Quality Improvement of Ground Works Process with the Use of Chosen Lean Management Tools – Case Study

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Abstract. Ground works are one of the first processes connected with erecting structures. Based on ground conditions like the type of soil or level of underground water different types and solutions for foundations are designed. Foundations are the base for the buildings, and their proper design and execution is the key for the long and faultless use of the whole construction and might influence on the future costs of the eventual repairs (especially when ground water level is high, and there is no proper water insulation made).

Article presents the introduction of chosen Lean Management tools for quality improvement of the process of ground works based on the analysis made on the construction site of vehicle control station located in Poznan, Poland. Processes assessment is made from different perspectives taking into account that 3 main groups of workers were directly involved in the process: blue collar-workers, site manager and site engineers. What is more comparison is made on the 3 points of view to the problems that might occur during this type of works, with details analysis on the causes of such situation?

Authors presents also the change of approach of workers directly involved in the mentioned processes regarding introduction of Lean Management methodology, which illustrates the problem of scepticism for new ideas of the people used to perform works and actions in traditional way.

Using Lean Management philosophy in construction is a good idea to streamline processes in company, get rid of constantly recurring problems, and in this way improve the productivity and quality of executed activities. Performed analysis showed that different groups of people have very different idea and opinion on the problems connected with executing the same process – ground works and only having full picture of the situation (especially in construction processes) management can take proper problems-preventing actions that consequently can influence on the amount of waste generated on the construction cite which positively influence on the external environment.

1. Introduction

Ground works are one of the first processes connected with erecting structures. Based on ground conditions like the type of soil or level of underground water different types and solutions for foundations are designed and executed around the world. Foundations are the base for the buildings, and their proper design and execution is the key for the long and faultless use of the whole construction and might influence on the future costs of the eventual repairs (especially when ground water level is high, and there is no proper water insulation made).
Due to the undoubted importance of this kind of structures it is crucial to pay attention to the quality of performed work. Lean Management methodology tools provides many possibilities in maintaining and improving [1] the needed quality of the processes and that is the main reason why it was chosen by authors for the analysis.

Described study involved ground works processes analysis based on the actual erection of the vehicle control station building being under construction in 2016 in Poznan Poland. Three different perspectives on problem-based approaches have been considered in the paper. The analysis involves physical workers, construction engineer and construction manager. Each of them judged at his own discretion the problems had noticed while performing duties, sought the source of it and proposed solutions.

The main goal of this research was to compare different attitudes towards the problems related to the processes connected with ground works and to analyze which group of problems is the most difficult for involved people in the process and why, showing what other direction can be made to fully incorporate Lean Management ideas for the purpose of quality improvement.

2. Lean Management in construction
Lean Management is an approach related to business management involving the elimination of waste [2, 3], which can be defined as consuming any resources for purposes other than creation value for the end customer. Removal of such waste, leads to increase efficiency and productivity with maximum focus on added value for the end customer. The simplest definition of Lean Management is “doing more with less”. This very simple idea can be both very powerful and inspiring. According to J. Womack [4], Lean is lean because it uses less of everything compared with mass production – half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a new product in half time.

Origin of Lean conception is older than name and it is dated back to the fifties of the XX century, when Taiichi Ohno employed by Eiji Toyoda introduced in the automotive system known today as Just in Time as a part of Toyota Production System. However, the term “Lean Production” was firstly used in 1988 by John Krafcik [5] and popularized in the book “The Machine that changed the world” [4]. Lean Management is a management methodology which creates such a job culture in the organization, which makes all participants of the organization interested in continuing the reduction of costs, raising the level of quality and shortening the delivery cycle. Everything is done to maximize the level of meeting customer expectations and prosper, adapting easily to the surrounding (and changing in construction sector) environment. Lean Production / Enterprise / Manufacturing may be treated as a relatively new philosophy to manage company or as a system of concepts and management methods [6]. With the further development of this methodology, term Lean Construction appeared which is related to use of Lean Thinking in construction sector [7, 8, 9]. There exist five key principles of Lean [10, 11], that are helpful in improving processes and enterprises which are presented in Picture 1. All of them are valid for construction sector.

Architecture, Engineering and Construction (AEC) industry is classified as a huge consumer of natural resources. It uses 50% of natural material resources, 40% of energy and is responsible for 50% of total waste generated [12]. It can be stated that AEC industry has enormous impact on world environment and the goal should be to use all available tools to limit and decrease this impact. Lean Management is one of such methods which contributes to improving construction processes and consequently results in decreasing waste in AEC industry. Recent study shows, that introduction of Lean Management has a great potential in construction industry taking into account waste reduction as well as productivity improvement [13, 14, 15].
3. Case study
For the purpose of the study authors decided to analyze construction site located in city of Poznan. The construction site is located in the city suburbs, and the project involves building vehicle control station for local community. Structure will have two levels, with place for the vehicles, where basic car control will be executed.

3.1. Research procedure
The analyzed process involved ground works for foundation of the designed building. During the investigation one member of the research team worked on the construction site in the position of an engineer in general contractor company which was responsible for building the object. In this situation research team had direct contact with the process, as well as site manager and blue collar workers who were interviewed for the purpose of the process analysis. In total there were between seven and ten blue collar workers everyday on the construction site but for the purpose of the study their voice is treated as opinion/comment of one person. Blue collar workers worked together and research team collected answers from all of them and combine it in one piece.

Each investigated group, with research team help, was obliged to prepare:
- Ishikawa diagram with the most important problems encountered in the process
- FMEA analysis for the assessment of the most important problems
- 5 Whys, as a Root Cause Analysis (RCA) for problem with the highest Risk Priority number (RPN)

Research team helped in preparation all the requested data and information. What is more during preparation of Ishikawa diagram there were given to the investigated people seven main groups of problems. Each worker completed the groups in his own discretion and observation during the process.

After completing of all tasks researchers decided to execute analysis of three points of view (construction manager, engineer and blue-collar worker) on problems, which occurs on site during executing works, and propose how it can be resolved. For this purpose, diagrams were prepared showing sum of RPN from FMEA analysis for each group of problems i.e.: logistics, people, management etc.
Researchers decided to use sum of RPN factor, because in each group of problems there was the same quantity of problems, so sum seems to be adequate number to analyze between different groups of people.

The scheme presenting each step of research procedure is presented in Figure 2.

![Figure 2. Research procedure for case study analysis](image)

It should be also noted that before the any action taken by the researchers, there was information meeting for workers organized to explain the purpose of the research and the most important tools that were used for analysis. It was very important step from the point of view of workers, so that they can exactly know what the task was and why data were collected.

3.2. Ground works process description

Analyzed process consists of several steps. It involves (in presented case) subcontractor choose step, preparation step regarding documentation analysis, digging foundations step and preparation the ground for foundation step. In the process there were involved also surveyors who had to set the excavation dimensions in the field, but their opinion on the process activities was not taken into account in the analysis.

The construction manager decided to hire a professional company that specializes in ground construction work. Subcontractors were mainly physical workers from executive companies. Subcontractors were involved in excavation process with the help of excavator and in removal process of that soil and debris remaining after the previous construction. In total 6 trucks were used in transportation of the material out of the construction site to the place of storage which was approximately 30 km away from the construction site.

It should be also noted that soil from the excavation was not suitable for reuse on the foundations, so trucks on the way back, were transporting soil, which was suitable for covering the foundations and storing it on the construction site for future use. Employees of the executive companies were responsible for finding all the pipes and cables that were in the ground and which were marked on the project with a spade. Construction engineer who was responsible from the contractor side for excavation had to check the depth of the excavation and looked for where the pipes and electrical cables could be.

Research team member acting as engineer form the GC was responsible for executed works and for control of ongoing operations on the construction site. Detail process map explaining step by step actions taken related to the preparation of the place for the foundations of the building is presented in Figure 3.
Figure 3. Ground works steps for analysed construction site

In the Figure 4 ready trench for foundation is presented with the water inside resulted by too depth excavation as well as soil delivered to the construction site for the purpose of future use after preparing the foundation to level the ground around them and for future use on the site.

![Figure 4a](image1.png)  ![Figure 4b](image2.png)

**Figure 4.** a) Ready trench for foundations with water inside (too depth excavation); b) Soil delivered and stored on the site

3.3. Results
Summary of the obtained by researcher’s results are presented in Figure 5 where FMEA comparison for all investigated group of workers is presented. Table is directly related to the Ishikawa diagram
|                     | BLUE COLLAR WORKERS                        | ENGINEER                                  | MANAGER                                |
|---------------------|-------------------------------------------|-------------------------------------------|----------------------------------------|
| PROBLEMS            | O  D  S  RPN                              | PROBLEMS                                  | O  D  S  RPN                           |
|                      |                                           |                                           |                                       |
| DELAYS              | 6  6  4  144                             | ear to primary school, a lot of children  | 1  1  1  10                             |
|                     |                                           | long journey (trucks)                     | 6  7  7  210                           |
|                      |                                           | traffic jams                              | 6  7  5  210                           |
|                      |                                           | small gate for trucks                     | 6  5  5  180                           |
|                      |                                           | for trucks                                | 6  6  5  180                           |
|                      |                                           | no crane                                  | 3  2  2  30                            |
|                      |                                           | excavator long wait for trucks without    | 5  7  6  210                           |
|                      |                                           | work                                     |                                       |
|                      |                                           | poor communication                        | 5  6  7  210                           |
|                      |                                           | short deadline                           | 5  6  7  210                           |
|                      |                                           | lack clear decision                       | 6  6  3  208                           |
|                      |                                           | lack clear decision                       | 7  8  9  504                           |
|                      |                                           | no experience engineer                    | 6  5  4  120                           |
|                      |                                           | no experience                            | 5  7  7  245                           |
|                      |                                           | poor meeting with site manager           | 7  7  5  245                           |
|                      |                                           | bed scheduling                           | 6  5  5  150                           |
|                      |                                           | had to control workers all time          | 5  6  7  175                           |
|                      |                                           | no experience                            | 6  5  6  180                           |
|                      |                                           | man did not understand                    | 7  7  9  444                           |
|                      |                                           | had to control workers all time          | 6  6  7  252                           |
|                      |                                           | lack control of earth works              | 6  5  3  90                            |
|                      |                                           | unreliable                               | 7  8  9  504                           |
|                      |                                           | bed measurements                         | 6  5  6  180                           |
|                      |                                           | lack of experience workers               | 6  7  8  338                           |
|                      |                                           | bad cooperation                          | 5  5  5  125                           |
|                      |                                           | had to control people all time           | 6  6  6  216                           |
|                      |                                           | no effectiveness work                    | 6  7  6  252                           |
|                      |                                           | lack of knowledge                        | 5  7  7  245                           |
|                      |                                           | bad communication                        | 6  5  6  180                           |
|                      |                                           | wind (rubbish)                           | 4  4  2  12                            |
|                      |                                           | temperature                              | 3  2  2  12                            |
|                      |                                           | rain                                     | 4  3  1  12                            |
|                      |                                           | problem with communication               | 7  5  2  70                            |
|                      |                                           | don't care about health & safety          | 3  4  4  48                            |
|                      |                                           | problem with solving issues              | 4  5  6  120                           |
|                      |                                           | problem with communication               | 5  4  5  100                           |
|                      |                                           | additional work with grade              | 6  5  2  60                            |
|                      |                                           | work only up to 2 p.m.                   | 4  4  3  48                            |
|                      |                                           | lack of knowledge                        | 5  4  5  100                           |
|                      |                                           | lack trench security                     | 4  3  3  24                            |
|                      |                                           | additional works (not included in contract) | 6  7  8  338                       |
|                      |                                           | additional works (not included in contract) | 6  7  8  338                       |
|                      |                                           | lack proper tools and materials          | 7  8  7  387                           |
|                      |                                           | lack proper tools and materials          | 6  7  9  372                           |
|                      |                                           | water in trench                          | 5  5  3  75                            |
|                      |                                           | elements in ground                      | 5  4  4  30                            |
|                      |                                           | in groundpipes, cables                   | 5  4  4  30                            |
|                      |                                           | insecure measurement of trench           | 6  5  3  90                            |
|                      |                                           | insecure measurement of trench           | 4  4  5  48                            |
|                      |                                           | mud                                      | 7  3  2  42                            |
|                      |                                           | stock a lot amount of sand on plot       | 4  6  5  120                           |
|                      |                                           | stock a lot amount of sand on plot       | 4  5  4  80                            |
|                      |                                           | mud                                      | 6  6  4  144                           |
|                      |                                           | rubbish and metal elements in ground     | 6  5  5  110                           |
|                      |                                           | building rubble in ground                | 6  5  5  110                           |
|                      |                                           | building rubble in ground                | 5  6  5  150                           |
|                      |                                           | plastic container                       | 5  6  7  140                           |
|                      |                                           | plastic container                       | 4  5  6  120                           |
|                      |                                           | steep scarp thus slipping off the ground | 6  5  2  60                            |
|                      |                                           | steep scarp thus slipping off the ground | 4  5  3  60                            |

**Figure 5.** FMEA results for investigated process with worker’s division

prepared 1 step earlier and had the same detailed problems inside. The scale which was adopted for the assessment of each issue was as follows:

- Detection: 1- easy to detect, 10- impossible to detect
- Occurrence: 1- never, 10- always
- Severity: 1- no influence on the process, 10 direct impact on the process
- RPN (Risk Priority Number) was calculated by multiplication of each above factors.
For the most important issues in each group the 5whys method was later conducted as the next step to define the causes of observed and noticed issues in the analyzed process.

Taking into account logistics group each workers group pointed different problems. Only “small gate for trucks” problem occurred three times. For workers it was the least important problem (RPN=2), the most important were “delays” (RPN 144). In total in the category they estimated RPN value from 2 to 144. For engineer the smallest problem was near neighbourhood of school (RPN=16) and the biggest was traffic jams (RPN=210). Total RPN was ranging from 16 to 210. For site manager logistic category resulted in RPN ranging from 180 to 294 with the most important problem of long journey of trucks to the construction site.

In management group all investigated worker groups pointed various problems: lack of experienced engineer, bad scheduling and lack of time to control exactly, lack of clear decision and bad organize orders. RPN factors were on similar level: workers- 120-288, engineer- 150-504, site manager- 160-294.

People group presents very similar point of view of engineer and site manager. They pointed three the same problems: no experience people, unreliable and need to control workers all time. RPN in this case was relatively high: for engineer RPN=180-504, for site manager RPN=252-504. This group of problems had the highest rate of all analyzed. What is interesting for blue collar worker’s problems in this group was of less importance, what is indicated by low RPN level (90-180)

Weather group of problems was the least rated group. All workers pointed comparable problems and RPN level was on similar level: for workers 12-32, for engineer 6-12, for manager 12.

Analogous situation was encountered with contractors group – similar levels of RPN: for workers 60-180, for engineer 48-120, for site manager 90-100. One particular problem was pointed by everyone: problem with communication solving issues. For workers the most important issue was poor quality of job (RPN=180), for engineer problem with solving issues (RPN=120) and for manager problem with communication (RPN=100).

In technology group similar pointed issues were: inaccurate measurement of trench, water and elements in ground. RPN rate was different among participants. Workers and engineer estimated similar high rate for specified problem, only manager assessed this group lower. For workers the biggest problem was lack of proper tools and materials (RPN=392) as for engineer (RPN=378). For manager the most problematic issue were elements in ground which were not pointed in project (RPN=180).

All workers estimated materials group on similar RPN level. Everyone mentioned rubbish, building rubbles and metal elements in ground. RPN was ranging between 40 and 160. The most problematical issue for workers, engineer and manager was building rubble and rubbish in ground.

3.4. Analysis

For better understanding the phenomena of different perspective of problems on the analyzed construction site, the comparison was prepared on both amount and level of RPN for each range and categories. Graph in Figure 6 presents the amount of problems depending on RPN range from FMEA analysis divided into worker’s perspective:
Each worker who participate in the research assessed 27 problems. The most often used RPN ranges were 0-100 and 100-200 (71.6%). This implies that majority of problems that occurred on site were not so important for the stability of the analyzed process. The highest rate 400+ was used only 4 times (4.9%) and only by engineer and manager. It is directly connected with huge responsibility and more detailed knowledge about consequences for not finishing project according to schedule and within planned budget.

Graphs presented in Figure 7a and 7b shows FMEA average values according to occurrence, detection, severity and general FMEA mean values for workers, engineer and manager in the considered process.

Figure 7. a) FMEA average component values for interviewed workers group, b) FMEA mean values for interviewed workers groups.

Average values for occurrence, detection and severity were similar for both engineer and manager. The highest difference can be seen between this two groups together and workers which for severity and detection was lower, and for occurrence higher. Mean values for RPN for all problems for managerial staff (engineer and manager) was almost the same (1.0 % of difference) and for workers was much lower (34.4%) compared to the engineer result. This phenomenon can be caused by various level of education.
and knowledge. Engineer and manager are more educated; workers most often do not have any specialized education.

![Figure 8. Reasons for RPN differences for different group of workers](image)

Authors decided to analyze the reasons for differences and came up with 6 major reasons for such situation which are presented in Figure 8. It can be said that for managerial staff problems of the highest priority were connected with workers, their approach to work and funds, because they took responsibility for finishing the project within schedule and planned budget. Managerial staff results were on similar level which was different than workers. It was also linked with character of job since workers estimated higher RPN values in management and technology groups, because they had direct contact with those problems each day. It can be summarized that main source of different points of view and various range of RPN values was connected with awareness of possible solutions and consequences of occurred problems. It was directly connected with education level, knowledge about construction processes and experience gained on site of each interviewed worker.

4. Conclusions

Presented case study and analysis conducted on the ground works process with the use of Lean Management tools led to the following conclusions:

1. Lean Management tools can be useful in construction sector helping to streamline processes so that it is easier to find, predict and eliminate problems. They also help to find the source of the problems, making it possible to avoid the same mistakes in similar processes in the future what points that Lean Management philosophy application has great potential in the construction industry.
2. The most crucial problem is related to the people involved in the process who in analysed case were unreliable, without willingness to work and with lack of knowledge or experience. What is more, blue collar workers raised the problem of lack of contact with the managerial staff and lack of suitable tools for work and materials.
3. RPN factors during analysis showed that 71.6% of the problems that appeared during groundwork process were of small importance, and only 4.9% was crucial for the stability of the process.
4. There exists difference in assessing similar problems by different people on different position in the process. The points of view presented by both construction engineer and manager were similar with only 1% difference in terms of overall RPN factor, while blue collar workers result of overall RPN was 34.4% lower than engineer.
It should be noted that during the analysis of the process interviewed people approached at first very sceptically to new ideas of Lean Management and productivity improvement. They were of the opinion that it was not needed and they are wasting time. What is more especially blue collar workers being afraid that in case of any problems, they would be blamed and that consequences would be drawn. However, with time, they understood the idea of the study and finally cooperation with them was much easier. They freely talked about what the problem was, about possible solutions and sources.

Authors are of the opinion that proposed methods and solutions can be implemented in other construction sites conducting similar processes. Authors point out the need of further research that should be made with the same workers to compare the final productivity of the process taking into account the turbulent construction environment.

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