supplier.
5) All processes must be constantly improved - they can never be said to be ready or good enough so that there cannot contain any errors or points of development.
6) Training and re-training is a vital part of all operations in any company. Training must always include explanations as to what the job actually is and why it is being done.
7) Leadership is more important than supervising and it should be insititutionalized in every compay. Combined to point number six is that true leadership is not giving orders but it is giving explanations.
8) Fear of anything inside the operations kills the respect for others and positive development of any process or company itself.
9) Departments should not build walls around themselves but they should fluently cooperate with all other departments. The most important asset of a company is the people working in the company and especially how they work together.
10) Employees should not be pressed into work better by slogans, commands and setting targets. Referring to point number seven is that employees must be led not ordered, or in other words, driven to do the job.
11) Numerical goals for anybody must be eliminated. It does not make sense to set numerical goals for any operations since there result is tightly connected to the process and how it works. Instead of the numerical goals the attention should be pointed into the improvement of the processes because it is the process only, not the goal, that generates the results.
12) Ratings and merit systems should be eliminated since they limit the pride of assessing that all work is vital in the company. Ratings do not improve the processes and they are easily done with subjective decisions that create bad spirit inside the company.

13) Education and self-improvement must be arranged to be possible for everyone. Connection to point number six is that training and developing people's minds are two different issues but they must be understood to be different points of view in the subject of personal development. People's minds must be enabled to be moving and not doing only what they have been exactly ordered to do.
14) Everyone in the company should be working towards the transformation since without a flexibility towards transformation it takes a long time to adopt any changes that have been found to be necessary to improve the operations. [20], [23]

Deming was an diligent supporter of bringing problems of management into surface. The shortest way to understand this attitude of his is taking a look at his famous *Red Bead Experiment* [24]. The experiment includes a box of red and white beans and another box that is empty. The box with the beans means the source of work an employee must do and he/she must take certain amount of beans to develop into something. Next there is a collecting board to where he/she *randomly* takes the samples of the beads and takes them into inspection. The purpose is that there are no red beads in the samples but only the white ones that represent acceptable products. After a few rounds of similar actions from several employees the results are inspected by managers: who brought the most red beads into inspection station. The worst employees that brought most red beans into inspection are fired. Only the part of the employees that performed better in average can stay. The operation is repeated with the employees that stayed in their position and finally they, too, are fired because they brought too many red beads into are inspection. This results no employee is good enough to do the work even if they had no any power to the result.

The key point of the *Red Bead Experiment* is that if a process is badly designed it is impossible to get good results. It is the manager who should have been fired since he/she has no any understanding of developing a process that generates good quality products. Management and process design is vital to any successful operation.

Joseph M. Juran (1904-2008)

Joseph M. Juran was a Romanian-born American engineer, executive and university professor who is famous for his *Juran trilogy,* which contains three managerial processes for quality: planning, control and improvement. He wrote hundreds of papers and 12 books on quality improvement. The key points to Juran’s approach can be expressed in condensed form by following list.

1) Improvement is always essential and understanding the need for it and creating opportunity for it is vital to success in any organization. The quality improvement should be visible in every job description and is not only meant to be implemented by a limited group of people, but there is a need for quality professionals that form a quality council to manage, facilitate and secure the improvement of processes.
2) An organization must be capable of selecting the quality improvement projects and arrange training how to reach excellent results out of them. The progress of quality improvement projects must be constantly followed since nothing happens by itself.
3) The results of the development projects must be made public to as wide audience as possible. Even though Deming opposed merit systems with a point of view that it is the process that generates the results, Juran’s view does not differ from this when he supports recognition of successful operation in order to be part of the result pubication and propagandizing the results. Also Juran pointed out that this reward system is also a process that should be under development at all times.
4) It is extremely important for the business plan of the organization to include quality improvement goals. This leads to the idea that business management in general should include quality as vital part of it. [20], [24]

It is also worth mentioning that it was Juran who implemented the popular *Pareto chart* into the quality work [25]. Pareto chart is an bar diagram where individual values – measurement results, time used to process something, amount of defects by source or for example quantity of material used – are presented in decending order and the cumulative share of each is presented with a line on top of the bars. Pareto chart is extremely good source of information in selecting correct development projects in Six Sigma methodology.

Philip B. Crosby (1926-2001)

Philip Bayard "Phil" Crosby was an American businessman and later an author who has developed several parts of management theory in general and especially methods to manage quality. Crospy's ideas have several points in common with Shewhart's and

Deming's but he is considered to be the originator of the concept widely known in Six Sigma theory nowadays as the *Zero Defects Concept*.

The Zero Defects Concept is also a sort of philosophy or at least an attitude. If people are in the very beginning told that there may not be any defects it improves the result of the process. If people are allowed to make mistakes by setting too loose requirement limits they will make mistakes since the attitude towards precise completion of work suffers – dangerously for quality level upkeeping. [20], [26]

Armand V. Feigenbaum (1922-2014)

Armand Vallin Feigenbaum, Doctor of Philosophy from Massachusetts Institute of Technology, was an American businessman and expert in quality control that generated the Total Quality Control into the world of quality. The key issues to quality according to Feigenbaum are that quality leadership must be an important step to reach the good quality level and in order to reach a good leadership culture there must be knowledge of modern quality technology and organization must be completely committed to good quality. He is famous of his book *Total Quality Control* published in 1951 where the basic ideas were presented. Several editions are still being taken of that book and it is used as a reference to various studies, papers and books not forgetting the quality systems used in companies throughout the world today.

The Total Quality Control has several elements that need to be taken into consideration in order to have the quality in total control. Main idea that Feigenbaum promoted is that it is the customer who decides what is good guality and not the company producing it. The cost of product equals the product quality and they have no any difference, and the lowest cost can be reached by good qualilty management with total individual and team commitment. The quality work in the company needs to be understood as managing the whole business, and that quality is not short-term solution to fix a problem but it is necessary to understand the importance of continuous process improvement. Like the Toyota Production System had already pointed out, partners, suppliers and customers need to be encompassed into the thinking of how quality is implemented in the company.

Kaoru Ishikawa (1915-1989)

The list of key people behind what is nowadays called as Six Sigma is not complete without mentioning the works of Japanese organizational theorist and professor Kaoru Ishikawa. He is considered to be the originator – even though based on Deming's work, but expanding it – of the Quality Circle meaning a group of people dedicated to solve quality problems and having a leader or manager who represents the results to the company management. Quality Circle as a term is nowadays more often called as Kaizen groups referring to the Japanese language term of continuous improvement. [20], [28]

Important addition to the quality toolbox still in use is also the *cause-and-effect diagram* that is also known as *Ishikawa diagram* or *fishbone diagram* based on the visual look of the diagram that's purpose is to divide possible causes of an effect to something into generic categories. The generation of cause-and-effect diagram starts with drawing a large diagram with possible main categories that may cause the undesireable effect, as the example in **Figure 3.3** below shows. [20], [28]

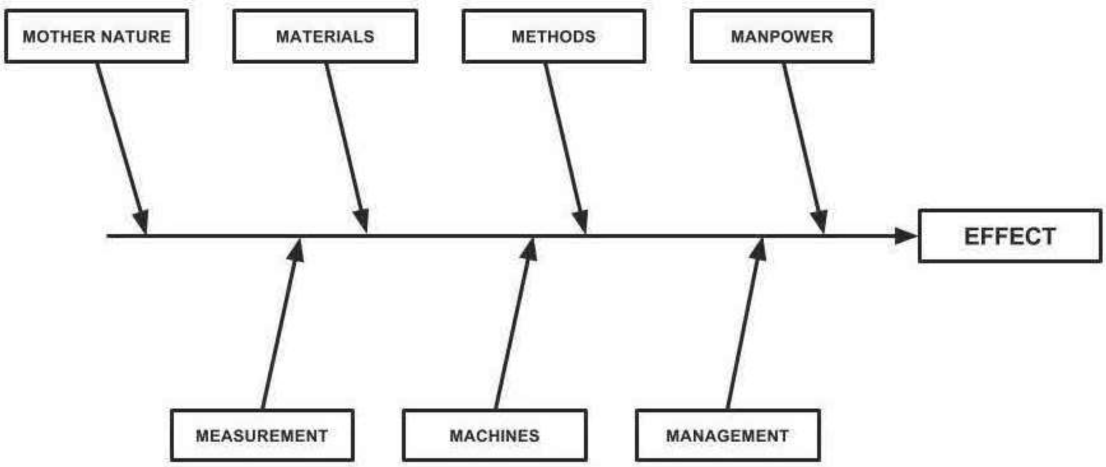

Figure 3.3. Cause-and-Effect diagram, situation in the beginning of a brainstorming session. [20]

Next a brainstorming session is arranged where the details will be added according to what people involved are suggesting, after which the diagram may look as in

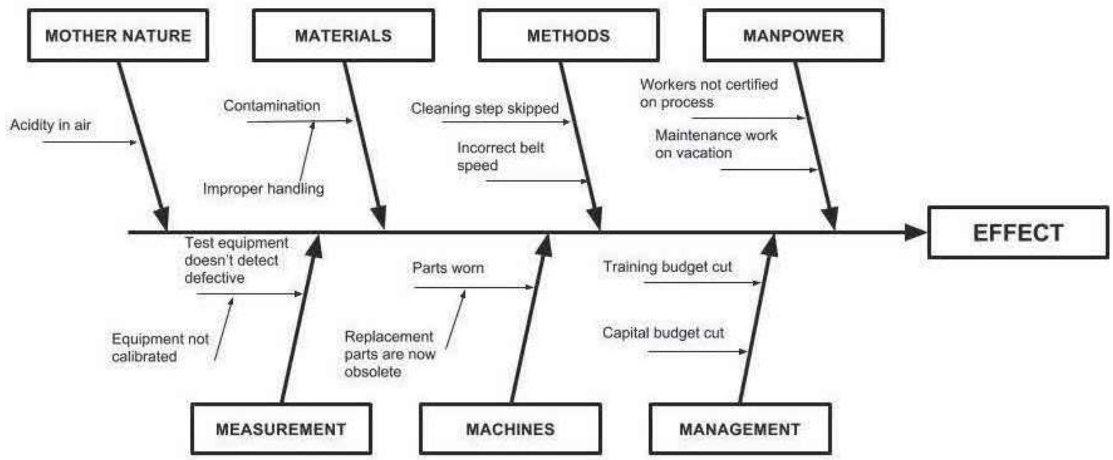

Figure 3.4. Cause-and-Effect diagram, situation after brainstorming session. [20]

The properly and carefully fulfilled cause-and-effect diagram is widely used in defining the projects that would improve quality and is important part of the Six Sigma methodology.

William B. Smith, Jr. (1929 – 1993) and the Six Sigma concept

William B. Smith, Jr. was a United States Naval Academy graduate and student in what is nowadays known as Carlson School of Management. He as a 35-year career in engineering and quality assurance joined Motorola in 1987 and invented the word "Six Sigma" as a quality management methodogy and philosophy. Smith has not been credited of developing any theories but pressed the importance of the work of the people mentioned previously. Implementation of the Six Sigma methods into Motorola business caused significant savings in Motorola business. He was in important role in Motorola's winning the Malcolm Baldrige National Quality Award given by the president of the United States. The award recognizes all types of organizations, public of private, for excellent performance to which quality work plays an important role. [20], [27]

"Six Sigma" is federally registered trademark of Motorola. [30]

3.3 SIX SIGMA PROJECT, CONCEPTS AND PROBLEM SOLVING TOOLS

In this subchapter a set of tools and concepts are presented that are vital in Six Sigma problem solving. This list is definitely not complete but gives an understanding of the subject. The references for this information Kubiak's and Benbows *The Certified Six Sigma Black Belt Handbook* [20], Brook's *Lean Six Sigma and Minitab: The Complete Toolbox Guide for Business Improvement* [19], the author's Lean Six Sigma Black Belt course material [31] and it also includes author's personal experience during over 10 years in quality work.

.A good Six Sigma quality improvement project

1) is based on measurable facts,
2) contains no guessing or proposals,
3) has a Six Sigma Black Belt or Master Black Belt always present to guide the project,
4) creates significant positive financial impact,
5) has good project selection and definition with boundaries,
6) has strong management support with link to strategy,
7) is prioritized,
8) follows DMAIC (Define, Measure, Analyze, Improve, Control) structure and a milestone meeting after each stage of DMAIC is arranged
9) is clearly connected to business needs,
10) has a strong, multidirectional communication process,
11) contains a measurement system that clearly shows whether project is really proceeding or not,
12) that's savings or increment in turnover have been defined in amount of money,
13) has a customer and its processes have owners,
14) do not need large cash flow,
15) can utilize history and current data,
16) is suitable size and scheduleable and
17) the results can be presented in graphical form

Project plan must be done in define stage but is constantly reviewed and sharpened, has milestones/deadlines, activities in each phase and tells who is responsible with estimated length of the project, has risk analysis and tells the need of outside resources - Gantt

Chart is popular way of planning a project: X axis has time and Y axis the tasks, milestones have been marked

FMEA

FMEA (Failure Mode and Effect Analysis) is there to a) recognize risks, b) estimate the risks and c) minimize the effect of risks. There are several types of FMEA's based on the usage:

Process FMEA: recognizes and documents the defect types of manufacturing process

Project FMEA: recognizes and documents the defect types that can happen during an important project

Software FMEA: recognizes and documents the defect types that affect the functionality of the software

Design FMEA: recognizes and documents the defect types of the products and components before the manufacturing has started

FMEA has several advantages since it

1) improves product or process quality, reliability and safety,
2) helps to improve customer satisfaction,
3) shortens the design time and costs,
4) lowers the amount needed to repair or scratch,
5) documents the improvement actions, and
6) prioritizes the deviances and helps to focus on important development targets

FMEA can clearly done in following defined steps:

1) define the process steps,
2) define the possible failure modes, either by
    a. define possible consequences or
    b. define possible causes,
3) describe current control methods,
4) calculate risk priority number (RPN = severity x occurrence x detection),
5) evaluate risks and define actions,

6) evaluete the effect of the actions

Severity = The entry in this column serves to quantify the severity of the impact of the failure mode. the scale for severity ranges from "no effect" on the low end to "safety hazard (up to and includin loss of life) with no warning" on the high end.

Occurrence = The entry int this column serves to quantify the frequency of occurrence of the failure mode. The scale for occurrence ranges from "very unlikely" on the low end to "highly likely" on the high end. Some users, teams and organizations will go to great lengths to provide absolute definitions for frequency of occurrences. For example, the Automotive Industry Action Group has gone as far as stating that an occurrence entry value of 1 designates a possible failure rate smaller than or equal to 0.01 per thousand vehicles / items, and an entry value of 10 designates a possible failure rate greater than or equal to 100 per thousand vehicles / items

Detection = The entry in this column serves to quantify the ability to detect the failure at a specific process step (that is, not at a previous or subsequent step, but tat the step under consideration) or at the product or component part level. The scale for detection ranges from "almost certain" on the low end to "not possible" on the high end.

Risk priority number = The entry in this colmun represents the multiplicative effect of values assigned to each of the previous three columns. Altough teams generally work the highest RPNs first, they may set additional prioritization criteria, such as working any line item on the FMEA where the detection value or teh severity value is at the highest level

Design of Experiment (DOE)

Design of Experiment (DOE) is a method where results of practical operations can be predicted based on previous results and the help of a statistical analysis software. The formula for DOE is as follows:

1) Define a problem and goal for the experiment
2) Plan the experiment.
3) Choose output response variables (*Y*'s).
4) Choose independent input variables (*X*'s) and levels for them
5) Do the experiment and carefully collect the data.
6) Analyze the data and draw statistical conclusions.

7) Validate the result by repeating the experiment.
8) Develop practical solutions and implement them.

Statistical analysis

Statistical analysis helps in analyzing the data, helps to describe process properties numerically, allows the history data to be processed in order to make forecasts of what might happen in the future, gives the basis for use advanced statistical problem solving methods and is based on numerical data, not intuition.

Hypothesis in statistical analysis is a theory of the nature of the relationship between the variables. Statistical tests are done in order to proof the relationship with a certain confidence. In statistical analysis there are two opposing hypothesis: 1) Zero hypothesis presumes that there IS NO difference or relationship which is the basic assumption of all statistical tests. Alternative hypothesis is that there IS a difference or relationship. This is the hypothesis under evaluation in most of the statistical tests. The common order for statistical tests is

1) Define statistical problem
2) Form practical targets for the solution.
3) Define hypothesis.
4) Plan or choose a suitable statistical test.
5) Form alfa risk that is also called type 1 error, *P* value or Producer's risk and means the probability that we are wrong in saying that something is different.
6) From beta risk that is also called type 2 error or consumer's risk means the probability that we are wrong if we say that things are similar even though they are different in reality. Beta risk is typically not calculated using statistical tests.
7) Define the delta or difference you want to find.
8) Define the sample size to detect the difference.
9) Plan how to take the sample.
10) Collect the data.
11) Make statistical test.
12) Draw conclusions from the result of the test.

Correlation

Correlation calculation is used when both of the variables are continuous and it measures the strength of the correlation between the variables using correlation factor *r*. The correlation factor can get values between –1 and +1, and if the value is greater than ± 0.8 it is said that the two variables are strongly correllated to each other and if smaller than ± 0.2 the correllation is weak. It is important to notice that even if a correllation between the two variables exist it does not mean there is change in other when other changes, that there might be other variables affecting the correllation of the two variables and especially that if there is a correllation of any strength between the two variables it does not mean that there is a cause and effect relationship between the two. The last point of the three is very widely made mistake among people.

Regression analysis

A statistical regression analysis is done to get exact numerical results. It calculates the prediction equation that predicts the *Y* value on a certain *X* value. Important part of regression analysis is the calculation of the residuals which means the distance of the actual result from the regression function. In order for the regression function to be usable the average of these residuals should be zero or very close to it and that the residuals are independent of each other. If this is the case, it is statistically proven that the regression function can be used to predict values between the maximum and minimum of the already measured results. It is for statistical analysis programs to calculate the regression function, and whether the relationship is linear, quadratic, cubic or exponential.

Value stream mapping

Value stream map is a systematic way to recognize and eliminate all activity that is non-value adding: shows the waste and the visualization of the big picture - cannot be used to solve all problems but should contain small steps only

Value Stream Mapping: 1) define customer requirements, 2) add suppliers and other agents, 3) add main process, 4) add supporting processes, 5) add delays, latenesses and stocks, 6) add time span, 7) find areas of development. Problem parts to be recognized: long cycle times or cycle time ratio or value added ratio, too large in-line stocks and waiting times, significant variation in customer needs or cycle times, too much personnel in order to act efficiently when customer requirement changes (increases or decreases), support processes, long acceptance or inspection times. Value Stream Mapping should be ready in one working day. Always results a picture with notes. Value Stream Mapping goals: 1) no waste, 2) minimum amount of hand-offs, 3) one touch processing, 4) fast changeover times, 5) just-in-time production and deliveries, 6) customer need fulfilled exactly, 7) best practices utilized, 8) well-organized workplaces, 9) deviations are immediately noticed. And all without any extra cost!

Variable concepts used in Six Sigma projects

5S is a name of the method to organize working place. It is an acronym of Japanese words *seiri, seiton, seiso, seiketsu*, and *shitsuke*, and translated freely into English (for example; to keep the words starting with letter s) "sort", "set in order", "shine", "standardize", and "sustain". It is considered vital to organize the working place in order to find items quickly, to show that the working place only contains of items that are necessary and that no time is wasted finding an item but the collection of an item is always equal amount of steps away.

Process descriptions are important part of quality and therefore also Six Sigma. Processes must always be described, since it 1) visualizes the process as it is, 2) helps to recognize areas of development, 3) marks the limits of a project, 4) helps to locate areas where training is needed, 5) locates areas where new processes are needed and most importantly 6) it standardizes operations between teams and operating units

Affinity diagram: generate ideas or collect data, show the ideas, sort the ideas, create headers, draw a picture

Kipling Checklist is a method used to find what actually is the voice of customer (VOC): 1) what is done, the purpose of it and is it necessary, 2) why it is done in general and this way, is it just historic, 3) when is it done, when would it be better, when should it be done, before or after, 4) How it is done, how can it be done better / easier / more efficiently / more effectively 5) where is it done, where is the best place to do it and where else it can be done 6) who does it, who could do it more easily / economically

Kano model: define must bes, more the betters and delighters: collect information about customer needs, group them into the three groups, prioritize the needs for critical to quality

Quality Functional Deployment (QFD): list critical items to quality, estimate their importance according to chosen criteria (9, 3 or 1) and multiply their sum with the voice of customer prioritization rating number (1—5)

Spaghetti diagram shows the process in an operation as it really has been done and the distance moved can be measured

Metro map shows the starting and end points of a journey, the stations where to be stopped (process phases, decision stops) and crossroads where a different route can be chosen according to carful estimation

Pareto chart measures amount of time or failures by units and shows the areas of significance and their relation to the whole amount of problems (the cumulative line). For example 20 % of *X*'s cause 80 % of problems, always in order of quantity, largest first, used to recognize the most important factors to the problem in order to be able to prioritize actions where to start

Tact time is calculated by (net working time in a shift) / (customer need in a shift)

Cycle time is time used in a process phase: may not be confused with tact time since cycle time is not dependent upon customer need

SMED (Single-digit Minute Exchange of Die) (part of TPS): to eliminate the changeover time used in changing the settings

Overall Equipment Effectiveness (OEE) is calculated using equation

$$\boldsymbol{OEE = EA \times EEP \times EQP.}$$

EA is Equipment availability which is calculated using equation

$$\boldsymbol{EA = \frac{t_{r,planned} - t_{d,unplanned}}{t_{r,planned}},}$$

where $t_{r,planned}$ = planned runtime and $t_{d,unplanned}$= unplanned disturbance time.

EEP is Equipment efficiency performance which is calculated using equation

$$\boldsymbol{EEP} = \frac{\boldsymbol{t_{ct,standard}} \times \boldsymbol{n}}{\boldsymbol{t_{ct,standard}} - \boldsymbol{t_{int,planned}}},$$

where $t_{ct,standard}$= standard cycle time, n= amount of units produced and $t_{int,planned}$= time spent for planned interruptions.

EQP is Equipment quality performance (amount of good quality units / all units x 100 %)

$$\boldsymbol{EQP} = \frac{\boldsymbol{n_{ok}}}{\boldsymbol{n_{all}}} \times \mathbf{100}\ \%,$$

where n_{ok} = amount of good quality units and n_{all}= amount of all units produced.

Little's law: *L* = *λ* × *W*, where *L* = average amount of units in queue, *λ* = average amount of time for an item to arrive into the queue, *W* = average queuing time. Application: stock must have two days of customer need ready at all times (FGI, Finished Goods Inventory)

Kanban quantity, *N* = (*DT* + *S*) / *C*, where *N* = Kanban quantity, *D* = need in the workplace, *T* = fulfill time (throughput time), *C* = amount of units in one box, *S* = safety stock

Cause and Effects (CE) matrix is a simple matrix that reveals the importance of customer requirements. It connects inputs (*x*'s) to outputs (*y*'s) commonly on basis of process description. *Y*'s are given ponts according to relevance to customer, and *x*'s are given points according to how much it has effect to *Y*.

Population means all products / items / persons, sample means the units researched in statistical analysis. Mean (average of the items), Median (50% of the items), Mode (the most common value)

Range is the distance between largest and smallest number

Variance average of squares of number distances from average of the numbers

Standard deviation is square root of average of squares of number distances from average = square root of variance

Graphical presentations are for example histogram, boxplot (from 25 %, which is Q1 Percentile, to 75 %, which is Q3 Percentile, 50 % value point which is median, maximum value, minimum value, outliers), probability plot, then descriptive statistics, then interpretation with organization's own language

Scatter plot shows possible relevance between *X* and *Y*: no relation, strong linearity, strong nonlinearity, relative linearity. Matrix plot: when there are lot of *X*'s, matrix plot shows the relation of all *X*'s to *Y*

Measurement System Analysis (MSA) is a concept where the confidence into measurement system or device used is tested and it is important part of Six Sigma knowledge. Important concepts in MSA are repeatability, where measurement result are done using similar method and same measurement system or device by the same employee, and reproducibility, where the measurement results are reproduced by different employee using different equipment. Statistical software is practically used to analyze the results and the analysis is based on statistical theories and formulas.

Poka Yoke is a Japanese concept meaning avoiding unintentional errors and which is in English language world called as Mistake Proofing. The idea of Poka Yoke is using very cheap, very effective and very clever solutions that make a mistake impossible to happen, and using these methods before anything happens since preventing mistakes is always more efficient than finding them. Examples of Poka Yoke solutions are sensors detecting wrong or missing part in a product on an assembly line, using colours to inform which paper should be put into which locker, picture of a product in a cashier machine to avoid typing the price wrong, or markers higher than a working table to immediately inform how long a piece of material is needed.

4 LEAN SIX SIGMA PROJECT: MATERIAL HANDLING IN A CLEANING COMPANY

4.1 PROJECT EXECUTIVE SUMMARY

The author was hired by his employer, a cleaning service company, in early 2016 to arrange all quality and organizational issues the company has as they had then recently gained more and more business and the turnover had thus been growing double figures. Very soon the author found out that there are lot of unorganized issues which causes uncertainty and unnecessary stress - although many parts of the management style were in good order: the nature of fair treatment and clear orders and possibility to earn an award for good ideas for example. Problem is that documentation and organized planning was not in good shape when it comes to general quality related documentation, and that was the area for the author first to fix. During this work, the author found out that an important area of a cleaning company's business was not working in an organized way: the detailed "manufacturing cost" – in cleaning company it means cleaning equipment and chemicals - follow-up to which I decided to do a research on. What materials and cleaning equipment are bought, when and by whom? What is the optimal way to handle material purchasing and storing and where is the optimal storage place? Can we affect the pricing of materials and equipment by diversifying suppliers and warehouses?

Important part in understanding this research project is that the price or weight or volume of an item plays no role in here. This project is made in order to research the amount of times material is fetched from supplier and to investigate whether better planning is possible and thus the separate visits to supplier to pick up odd material – whatever happens to be needed – could be minimized. To completely remove the need for separate material fetching from supplier is not possible but *target of the research is to reach significant drop and show how much time and money is saved by doing better planning*.

4.2 DEFINE: PROJECT SELECTION

Customer Requirements

This project was originated completely by author and there was no special customer requirement. In an inorganized material handling the author was sure he can find some time and money savings and rationalization of operation. The management had per my view five reasons why material purchasing and logistics were not followed and organized thoroughly:

1) The cost of the materials is not playing an important part in company's costs and thus big savings cannot be done (employee salaries are the most important);
2) It is not possible to estimate the amount of needed materials in certain cases and thus the monthly order of materials cannot remove the need for separate pick-ups;
3) It is not significant amount of time that picking the odd material that was needed to be separately picked up from the material supplier took of the Service Leaders' or Service Supervisors' time;
4) It is very easy to handle all purchases, including small ones, using a single supplier, the cooperation and selection of equipment and chemicals is superb, you don't need own warehouse of significant size and you can be sure there won't be lack of any material or equipment and
5) They are busy running the other daily operations and sales.

The main achievement for this research is to – in addition to question the relevance of the above issues: <u>Reduce the amount of time needed to be used in separate pick-ups by at least 90 %</u> and consolidate the meaning of monthly warehouse orders. The picking up reduces the time the Supervisor or Leader level employee can use to serve customer and guide and supervise the cleaning workers.

The beneficiaries of this project when successful are everyone: Service Leaders and Service Supervisors may do what they are best in and actually hired to (making sure the jobs are done correctly and on time), customers get better service when more professional employees are around more often to guide cleaning workers and also discuss with customers about the needs and improvements, and naturally the management who can have more done with same number of employees and even save money on the way.

As was previously explained, customer's requirement does actually not exist in this project but the goal is to show that there *should be one*: to significantly rationalize the material logistics in day-to-day operations.

Problem Statement

The cleaning company's organisational structure is presented in Figure 4.1. The Company's Business Objective is (unofficially at completion of this research report) to serve customers by giving exceptionally good customer service and handle all agreed cleaning jobs the customers require. The most important drivers are

a) short response time to any problem the customer might have
b) exceptional reachability at any time and
c) professionality in finishing the agreed tasks in time and with good quality.

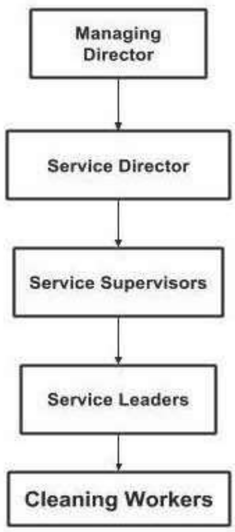

Figure 4.1 Cleaning company's organisational structure.

The objective of this research project is to reduce unnecessary movement of Service Supervisors and Service Leaders when an employee became short of material or materials needed to finish an agreed cleaning task.

Problem that I need to find a solution to is presented in *Figure 4.2* and *Figure 4.3*. They represent the amount of different materials transported from supplier by supplier according to monthly order versus fetched material from supplier that have been fetched separately by Company employees. “Row” means a single type item transported or fetched than can be seen as a row in invoice.

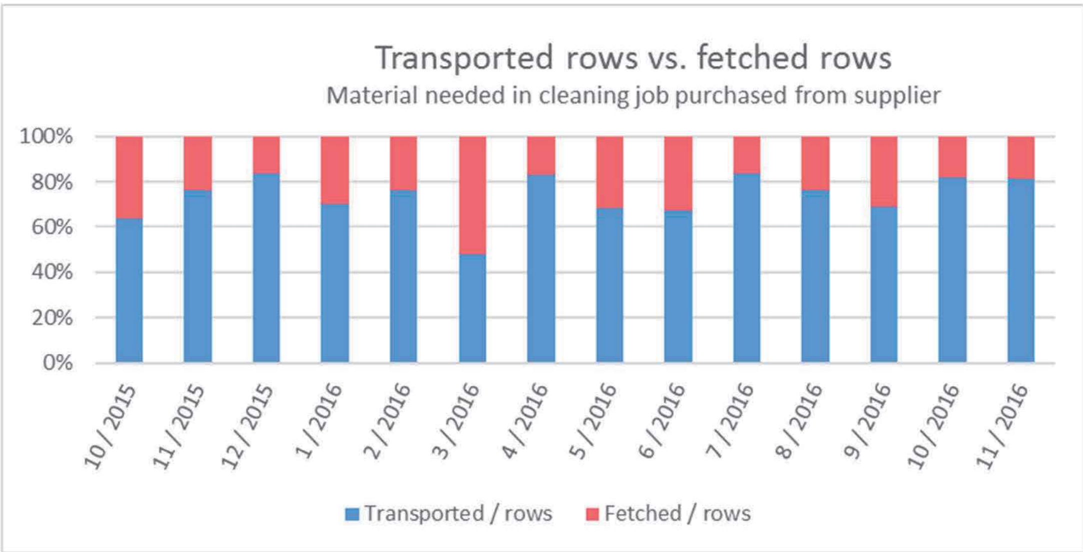

Figure 4.2 Problem statement. Amount of red rows in material invoice lists are waste since the time used in fetching material separately is off from guiding cleaning workers and meeting customers.

As the Business Objective of the Company has been defined as short response time and exceptional reachability the figure 2 shows the <u>fetched rows of material are all pure waste since Service Leader or Service Supervisor is wasting time in being away from customer premises</u>. The amount of fetching must be minimized. In order to choose a problem in a correct way it is necessary to ask following questions of SMART (an acronym of the point of views) method and then find answers to them.

Is the problem statement

a) **S**pecific? Every time material is fetched is waste of time and reduces the quality of service.
b) **M**easurable? The quantity, time used of separate fetching is easily counted.
c) **A**chievable? It is possible to plan the need for material so separate fetching is not needed.
d) **R**elevant? Time for guiding the employees, being reachable in customer premises is the business objective of the Company.

e) **T**ime Bound? The data used to measure the time used for fetching materials separately is time bound since the dates of fetching and transporting material are seen in the orders / invoices.

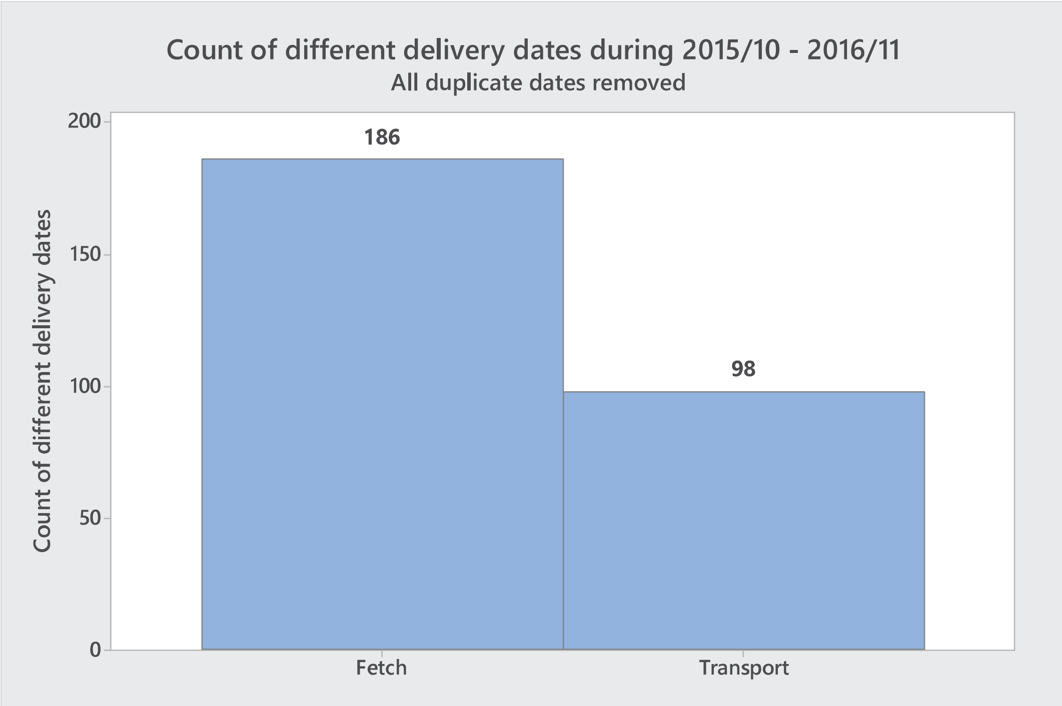

Figure 4.3 Amount of separate fetching and transportation dates (occurrences) during the period of interest (October 2015 - November 2016).

In this project the amount of fetching rows are being minimized and it is showed by planning that these fetching trips were not necessary. This yields a planning method that will be used in the future.

Response Variables and Metrics

Response variables in this research project are Y_1 which is the change in amount of fetching trips to supplier, and Y_2 which is the direct financial impact of the fetching trips to supplier caused by working time and gasoline savings when fetching trips are reduced (time and money savings are linked to each other and are both directly proportional to the result of Y_1).

The actual specification for this improvement research project has been set up to be 90 % cut in fetching trips by the author of this report (result for response variable Y_1). It's based on the project Champion's and Business Controller's comments that "financial effect on the company's business is not significantly affected by material cost since the only actual cost for the company are employees' salaries". By "employee's salaries" the Champion and Business Controller mean the salaries for the actual cleaning job which is out of the scope of this research project.

Primary metric of the project's response variable Y_1 is that the target of 90 % cut in fetching trips is reached by the result of this research report. The secondary metric of the project's response variable Y_2 is directly proportional to the fetching trip reduction and is calculated in detail. The result for Y_2 does not have specific target since it is as low as the result for Y_1 determines.

Business Impact

The two response variables selected are different in nature: Y_1 reflects to the The amount of fetching trips to supplier and Y_2 is the direct financial impact of the fetching trips to supplier.

To estimate the financial impact of the problem, that is minimize the response variable Y_2, we need to estimate the cost of one fetching trip without thinking about the main problem about improved service which cannot be measured reliably using money as a metric.

Since the data available to estimate the problem was not detailed about where the fetched material was delivered, and since it is not possible to accurately know the location from where the fetching trip started nor ended, the estimation has been made that all fetching trips start from the Company headquarters, lead to the supplier and come back to the Company headquarters. Figure 4.5 shows the distance and time required of one fetching trip. This can be considered to be good estimation when the service area of the company and the location of the customers are taken into account.

Estimation is based on calculation of distance form a set of customers to supplier and back according to Figure 4.4.

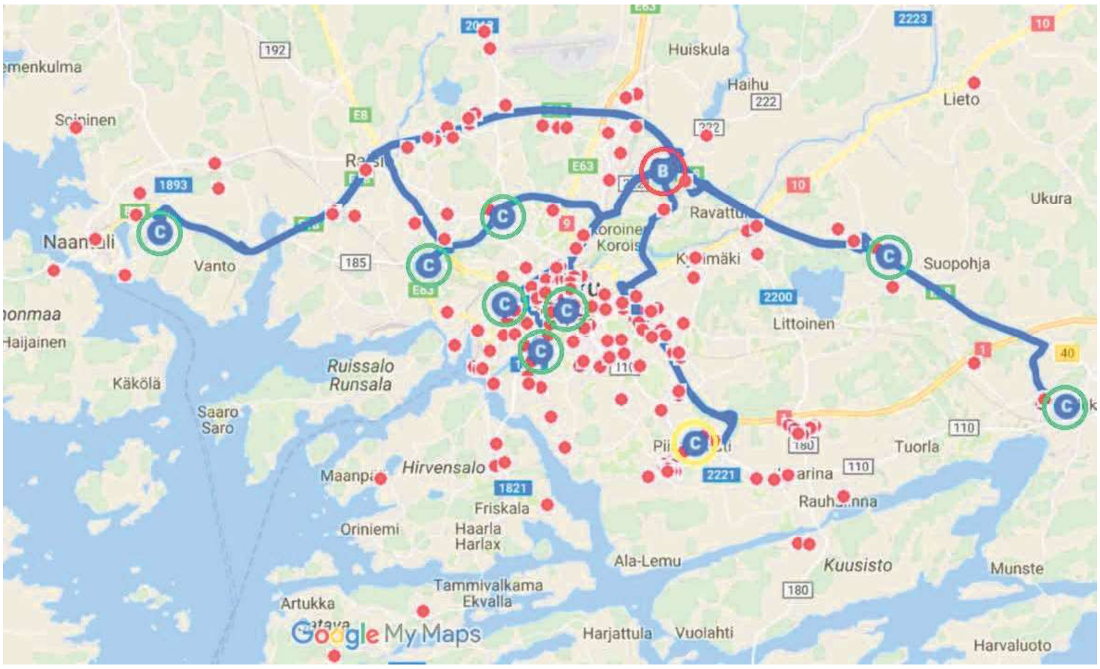

Figure 4.4 Distance calculation validation. Estimation of validity of using distance from Company headquarters to supplier and back as generally valid estimate of distance and time used when all customers are taken into account. Yellow-circled “C” is Company headquarters, green-circled “C’s” are selected customers as samples.

Table 4.1 Distances and times of selected customers in Figure 4.4 measured using Google Maps. C1 is the ID for Company headquarters (yellow-circled in Figure 4.4) and selected customers representing the whole customer base are ID’d C2-C9 (8 samples, green-circled in Figure 4.4).

Customer ID	Total distance	Total time
C1	21.6	29
C2	11	24
C3	36	35
C4	22	25
C5	13	24
C6	11	19
C7	15	17
C8	15	29
C9	29	27

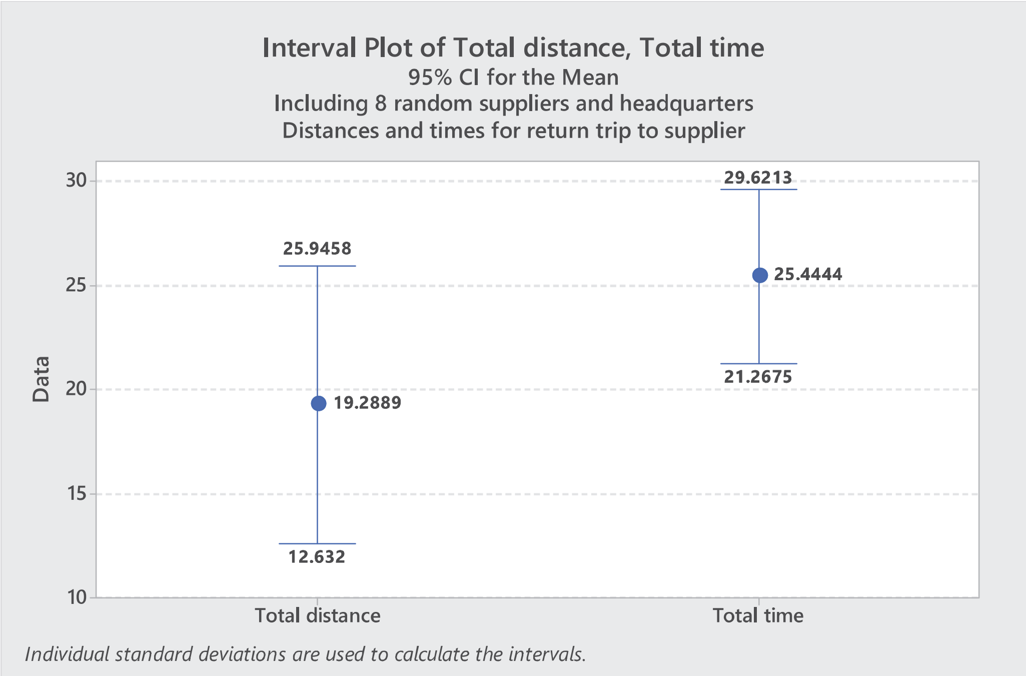

Figure 4.5 Mean values and confidence intervals for both distance and time measurements.

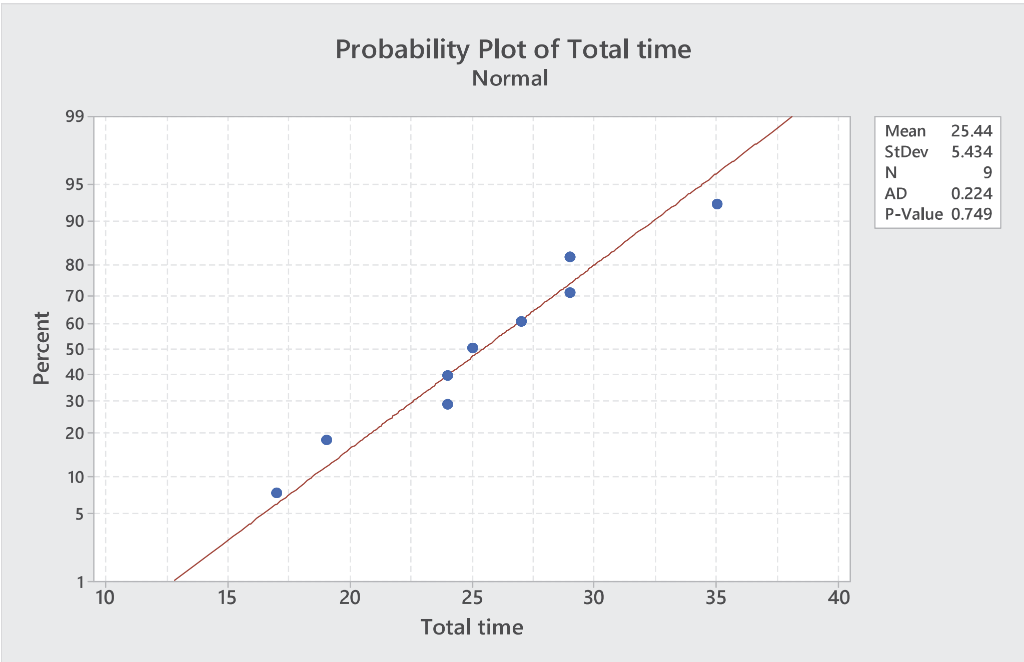

Figure 4.6 Normality test for the Total time measurements of the headquarters to supplier and selected customers to supplier. P value is 0.749 thus the data is normally distributed and mean value can be used.

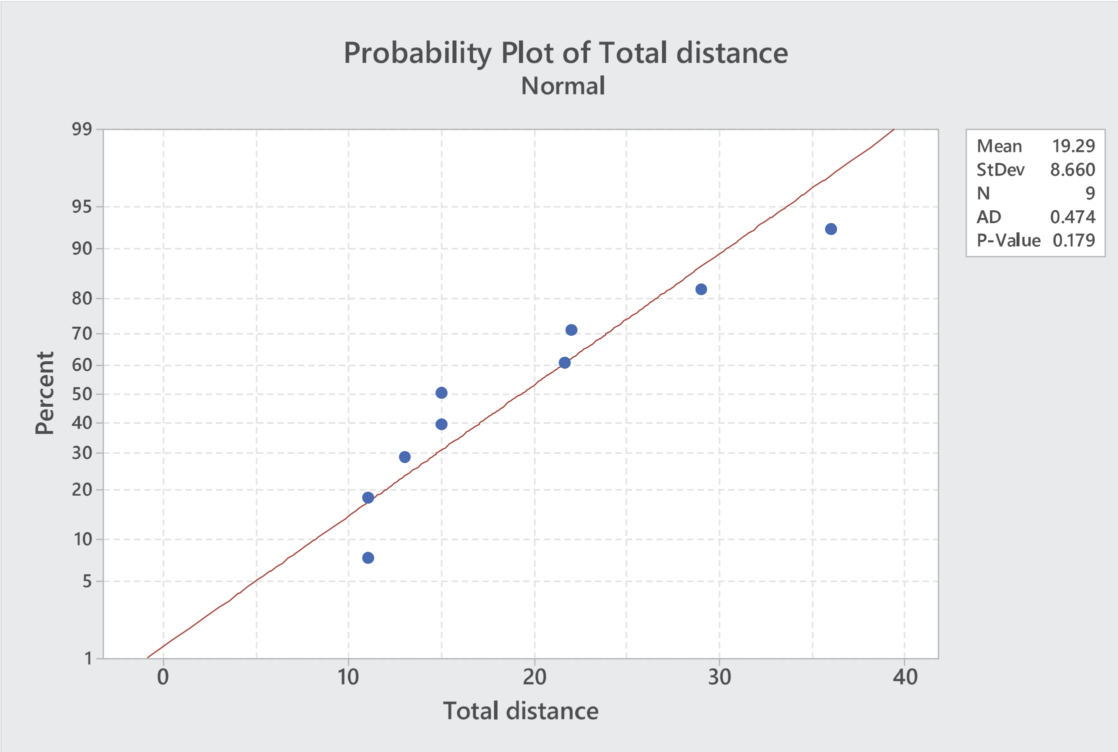

Figure 4.7 Normality test for the Total distance measurements of the headquarters to supplier and selected customers to supplier. P value is 0.179 thus the data is normally distributed and mean value can be used.

Since most of the cars used by the Company employees are of model Fiat 500, we can estimate the consumption using measurements made by several dedicated websites.

The car manufactrurer website says the Fiat 500 car gasoline consumption is 4.8 liters / 100 km [32], thus the consumption is

4.8/100 × 19.2889 ≈ 0.93 l / 19.2889 km

(see Figure 4.5).

U.S. Department of Energy publishes general fuel consumption per car type. For Fiat 500 it says: “2013 Fiat 500, 4 Cylinder, 1.4 Liter, Manual 5-spd, average MPG = 42.4” [33].

42.4 miles / 3.785 l

= 42.4 × 1.609 km / 3.785 l

= 68.2216 km / 3.785 l

= 18.02 km / l

→ 19.2889 km thus takes 19.2889 / 18.02 l ≈ 1.07 l

(see Figure 4.5).

Use average of these two: (0.93 + 1.07) / 2 = 1.0 l / fetching trip.

A local gasoline price comparison site says: “95E10 gasoline costs 1.39 € / l” [34]

→ One trip to supplier costs 1.0 l × 1.39 € / l ≈ 1.39 €.

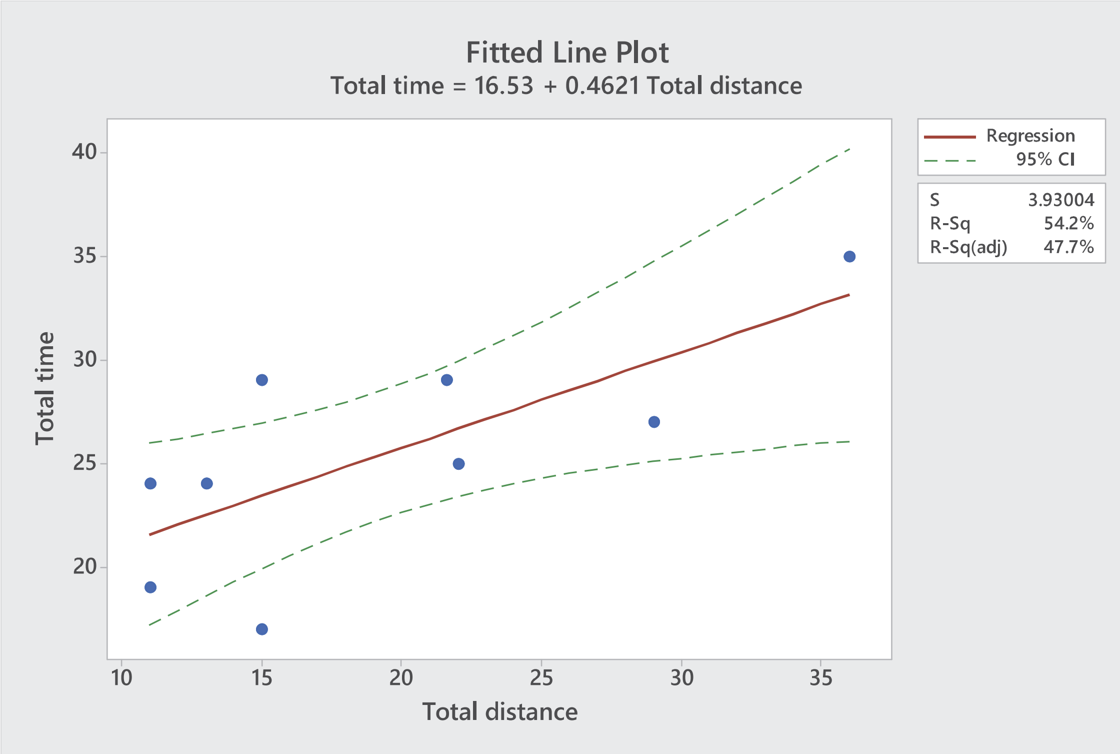

Figure 4.8. Regression analysis between the distance and time for return trips to supplier. ANOVA table tells us the regression P value is 0.024 meaning the linear regression model fits well to the data even though the low R squared value (54.2 %) tells the fit could be better (there is substantial amount of error).

The hourly salary for Service Leader is on average gross 12.5 € / h and the costs for the company are estimated to be 50 % on top of the hourly salary (social security payments, pension payments, holiday effect etc.) and thus the hourly cost for company for a Service Leader is

$$12.5 \times (1 + 50\ \%) = 18.75\ € / h.$$

The Service Supervisor costs as paid average gross salary of 16 € / h and thus the cost for the company can be estimated to be

$$16 \times (1 + 50\ \%) = 24.00\ € / h.$$

In the data used for this research we can find 151 times that a Service Supervisor has fetched material from supplier and 121 times that a Service Leader has done the same. The material lines including duplicates include here 612 lines in total, thus there are 272 marked rows which means that 340 rows are unmarked. Thus I'm going to make a rough estimate that fetching is done 50 % by Service Supervisor and 50 % by Service Leader and thus the hourly cost for the company is average of their hourly cost for the company, which is

(24.00 € / h + 18.75 € / h) / 2
= 21.375 € / h

Thus, a 25.44 minutes' trip (see **Figure 4.5**) to supplier costs (incl. salary and gasoline)

25.44/60 h × 21.375 € / h + 1.39 € (for gas)
= 10.453 €.

Money saved if 90 % fetching trips are cut off.

10.453 € / trip × 186 trips × 0.9
= 1749.83 €.

This figure is the secondary metric Y_2, which according to above is calculated as

$$\boldsymbol{Y_2} = \left(\boldsymbol{X_1} \cdot \boldsymbol{X_2} \cdot \boldsymbol{X_3} + \boldsymbol{X_4} \cdot \frac{\boldsymbol{X_5}}{60}\right) \cdot \boldsymbol{X_6}$$

where

X_1 = Distance to supplier (the average value calculated previously)
X_2 = Gasoline consumption (the average value, based on actual data presented previously)
X_3 = Gasoline price (based on the value of the source presented previously)
X_4 = Employee hourly salary (in average) (the average value calculated previously)
X_5 = Time used when driving to supplier in minutes (the average value calculated previously)
X_6 = Number of fetching trips

The calculation is done accordingly by inserting the actual values (how much is saved if 90 % of the fetching trips are reduced):

$$Y_2 = \left(19.2889\ \text{km} \cdot \frac{\left(\frac{4.8\ \text{l}}{100\ \text{km}} + \frac{1}{18.02\ \frac{\text{km}}{\text{l}}} \right)}{2} \cdot \frac{1.39\ €}{\text{l}} + \frac{21.375\ €}{\text{h}} \cdot \frac{25.44\ \text{min}}{60\ \text{min/h}} \right) \cdot 186 \cdot 90\ \%$$

Working time saved **in a month** if 90 % fetching trips are cut off.

> 25.44 (minutes / trip) x 186 (trips / 14 months) x 0.9 (90 % reduction) / 14 (months) / 60 (minutes / hour)
> <u>= 5.1 hours</u>.

The financial benefits are not significant in this project but the objective is to improve the efficiency of the Service Supervisors and Service Leaders by removing the need for visiting the supplier by ordering the material in advance. This is considered to reduce stress and making their working day more fluent and *especially fulfilling the Company's Business Objective of giving better service to customers.*

The main disadvantage of this problem is the stress caused by having the need to remember to pick up certain material in order for the employees to be able to finish their job.

4.3 MEASURE: PROCESS EXPLORATION

Initial Process Capability

In this section the images of the material values 1) transported according to monthly order made by Company and 2) fetched separately by an employee are being presented. The material is collected in supplier's premises in either of the two ways during the time span of October 1, 2015 – November 30, 2016.

Process Map

Table 4.2 Response variables Y1 and Y2 and their arguments (X's).

Arguments (*X*'s)	Response variable Y_1	Response variable Y_2
X_1	Small equipment and tools fetched	Distance to supplier
X_2	Cleaning and disinfection chemicals and detergents fetched	Gasoline consumption
X_3	Floor waxes and floor condi-tioners fetched	Gasoline price
X_4	Cleaning machine plates fetched	Employee hourly salary (in average)
X_5	Smaller machinery and for example cleaning wagons fetched	Time used when driving to supplier in minutes
X_6	Towels, cloth rags and sponges etc. fetched	Number of fetching trips
X_7	Sanitary paper types fetched	(non-existent)
X_8	Rubbish bags fetched	
X_9	Gloves fetched	

Measurement System Analysis

The data for this report has been received from material supplier's database and it is actual data of material purchase during the time span of the project. It will be directly used in material order planning as value of the fetched material does not effect of the cash flow.

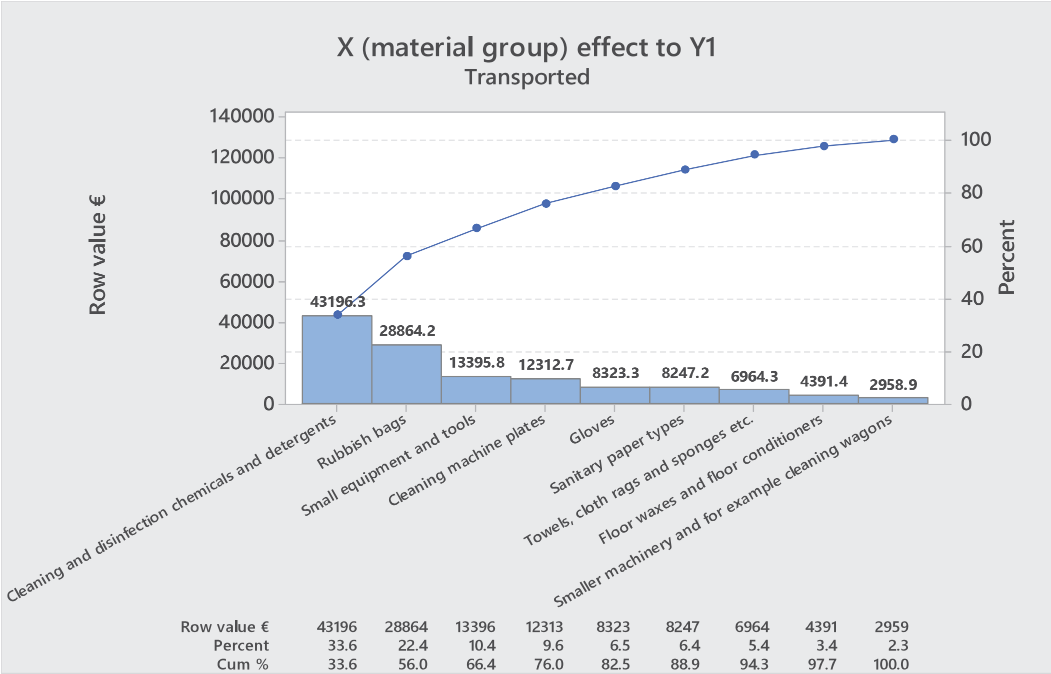

Figure 4.9 Pareto chart of values of groups of transported materials.

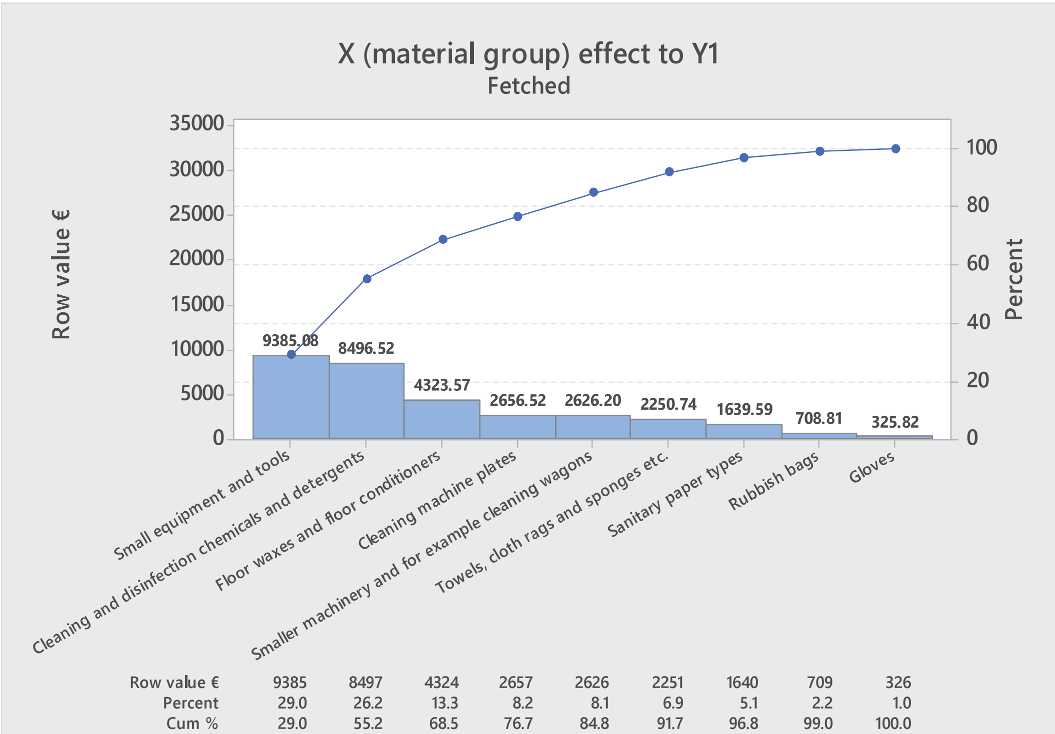

Figure 4.10 Pareto chart of values of groups of fetched materials.

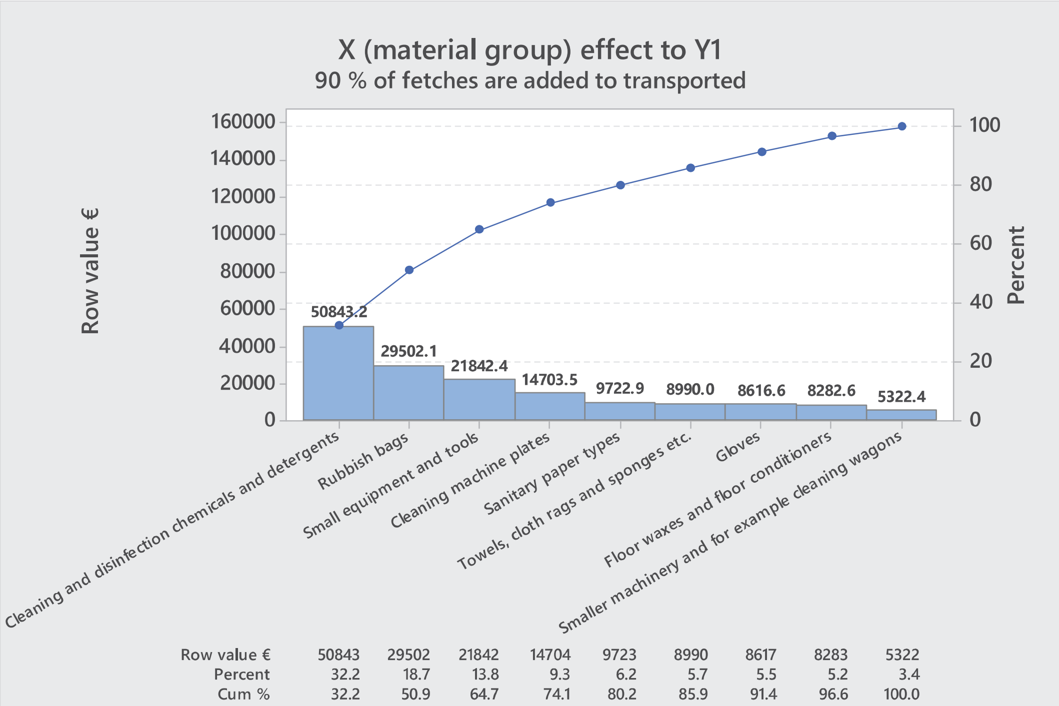

Figure 4.11 Pareto chart of values of transported materials when 90 % of fetched material values have been added to transported materials.

4.4 ANALYZE: DATA

Data value analysis

The goal is to reduce amount of material fetches from supplier and this is only achieved by better planning and calculations of material prices and their effect to stock value. The detailed analysis of the values of material is done in the **Appendix 1**. The conclusion of that table can be seen here. First, for clarity purposes, I repeat the figure from the problem statement earlier in this report that shows the division between fetched rows and transported rows.

By comparing figures and (current situation of item row quantities and their values respectively) and and (target situation of row quantities and their values respectively) we can see they are significantly related to each other.

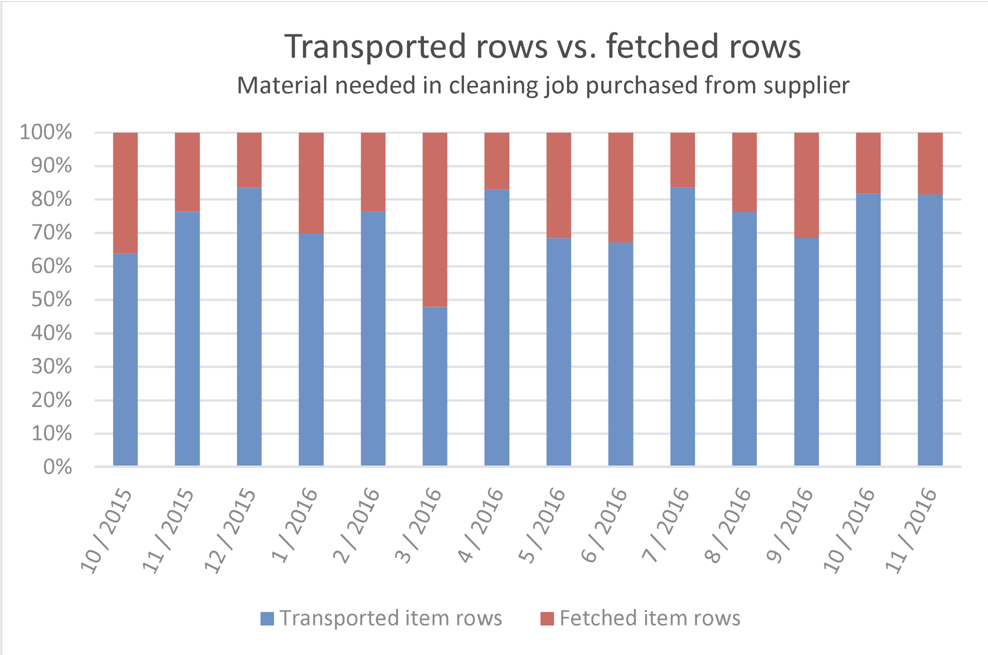

Figure 4.12 Transported item row quantity vs. fetched item row quantity - current situation.

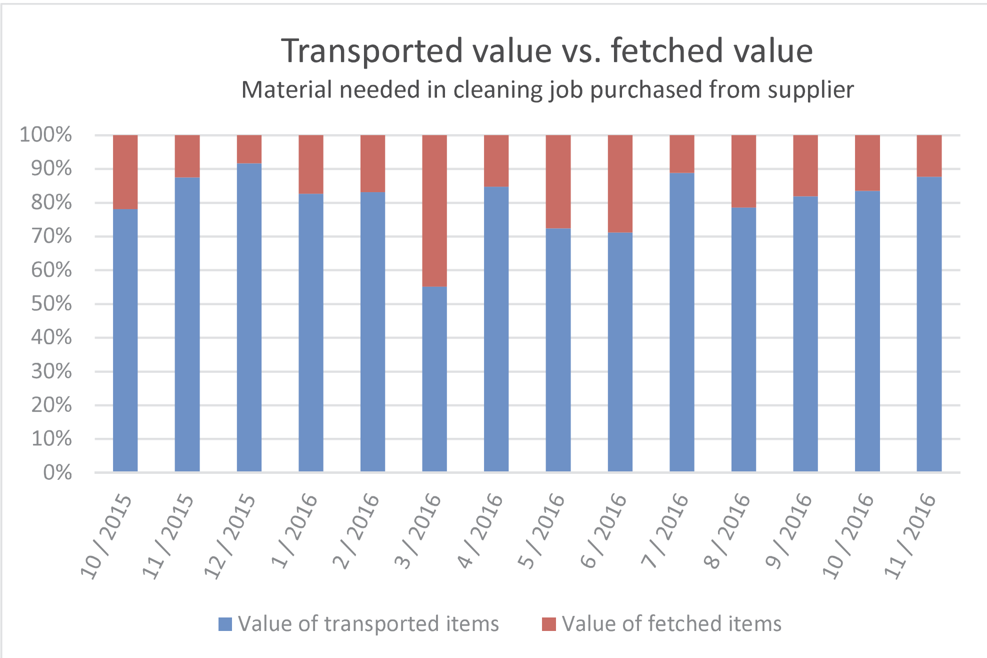

Figure 4.13 Value of transported items vs. value of fetched items – current situation.

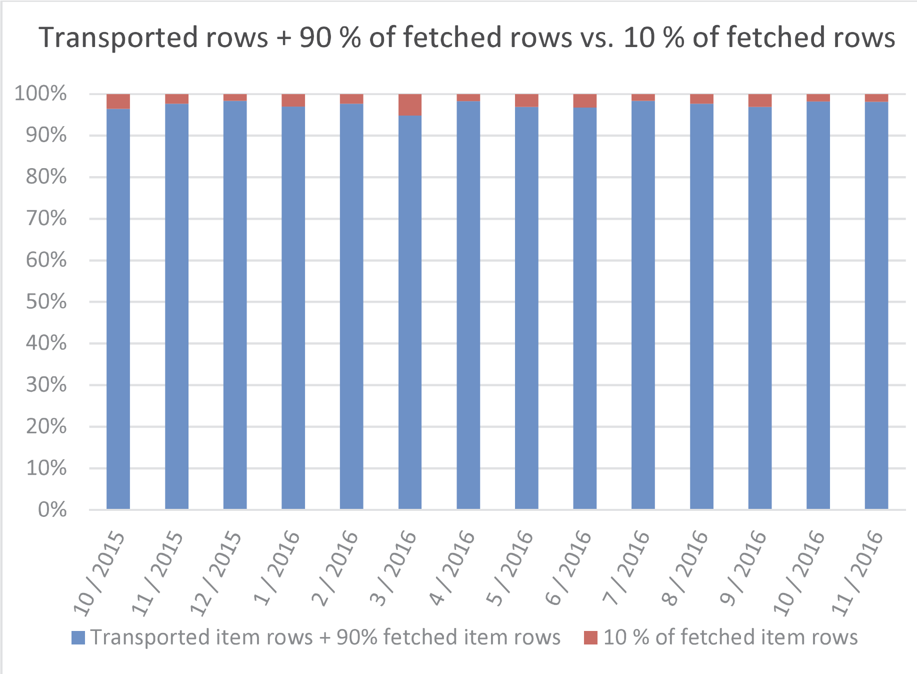

Figure 4.14 Transported item row quantity + 90 % of fetched row quantity vs. 10 % of fetched row quantity - target situation.

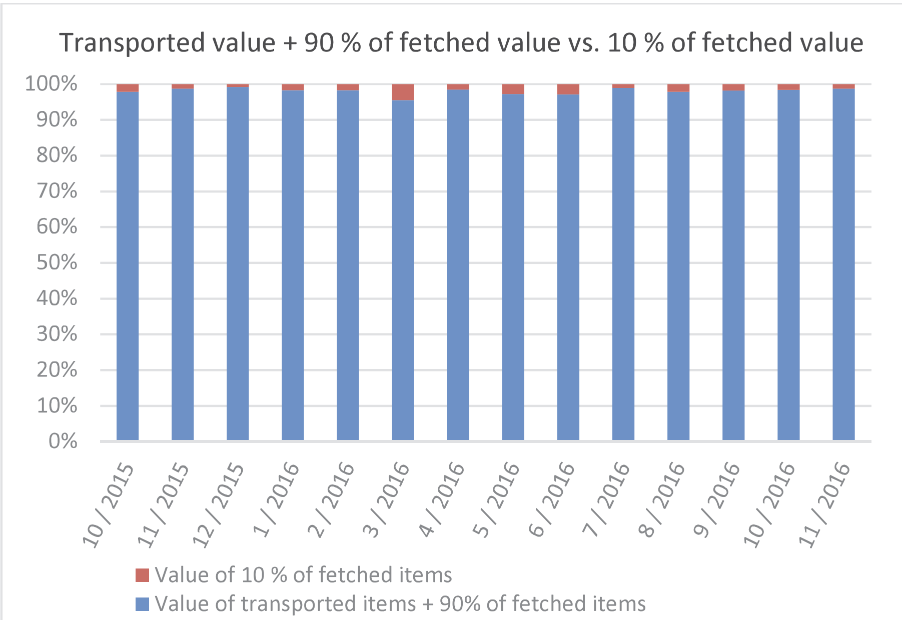

Figure 4.15 Value of transported items + 90 % of fetched items vs. value of 10 % of fetched items - target situation.

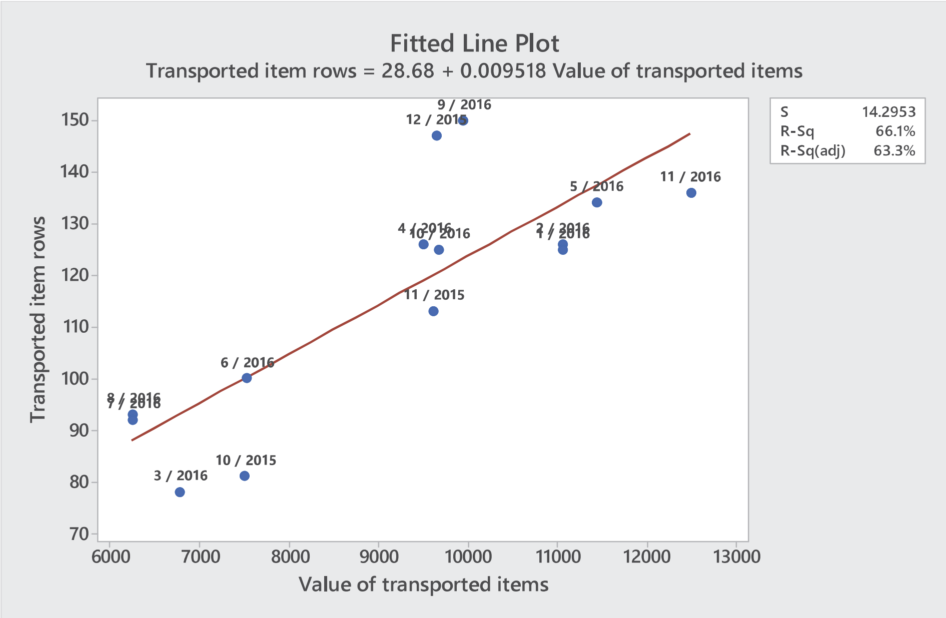

Figure 4.16 Regression analysis between Transported item rows and Value of transported items before any optimization has been done.

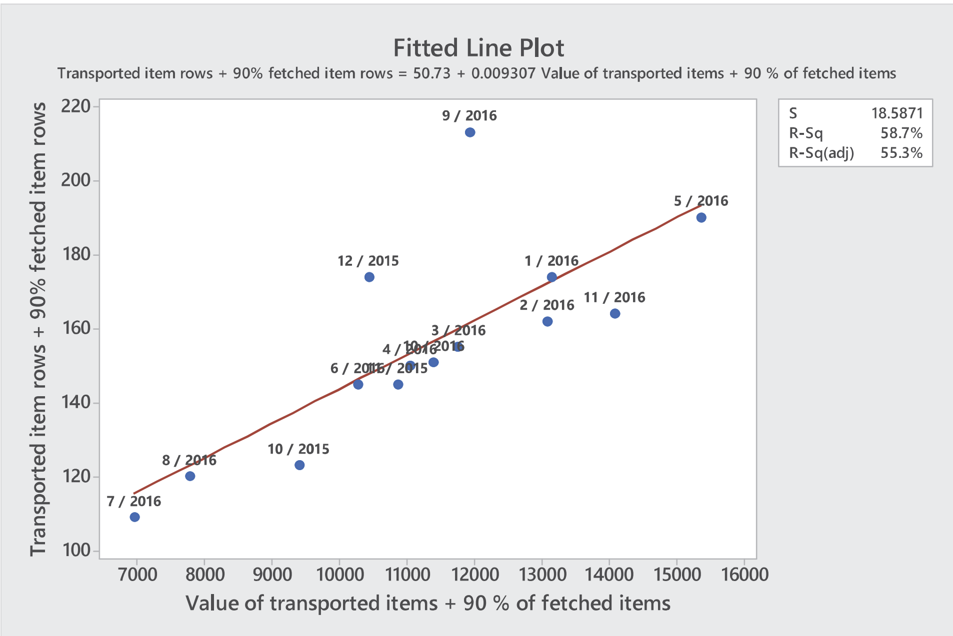

Figure 4.17 Regression analysis between the Transported item rows with 90 % of fetched included vs. Value of transported items with 90 % of fetched included.

The ANOVA table says the *P* value is 0 and thus the linear regression model used in **Figure 4.16** is a good fit to the data.

This means the analysis is done after the optimization (transferring 90 % of fetches to transported which is the monthly order). The ANOVA table says the *P* value is 0.001 and thus the linear regression model used here is a good fit to the data.

4.5 IMPROVE: CONCLUSIONS AND ACTIONS

Improvement Conclusions

The vast data analysis done in this project shows that the amount of fetching trips can be dramatically lowered without it affecting financial performance or cash flow of the company.

Because the Company hasn't collected detailed data about what products are needed, how much, when and to which location this system must be created first. It doesn't make sense to collect or create forecasts or order lists based on the data used in this report since the materials have been ordered according to history knowledge about consumption levels instead of detailed data, which is also the reason why there are so much of those separate fetching needed. It must be known better what products are needed in which location and how much.

Improvement Actions

A material follow-up documentation must be created in order to track down the consumption of each material. This has been agreed together with the Business Controller (= Service Director of the Company).

An example of the follow up documentation is as follows:

Table 4.3 Example of the structure the follow-up documentation should follow.

Date	Material name	Unit	Quantity / unit	Quantity (total)	Destination	Value
dd.mm.yyyy	xxx	yyy	zzz	yyy * zzz	Customer name	Value of the order

This is the first priority job in order to be able to follow the requirements defined in this report: maximum amount of fetches may not exceed 10 % of the value of the transported

(= monthly ordered) value of any item. Thus the alarm level is to be set up to be this 10 %.

4.6 CONTROL: REPORTS

Control Plan

The visits to the supplier must be monitored as this hasn't been done previously. The supplier can give detailed reports about a) transported and b) fetched materials by just asking them to do so. Similar report was used in making this research and concluding the benefit of making the Service Supervisors' and Service Leaders' job more fluent and stress free. Control plan document can be found in the Appendices.

Reports

Service Director needs to appoint persons who will be collecting following reports:

1) Material transported and fetched monthly from supplier
2) The customer by customer material usage history (the material follow-up documentation described in chapter 6.2)
3) The supplier needs to be obligated to collect details to which customer each ordered material row is appointed. This can be done on a higher level also like bunch of customers handled by a cleaning patrol that usually consists of two cleaners.

5 DISCUSSION

The effect in business is moneywise explained in Business Impact -section in Chapter 4.2. The money saved is very small and therefore we can think the project has not been successful if money is considered. However, the importance in organizing the employee's daily routines by showing that by better planning the visits can be reduced can have significant effect since employees know that there is much less need for spending time and energy in fetching material from supplier. The point of the research is to show to the company that not all projects – even though it is normally and generally the foundation of Six Sigma projects – reduce costs but that they also can reduce stress by increasing the level of organized operation. In author's opinion, this is often a forgotten issue when it comes to quality enhancement projects. By showing the significance of this simple planning example it is expected to have appreciation towards organized operation to increase and therefore the need for other organization projects might become more desireable to the top management.

It is the author's main message that all operations in any company are not related to the costs but there is also employee satisfaction involved. Employee satisfaction to working in a company can be catastrophically lowered if unorganized operations cause unnecessary stress in everyday life of the employees.

The importance of detailed data collection is therefore the message of this project and will be part of company culture and philosophy. It must be anyway noted that not all data collection is necessary but that it needs a quality expert to create processes that collect data that is vital to the company operations.

6 SUMMARY

After the history and etymology of Lean and Six Sigma consideration it is necessary to discuss general ideas that the history and theory in previous subchapters lead to. In a practical world, a lean process is defined to be a process that produces products or services that customer wants at a price he/she is willing to pay for [19]. This is naturally the idea behind all businesses around the world but the key question is that lean process uses tools, methods and philosophy of how the customer satisfaction is reached.

A lean process needs to be a fast one which is to say the process flow must be fluent without any or very little waiting time, however, at the same time this fluency is never fixed but is always flexible to in order to match the customer expectancy better.

What customers never want is to pay for costs that do not generate the product or service they want. Normal consumers never think about things of this kind since they do not understand the process that generated the product or service that they paid for but managers who do understand quality related issues know that you can always either

a) sell the product or service cheaper or
b) gain more profits

if the process does not have any incompetent contents. These incompetent contents are generally called in a lean world as waste since it is the word easily understood by any person independent of education level or geographical location to describe anything that is not necessary or wanted.

Getting into more professional description of what a customer does not want gives us the following incomplete, exemplary list of what customers are not willing to pay for:

a) Manufacturing or any other way keeping too much ready made products or resources ready for selling before they actually are needed or sold – that is to keep the stock level low which is easily understood in manufacturing industry but can be understood as too many resources ready to serve in service industry.
b) Unnecessarily throwing away products that cannot be fixed, giving extra service that customer is not paying for or fixing products or services that have some problem or possibility of improvement in them.

c) Any delay or communication that does not cause immediate progress in making the product acceptable.
d) Any wasted time, movement, energy, money or provisioning of the product or service. [19]

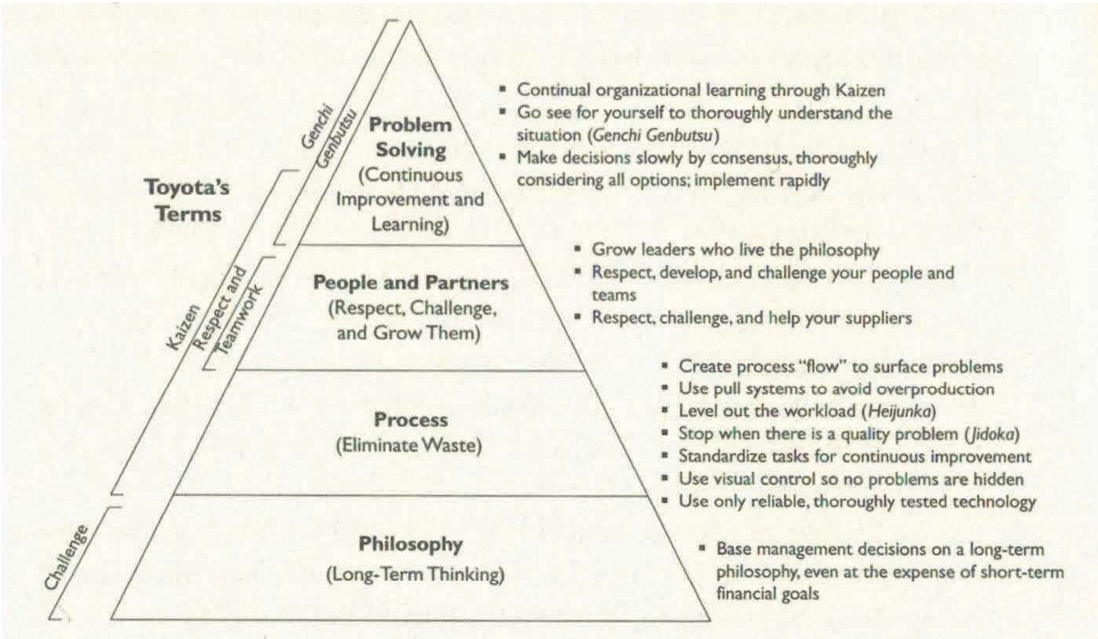

Figure 6.1 The "4 P" model of the Toyota Way [18]

Figure 6.1 is an illustration of the Toyota Production System (TPS) way of reaching excellent results in organizing quality. The Figure 6.1 gives the whole idea of the philosophy of what is nowadays called a lean process. The main idea why the picture is presented here is that most of the organizations according to my experience think that they are lean organizations when they make a budget and they eliminate waste in production. As the picture shows this attitude is not even close to matching lean thinking as it has been defined and most importantly proven to be the lean philosophy that creates excel-lent results every time.

First, the budgeting is a good way to start the financial-based operational planning of what the company is going to do in the budgeted time frame but the problem is that a budget is never a philosophy since the contents of the budget is known only by top management. Lean philosophy is at the heart of every single employee in the company. Long term thinking as lean philosophy means there is a company culture. A lean philosophical culture is not easy to establish if there is no knowledge of lean thinking in the company's top management. To my great surprise, several companies do not even budget anything or have the faintest idea of cost structure or allocation.

Second false comprehension is that a company is lean if it utilizes waste removal and has operational processes that minimize waiting, stocks and movement and thus think that the operational flow is working efficiently. In addition to my work experience, I have been auditing a long list of companies in order to find threats to businesses, and too many times I have faced a situation where company operations are fulfilling all requirements of a neat arrangement needed for employees to operate as efficiently as already Henry Ford required them to one hundred years ago and the requirement of the lowest possible stock levels in order to keep possible problems visible. This is all fine but missing are the respect for other people including the suppliers and partners, genchi genbutsu that is the constant management involvement in understanding the problems and the spirit of understanding the kaizen, the need for continuous improvement and problem solving.

Third sin is to acquire quality management system certificates by reading the requirements of for example several ISO standards and making documents that fulfil the criteria, ask for an auditor to come to read the documents and stamping the certificate without the Quality Manager of the company having any understanding why this is to be done. The only purpose is to improve the company operations. If the company completely fulfils the TPS, or nowadays Lean Manufacturing Process principles, the company operations are on a solid ground without any certificates.

As Walter Edwards Deming put it in an interview [35]:

> “Finding what is wrong is not improvement of the process. If there were a fire here in this building and somehow we put it out that is not improvement, that is putting out fires.
> …
> that is a path toward destruction because they are not studying the system, they are managing outcomes, managing defects instead of looking at the system that produced the defects.”

Improving the processes in all operations is vital for them to improve their operations in general and this is generally far from being generally understood or accepted. Without understanding about Lean and Six Sigma philosophies – not that they are the only ones, but I am referring to a standardized way of operating – there cannot be good management. I strongly disagree if one says they are good at managing a company and have no idea about what is taught in Lean and Six Sigma theories and anything that follows similar principles.

To understand the message of this thesis is in my opinion as important for managers as reading is for school kids. Quality theories should be taught in schools and universities much more than what is being done at the moment since that will change the understanding about efficiency and respect for other people to completely another level and remove stress from people thus causing a vast improvement in quality of living. Quality and fresh air have this one thing in common: they both remove stress when breathed.

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