III. CHALLENGES IN INTERNAL SUPPLY CHAINS PROCESSES

Filip Karaśkiewicz
Politechnika Poznańska
e-mail: filip.karaskiewicz@put.poznan.pl
Łukasz Hadaś
Politechnika Poznańska
e-mail: lukasz.hadas@put.poznan.pl
Hubert Wojciechowski
Politechnika Poznańska
e-mail: hubert.wojciechowski@put.poznan.pl

ENGINEERING CHANGES IMPLEMENTATION PROCESS MAP FOR AUTOMOTIVE INDUSTRY

ABSTRACT

Background: This paper is devoted to the process of implementing engineering changes. Based on the analysis of implementing engineering changes process and the specific requirements of automotive industry, the map of process was designed. This map shows connections between actions, few levels of details and resources that are being used at following steps. Map is also divided into few rows, each representing one of department of a company. The objective of map of implementing engineering changes process is to provide crucial data to project managers to let them manage the processes of changes having fuller information.

Methods: Basing on the in-depth interview with experts from different automotive companies and results from survey a map of process of implementing engineering changes in automotive companies was designed.

Results: The designed map of process of implementing engineering changes in automotive companies shows steps of accomplishment of each action. Involvement of each department of a company and clients was also specified in the map. Created map was presented to managers from automotive companies to get feedback on the map and to upgrade it.

Conclusions: Map presented in the article is a guidance for managers showing how to perform correctly engineering changes implementation process. The map is a useful tool to coordinate the different aspects (participants, sequence and responsibilities) of this complex process so as to enable them to work together effectively.

Keywords: map of process, engineering changes, automotive industry.

P. Cyplik et al. (eds.), *Contemporary challenges in supply chains, Vol. 2*,
https://doi.org/10.17270/B.M.978-83-66017-89-4.10

INTRODUCTION TO BUSINESS PROCESSES MAPPING

Business process mapping is an important aspect of management. The main purpose of mapping is to increase the efficiency of implemented processes. The basis for making the map is understanding the interrelationships between the elements involved in the implementation of the analysed process. Maps can be made at various levels of detail and reflect both general process dependencies and a detailed algorithm for the implementation of individual tasks. A clear and legible map of the process is the starting point for further analyses serving both to improve the process and its efficient implementation. Process map is also the basis for process automation. It has been long established that automation of specific functions of enterprises will not provide the productivity gains for businesses unless support is provided for overall business process control and monitoring [Ruopeng Lu and Shazia Sadiq 2007].

The generic structure of map consists of two main features. One is to present business processes from different points of view, so that multiple layers of abstractions can be shown. The second feature creates the possibility to verify and validate the model. [Fu-Ren Lin et al. 2002]

Created business process models can be a base for process analysis [Verbeek et al., 2007] and process execution [van der Aalst and ter Hofstede, 2005] in companies. Authors decided to create a map of process of implementing engineering changes in automotive industry. The reason for it was a lack of information for managers in term of who is responsible for a certain task, and what is the sequence of processes. Many times, tasks were realized in different sequences. Organizations can use business process modelling to increase their business value by proper knowledge management [Bandara et al. 2005]. This map can help to figure out at what stage of development is a certain task, and what has already been done, and what will be next steps.

Language chosen for business modelling was BPMN (Business Process Modelling Notation). Authors are aware that BPMN can have lower usability than e.g. UML AD, BWW model for business in certain cases [Birkmeier 2010, Recker et al. 2009]. However, in literature and by standardization organization e.g. Object Management Group [OMG 2013] BPMN is claimed to have more usability [Nysetvold & Krogstie 2005, Weske 2007, White 2004].

P. Cyplik et al. (eds.), *Contemporary challenges in supply chains, Vol. 2*,
https://doi.org/10.17270/B.M.978-83-66017-89-4.10

RESEARCH METHODOLOGY

The aim of the research was to create process map of implementing engineering changes in automotive industry. This map should show connections between each task and, departments that are being used at following steps. Developing a map of the process of implementing technical changes in products in the automotive industry included the following steps:

- In-depth interview with experts;
- Preparation of a survey questionnaire, computer-assisted web interviewing (CAWI) survey;
- Analysis of results of CAWI survey;
- Preparation of process map of implementing engineering changes.

The first step of the research was in-depth interview with experts with experience in implementing technical changes in the automotive industry to verified the list of tasks necessary to engineering changes implementation. At this stage, the previously prepared task list was verified and a list of key decision nodes in the process was developed. In the next step was prepared survey questionnaire to verified departments involved in the process of implementing engineering changes and if need be extension of list of tasks.

The survey was addressed to employees from the automotive industry (from tier 1 suppliers, which work directly with OEM companies) with proper experience like necessary seniority, position and department. The obtained results were an important clue to create map of process. Based on the information collected from the entire research process, the authors developed the final version of the map as a result of several joint meetings. The graphical notation of process steps was made in accordance with the Business Process Modelling Notation (BPMN).

Survey results from assigning tasks in implementing engineer changes to departments in automotive industry

In the first stage of this research, a general list of tasks in implementing engineer changes in the automotive industry was used as a basis for further research process. The results of the survey were obtained from experts from the automotive industry. The results are presented in percentages and the sum may exceed 100%, because the experts were able to select more than one department for each task (table 1.).

P. Cyplik et al. (eds.), *Contemporary challenges in supply chains, Vol. 2*,
https://doi.org/10.17270/B.M.978-83-66017-89-4.10

Table 1. Results from survey in term of assigning tasks to appropriate departments involved in the process of implementing engineering changes or customer

Tabela 1. Wyniki badania ankietowego w zakresie zaangażowanych działów lub klienta w realizacji poszczególnych zadań

Task number		CUSTOMER	THE HEAD OF THE PRODUCTION UNIT	ENGINEERING DEPARTMENT	PRODUCTION DEPARTMENT	QUALITY DEPARTMENT	LOGISTICS DEPARTMENT	WAREHOUSE	MAINTENANCE DEPARTMENT
1	**Launching the procedure for implementing the engineering change. Asking for an opinion (assessment) members of the team responsible for the product about launching the engineering change.**	**40%**	**40%**	**93%**	**40%**	**53%**	20%	13%	7%
2	**Checking whether the introduced engineering change will affect the load of the machine park**	7%	27%	**80%**	33%	7%	20%	7%	20%
3	**Preparing 3D model design**	27%	0%	**100%**	0%	0%	0%	0%	0%
4	**Changing the material from which the product is made**	**53%**	33%	**100%**	**47%**	**60%**	33%	33%	7%
5	**Updating the history of all existing changes (logs) saved and sending it to customer**	29%	14%	**86%**	14%	**64%**	21%	7%	0%
6	**Changing the part number for production is given in the form of an engraver or a stamp**	20%	**40%**	**80%**	**67%**	**47%**	**40%**	27%	**40%**
7	**Update of the list of materials and components (BOM) used for the production of a given product**	7%	29%	**93%**	**43%**	36%	**43%**	21%	0%
8	**Change of the test / trial part number not released into the production process, usually in the form of a label – packaging label**	29%	14%	**79%**	29%	**50%**	**43%**	21%	0%
9	**Updating the information on the label / sticker**	**40%**	27%	**87%**	**47%**	**53%**	**40%**	**40%**	7%
10	**Updating 2D documentation**	21%	0%	**100%**	14%	**43%**	0%	7%	0%
11	**Transfer of 2D documentation to all required departments for expressing opinions**	0%	20%	**100%**	33%	**40%**	0%	0%	0%
12	**Update of ANDON system settings (information exchange in production processes)**	0%	**46%**	**54%**	**77%**	15%	23%	8%	38%
13	**Change of the machine/tools used for producing the product**	**40%**	**53%**	**87%**	**60%**	**47%**	13%	0%	**47%**
14	**Modification of the machine park/tools for the purpose of introducing a engineering change**	15%	38%	**77%**	**46%**	15%	8%	0%	**62%**
15	**Change / modification of controls and measuring devices**	21%	21%	**79%**	36%	**64%**	0%	0%	21%
16	**Receival of components and materials for the trial series**	0%	27%	**53%**	27%	27%	**73%**	33%	0%
17	**Updating the plan of machine and tooling inspections (Preventive Maintenance Schedule)**	0%	33%	**47%**	27%	7%	0%	0%	**87%**
18	**Preparation of work instructions for spare parts**	0%	27%	**47%**	33%	7%	7%	7%	**73%**
19	**Changing the layout of machines on the production floor**	13%	**67%**	**60%**	**53%**	7%	13%	0%	**40%**
20	**Checking the production process in terms of performance and quality (Run & Rate)**	20%	**47%**	**87%**	**73%**	**60%**	13%	7%	0%
21	**Developing process sheet**	0%	20%	**100%**	**47%**	27%	0%	0%	0%
22	**Preparation and training of machines operators to work according to new rules and instructions**	0%	**50%**	**57%**	**86%**	29%	0%	0%	7%

P. Cyplik et al. (eds.), *Contemporary challenges in supply chains, Vol. 2*,
https://doi.org/10.17270/B.M.978-83-66017-89-4.10

Task number		CUSTOMER	THE HEAD OF THE PRODUCTION UNIT	ENGINEERING DEPARTMENT	PRODUCTION DEPARTMENT	QUALITY DEPARTMENT	LOGISTICS DEPARTMENT	WAREHOUSE	MAINTENANCE DEPARTMENT
23	**Changing the way of packing and transporting products**	20%	27%	**87%**	**47%**	33%	**73%**	**40%**	0%
24	**Significant change in labour intensity (analysis of demand for human resources, Methods Time Measurement - MTM)**	15%	**54%**	**69%**	**62%**	8%	8%	0%	0%
25	**Update of production parameters (cycle, TAKT, lead time)**	0%	33%	**93%**	**73%**	13%	7%	0%	0%
26	**Determining the amount of parts in stock buffer before the change is implemented**	7%	**53%**	**53%**	**67%**	7%	**60%**	33%	0%
27	**Change of the inspection plan on the supply control (frequency, type of control)**	0%	33%	**67%**	20%	**73%**	0%	0%	0%
28	**Change of instructions according to which the measurement of the product is to be made**	7%	20%	**73%**	20%	**73%**	0%	0%	0%
29	**Change of instructions on checking the visual aspects of the product**	20%	33%	**73%**	33%	**93%**	0%	0%	0%
30	**Control of special characteristics of the product (e.g. weight, functional dimension)**	7%	20%	**60%**	**47%**	**93%**	0%	0%	0%
31	**PFD update (process flow diagram)**	7%	20%	**93%**	33%	**53%**	7%	0%	0%
32	**FMEA update (analysis of the types and effects of possible errors, Failure Mode and Effects Analysis - FMEA)**	7%	20%	**100%**	**47%**	**80%**	7%	0%	7%
33	**Update of the control plan (Control Plan document)**	13%	20%	**73%**	**40%**	**87%**	0%	0%	0%
34	**Checking the correctness of the selected system and measurement system analysis (MSA)**	7%	13%	**53%**	27%	**93%**	0%	0%	0%
35	**Development of the work instructions**	0%	27%	**93%**	33%	20%	0%	0%	0%
36	**Validation tests / material certification (Design Validation Plan and Report - DVPR)**	21%	14%	**86%**	14%	**71%**	0%	0%	0%
37	**Report of visual inspection of parts produced after the change (Appearance Approval Report - AAR)**	31%	15%	**46%**	23%	**92%**	0%	0%	0%
38	**Changing patterns for error checking - error proofing samples (poka-yoke samples)**	7%	27%	**93%**	**60%**	**60%**	0%	0%	0%
39	**Rating of Customer Special Requirements (CSR)**	23%	15%	**77%**	23%	**92%**	0%	0%	0%
40	**Part approval by the customer (Production Part Approval Process - PPAP)**	**53%**	20%	**60%**	7%	**93%**	7%	0%	0%
41	**Registration of a new material supplier according to norm ISO9001**	15%	8%	**62%**	8%	**54%**	**46%**	8%	0%
42	**Change of destination for shipments of final products**	27%	20%	33%	7%	7%	**93%**	27%	0%
43	**EDI upgrade for customer orders (Electronic Data Interchange)**	**40%**	7%	20%	7%	7%	**93%**	20%	0%
44	**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**	7%	33%	**73%**	20%	**40%**	**73%**	20%	0%
45	**Change in the location of inventory (components, materials and finished products) in the warehouse (for parts before and after engineering change)**	0%	36%	21%	14%	7%	**79%**	**79%**	7%

P. Cyplik et al. (eds.), *Contemporary challenges in supply chains, Vol. 2*,
https://doi.org/10.17270/B.M.978-83-66017-89-4.10

Task number		CUSTOMER	THE HEAD OF THE PRODUCTION UNIT	ENGINEERING DEPARTMENT	PRODUCTION DEPARTMENT	QUALITY DEPARTMENT	LOGISTICS DEPARTMENT	WAREHOUSE	MAINTENANCE DEPARTMENT
46	**Changing the mailing label - whether the labelling of the product for shipment changes with an engineering change or not**	36%	14%	**71%**	14%	21%	**71%**	29%	0%
47	**Implementation of assumptions regarding the preparation of a safety stock**	0%	**43%**	**43%**	36%	7%	**71%**	29%	0%
48	**Determining technological capabilities (machine feasibility)**	0%	**40%**	**87%**	**40%**	13%	13%	0%	20%
49	**Checking the machine availability in terms of technology (machine capacity) and determining the required buffer of parts**	7%	**40%**	**73%**	**53%**	13%	27%	0%	13%
50	**Determining supplier capabilities (supplier feasibility)**	0%	15%	62%	8%	**46%**	**62%**	8%	0%
51	**Performing tests after the pilot batch**	0%	27%	**80%**	33%	**67%**	0%	0%	0%
52	**Receival of materials and components**	0%	13%	27%	20%	20%	**73%**	**60%**	0%
53	**Updating the IMDS (International Material Data System) database**	8%	15%	**54%**	0%	**62%**	23%	0%	0%

Źródło: opracowanie własne

Source: own work.

The obtained results were an important clue to determine the departments that usually accomplish each task, which was generally reflected in the process map. Nevertheless, the survey results were given a critical assessment, and they are not always consistent with the prepared map. Tables 2 – 6 presents the data about respondents i.e.: size of company they work for, their position and department in enterprise and their experience.

Table 2. Experts' company current size

Tabela 2. Wielkość przedsiębiorstwa, gdzie obecnie pracują eksperci

The size of the company in which you currently work:	
Medium enterprise. Less than 250 employees	27%
A large enterprise. Over 250 employees	73%

Źródło: opracowanie własne

Source: own work.

P. Cyplik et al. (eds.), *Contemporary challenges in supply chains, Vol. 2*,
https://doi.org/10.17270/B.M.978-83-66017-89-4.10

Table 3. Experts' current position in automotive industry

Tabela 3. Obecna pozycja ekspertów w branży automotive

Position held in the enterprise:	
Management board	7%
Manager	13%
Expert	60%
Support worker	13%
Physical Worker	7%

Źródło: opracowanie własne

Source: own work.

Table 4. Experts' current departments in automotive industry

Tabela 4. Obecna wydział ekspertów w branży automotive

Please select the department in which you are currently working:	
Management board	7%
Engineering department	73%
Production department	13%
Quality department	7%

Źródło: opracowanie własne

Source: own work.

Table 5. Experts' experience in given position

Tabela 5. Doświadczenie ekspertów na obecnym stanowisku

Years of experience in a given position:	
43	Max
Less than 1 year	Min
5	Median
9.214285714	Average

Źródło: opracowanie własne

Source: own work.

Table 6. Experts' experience in automotive industry

Tabela 6. Całkowite doświadczenie ekspertów w branży automotive

Years of experience in the automotive industry (total):	
34	Max
2	Min
7,5	Median
10.92857143	Average

Źródło: opracowanie własne

Source: own work.

P. Cyplik et al. (eds.), *Contemporary challenges in supply chains, Vol. 2*,
https://doi.org/10.17270/B.M.978-83-66017-89-4.10

All respondents had at least 2 years of experience in the automotive industry and worked in departments involved in implementing engineering changes.

Map and list of tasks in implementing engineer changes in automotive industry

Based on survey results a list of tasks in implementing engineer changes in automotive industry was created and tasks were assigned to corresponding departments. Tasks were sorted to correspond with order on the map. After consultation with experts certain tasks were divided or joined together to let the map illustrate the process of implementing engineer changes more accurate to reality. Processes on the map are allocated to main departments. List of tasks can be used as a legend for a map. Here is the list of tasks, followed by a map:

1. Engineering change request procedure launch (ECR)
2. Rating of Customer Special Requirements (CSR)
3. Part revision change
4. Updating the information on the label / sticker / laserprint
5. Determining technological capabilities (machine feasibility)
6. Preparing 3D model design
7. Updating 2D documentation
8. Transfer of 2D documentation to all required departments for expressing opinions
9. Material change
10. BOM update
11. Supplier feasibility check in case of outsourced parts change
12. Determining supplier capacity in case of outsourced parts change
13. Checking material availability on the market
14. Checking the machine availability in terms of technology (machine capacity) and determining the required buffer of parts
15. PFD update (process flow diagram)
16. FMEA update (analysis of the types and effects of possible errors, Failure Mode and Effects Analysis - FMEA)
17. Update of the control plan (Control Plan document)
18. Change / modification of controls and measuring devices.
19. Checking the correctness of the selected system and measurement system analysis (MSA)
20. Change of the inspection plan on the supply control (frequency, type of control)

P. Cyplik et al. (eds.), *Contemporary challenges in supply chains, Vol. 2*,
https://doi.org/10.17270/B.M.978-83-66017-89-4.10

21. Change of instructions according to which the measurement of the product is to be made
22. Change of instructions on checking the visual aspects of the product
23. Control of special characteristics of the product (e.g. weight, functional dimension)
24. The way of using the parts in stock buffer before the change in production (running change, stock scrap)
25. Determining the amount of parts in stock buffer before the change is implemented
26. Registration of a new material supplier according to norm ISO9001
27. Implementation of assumptions regarding the preparation of a safety stock
28. Receival of components and materials for the trial series
29. Change in the location of inventory (components, materials and finished products) in the warehouse (for parts before and after engineering change)
30. Receival of materials and components
31. Updating the IMDS (International Material Data System) database
32. New machine/tools used for production
33. Modification of the machine park/tools for the purpose of introducing an engineering change.
34. Changing the layout of machines on the production floor.
35. Updating the plan of machine and tooling inspections (Preventive Maintenance Schedule).
36. Developing process sheet
37. Changing the way of packing and transporting products
38. Prototype marking change
39. Performing tests after the pilot batch
40. Changing patterns for error checking - error proofing samples (poka-yoke samples)
41. Development of the work instructions
42. Significant change in labour intensity (analysis of demand for human resources, Methods Time Measurement - MTM)
43. Preparation and training of machines operators to work according to new rules and instructions.
44. Update of production parameters (cycle, TAKT, lead time)
45. Update of ANDON system settings (information exchange in production processes).
46. Report of visual inspection of parts produced after the change (Appearance Approval Report - AAR)

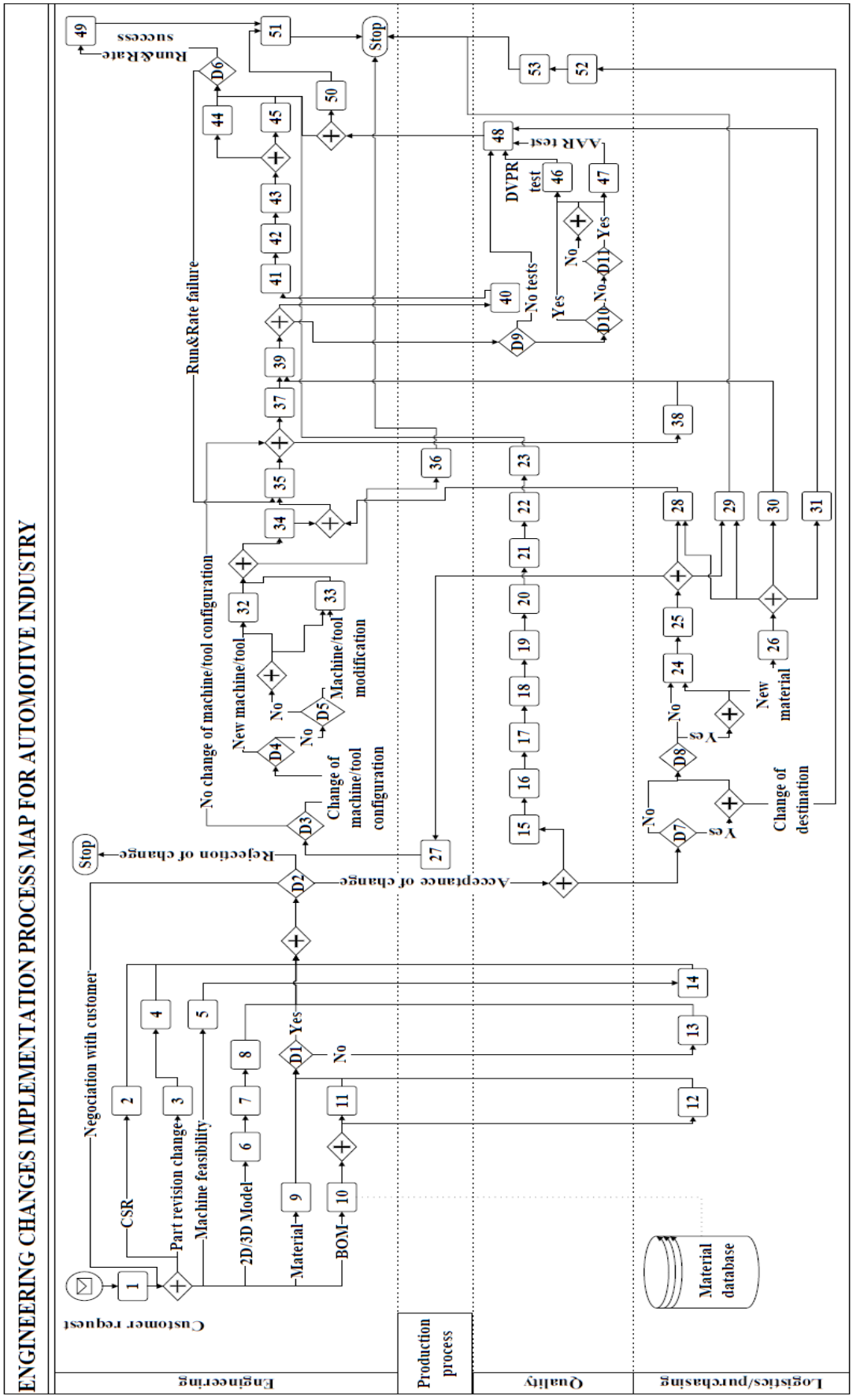
P. Cyplik et al. (eds.), *Contemporary challenges in supply chains, Vol. 2*,
https://doi.org/10.17270/B.M.978-83-66017-89-4.10

47. Validation tests / material certification (Design Validation Plan and Report - DVPR)
48. Part approval by the customer (Production Part Approval Process - PPAP)
49. Preparation of work instructions for spare parts
50. Part history log
51. EDI upgrade for customer orders (Electronic Data Interchange)
52. Change of destination for shipments of final products
53. Changing the shipping label

In addition to the list of tasks, key decision nodes have been identified in the process.

D1. Does the material exist in the internal material database?
D2. Does the company accept the engineering change?
D3. Does change require a new machine or a machine modification?
D4. Does the change only require a new machine?
D5. Is only the modification of the machine needed?
D6. Checking the production process in terms of performance and quality (Run & Rate).
D7. Is change of destination for shipments of final products required?
D8. Does the change only require new materials?
D9. Are any tests required? (DVPR or AAR)
D10. Is only DVPR testing required?
D11. Is only AAR testing required?

P. Cyplik et al. (eds.), *Contemporary challenges in supply chains, Vol. 2*,
https://doi.org/10.17270/B.M.978-83-66017-89-4.10



P. Cyplik et al. (eds.), *Contemporary challenges in supply chains, Vol. 2*,
https://doi.org/10.17270/B.M.978-83-66017-89-4.10

Fig. 1. Map of implementing engineer changes in products in automotive industry Source: own work.
Rys. 1. Mapa wdrażania zmian technicznych w produktach w branży automotive. Źródło: opracowanie własne.

As a result of research study, there are 52 tasks on the map followed by 11 decision nodes.

SUMMARY AND CONCLUSIONS

Developing the process map of implementing engineering changes in automotive companies provides project managers with wider view and fuller information during the process of scheduling tasks. The map is a useful tool to coordinate the different elements (participants, sequence and responsibilities) of this complex process. The main benefit of using well designed map of processes is to enable each of previously mentioned elements to work together effectively.

Creating a well-designed map is a difficult task because:

- its level of detail should be expressed accordingly to needs,
- the main decision nodes (often acting as "milestones") have to be identified,
- general dependencies are required to be taken into account, rejecting unnecessary complexity,
- lead department and auxiliary units needs to be correctly assigned,
- sequence of activities within all departments and the entire process are essential to be shown.

The aim of the authors was to develop a map, which can be adapted in implementing engineering changes in any conditions of the company from automotive industry.

ACKNOWLEDGMENTS

This research was funded by the Poznan University of Technology, Faculty of Engineering Management [project number: 11/140/SBAD/4168].

REFERENCES:

Bandara, W., G. G. Gable, and M. Rosemann (2005) "Factors and Measures of Business Process Modelling: Model Building Through a Multiple Case Study", European Journal of Information Systems (14)4, pp. 347-360, DOI: 10.1057/palgrave.ejis.3000546

Birkmeier Dominik Q, Klöckner Sebastian, Overhage Sven, 2010, An Empirical Comparison of the Usability of BPMN and UML Activity Diagrams for Business Users, ECIS 2010 Proceedings European Conference on Information Systems

Fu-Ren Lin, Meng-Chyn Yang, Yu-Hua Pai, 2002, A generic structure for business process modelling, Business Process Management Journal, ISSN: 1463-7154, 1 March 2002, DOI: 10.1108/14637150210418610

Nysetvold, A.G. and J. Krogstie (2005). Assessing Business Processing Modeling Languages Using a Generic Quality Framework. In CAiSE'05 Workshops, pp. 545-556, DOI: 10.4018/978-1-59140-935-9.ch005

Object Management Group, Information technology - Business Process Model and Notation ISO/IEC 19510:2013(E) November 2013

Ruopeng Lu and Shazia Sadiq, 2007, A Survey of Comparative Business Process Modeling Approaches School of Information Technology and Electrical Engineering, The University of Queensland, Brisbane, QLD, 4072, Australia International Conference on Business Information Systems BIS 2007: Business Information Systems pp 82-94, DOI: 10.1007/978-3-540-72035-5_7

Van der Aalst W. M. P. and ter Hofstede A. H. M. (2005), YAWL: Yet Another Workflow Language, Information Systems (30)4, pp. 245-275, DOI: 10.1016/j.is.2004.02.002

Verbeek, H. M. V., van der Aalst W. M. P., and ter Hofstede A. H. M. (2007), Verifying Workflows with Cancellation Regions and OR-joins: An Approach Based on Relaxed Soundness and Invariants, The Computer Journal (50)3, pp. 294-314, DOI: 10.1093/comjnl/bxl074

Weske, M. (2007). Business Process Management: Concepts, Languages, Architectures. Springer, Berlin, Heidelberg.

White, S.A. (2004). Process Modeling Notations and Workflow Patterns. In the Workflow.

Handbook 2004 (Fischer, L. Ed., pp. 265-294, Future Strategies Inc., Lighthouse Point, FL.

P. Cyplik et al. (eds.), *Contemporary challenges in supply chains, Vol. 2*,
https://doi.org/10.17270/B.M.978-83-66017-89-4.10