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IDENTIFICATION AND CHARACTERISTIC OF NECESSARY TASKS IN IMPLEMENTING ENGINEERING CHANGES IN AUTOMOTIVE INDUSTRY

ABSTRACT

Background: This chapter is devoted to the identification and characteristic of necessary tasks of implementing engineering changes in automotive industry. Each engineering change commissioned by a customer need a specific set of tasks to be implemented successfully in a company. Engineering changes affect especially these departments in companies: engineering, production, quality, logistics, warehouse and maintenance. Each task has its own rank and material scope. Identification and characteristic of necessary tasks of implementing engineering changes have to include customer specific requirements, industry, engineering and automotive industry standards. Complete list of tasks is required during planning, organizing and controlling the process of implementing engineering changes.

Methods: Based on the in-depth interview with experts from different automotive companies and results from survey let a list of necessary tasks of implementing engineering changes in automotive companies be created.

Results: The list of necessary tasks of implementing engineering changes in automotive companies include identification and characteristic of each task. Each task has been allocated to departments, whose involvement is required for successful implementation of engineering changes.

Conclusions: Project managers can use the list of necessary tasks of implementing engineering changes in automotive companies as a type of a check-list. This will provide project managers with wider view and fuller information during the processes of change

management. Using this list can also be beneficent as a tool to prioritize tasks, because critical path of necessary tasks of implementing engineering changes in automotive companies, in most cases does not need all the task to be done before implementation. Some tasks can be done in less occupied times.

Keywords: engineering changes, change management process, automotive industry.

INTRODUCTION TO IMPLEMENTING THE ENGINEERING CHANGES IN AUTOMOTIVE INDUSTRY

The engineering changes is described in literature as “all kinds of activities aimed at the process of using the company's available resources to obtain the proposed future state in the course of negotiations with the client regarding the finished product” [Mikołajczyk 2003]. The engineering change in the product contains many components and does not only affect management, but also organization, economics, technology, and even psychology and sociology [Bartnicki 1998]. Change management is a separate, specialized management method [Clarke 1997].

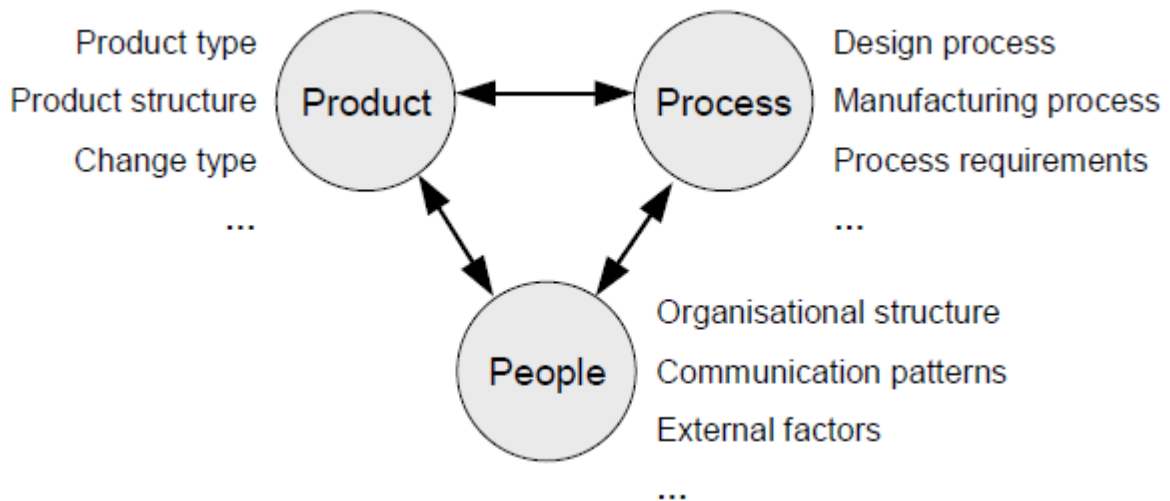


Figure 1. Interactions the product development process and the change process. Source: [Eger, Eckert, Clarkson, 2007]

The scope of engineering changes relates to human resources management, processes with product and the product itself (fig.1). In automotive company those changes can affect:

Operations (e.g. logistics, production, after-sales)

Product lifecycle management (configuration management, collaboration & disciplines integration, system engineering, modules & re-use, monitoring):

- Local processes & tools (e.g. electrical, software, mechanical, processes, purchasing)

- External (e.g. suppliers, partners, subcontractors) [Urban-Galindo and Ripailles 2019.]

Based on literature analysis authors decided that engineering changes term in this chapter will be understood as activities using company's resources to fulfil customer needs by changing and managing whole organization (product, process and people).

The authors, while conducting research using the method of in-depth structured interviews, noticed that engineering changes require many different activities that are not always product-related, but may relate to economic aspects in terms of the cost-effectiveness of introducing a given engineering change. The sociological and psychological knowledge of managers is also often used during employee training in order to quickly understand the reasons for introducing a given engineering change by production employees. The scope of strategic management is not taken directly into account when introducing engineering changes in products in the automotive industry. However, it is included in negotiations regarding the scope of implementation of a given change with the client.

Most often, an engineering change in a product is caused by external factors [Wirkus, Roszkowski, Dostatni and Gierulski 2014]. Mainly in the automotive industry they are customers who order such a change. Much less often there is a need to implement an engineering change caused by internal factors, and even then, due to the specificity of the automotive industry, such a change must be forwarded to the customer whose product the change concerns. In the process of implementing engineering changes there are three main stages: design, ordering & configuration and production planning & realization [Buergin et al. 2018]. Each company in automotive industry needs to be able to implement changes in products. "It is crucial for companies to continuously introduce innovative products and make variations to existing products to remain competitive in the market" [Rossini 2016]. This ability is called changeability [ElMaraghy 2009]. There is also flexibility which relates to implementing changes during assembly processes [Koren 2010]. The rate of product change requests, based on Volkswagen AG data from 2010 – 2013 years, grow up by ~300% [Sivri, Krallmann 2015].

In the general design, there is no specific and formalized template for change request document, and in another template such document is set by the project team. Any change that the customer would like to apply should be included in such an application [Wysocki 2005]. The change request itself initiates only the procedure of implementation engineer changes. All steps of the change management implementation should be controlled. Controlling change management steps in the project may be as follows:

- "Integrated change control (communication with project participants),

- Formalized application registration procedure (some independent decision of the project manager is allowed),
- Classification of the application into one of the established categories (external, internal, other),
- Giving opinions on the application (project manager, change control committee, experts),
- Assessment of potential effects of changes (risk, costs, schedule, other consequences),
- Assessment of possible solutions (causes, effects and conditions of modification),
- Analysis of the impact of changes on the project (timeliness, costs, scope, quality),
- Redefining project parameters (based on the analysis of budget deviations, schedule and scope of work),
- Presentation of the results of the analysis of the Change Control Committee or Steering Committee (approval or rejection of the application),
- Implementation and documentation of results (acceptance of modifications for implementation or registration of rejection).” [Bukłaha 2012].

In the automotive industry, an engineering change is realised in accordance with the customer requirements. A key document containing a number of information necessary for making changes in automotive industry is Customer Specific Requirements (CSR). The CSR document covers only the borders, in which supplier can move to fulfil OEM’s requirements. CSR documentation does not determine the processes. [CSR: Daimler AG 2017, BMW Group 2017, Ford Motor 2017, General Motors 2019, PSA 2017, Volkswagen 2018, IATF 16949: 2016]. The formalized application registration procedure is recorded in CSR documents. The material scope of changes in implementation the engineering change in the automotive industry also consists in determining what elements of the process a given engineering change will affect. To determine what will be affected in a company usually department managers, product managers and client delegation need to create all of necessary tasks for implementation the engineering change. Next step is to ask, for an opinion, all required departments. This opinion is the basis for making a decision on the acceptance of the request for engineering change. For changes proposed by the customer that cause increased costs, the rates for a given finished product may be renegotiated. Solutions most often involve a change or modification of the machine park, a change in the model design, or a decision on what to do with the products before the change. After obtaining information on solutions, company’s management can develop elements based on the potential effects of changes that

will be affected by the change in the product. The results of the analysis can be used to negotiate with the client to introduce additional entries in the request for engineering change. Acceptance of the change for implementation causes distribution of tasks to be performed by all required departments.

The specificity of the automotive industry in the field of implementing engineering changes is particularly noticeable in terms of the deadlines set for introducing changes and the speed of achieving satisfactory final results obtained after introducing the change in the scope of the finished product delivered to the customer.

RESEARCH METHODOLOGY

The main goal of the research is to identify and characterize the necessary tasks related to engineering changes in the automotive industry. To achieve this goal, the following research methodology was subordinated. The methodology includes the following steps:

- In-depth interview with experts with experience in implementing technical changes in the automotive industry;
- Preparation of the list of tasks, as well as the initial allocation to departments;
- Preparation of a survey questionnaire, CAWI research;
- Analysis of results of CAWI research,
- Preparation of the final list with a brief description.

The first stage of the research was based on in-depth interview with experts with experience in implementing technical changes in the automotive industry. As a result of the work, a list of tasks was created, with an initial assignment of tasks to departments and a specification of the material scope of each task. In the next step, a questionnaire has been prepared to verify the list of tasks. The research was carried out using the CAWI method. The list of tasks was verified by managers and senior specialists from the automotive industry (from tier 1 suppliers, which work directly with OEM companies). Managers and specialists verified the list of required tasks based on several years of experience in their own departments involved in the process of implementing engineering changes. Finally, based on analysis of results of CAWI research, final list has been prepared.

LIST AND CHARACTERISTICS OF EACH NECESSARY TASKS IN IMPLEMENTING ENGINEERING CHANGES IN AUTOMOTIVE INDUSTRY

In the following part of this chapter, there are 65 different necessary tasks in implementing engineering changes in automotive companies identified and characterized. Each task is also assigned to one of four main departments in automotive industry. Main departments are: engineering, production, quality and logistics with purchasing. Each of these tasks were consulted with corresponding chair of department.

Each task must have at least one main department and may need support from auxiliary departments. Main department is defined as a leader for a task. Auxiliary department can be asked to conduct certain operations for a selected task, but their role is not significant. Departments in columns “main departments” and “auxiliary departments” are sorted in descending order in terms of their degree of involvement in realised tasks.

Material scope of changes can be: product, direct process, indirect process, organizational change, change of documentation. Material scope of the change during the implementation of the activity can concern:

- product (change of dimensions, functionality, product structure, material),
- direct process (technological process of product processing, eg: plastic and thermal processing, operations and assembly techniques),
- indirect process (auxiliary process: transport, quality control, warehouse operations, product and / or process identification),
- organizational change (training, change in the structure of resources, change of responsibility, work schedule),
- change of documentation (development of new documentation, updating the database).

Engineering department is responsible for these tasks (table 1.).

Table 1. List of tasks from engineering department

Task number	Name of task	Description	Main departments or customer	Auxiliary departments or customer	Material scope of changes
1	Engineering Change Notice (ECN) Procedure Launch	Launching the procedure for implementing the engineering change. Asking for an opinion (assessment) members of the team responsible for the product and process affected. ECN is the initiation point for the company after business agreement with customer. ECN Procedure Launch is assigned mainly to Engineering department.	Engineering Quality	Customer The head of production unit Production department	Product
2	Capacity check	Checking whether the introduced engineering change will affect machine park capacity. If yes it should be calculated in business agreement.	Engineering	Not required	Direct process
3	Preparing 3D model design	Preparing 3D model with change. Additionally, check assembly environment if there is no negative influence of parts crashes, possible temperature, fluid, electricity influence on environment.	Engineering	Not required	Product
4	Material change	Changing the material from which the	Engineering	Production	Product

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Task number	Name of task	Description	Main departments or customer	Auxiliary departments or customer	Material scope of changes
		product is made. Notice that this change can influence on parts dimensional stability and need to go together with IMDS system change according to IATF standards.	Quality Customer		
5	Part history log	Updating the history of all existing changes (logs) saved and sending it to customer. All changes need to be tracked and marked with part number change, production and first shipments to customer dates.	Engineering Quality	Not required	Change of documentation
6	Part revision change	Each engineering change should rise up affected parts revision, Changing the part number for production is given in the form of an engraver, stamp, label or with any other marking.	Engineering Production Quality	The head of production unit Logistics Maintenance	Product
7	BOM update	Update of the list of materials and components (BOM) used for the production of a given product. BOM correctness is very important for inventory status in ERP system. Every missed information may have direct influence on inventorisatation results.	Engineering	Production Logistics	Change of documentation
8	Updating the information on the label / sticker / laserprint	If parts are tracked and mark with part revision or production batch – this marking should be updated.	Engineering Quality	Production Customer Logistics Warehouse	Indirect process
9	Updating 2D documentation	All changes including dimensions, tolerances, material, revision, marking etc changes should be included in 2d drawing as this document is a baseline for process preparation. Also, drawings are usually a baseline specification for external claims.	Engineering	Quality	Change of documentation
10	Transfer of 2D documentation to all required departments for expressing opinions	Sharing documentation with all affected departments within the company.	Engineering Production Quality	The head of production unit	Change of documentation
11	Change of the machine/tools used for producing the product.	Some engineering changes are forcing tools / machines changes within machine park.	Engineering Production The head of production unit	Maintenance Quality Customer	Direct process
12	Modification of the machine park/tools for the purpose of introducing an engineering change.	Some engineering changes are forcing tools / machines modifications that have to be done before final production.	Engineering Maintenance	Production	Direct process
13	Changing the layout of machines on the production floor.	Engineering Change might force to change production line layout.	The head of production unit Engineering Production	Not required	Direct process
14	Checking the production process in terms of performance and quality (Run & Rate).	Final check of engineering change performance in production process – efficiency, quality and downtimes.	Engineering Production Quality	The head of production unit	Direct process
15	Developing process sheet.	Machines, tools and other equipment setup and parameters sheet created by engineers during trials. This is base information for shop floor workers to keep process stable.	Engineering	Production	Direct process and change of documentation
16	Packing	Changing the way of packing and transporting products. Often it has to be approve based on packaging and transportation trials.	Engineering Logistics	Production Warehouse	Indirect process
17	Significant change in labour intensity	Analysis of demand for human resources, Methods Time Measurement - MTM	Engineering Production The head of production unit	Not required	Direct process
18	Update of production parameters (cycle, Takt time, lead time)	Update needs to be done both in documents and machines.	Engineering Production	Not required	Direct process
19	Development of the	Manual for production operators and	Engineering	Not required	Change of

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Task number	Name of task	Description	Main departments or customer	Auxiliary departments or customer	Material scope of changes
	work instructions	technicians describing operations, correct sequence and safety rules of performing production process			documentation
20	Determining technological capabilities (machine feasibility)	Engineers need to make sure that present machine park is ready and able to produce parts after EC.	Engineering	The head of production unit Production	Direct process
21	Determining supplier capabilities (supplier feasibility)	If suppliers are involved in EC they need to be verified in terms of feasibility and capacity.	Engineering Logistics	Quality	Indirect process
22	Performing tests after the pilot batch	Depending on Customer requirements specify tests need to be done to approve implementation process.	Engineering Quality	Not required	Direct process
23	Changing the shipping label	Shipping label changes according to engineering change.	Engineering Logistics	Not required	Indirect process and change of documentation
24	Prototype making change	If Engineering change requires to create prototype parts before release it need to be marked accordingly. It is a change of the test / trial part number not released into the production process, usually in the form of a label on part or packaging container.	Engineering Quality	Logistics	Indirect process
25	PFD update (process flow diagram)	This document is part of APQP and needs to be prepared as a part of PPAP and part of IATF requirement.	Engineering	Quality	Change of documentation
26	FMEA update (analysis of the types and effects of possible errors, Failure Mode and Effects Analysis - FMEA)	This document is part of APQP and needs to be prepared as a part of PPAP and part of IATF requirement. IATF is strongly focused on risk analyses – FMEA as well. This should be prepared in interdisciplinary teams.	Engineering Quality	Production	Change of documentation
27	Changing patterns for error checking - error proofing samples (poka-yoke samples)	Error-proofing is required by IATF certification for all special characteristics and process control. Before every production run all control points should be checked and confirmed as correctly working.	Engineering Production Quality	Not required	Indirect process
28	Checking the machine availability in terms of technology (machine capacity) and determining the required buffer of parts	EC might enlarge production takt time/lead times what will have influence of accessible time.	Engineering Production	The head of production unit	Direct process
29	Registration of a new material supplier according to norm ISO9001	Registration need to be performed within company database.	Engineering Quality	Logistics (purchasing)	Change of documentation
30	Validation tests / material certification (Design Validation Plan and Report - DVPR)	This is test showing if product design is efficient and have no failures. Specific tests are usually required by OEMs depending on final part material, design and functionality.	Engineering Quality	Not required	Indirect process
31	The way of using the parts in stock buffer before the change in production (running change, stock scrap)	Assessment whether after the engineering change the inventory should be disposed of before the change, or it can be used	Engineering Logistics	Quality	Indirect process
32	Change / modification of controls and measuring devices.	Production is controlled by specific measures and devices that may need to be modified.	Engineering Quality	Not required	Indirect process

Zródło: opracowanie własne.

Source: own work.

Production department is responsible for these tasks (table 2.).

Table 2. List of tasks from production department

Task number	Name of task	Description	Main departments	Auxiliary departments or customer	Material scope of changes
1	Updating the plan of	This is a consequence of changing/adding	Maintenance	Engineering	Indirect process

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Task number	Name of task	Description	Main departments	Auxiliary departments or customer	Material scope of changes
	machine and tooling inspections (Preventive Maintenance Schedule)	tools/ machines to factory production park.	Production		
2	Preparation of work instructions for spare parts.	Every part number of final goods required to have their spare part, which is sometimes different by BOM or/and production process. This need to be notify in special work instruction.	Maintenance Production	Engineering	Change of documentation
3	Preparation and training of machines operators	Training of machines operators to work according to new rules and instructions – including new operations, work instructions and new standards review.	Production Engineering The head of production unit	Not required	Organizational change
4	Update of ANDON system settings (information exchange in production processes)	ANDON is a fast response system for production control. System is usually calculating line efficiency, scrap levels and other production parameters so every change need to be updated to collect correct information.	Production Engineering	The head of production unit	Direct process
5	Determining the amount of parts in stock buffer before the change is implemented	Often implementation the change request process is forcing to shutdown production lines and machines. For that reason, final parts need to be produced on buffer.	Production Logistics The head of production unit Engineering	Not required	Indirect process

Zródło: opracowanie własne.

Source: own work.

Quality department is responsible for these tasks (table 3.).

Table 3. List of tasks from quality department

Task number	Name of task	Description	Main departments	Auxiliary departments or customer	Material scope of changes
1	Update of the control plan (Control Plan document)	This document is part of APQP and needs to be prepared as a part of PPAP and part of IATF requirement. Control plan is based document for many audits in automotive industry.	Quality Engineering	Production	Change of documentation
2	Checking the correctness of the selected system and measurement system analysis (MSA)	Each measurement equipment needs to be check if system equipment + operator can be metrologically efficient.	Quality Engineering	Not required	Indirect process
3	Development of incoming inspection instructions	Change of the inspection plan on the supply control (frequency, type of control)	Quality Engineering	Not required	Indirect process
4	Development of quality inspection instructions	Change of instructions according to which the measurement of the product is to be made	Quality Engineering	Not required	Change of documentation
5	Development of visual inspection instructions	Change of instructions on checking the visual aspects of the product	Quality Engineering	Not required	Change of documentation
6	Development of quality control charts	Control of special characteristics of the product (e.g. weight, functional dimension)	Quality Engineering	Production	Indirect process and change of documentation
7	Report of visual inspection of parts produced after the change (Appearance Approval Report - AAR)	Document that customer approves visual parts appearance.	Quality	Engineering	Indirect process
8	Part approval by the customer (Production Part Approval Process - PPAP)	Final package of documents, often including final goods physically that is presented to customer and needs to be approved.	Quality Engineering Customer	Not required	Change of documentation

9	Rating of Customer Special Requirements (CSR)	Engineering change needs to be verified if it doesn't violate CSR.	Quality Engineering	Not required	Change of documentation
10	Updating the IMDS (International Material Data System) database	Global database for materials specifications with assignation to companies.	Quality Engineering	Not required	Change of documentation

Zródło: opracowanie własne.

Source: own work.

Logistics department is responsible for these tasks (table 4.).

Table 4. List of tasks from logistics department

Task number	Name of task	Description	Main departments	Auxiliary departments or customer	Material scope of changes
1	Receival of materials and components	Delivery of goods required for test batches, proto runs and Run&Rate production.	Logistics Warehouse	Not required	Indirect process
2	Receival of components and materials for the trial series.	It is about making sure that new components are in the factory ready to use for first production run after change.	Logistics Engineering	Not required	Indirect process
3	Change location of inventory	Change location of inventory (components, materials and finished products) in the warehouse (for parts before and after engineering change)	Logistics Warehouse	Not required	Indirect process
4	Change of destination for shipments of final products	EC may open new target destination for final goods – this has to be verified and plant needs to be prepared for incoming/shipments schedules change.	Logistics	Not required	Indirect process
5	EDI upgrade for customer orders (Electronic Data Interchange)	EC force to rise revision of final goods, and this need to be clearly stated in orders ass well. Customer should inform from what date new revision is required.	Logistics	Customer	Indirect process
6	Implementation of assumptions regarding the preparation of a safety stock	Meaning realising scheduled production plan and additional needs	Logistics	The head of production unit Engineering	Indirect process

Zródło: opracowanie własne.

Source: own work.

CONCLUSICE REMARKS

Created list of necessary tasks in implementing engineering changes in automotive companies is a useful tool for managers. This list can take a role of a checklist that can come in handy for engineering changes management.

In practice of specific company from the automotive industry, both the list of tasks and the allocation to individual departments may be partly differ. The main reasons for the differences may be:

- specificity of offered products (including their technical complexity),
- scope of engineering changes,
- various organizational chart and department names.

The aim of the authors of the chapter was to develop a list of largely universal, which can be adapted to the any conditions of the company from automotive industry.

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