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An holistic implementation of lean six sigma methodology on maintenance subsystem

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ABSTRACT

Purpose: One of the main problems relevant with enterprises is to be able to cope with maintenance problems in order to maintain decrease of stoppages, time and economical losses in the production area. In order to acquire an effective and profitable maintenance policy in a production company, there is high demand of methodological strategy to improve the maintenance subsystem. Purpose of this research is to be able to implement the lean six sigma methodology on maintenance subsystem as successfully and supply more effective sustainable maintenance system.

Design/methodology/approach: Lean six sigma methodology purpose on eliminating defects and improve the effectiveness of a process. Research methodology is designed according to the purpose and goals of the research which is based on DMAIC tool within the phases those include quality tools relevant with lean six sigma methodology.

Findings: According to the research results; it is estimated that by implementing improvements and eliminating root causes, wastes; 50% performance increase is possible in maintenance related effectiveness. Lean philosophy and six sigma methodology has high improvement potential on maintenance processes; also successful with gaining on the eliminating of defects and consequently increasing the economical outputs.

Research limitations/implications: This research is limited with the experience and information from real case companies, information from relevant scientific books and theory from scientific databases.

Practical implications: Lean six sigma methodology can be applied appropriately for improving the quality of the maintenance system and maintenance activities those will induce maintenance effectiveness as consequently. More effective maintenance system means decrease in the maintenance related cost, decrease in the maintenance related time due to increase in the speed and increase in the maintenance related quality.

Originality/value: The originality of this research work base on implementation of advanced quality tools in DMAIC phases on maintenance subsystem and studying the quality of maintenance in multi perspective scale.

Keywords: Maintenance; Lean six sigma; DMAIC; Quality; MCDM

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METHODOLOGY OF RESEARCH, ANALYSIS AND MODELLING

1. Introduction

Maintenance is a crucial factor in the economical area between the private industries especially nowadays on the competitive global market. Within the importance of maintenance, it needs to be effectively implemented for improvement of the economical profitability; so that, there have been some methods applicable for the effective implementation of maintenance issue. One of the methods for implementing maintenance as effectively is considering the application of lean six sigma methodology on maintenance area.

Lean six sigma methodology purpose on eliminating the defects and improving the effectiveness of a process. As the maintenance is a process that is crucially needed for a company which is using machines for production and needs to be implemented in the right and effective way, lean six sigma methodology can be applied appropriately for improving the quality of the maintenance system and maintenance activities; those will be induction in maintenance effectiveness as consequently [1-14].

Six sigma is decomposed in two methodologies as DMAIC and DFSS. DMAIC (which is an acronym for Define, Measure, Analyse, Improve, Control) works about developing actual performance and process. During Design for Six Sigma (DFSS) works about creating new service, process, plant, product, service to reach customer requirements (CTQ) in the Six Sigma level [5].

Six sigma methodology represents a valuable process development methodology that is systematic, easy to handle, and structured. The DMAIC methodology begins with the Define Phase, that the process or product needs improvement and it is identified. It activates over fourher specific phases: measure, analyse, improve, and control [10].

Lean philosophy studies on decreasing the costs by the optimization of the process. Six- sigma focuses on the satisfaction of customer's, stakeholder's needs and expectations; increasing the quality by measure and eliminating the defects. The lean six sigma methodology bases on the combination of the tools and principles of these both concepts. Also, lean six sigma's aim is growth, not only cost reducing; and consequently, it works for effectiveness near efficiency [3].

Business professor Shivraj Kanungo from George Washington University reports that, lean six sigma methodology is the combination of the tools, techniques and methods that supplies organizations to increase their efficiency and also effectiveness. That method aims for elimination of wastes and decreasing the variation to reduce the costs and for improving the quality [7].

Carreira and Trudell reports that, lean six sigma is the integration of the most useful aspects of the six sigma and lean manufacturing. Lean six sigma effectively integrates the main issues of the lean philosophy and six sigma that will reflect in the sustainable improvement which is needed for enterprises. Lean helps for faster process flow and six sigma helps for increasing the quality; as it is easy to understand, integrating the lean and six sigma will give more benefits [14].

For gathering the biggest benefits from the lean six sigma, clever enterprises determine X- ray of their work for identifying the process changes those would yield the highest saving. After X-ray has determined the most forcing issues, enterprises start to implement DMAIC with its 5 phases on purposed areas [11].

2. Materials and method

This research has been focused on the relevant theories and their previous implementations on similar areas and also empirical findings from a case company and possible implementations of the claimed methodology on the case company's production station. So that, research has been approached on theory, empirical findings from a case company.

Research materials are collecting the theory from the literatures, collecting the data from the case company, implementation of the claimed improvements on the case company and analysis process.

This research includes the research method that is selected to be used in this case study is a qualitative method, as based on the availability of the data.

Research methodology is designed according to the purpose and the goals of the research which is based on DMAIC tool within the phases those includes quality tools relevant with lean six- sigma methodology.

In this chapter, basis and data of the tools have been presented. The given data belongs to the these tools as MCDM, Critical to Customer (CTQ), Maintenance process map, SIPOC diagram, Cause-effect diagram, Corrective Action Plan (CAP). These tools are selected according to the informative properties that will handle with the problem formulation. And these data have been used for studying on it in the analysis chapter.

Data about MCDM table based on maintenance

For the multiple criteria decision-making table; scale 1-10 is used for inspecting the feedback from the each project for each criteria. The scale is decided as 1 (lowest)-10 (highest) and higher sum of the scores reflects the most successful project name. Scoring has been done according to the criteria and project relation respect to the gaining of the criterions from each project.

In the MCDM Table 1, weights of the criterions are considered according to their importance for achieving the purpose. The weights are scaled in proportional scale as (%).

The criterions:

- Cost effectiveness: Weight of the cost effectiveness is 30% and highest rate in the criterions. Cost effectiveness is the most important issue that would be gathered from the projects.
- Process output: Weight of the process output is 20%. Process output is crucial and relevant for eliminating the wastes.
- Customer satisfaction: Weight of the customer satisfaction is 15%. Customer satisfaction is directly related with the quality and marketing shares.
- Non-technical complexity: Weight of the non-technical complexity is 10%. Non-technical complexity is crucial for the health of the process activities as continuous.
- Adaptability: Weight of the adaptability is 15%. Adaptability regards the current situation of the case company, policy and strategic goals.
- Non-organizational complexity: Weight of the non-organizational complexity is 10%. Non-organizational complexity depends on whether there is harmony in the success of the methodology implementation respect to the current organizational structure or not.

Data for CTQ table based on maintenance

Factors those are critical to customer: Feedback; continuous service; environmental friendly.

Factors those are critical to process: Analysing, improving; less failures; green activities.

Factors those are critical to compliance: Customer oriented standards, ISO standards.

Data about maintenance process map

Maintenance process map includes the activities within a production company maintenance implementation and policy. Activities those take place at the production company are: calibrating the condition monitoring (CM) tools; condition monitoring (CM) measurements; analysis of the measurements; order form; preparation of order; sending the order to maintenance department; check the resources; locate the resources; repair, maintenance.

Data for SIPOC table based on maintenance

Supplier of inputs: Human resources, tool suppliers, material suppliers.
Inputs of the process: Manpower, CM tools, repair tools, maintenance materials.
The process: Maintenance process.
Process start: Due to condition monitoring (CM) measurings and breakdowns.
Process end: Reaching normal parameters.
Outputs of the process: Continuous production Customers of the output: Community.

Data for cause-effect diagram based on maintenance

Ineffective maintenance could be a consist of the causes a less quality maintenance which caused by the following essential reasons:

- Unclear procedure; timing fault.
- Not accessible procedures; no priority.
- Missing personnel; insufficient training; nonsense for urgency.
- Organizational defects; gaps and overlaps.
- Frictions; non-scientific strategy.
- Expensive equipment; missing equipment; calibration.
- Problems.

Table 1.
Data for MCDM

Criteria	Improvement of predictive maintenance implementation	Speeder breakdown maintenance	Employing extra personnel ·	Improving condition monitoring tools	Reducing overlaps
Cost effectiveness	10000 KSEK	9000 KSEK	9000 KSEK	9000 KSEK	9000 KSEK
Process output (h)	8000	8000	10000	9000	9000
Customer satisfaction (%)	50	70	80	100	80
Non-technical complexity (%)	8	8	8	9	7
Adaptability (%)	8	8	7	9	7
Non-organizational complexity (%)	7	6	6	9	6

Data for corrective action plan (CAP) based on maintenance

Table 2.
Data for CAP

Equipment	19%
Missing equipment	6%
Expensive equipment	5%
Calibration problems	8%
Human	42%
Forget to review order status	15%
No sense for urgency	13%
Training insufficient	8%
Missing personnel	6%
Process	15%
Timing fault	2%
No rules for many exceptions	4%
Unclear procedure	9%
Material	6%
Loose papers, no priority	2%
No trays to organize in/out	2%
Procedures not accessible	2%
Supplier	13%
Late delivered by vendor	8%
Out of stock	4%
Order lost	2%
Customer	5%
Changes mind/order	4%
Few feedback from customer	1%

3. Implementation of DMAIC steps

3.1. Define phase

The essential steps of define phase has the implementation procedure as here below:

Step 1: Generate improvement projects respect to the maintenance

First step of Define Phase starts with generating improvement projects using the empirical findings and theory about the lean six sigma implementations and the case company as a source of the information. There are five essential areas in the maintenance subsystem can be improved, the business idea in the production industry is to meet the customer needs and expectations. The improvement idea is to improve the maintenance process performance within the production line.

The suggested projects are by Brainstorming:

- Project 1 (P1): Improve predictive maintenance implementations
- Project 2 (P2): Increase the speed of breakdown maintenance
- Project 3 (P3): Educate the extra maintenance personnel for decreasing the maintenance time
- Project 4 (P4): Improve the condition monitoring tools
- Project 5 (P5): Reduce overlaps between maintenance subsystem and other subsystems Table 3 presents the potential Lean Six Sigma projects in more details with the business objective, indicator, and area indicator.

Step 2: Implementing MCDM

Step 2 of Define Phase is implementing MCDM to rank order the priority of the projects and choosing the most crucial one. Give a weight score for each criterion; evaluate each project respect to a set of criterions on a given scale. Use the scale from 1 (very low) to 10 (very high). It should be understood that this type of evaluation has some elements simulated. Each member in the group evaluates the projects simulated with cooperation with the personnel in the case company. See Table 4.

Normalizing the scales, by dividing each scale in the previous table to the optimum value that=10. Therefore, all the scales are between 0 and 1, 0 is the worst and 1 is the best. Thus, estimate the total rating score for each project by multiplying each score rate by the criterion weight, the consequences of the projects rating represents in Table 5.

Table 3.
Potential lean six sigma projects

Potential Six Sigma Projects	Business Objective	Business Indicator	Area Indicator
Project 1	Decrease maintenance cost	Maintenance cost/month	Maintenance cost
Project 2	Decrease maintenance time	Maintenance time/month	Maintenance time
Project 3	Decrease failure rate	Failure rate/month	Failure rate
Project 4	Increase customer satisfaction	Stability	Customer feedback
Project 5	Increase maintenance quality	Output	Output

Table 4.
Priority of projects and criterions (Normalized)

Criteria	Weight (%)	P1	P2	P3	P4	P5
Cost effectiveness	30	10	9	9	9	9
Process output	20	8	8	10	9	9
Customer satisfaction	15	5	7	8	10	8
Non-technical complexity	10	8	8	8	9	7
Adaptability	15	8	8	7	9	7
Non-organizational complexity	10	7	6	6	9	6

Table 5.
Scores of the projects

Criteria	Weight (%)	P1	P2	P3	P4	P5
Cost effectiveness	30	1	0.9	0.9	0.9	0.9
Process output	20	0.8	0.8	1	0.9	0.9
Customer satisfaction	15	0.5	0.7	0.8	1	0.8
Non-technical complexity	10	0.8	0.8	0.8	0.9	0.7
Adaptability	15	0.8	0.8	0.7	0.9	0.7
Non-organizational complexity	10	0.7	0.6	0.6	0.9	0.6

According to the results in Table 5, project 4 (P4): Improve the condition monitoring tools; has the highest score which is 0.915; this project has the highest priority to be studied and determined.

Step 3: Develop project and team charter relevant to maintenance

Develop and formalize both the project and the team, the best practice in Six Sigma implementation is realizing that go al through a simple project and team charter, see the template in Table 6. The project team consists of a project manager, team members, and project sponsor.

Develop a plan for that project; the plan determined by the author presents in Table 7.

This is an example table; it can be modified according to the possibilities and needs.

Time Based Project Plan is shown in Table 7.

Step 4: Study y or (y) s to be improved

The output of this project (*y*); is increasing the maintenance quality. The output should be improved respect to the critical to quality characteristics, see Table 8. CTQ Table respect to the Maintenance is shown in Table 8.

Table 6.
Project Charter

Business case	Lean six sigma is a methodology that is useful for improving the processes and eliminating the wastes. Maintenance process is a crucial element needs to improved for less stoppages and economical losses in a production line
Project formulation	There are some aspects of maintenance process needs to be improved for more functional and gainful such as eliminating the speed losses, economical losses, quality losses related to maintenance process
Project scope	The output(y) in that Project that needs to be improved is less time, cost, quality loss about maintenance
Team members	Human power that is related with lean six sigma Project and maintenance
Project plan	The chosen model for that plan is DMAIC model

Table 7.
Time based Project plan

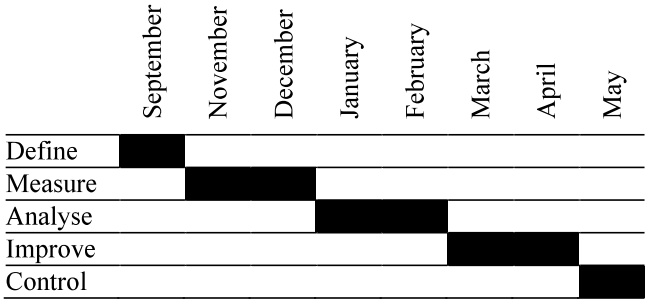

Table 8.
CTQ Table

Critical to costumer	Critical to process	Critical to compliance
Feedback	Analysing, improving	Customer oriented standards
Continuous service	Less failure	ISO standards
Environmental friendly	Green activities	ISO standards

Step 5: Determine performance/process map

For providing the project group to understand and concentrate more about the flow of the current maintenance process, process mapping is a crucial tool to determine all of the activities needed to achieve the aimed goal, see Fig. 1. Process Map is show in Fig. 1.

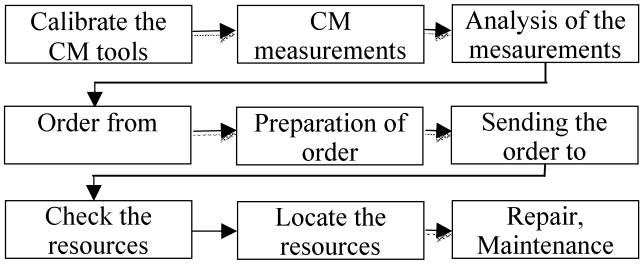

Fig. 1. Process map

SIPOC Table respect to the maintenance:

One of the another important six sigma tools could be used to define the overall process is SIPOC table, it identifies the supplier, input for the process, the main process, the output, and the customer for Maintenance. SIPOC presents in Table 9.

Table 9.
SIPOC table

	Questions	
Suppliers	Who are the suppliers of inputs?	Human resources, tool suppliers, material suppliers
Inputs	What are the inputs of the process?	Manpower, CM tools, repair tools, maintenance materials
Process	What is the process?	Maintenance process
	Why the process starts?	Due to CM measuring and breakdowns
	How the process ends?	With the supplying of normal parameters?
Outputs	What are the outputs of the process?	Continuous production
Customers	Who are the customers of the output?	Community

3.2. Measure phase

Measure phase has the following essential steps to implement:

Step 1: For each y, identify xs

Determine the input factors, (*x)s*, which could effect (y). Use cause and effect (Ishikawa) diagram for visualization of the interactions between (*y)* and related (*x)s*. Diagram represents the cause-effect diagram to identify (*x)s*.

Cause-Effect Diagram relevant to maintenance:

There are different reasons effect on quality of maintenance process, such as the method, tools, and the personnel. The essential reason for less quality maintenance is ineffective maintenance policy. Ineffective maintenance could be a consist of the causes a less quality maintenance which caused by the following essential reasons:

1. Unclear procedure; timing fault.
2. Not accessible procedures; no priority.
3. Missing personnel; insufficient training; nonsense for urgency.
4. Organizational defects; gaps and overlaps.
5. Frictions; non-scientific strategy.
6. Expensive equipment; missing equipment; calibration problems.

Corrective Action Plan relevant to maintenance:

Corrective action plan is useful for identifying the problems and possible corrective actions those could be implemented.

Data Collection Sampling Plan relevant to maintenance:

Data collection sampling plan is helpful for planning and determining the parameters, their measurement and some other related issues which will provide the project group personnel systematic way of collecting data.

3.3. Analyse phase

5 Whys analysis based on maintenance:

5 whys analysis is very useful and helpful for achieving the causes by focusing and decomposition of the problem statement with 5 key questions which are the parts of same chain.

Problem statement 1: The maintenance costs are high

Why the maintenance costs are high? Because there are wastes in maintenance.

Why there are wastes in maintenance? Because, lack of lean maintenance understanding.

Why there is lack of lean maintenance? Because of the lack of maintenance policy.

Why there is lack of maintenance policy? Because of the lack of target strategy.

Why there is lack of target strategy? Because of the lack of target goals.

Problem statement 2: Maintenance time loss

Why there is maintenance time loss? Because of the insufficient maintenance personnel.

Why the maintenance personnel is insufficient? Because amount of maintenance personnel is not enough and not trained as well.

Why the amount of maintenance personnel is not enough and not trained as well? Because of the difficulty in supplying human power.

Why is it difficult to supply qualified human power? Because, well trained qualified human power needs to be expertise on the case work.

Why the human power needs to be expertise on the case work? Because, it's a special designed production line.

Problem statement 2: Quality failures

Why there are quality failures? Because of the difficulty in data collection and analysis.

Why there is difficulty in data collection and analysis? Because of the measuring system and lack of CMMS.

Why there is not strong measuring system and CMMS? Because of the lack of strong maintenance policy.

Why there is lack of strong maintenance policy? Because of the wrong strategy.

Why there is wrong strategy? Because, lack of definition of the goals.

3.4. Improve phase

Tree diagram given in Fig. 2 helps for improving of the identified goal with creative suggestions which completes and supports each other's.

5S Implementation based on maintenance:

5S implementation helps us arranging and improving the effectiveness of maintenance process activities.

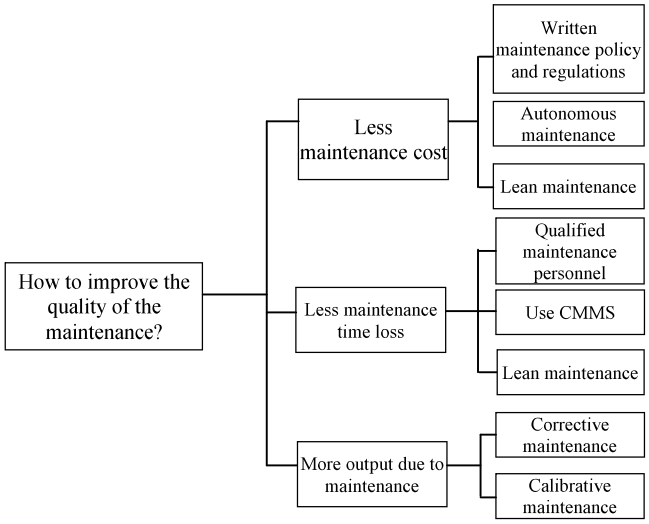

Fig. 2. Tree diagram

Sort:

Organize and separate needed from unneeded:
Define the steps and tools of maintenance at the plant; prepare detailed mapping such as value stream maps for maintenance activities at the plant and separate the needed implementations from unneeded. Also, use red label method for put away the not frequently used equipments.

Straighten:

Arrange and identify for ease of use:
All of the tools and spare parts for maintenance should be well arrange for easy reaching by the maintenance personnel. Labelling, colouring and arranging the tools and spare parts to the specific storages will supply the maintenance personnel speed and to understand the missing parts.

Shine:

Clean and look for ways to keep it clean:
For a better working environment of maintenance personnel, there is need to be cleaning of the maintenance equipment, storages, workshops; and also enough lightning is a crucial factor for a motivated working area. The root causes of the dirtiness in the working environment should be determined and eliminated.

Standardize:

Maintain and monitor the first 3 S's:

For a continuous effectiveness in the implementation of 5S, there is need to supply fiction and systematic system such as plan, create the resources, apply, control. This standardization will supply continuous improvement for the systematic processing of maintenance policy and activities.

Sustain:

Discipline, stick to the rules and maintain motivation: Continuation of the 5S implementation needs to have attention on it; otherwise it will lose its importance and sensitivity in application by the time. To prevent this consequence, comparison of the results of the 5S implementation, motivation on the personnel, training and visual stimulators should take place in the organization regularly.

Poka Yoke based on maintenance:

Poka Yoke method helps us for prediction and elimination of human and mechanical errors.

1. **Processing error**
   Process operation missed or not performed per the standard operating procedure. Prepare maintenance regulation list due to maintenance policy; also prepare a check list within the standard operating procedure.
2. **Setup error**
   Using the wrong tooling or setting machine adjustments incorrectly.
   Make a plan about possible failures and their maintenance activities within the regulation list of the right tooling and right adjustments, calibrations.
3. **Missing part**
   Not all parts included in the assembly, welding, or other processes.
   Determine the maintenance process map; and find the parts which are missing in the maintenance process and add them to the process.
4. **Improper part/item**
   Wrong part used in the process.
   Determine the maintenance process map; and find the parts which are used wrong in the maintenance process and eliminate them.
5. **Operations error**
   Carrying out an operation incorrectly; having the incorrect version of the specification.
   Check the maintenance operations respect to the advanced version of specifications, regulations, time study, maintenance orders and maintenance planning.
6. **Measurement error**
   Errors in machine adjustment, test measurement or dimensions of a part coming in from a supplier.

Check the calibration standards of the tools, check the measuring system; find a software programme that will work appropriate for saving and analysing the measurements.

3.5. Control phase

Step 1 Verify the planned improvements in y

Planned improvements for the output y as defined as effectiveness in maintenance showed that eliminating the root causes of the problem will consequence in success of reaching the goal.
Pl anned improvements as the 5 projects in the Define Phase have increasing potential for reaching the effectiveness goals in the maintenance activities. Especially, eliminating the root causes and improvement suggestions are expected to increase the effectiveness of maintenance almost 50% more.

The actual verifying is based theoretical framework which are simulated on the real samples and similar maintenance activities.

Step 2 Estimate the cost saving relevant to maintenance

Cost saving is directly related with the goal of this case study. For reaching the effective maintenance means speed and quality in the maintenance that effects the cost saving directly.

As implementation of different quality tools in each DMAIC phases; there had been improvement in the outputs of the maintenance activities which are the results of eliminating the wastes and losses in maintenance activities. Consequently, it is expected and targeted that almost 50% cost saving is succeed the by the implementation of quality tools in DMAIC phases.

4. Results and discussion

The main results obtained from adapting DMAIC model are summarized below.

Phase 1 Define:

In the Define phase, it's very clear that Project 4 and Project 2 are the most crucial and supportive projects which will result positive increase in the effectiveness of

maintenance process as understood. Project 4, that is improving of condition monitoring tools is important and helpful with the predictive perspective. By the improvement of condition monitoring tools, there will be more measurements of different factors and also will help to determine KPIs. In this way, predictive maintenance will eliminate the failures before occur that will result in economical gaining, maintenance speed and maintenance quality respect to the lean six sigma methodology in maintenance area.

Phase 2 Measures:

In the Measure phase, it's very important to determine the right measuring system respect to the effective results. In the measuring phase, it is understood that ineffective maintenance has cause roots which can be eliminated.

In the Measure phase, it is understood that there is not enough actual data to calculate variances such as quantities data. But if we observe the quantities data and possible root causes and possible defects; there is also valuable data for the analysis and improvement possibilities.

Phase 3 Analyse:

In the Analyse phase, it has been seen that whys and affinity diagram methods gave creative results that is based on the empirical findings and data.

Analyse phase reflected the actual situation of the maintenance effectiveness and some informations for the improvement phase those would be appropriate for implementing the improvement models.

As the result of analysis phase, it has been seen that, there are gaps, overlaps and lacks in the maintenance activities and maintenance policy of the case company.

Phase 4 Improve:

In the Improve phase, tree diagram, 5s and Poka Yoke quality tools are used for achieving the target purpose. Improvement model is based on the effectiveness of maintenance as decreasing the maintenance cost, decreasing the maintenance time in relation with increasing the maintenance activities speed and increasing the maintenance quality. As the result of improvement phase it is very clear that there is actual improvement potential on maintenance effectiveness.

Phase 5 Control:

The aim and result of the Control phase should be checking the reaching the goals and due to improvements, comparing the gainings. As the strategic goal of implementation lean six- sigma methodology is defects 3.4 per million or 50% increases in the effectiveness of the process. As in this study, the improvement models are applied respect to the lean six- sigma and relevant quality tools. As the result of Control phase; it is estimated that by the implementing the improvements and eliminating the root causes and wastes; 50% performance increase is possible in maintenance related effectiveness.

5. Conclusions

The main conclusions and recommendations about the lean six sigma methodology and DMAIC implementation on maintenance, here below.

This study has prepared for reflecting the importance and benefits of implementing six sigma methodologies on maintenance area.

The maintenance effectiveness is directly related with the private industries' strategic goals in the competitive market. Consequently, there are researches on increasing the effectiveness of maintenance activities. The most crucial root causes of the ineffective maintenance activities are wrong maintenance policy, strategy and wastes in maintenance activities. Lean six sigma methodology is a good implementation method for improving the efficiency of maintenance and eliminating the wastes especially by the DMAIC phases which is the combination of the quality tools relevant with each phase of DMAIC.

It is clear that lean understanding and six sigma methodology known by the other researches as improving capable on different processes and they have big success and gaining on the eliminating of defects and consequently increasing the outputs. Respect to this benefits of two philosophies as lean and six sigma results in higher effectiveness when they complete each others. With the crucial benefits of the lean six sigma methodology, maintenance activities have big potential to gain increasing in the effectiveness in the private industries.

Any case company is suitable for the implementation of the lean six sigma methodology and DMAIC phases that will bring the more effectiveness in the maintenance activities exactly. For any case company, it is suggested that implementing the lean six sigma methodology and DMAIC phases as soon as possible will bring the world class maintenance quality.

Additional information

Selected issues related to this paper are planned to be presented at the 22nd Winter International Scientific Conference on Achievements in Mechanical and Materials Engineering Winter-AMME'2015 in the framework of the Bidisciplinary Occasional Scientific Session BOSS'2015 celebrating the 10th anniversary of the foundation of the Association of Computational Materials Science and Surface Engineering and the World Academy of Materials and Manufacturing Engineering and of the foundation of the Worldwide Journal of Achievements in Materials and Manufacturing Engineering.

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