REDESIGN OF THE ENGINEERING CHANGE PROCESS OF A SUPPLIER IN THE AUTOMOTIVE INDUSTRY

Abstract

Engineering change (EC) processes often involve many functions and deal with dependencies inside and between products, organizations and production facilities. Therefore, it is complicated and sensitive to disturbances. Lean Product Development is a promising approach for reorganizing product development according to certain principles. The objective of this study was to find possibilities to improve the performance of EC processes, and the lead time of information transfer in particular. Another objective was to test if methods from Lean Product Development could be used to improve the EC process. A case study was performed at an automotive industry supplier to investigate their EC process. Methods used for data collection and analyses are process mapping, including estimation of lead-times within the process, interviews and questionnaires. Support for the redesigned process was implemented in the PLM system of the company. To redesign the EC process Lean Product Development principles were used. The study concludes that lead-times for information transfer of information in EC processes can be reduced to some extent by using this approach.

Keywords: Engineering change management, Process redesign, Lean product development, PLM

1 Introduction

Engineering changes (EC) in this paper are defined as changes to designed and manufactured products that are made after the first release of drawings for tool manufacturing or serial production. Underlying causes included changes in the customer specification, altered production requirements, weaknesses identified in testing and many other reasons. To implement the change, the documents or sets of information that describe the product are changed resulting in a change in the actual product and in some cases also the production and sourcing process of the product.

Pikosz and Malmqvist give a general description of EC management in [2] based on three cases studies in Swedish industry. A thorough investigation on how ECs are handled in UK industry is presented in [2]. An assessment method of the EC process is introduced in [3] and the EC process is investigated in individual and mass production. Propagation of ECs causing side effects of a change is treated in [4] and [5]. The problem of changes in ongoing product development project and the use of the change propagation method are described in [6]. A solution to capture and reuse of knowledge in the EC process is suggested in [7].

This earlier research indicates that a major challenge when implementing an engineering change request is to analyze its impact and to make changes to all related resources. This is demanding since here are often multiple dependencies between the changed parts or product(s) and production facilities, other products [4], personnel at different positions, logistic systems, customer requirements etc [5, 6]. If fit, form or function is changed the changed part is often incompatible with the old part. This will lead to a need for other changes to parts, which can be considered as unwanted side effects to the change [4]. ECs are often done under time pressure and if the change does not work as expected the time to do corrective measure will be even shorter. ECs are often unplanned and invoked late in the product development (PD) process. Unplanned changes late in a PD project or in a product that is in production can cause enormous problems due to the circumstances described above. The EC will tie up resources that were planned to be used for other purposes. The ability to avoid ECs, master ECs and foresee the side effects of ECs will strengthen the organisation and leave more resources to be used for strategic product development. For these reasons it is important to gain more knowledge about ECs.

However, the confidential and competitive nature of data on engineering changes is a major reason why there is little empirical data on engineering changes available [8]. There is also a lack of research that describes how engineering change processes can be diagnosed and re-designed, along with evaluations of the effects of such a process redesign effort.

The aims of this paper are thus to

1. Provide empirical data on the engineering change process in a company
2. Evaluate the applicability and utility of categorisation of waste [9] and lean product development principles [10] when redesign and engineering change process
3. Evaluate the benefits of automating the engineering change process in a PLM system, essentially to reduce lead-times for information transfer.

The remainder of the paper is structured as follows: In section 2, the research approach of the study is described. In section 3, the results of the diagnosis of a company's engineering change process are discussed. The redesigned process is presented in section 4 along with some experiences on its utility. Conclusions are listed in section 5.

2 Research approach

The research was carried out as a case study out at a supplier in the automotive industry – Supplier A. Supplier A had at the time of the study 2300 employees. The products of the company are gear shifters, seat heating equipment, head restraints, clutch actuation equipment and other related products. Supplier A is a global actor in the automotive segment.

The dynamic situation of a supplier in the automotive sector demands that investigations on business processes with corresponding process improvements have to be done on site in close cooperation with supplier A. This is necessary to be able to verify the results from the investigation evaluate process improvements and implement them before the state of the firm has changed.

Methods used to analyse the EC process were:

- Process mapping using the FlexMAP method [11]
- Study of existing documents for engineering change control and documentation
- Estimation and measurements of lead-time in the company's engineering changes process
- Identification of waste in the processes
- Comparing current status with lean principles and waste classification

The application of the methods is discussed in more detail below. The data was mainly collected through interviews. Questionnaires with complementary questions were also used.

2.1 Process mapping and questionnaire with complementary questions

The process mapping method used was FlexMAP. This method is described in [11]. Process mapping interviews were conducted at the three different divisions of Supplier A. Between 5 and 15 persons were interviewed at each division. A questionnaire was put together to get answers on unanswered questions as a complement to the process mapping. Answers were analysed and added to the case description.

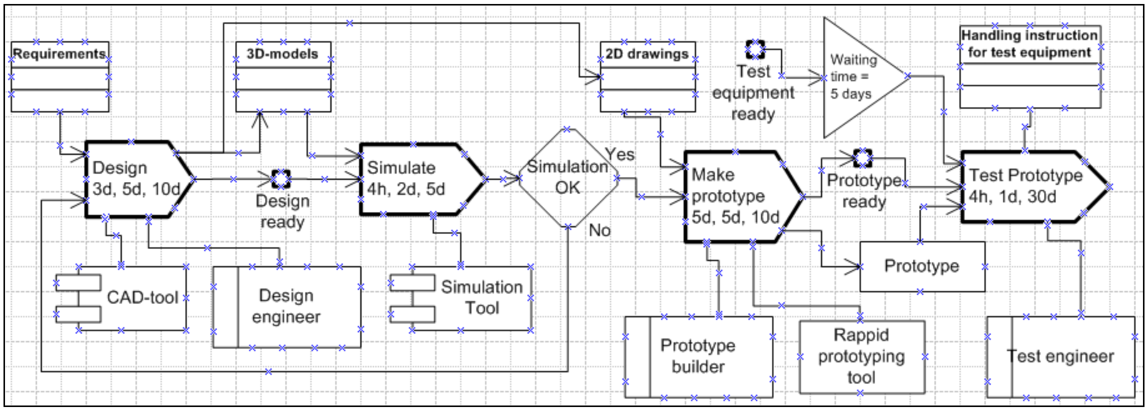

Figure 1. Example of process map developed with the FlexMAP method.

2.2 Estimations and measurements of lead-times

Time measuring was done in two different ways. One way was to confront a group of persons working with EC issues with a process map of a general EC process mapped at Supplier A. The group was asked to estimate the shortest, longest and most likely time for each task and each delay in the process. This was noted directly in the process map and later transferred to a MS Excel spreadsheet to make calculations of the overall shortest, longest and most common time.

The other way of measuring the time duration of a specific process and its activities was to track down the process by checking dates in e-mails, meeting minutes and in personal diaries.

2.3 Waste map

Bauch's [9] method to identify waste in the engineering change process was applied. Bauch has identified different kinds of waste and classified them according to a waste map. The waste drivers are:

- Over production
- Waiting
- Transport/hand-offs
- Inventory
- Over-processing/unnecessary processes
- Unnecessary measures
- Defects

- Knowledge
- Lack of system discipline
- Limited IT resources

The generated waste map was compared with findings from this case study during process mapping and time measuring of the EC processes. The waste found was noted and solutions to eliminate the waste were sought.

2.4 Lean product development principles

Finally, lean product development principles were applied in order to find ideas on how to re-deign the process. The principles applied are described by Morgan and Liker [10]. They suggest 13 different principles:

1. Establish customer-defined value to separate value added from waste.
2. Front-load the product development process to explore thoroughly alternative solutions while there is maximum design space.
3. Create a levelled product development process flow.
4. Utilize rigorous standardization to reduce variation, and create flexibility and predictable outcomes.
5. Develop a chief engineer system to integrate development from start to finish.
6. Organize to balance functional expertise and cross-functional integration.
7. Develop towering technical competence in all engineers.
8. Fully integrate suppliers into the product development system.
9. Build in learning and continuous improvement.
10. Build a culture to support excellence and relentless improvement.
11. Adapt technology to fit your people and process.
12. Align your organization through simple, visual communication.
13. Use powerful tools for standardization and organizational learning.

These principles were compared with the results from the process mapping, interviews and time measurements and waste maps. Deviations from the principles were noted and analysed. Improvement was sought that was in line of what was imposed by the principle (see figure 2).

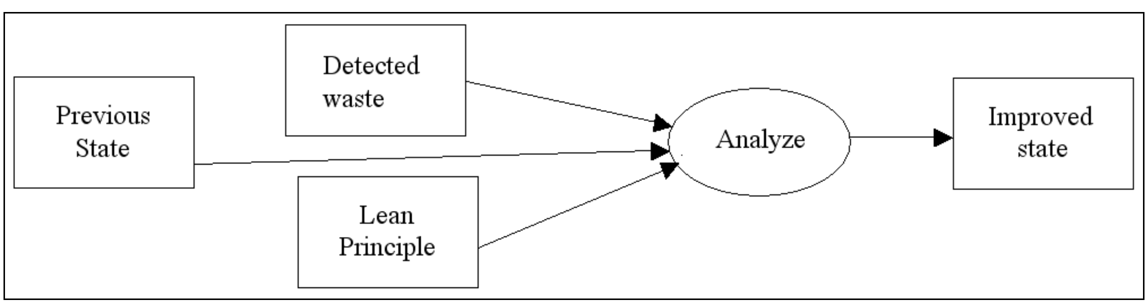

Figure 2. Schematic view of the process of using the lean principles and waste maps to find improvements of the EC process

3 Diagnosis

In section, we account for the diagnosis of the company's EC process, divided into sections derived from analysis of process mapping, interviews and documentation, lead-time estimations and measurements, waste analysis and lean product development principles.

3.1 Findings from process mapping, interviews and document analysis

The analysis of interviews and documentation at Supplier revealed a number of issues. These are summarized in the following:

- Lack of overview over an EC issue affecting more than one part due to a one-to-one relationship between the existing EC document and the changed part.
- Communication in the company made more difficult due to that seven different EC documents were used at different sites of Supplier A for the same purpose
- Difficult to coordinate the introduction of parts when several parts are changed
- Lack of EC status information due to a lack of formal signal from production when the change had been implemented
- Lack of visibility of EC status for all involved and affected actors
- Time consuming physical handling of documents
- A lot of paper work in production even for small changes
- Long lead-time for approval of drawings when customer involved
- The use of paper documents imposes a serial manner process instead of a parallel process with shorter lead-time.
- Information transfer takes time, manual routines are used
- No way to capture and reuse knowledge gained in the process
- Process was too focused on the release of the change specifications in contrast to a more front-loaded process.
- The relation to the current process for product development was weak
- Unclear roles in engineering change process

3.2 Analysis of lead-time data

The process map and the lead-time estimations and measurements were first used to get an averaged assessment on the time that Supplier A used to complete an EC issue. To relate this estimate to a new EC process the phases of the new process are marked where the corresponding steps of the previous process is done. The result from this estimation is shown in figure 3. The longest time for an EC issue to is slightly over 550 days and the shortest times approximately 40 days. The average time is approximately 180 days.

As a complement to this estimate, data from two specific EC cases at another division of Supplier A were sought out. The results from measuring these two processes showed that there was a lot of unwanted rework in the process. The results from these measuring are shown in figure 4 and figure 5. Activities in these two processes (gaiter and sensor arm) were also mapped towards the phases (see table 1) of the new process. This mapping shows that the processes in both cases are fragmented and that a lot of rework (waste) is done in the process. The result from this mapping is shown in figure 6. Each phase in the new process is assigned a unique colour. Each step in the mapped processes is mapped to the phases of the new process and the marked with the colour of that phase. Every time rework is needed we need to go back to earlier phases in the flow and do rework. The mapping is done for two processes which are EC of a gaiter and EC of sensor arm. The gaiter is in two versions and the change on each version differs slightly. The gaiter is therefore shown in two graphs.

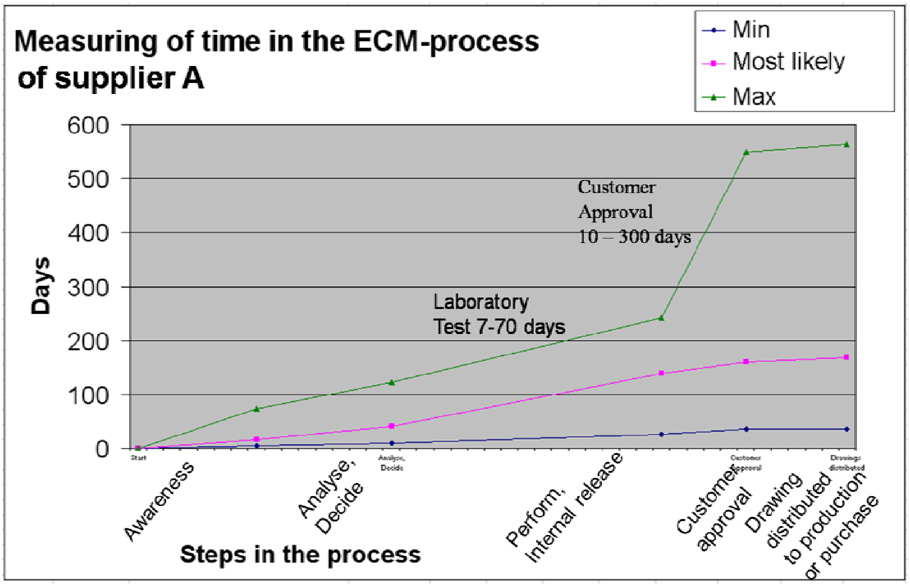

Figure 3. Lead-times for engineering changes at Supplier A.

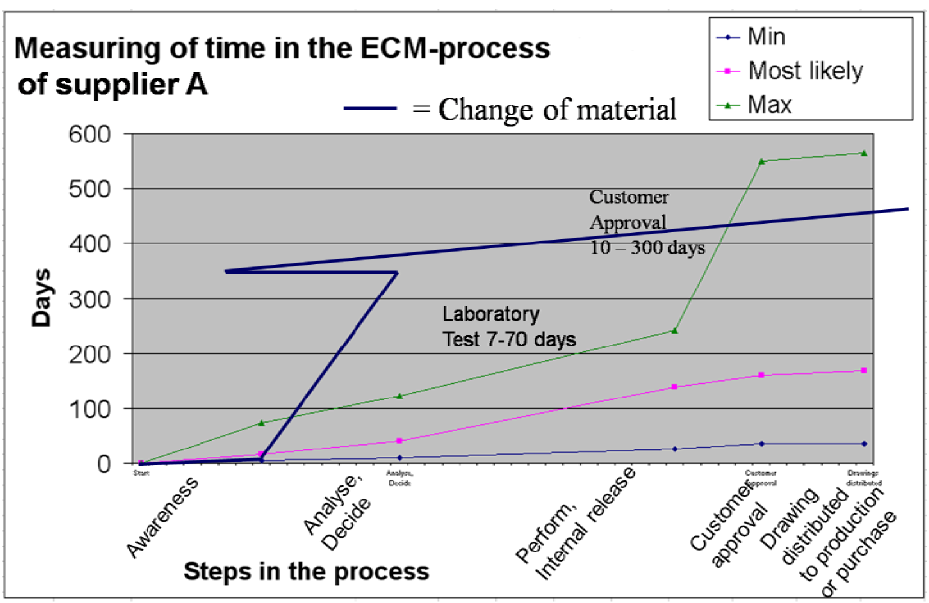

Figure 4. This change is to a gaiter that is part of a gear shifter. It is shown together with the graph from the measuring at the other division in figure 3. The thick line shows the progress of this change.

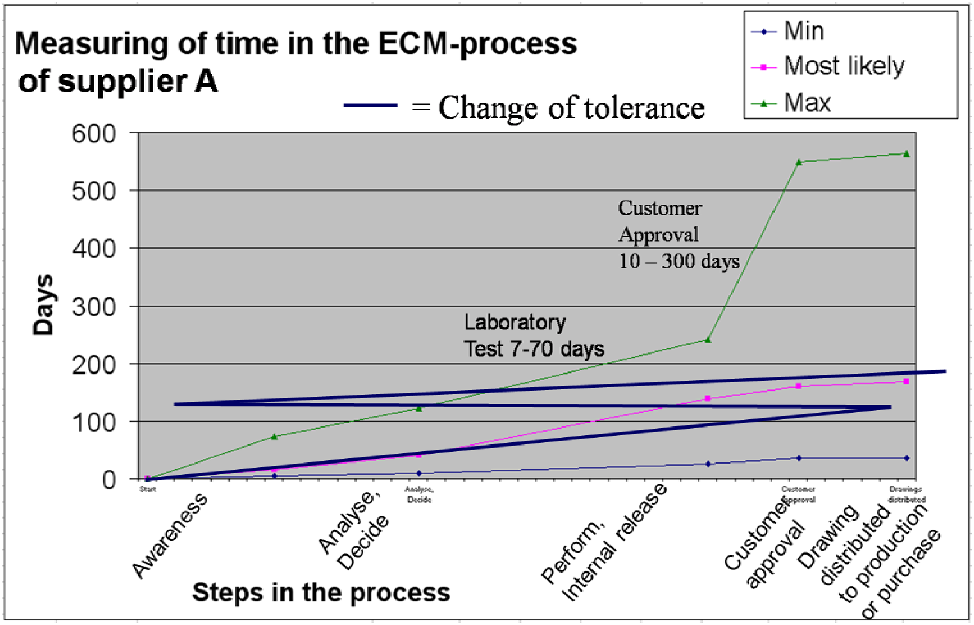

Figure 5. This is a change of a sensor arm in a gear shifter. It is shown together with the graph from the measuring at the other division . The progress of the change is shown with the thick line.

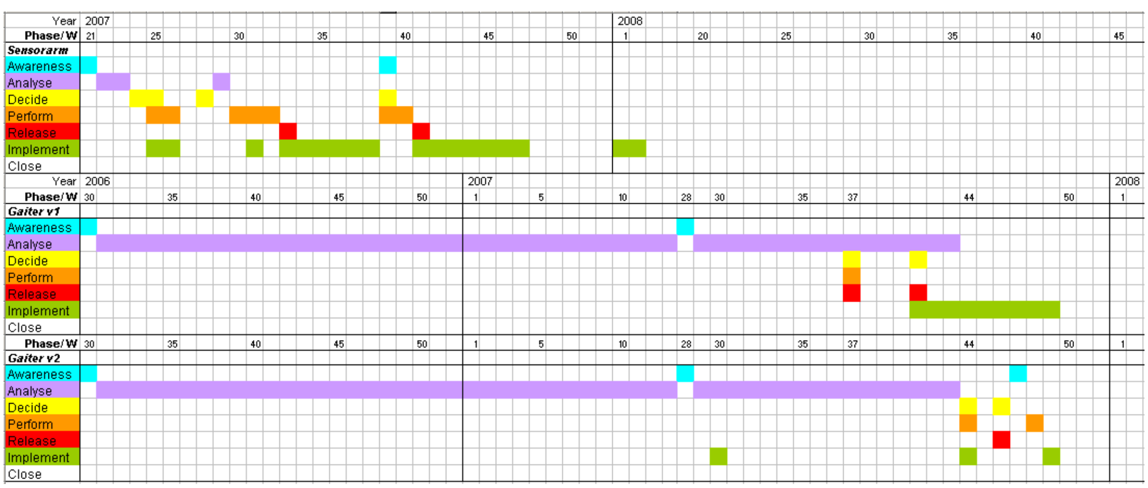

Figure 6. Process fragmentation.

3.3 Waste analysis

The next analysis dimension focused on waste. Several types of waste were detected:

- Work efforts due to rework
- Waiting due to busy people
- Work due to process redundancy
- Waiting because of poor information transfer
- Time spent on finding information about the change
- Time spent on unnecessary coordination because of lack of information
- Physical handling of documents
- Knowledge is scattered and sometimes lost when the EC issue is closed
- The EC process was also fragmented. Figure 6 shows that early phases of the EC process had to be done all over again because of decisions based on poor facts or mistakes due to poor knowledge about the needs in production.

3.4 Use of lean product development principles to generate process improvement ideas

In summary, the performed investigations revealed a number of problems. They showed that lean principles were violated and that the overall control mechanism of the company needed to be improved according to these principles to be more efficient.

When comparing with the principles of LPD according to [10] we noticed that some of the principles could serve as a guide when improving the EC process.

Principle 1 imposes that information shall be gathered in the first step of the process to be able to focus the work in the right direction.

Principe 2 can be used as an argument to front load the EC process and make the first part of the process more work intensive and more thoroughly described. An early “analyse, design and test” loop is suggested. The change team shall be put together in the beginning of the process to involve the right people from the start. Root cause of the EC is sought early in the process.

Principle 4 suggests to use the same tools in the EC process that are used in the regular PD process to achieve a higher degree of standardisation in processes regarding PD. Principle 4 also suggests that the same document types shall be used for all EC issues instead of the seven different forms found at Supplier A.

Principles 6 and 8 points out the necessity of having a cross-functional EC team where also suppliers are represented assigned to each change.

Principle 11 suggests using some kind of powerful tool to manage ECs. In this work we have used a PLM system to manage the information transfer in the process to some extent.

4 Improvements of the EC process and tools

A new set of tools to manage the EC issues were suggested. The set of tools are:

- New EC processes for both products that are in production and products that are not yet in production.
- A new information model for storing information about changes.
- A new document type for controlling and documenting an EC issue. This document type is called Product Change Plan (PCP)
- A new document type to control and document the change of individual parts. This document type is called Engineering Change Notification (ECN)
- A set of functions implemented in the PLM system of Supplier A.
- A training package to educate and disseminate information about the new tools in the organisation of Supplier A.

The new document types PCP and ECN replaced the existing document types ECR (Engineering Change Request), ECO (Engineering Change Order) and ECN (Engineering Change Notice). A requested change (ECR) is equal to a not yet approved PCP. An approved PCP is equal to an approved ECO. An ECN is in this case the same as an ECN in general. In this particular case, the two new document types replaced seven different existing document types used at different sites at Supplier A.

4.1 The new EC process

The new process is divided into six phases. A description of each phase is found in Table 1. The main improvements of the new process include:

- Responsibilities are clarified.
- The process is more front-loaded. The early phases of the EC process are more thoroughly described. An early analyse, design and test loop is implemented.
- Persons expected to be involved or directly affected by the change are gathered in the very beginning of the process.
- The process uses as much as possible regarding tools and routines from the regular product development process of Supplier A to achieve a higher degree of standardisation of business processes.
- The process is flexible enough to suit different cases: The process has a fast track option and a full track option. Small changes shall follow the fast track and big changes the full track.
- When the process is finalized gained knowledge is captured and stored in a way it can be found and reused.

Table 1. The phases of the new engineering change process.

Phase	Explanation
Awareness	Someone in the organisation becomes aware of that there is a need for a change. Information of the change is collected. The issue is passed on the person having the dedicated role of being responsible for engineering changes.
Analyze (analyse-design-test loop)	A change team is put together and the requested change is analysed, an analyze, design and test loop is performed, work is planned and a solution is worked out
Decide	Decision is taken whether to do the change or not
Perform	The change is performed and specifications are changed
Release	Specifications are approved and released
Implement	The change is implemented in operation
Close	The responsible person checks that everything is done, the EC is then closed and lessons learned are documented

4.2 The new information model

A new information model for the company's engineering change information was developed. It is shown in Figure 7. The Classes in the information model are: The company "Supplier A", Projects or products in production, PCP – Product Change Plan, ECN – Engineering Change Notification, Specification (document describing the part that is subject to change), Part subject to be changed.

The Company (Supplier A) has many projects. In each project, there can be many change issues. Each change issue is controlled and documented with a PCP document. Each change can affect many parts and each part can have a relation to one specification (often a drawing but can also be source code). For each part that is subject to change there is an ECN document to control and document the change on the part. Each specification is related to one ECN. The ECN is used for managing the approval and release process of the specification. If the change is on a product that is in production and the original product development project is closed the class Project is not used.

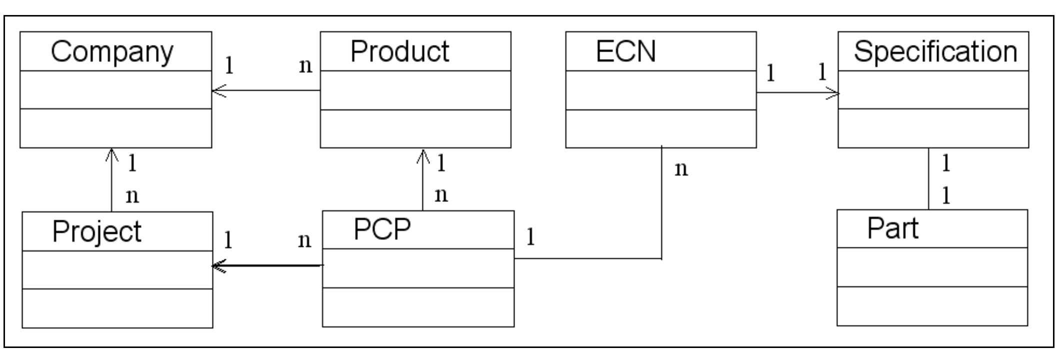

Figure 7. This is a simplified view of the new information model.

4.3 Implementation in PLM

Supporting functions are implemented in PLM. One purpose with the PLM system of Supplier A is to share product data globally and locally. The PLM system can be accessed at most sites of Supplier A. This way persons involved in a change issue at different sites get a way to communicate basic information about the change independent of where the persons in the change team are located. Both the PCP and the ECN are managed in the system. Progress of a change issue can be monitored. The PLM system is used to do the formal approval of all changed specifications and associated ECNs. The PLM system has facilities for making links between PCPs and ECNs and changed specifications. All objects in a change issue can be linked to each other. This means that you can enter the PLM system and by using the links see all parts involved in this change issue.

4.4 Use of the improved process and the new tools

The improved EC process was well received at supplier A. It has been used with some success: The lead-time for information transfer in the EC process has decreased when managing the ECs with the new PLM system. Moreover, the new information model and the ability make links in the PLM system gives everyone involved an overview of each EC issue that was not possible to get before.

However, some individuals feel that the new process is more bureaucratic compared to the previous one. The time for doing the actual approval of drawings has increased because of the system. This is because the design managers who usually do the formal approval of drawings are not skilled enough in the PLM system and need assistance from an engineer skilled in the system. This also ties up resources.

5 Conclusions

The main conclusions or the study are:

The existing engineering change process at the company was characterized by long and varying lead-times, fragmentation and featured major iteration loops. A number of issues were identified including unclear roles, multiple documents and poor communication.

Waste analyse of an EC process can be useful to identify shortcomings in an engineering change process.

The principles of lean product development can be useful to identify engineering change process improvements. In this case, the principles that were applicable were principles 1, 2, 4, 6, 8 and 11. Although the principles of lean product development are intended to be applied on a higher level of the organisation of the firm, they are also feasible to apply on this level.

Time for information transfer in a global EC process can be reduced by using a PLM system. The PLM system can also give all involved actors involved a good overview of the current state and progress of an EC issue. To do this we need an information model that reflects the structure of the information in the EC process. The information model shall have a root or header for every change issue to make it possible to find all connected information objects (PCP, ECN, specifications) in a change issue. This is especially important when the change incorporates more than one specification to be changed. It is also important to be able to relate the EC issue to a development project or a manufactured product.

It is important to front-load the EC process to avoid rework later on. Rework can be avoided if the process is more front-loaded and if the right persons are involved early in the process. Also suppliers should be involved as early as possible.

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