Lead Time Reduction for managing Engineering Changes

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Abstract. Engineering changes need to be done in a product because of design improvement, product and process optimization, government regulations, etc. Implementation of those changes in the production shop floor involves multiple stakeholders and functions within and outside the company. Engineering change management (ECM) is the process of communication between all stakeholders to implement and document the engineering change on the shop floor. This involvement of multiple stakeholders and responsibilities increases ECM lead time and creates a challenge for change implementation on the shop floor. This paper presents such a case of engineering changes for factory shop floor implementation. Causes like delay in decisions behind an increase in lead time have been investigated. Process automation solutions that can reduce the ECM lead time drastically have been proposed and implemented. The developed solution for tool selection and layout problems achieves almost a 66% reduction in lead time and helps the factory for process standardization and resource optimization.

Keywords: Engineering change Management, lead time, Process standardization

1. Introduction

Engineering change management (ECM) is related to are changes made in forms, fits, functions, materials, dimensions, etc., of products or Processes. ECs usually induce a series of downstream changes. Multiple stakeholders are, therefore, involved in change management [1]. The involvement of various stakeholders and responsibilities increases ECM lead time and creates a challenge for change implementation on the shop floor. Multiple communications between stakeholders add waiting time in ECM process. Most of the research conducted so far is on ECM requirements and the effect of engineering changes for different product types. However, research needs to be done on the micro-level processes of ECM and interrelation between ECM stakeholder's activities.

In this study, we used lean methodology to solve this problem here as we know lean tools are the best way to reduce non value added activities and improve efficiency. In this study, we first mapped the current state for the ECM process. After current state mapping, we analyzed the process in detail to investigate the root causes for ECM higher lead time. As a result of analysis we could find that multiple communications with stakeholder for Torque assignment is the primary root cause contributing highly to increase ECM lead time. We developed a process automation application that can suggest preferences for tool assignment based on the current tooling data. With the help of this application, decision making related to tooling assignment is done with a single communication. ECM lead time reduced by reducing the waiting time and process standardization.
2. Engineering Change Management

Engineering change management (ECM) is an organized way to document changes in the product through effective planning from its identification to implementation. Before starting work for solutions on this problem, a detailed literature review has been done. But there are very few case studies or ECM related papers available. Research has been done mainly on the comparison between EMC paperwork web solutions have also tried [1] for ECM smooth flow. It was mostly related to the reduction of ECM throughput time by web base solution. There have been several industrial case studies on the ECM subject. Saeed et al. [2] have conducted an intensive case study for studying the effect of sound process knowledge on the Engineering changes. In the case of our problem statement, despite strong Process knowledge, we need to work on EC due to engineering changes and continuous improvement activities. So for us, EC reduction is not an option. Hegde et al. [3] have carried out a field investigation on the impact of Engineering Change Orders (ECOs) on the completion time of jobs in repetitive manufacturing environments. In this study, the effect of engineering changes on part supplier and their quality issues and effect on the overall impact on Manufacturing Schedules. This study is talking about external factors that may not always be in our control. Balcerak and Dale [4] have examined ECM in an automotive manufacturer and made several specific suggestions on EC classification and prioritization, and selectivity analysis. Balcerak and Dale put the focus on the difference between purpose and reason for the engineering change. Based on this literature review, we defined the purpose of our project is to improve efficiency by reducing decision-making time. Harhalakis [5] has carried out industrial case studies on engineering change management for made to- order products. He studied the effect of many Engineering changes on the bill of material and material requirement planning and came up with a system that integrates these Processes. Watts [6] has told his experience in re-engineering the EC control process in an electronic product manufacturer. Perhaps, Dale’s early work in 1982 was among one of the best papers that provided a comprehensive framework and yet specific proper practice guidelines [7]. Based on his company case studies, Harhalakis [5] also outlined an ECM system. These contributions not only identified ECM activities but also described responsibilities. The literature has highlighted a clear message that EC is a severe issue that cannot be underestimated, and ECM is of significant concern to most companies that design and manufacture products. This has been confirmed in a survey conducted by the authors within the UK manufacturing industries [8]. In addition, the limited number of references has also highlighted that ECM is, in general, under-researched, and ECM deserves much more attention compared with its extent of severity, as highlighted in the literature.

3. Objectives of the study

Considering all the literature research, so far, research has happened on the ECM process, its components, Style of ECM execution (Paper-based or web-based). The main objectives of this study:

i) To identify and remove internal non-value-added activities carried out in the process.
ii) To study inter-relation between various ECM activities and the stakeholder involved.
iii) Develop effective communication strategy among various stakeholder, and avoid decision waiting time between multiple stakeholders to reduce ECM lead time

3.1 Problem Statement -
A manufacturing factory has some process change activities going on because of changes by product engineering. Those changes must be absorbed on the shop floor to start the production. To check its feasibility and system integration, those changes are updated in the system before it goes for implementation on the shop floor. This task of updating changes and its documentation in the system has been assigned to a manufacturing service provider. The service company works remotely and has only virtual access to the factory shop floor. Therefore, at present service company has to rely on the factory for most of the inputs and decision making.
Since the service company person is not able to make all decisions, he must wait for the response from the factory. In most of the cases, response time is up to 3 days. Hence, till the time the current ECM is waiting for a response, one has to work on multiple ECMs in parallel. Various touch points for single ECM lead to an increase in the execution time of ECM by 15%, depending on the complexity of ECM. As in this problem, we are dealing with waste like waiting time for decision and multiple touch points for an ECM, and we can use lean methodology.

4. Problem Priority Matrix

After analysis of the complete Engineering change management data from history, it has been observed that some steps in change management are heavily contributing to an increase in change management lead time increase. Execution time vs Lead time comparison shows that for ECMs, execution time is 0.5 to 2 hrs whereas the lead time for these ECMs is up to 72 hrs (Shown in fig.1).

Lead time = time elapsed between receiving requests from factory for Engineering changes implementation and the change implementation and documentation completed in the system by the service company.

Execution time = Actual time spent by service company resource for implementation and documentation of the change.

Lead time = Execution time + time for decision making on changes + waiting time for inputs based on a decision made

From problem priority matrix and Pareto analysis for various types of changes handled by a service company and execution time required for these changes, below are the changes are contributing for more lead time for changes implementation because of waiting and decision-making time (As per Fig. 2) -

- Duplication of existing tooling's for a new application.
- Assembly part station changes
- New tool procurement for assembly stations

Therefore, based on the Pareto chart, changes that are related to new assembly tooling and torque controls, existing tooling duplications are contributing heavily to an increase in change implementation lead time. So, only these types of changes have been considered as a scope for this project.
5. Current state mapping

Current state Mapping shows the current Process flow. It shows the current relationship between multiple stakeholders involved in Engineering change management activities.

5.1 Change management Process flow chart

Change management process flow chart shows typical 4 phases of change management like input, Analysis, Execution, and Delivery to customers.

Fig. 3. ECM flow process chart

5.2 SIPOC

In Order to understand the complicated relationship between stakeholders and process, we have mapped the Engineering Change Management process under SIPOC. (Fig.4)

Wherein the supplier is a factory that provides inputs like design and Process changes happened. In the process, we have listed down the detailed process of tooling assignment ECMs, which gives a comprehensive understanding of process flow. Output in this process is the changes made in the system and delivered it back to the customer, which is Factory ME.

Fig. 4. SIPOC

5.3 Swim Lane diagram

Based on the detailed Process flow from SIPOC Diagram, we mapped the flow or Steps of the transactions that happen between stakeholders like engineering, Unit ME, and service company.
6. Analysis

6.1 Fishbone Diagram
In Current state mapping (Fig. 5) we could understand that multiple transactional activities between Factory ME and Services for information and decision making are causing higher ECM lead time. To understand root causes for this multiple communication for information’s and decisions we plotted Fishbone diagram.

6.2 Why-Why Analysis

![Fig. 6. Fishbone Diagram](image)

![Fig. 7. Why-why analysis](image)
From fishbone diagram (Fig. 6) it can be seen that waiting for tool station number, waiting for the decision for if we can use the same tool or duplicate it, waiting for tool number are the reasons from method category and unstructured data tooling from material category leading to higher ECM lead time.
Tools are not mapped to the station, and tool racks layout not available is the significant root cause for higher ECM lead time.

7. Proposed Solution

7.1 Tooling Layout

There are 10 ME looking after these 3 departments the main changes have been observed is related to standardization of data storage related to tooling especially not standard tooling used on the assembly line because standard tools which are connected to manufacturing execution system can easily be tracked or assigned based on system data, but the main challenge is about custom tool built for specific product order use. These tools are not mapped to stations rack, and there is no custom tooling racks standard layout as such, so the service company team assigns the tools based on old references, which leads to quality issues. (Need to create tooling layout and map the racks to stations with the alignment of factory Engineer)

So, we developed the tooling layout and mapped all stations to particular tool racks (see Fig. 8). Then with alignment with factory ME rules have been set for the use of tools from specific shelves. These rules have been used to set logic for tool assignment automation.

![Fig. 8. Tooling layout](image)

7.2 Tool selection Automation

![Fig. 9. Tool selection Automation window](image)  ![Fig. 10. Tool Visualization](image)
Another problem observed while analysis of the process is that there is no standard procedure available to track tooling information. So, each ME keep that information in a different format as per different departments requirement. (Need to create a location where all ME will update the tooling information at the standard format). After making tooling layout, tool assignment rules, data tracking standardization, we developed tool assignment applications (Fig. 9 and 10). It gives preferences for tool assignment based on hardware attributes, assembly station, and torque specification. It also suggests preferences for tools duplication and torque standardization across multiple stations.

We added all images of tools and labels for visualization and easy identification of the tool. We defined the nomenclature for the tools. So, it can be easily identified and have the track for the stations and tool rack.

3D models for these tools are not available in PDM as these are a non-standard and custom tool; adding images and labels helps service company person to validate tools reachability and accessibility considering other parts to be installed on a particular station. (Fig 11 and 12 shows the difference in tool socket length)

8. Implementation

This solution has been successfully implemented for both manufacturing factory for all tool tracking standardization such as tool data tracking, tool racks mapping, tool usage rules and service for tool selection automation.

Success for this project can be seen from the above swim lane diagram after implantation of this project. Tooling assignment multiple communication and waiting for decision has been completely removed with the new process. New tooling addition and old tool deletion form has been provided in
application to be able to update the tooling database in standard way. Limited user access has been provided so as to keep data up to date and controlled.

9. Results
Lead time for tooling assignment ECM has been reduced from 3 days to 1 day (66% reduction). That too, this 1 day is for complete looping of ECM. The number of tooling assignment related communication has been reduced to 1 from 3 earlier. Tooling assignment time has been reduced to on an average 4.34 min from 12.7 min earlier (65% reduction).

10. Conclusions
In this project, we have successfully used lean tools for service companies and reduced the service lead time by reducing the waiting time for decision making. This project has reduced the multiple communications between manufacturing factory and service industry. Hence, there is reduced the dependency on manufacturing factory to get all inputs. Also, numerous touch points per ECM has been minimized, which at the end resulted in overall execution time for change implementation in the system. Also, the factory is getting a lot of suggestions torque standardization by using this application which in turn going to reduce the process complexity online and reduce the number of tooling count in factory.

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