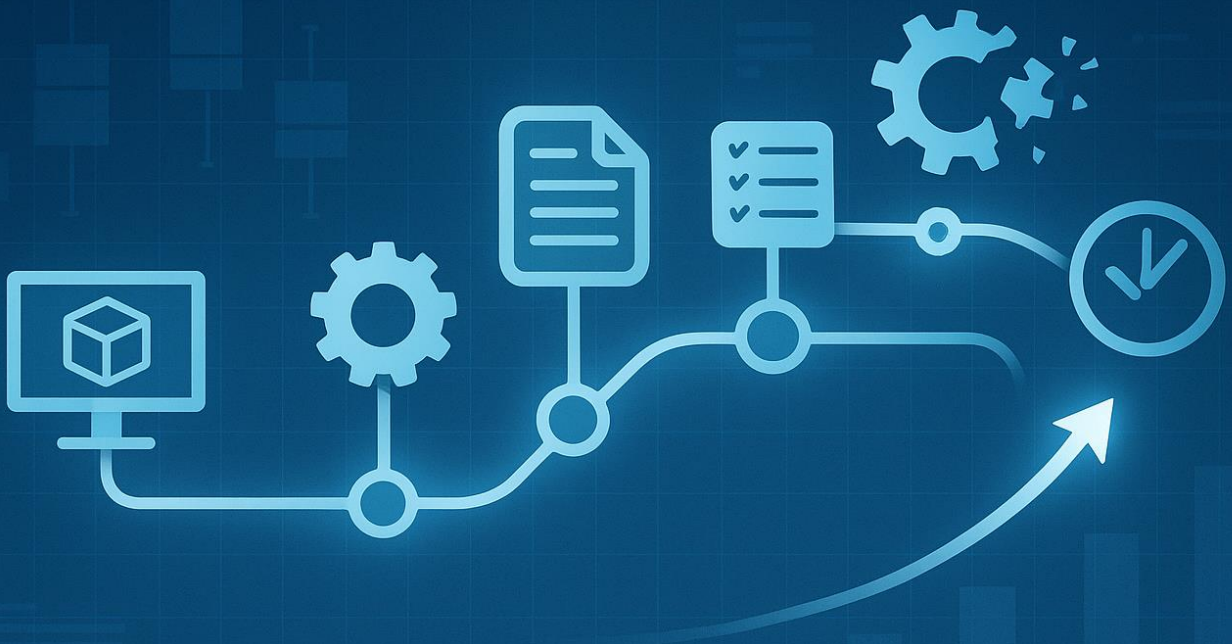




CHALMERS
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PLM



Investigation into the efficiency of a PLM system

Master's thesis at Master Program Production Engineering

Markus Kåreby

MASTER'S THESIS 2025

Investigation into the efficiency of a PLM system

MARKUS KÅREBY



CHALMERS
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Department of Industrial and Materials Science
Division of Engineering materials
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2025

Investigation into the efficiency of a PLM system
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Cover: A visualization of the PLM process

Gothenburg, Sweden 2025

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Abstract

This thesis explores time-related data recorded within a Product lifecycle management (PLM) system, with a focus on Engineering Change Requests (ECRs). A total of 166 ECRs were collected, categorized into four distinct cases, and analyzed to understand process times, task distribution, outlier occurrences, and iterative work. Data was manually gathered and visualized using box plots.

The analysis showed that cases handling Product Change Requests (PCRs) had significantly longer and more variable processing times, often due to inactive time being recorded as active work in the data. Furthermore, a noticeable proportion of outliers and iterative work were found in certain data sets generally believed to be caused by the requirement of PCRs.

Limitations in the data included lack of clear project identifiers, inconsistencies in how time was recorded, and the inability to differentiate between rework and multi-article tasks. Despite these constraints, inefficiencies were identified such as idle time, undocumented steps, and inconsistent timestamping.

The thesis finds that the PLM data is not fully representative of actual work, but inefficiencies are and were still possible to be identified from the data. Recommendations for improving data quality include automation of data collection, better categorization of ECRs, and improving data tracking. These measures would support better process understanding and lead to potential efficiency increase in the product change workflows.

Keywords: Product lifecycle management, Operational Product Lifecycle Management, Bill of material, Engineering change request, Product Change Request, Teamcenter

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Markus Kåreby, Gothenburg, June 2025

Contents

1	Introduction	1
1.1	Background	1
1.2	Purpose.....	2
1.2.1	Clarification of the research questions of the thesis	2
1.3	Delimitations	2
2	Theoretical framework	4
2.1	PLM.....	4
2.1.1	Teamcenter	4
2.1.2	Engineering change request.....	5
2.2	Engineering transaction.....	5
2.3	Box plot.....	6
2.4	Bottlenecks.....	8
3	Method	10
3.1	Project upstart.....	10
3.2	Data gathering	11
3.2.1	Acquisition of cases	11
3.3	Step mapping.....	12
3.3.1	Data filtering.....	13
3.4	Data analysis	13
4	Results	16
4.1	Results from data gathering	16
4.1.1	Results from Acquisition of cases	16
4.1.2	Results from case mapping.....	17

4.2 Results from data analysis.....	17
4.2.1 Box plot	18
4.2.2 Iterative work.....	22
4.2.3 Outliers	24
4.2.4 Time credibility	24
5 Discussion	27
5.1 On data gathering	27
5.2 Regarding data analysis.....	27
5.3 Answers on research questions	29
6 Conclusion	32
Bibliography	34
Appendix A	36
Appendix B	39
Appendix C	42
Appendix D	46

1 Introduction

Operational Product Lifecycle Management (OPLM) is a department that supports engineers throughout the product development process with product documentation and releases data management in the PLM system. The data release process is a complex and integrated process within the New Product Development System. The data release process can be described in well-defined processes, steps, and workflows, like a traditional manufacturing process. However, it should be noted that the work steps here are generally very administratively heavy. This in turn leads to steps that are generally not as detailed as a traditional process due to the need for flexibility. This in turn leads to the likelihood that this system is filled with administrative waste due to the process not being streamlined. In a highly competitive market, the need for reducing waste is always there however, due to its complexity streamlining the process can be hard and if incorrect methods are applied more waste can be introduced to the system or a loss in quality can occur.

1.1 Background

Every product goes through multiple stages in its lifecycle, these stages can include everything from everything from the innovation process to the design and recycling of the product (Corallo & Tontodonati, 2013). Throughout these stages, decisions must be made, and actions must be taken to increase the value of the product. The value of a product is determined based on how well it can fulfil a customer's need and thus actions taken to make the product more closely aligned with customer's needs increase its value (D'Amico, Giustiniano, Nenni, & Pirolo, 2013).

Zeekr Technology is a research and development center for the Zhejiang Geely Holding Group, which develops automotive technology that aims to be at the forefront of the technological market. The PLM system within Zeekr Technology contains massive amounts of data points and recordings that are not being utilized to improve the system. With this thesis, Zeekr Technology wants to look at the potential of these data points and see if value can be drawn from them to improve the current system. To do this Zeekr Technology wants to look at the possibility of describing the data release process in process steps and workflows, like a traditional manufacturing process. They also believe that since the PLM system contains a massive amount of data points there should be a way to the data in a way to measure the product development process utilizing traditional manufacturing metrics and identify potential efficiency improvements.

1.2 Purpose

The purpose of the thesis is to investigate the product development process at Zeekr Technology and analyze the process. This will be done by investigating the company's PLM system. Areas and reasons for waste shall also be highlighted. Finally, suggestions on how to improve the process efficiency shall be suggested.

1.2.1 Clarification of the research questions of the thesis

Questions that will be answered by the master's thesis project are:

Research question 1: Is the data retrieved from the PLM system representative of the actual work?

Research question 2: How can the data be used to improve the efficiency of the release in BOM process

Research question 3: What are the major types of waste in the system?

1.3 Delimitations

Delimitations that will be applied to the master thesis project are:

- The thesis will be conducted in English.
- Analysis will be conducted utilizing only data provided by Zeekr Technology.
- The extent of the analysis will be limited to a small part of the PLM system.
- Only data extracted from the system will be analyzed.

2 Theoretical framework

This chapter describes the theories, systems, and methods applied and or mentioned in the project.

2.1 PLM

PLM is a business approach to handling the digital data that makes up a product and its lifecycle. The lifecycle refers to the time of the inception of a product up until it has been fully discontinued. With this approach, it is possible to cover different products' initial development processes, future development, services required to support them, and their disposal. In other words, PLM is a way to manage everything involved with a product (Saaksvuori & Immonen, 2008). To achieve this there are three main things a PLM approach requires. The first is secure product data management and its accessibility. The second is a clear definition and information related to a product throughout its lifecycle. The third is managing business processes regarding handling information (CIMdata, 2024). With these conditions set a standardized workflow is enabled, which drastically reduces the time it takes from a product being just an idea to being out on the market. Furthermore, with the great overview of products and their different stages flexibility is possible where a product can be adjusted at any stage of its lifecycle. This allows for errors or inefficient parts of a product to be fixed and, or adjusted quickly, furthermore it is also possible to develop new products from existing products by adjustment in its manufacturing and makeup. This again further drastically reduces the time it takes for a product to come out onto the market. Finally, the points made combined often leads to a payoff period of 1-2 years in development cost (Nancholas, 2024).

2.1.1 Teamcenter

Teamcenter is a PLM software developed by Siemens and the world's most widely used. It is used for storage and management of product lifecycles. Teamcenter has the capabilities of storing information such as blueprints, CAD files, assembly instructions, spare parts, maintenance instructions and much more. Teamcenter is used like other PLM software to provide an overview of data and enable adjustments of a product's entire lifecycle, from inception to discontinuation (Siemens, 2008).

2.1.2 Engineering change request

Engineering change request (ECR) is a document describing details relating to a new product or proposed changes to an old one. The details usually include product design, a list of assembly components, and other product relating documents. The ECR is supposed to be shared with all the necessary stakeholders, not limited to but including the engineering department, quality assurance, manufacturing, design, and supply chain partners. For the changes or introduction of new items to take place all the necessary stakeholders must first send their approval. Refusal can occur when the stakeholders do not see the timeframe as reasonable or other limiting factors that do not make the ECR possible to implement. In these cases, the ECR must be reimagined or scrapped (Arena Solutions, n.d.). Some of the more common reasons for an ECR are the need for either product, regulatory or documentation related changes. A product-related change is when the actual product is affected, the need for this can be when better suited raw materials are found or when an old product is in need for competitive updates. Regulatory changes are changes to your regulations or standards in how you develop things, it can happen as the company grows and finds better approaches to development. Documentation changes are changes to documents, for example work instructions and when they change, they need to be updated and thus a documentation change has occurred (Lyons, 2024).

2.2 Engineering transaction

Zeekr Technology has a particular way their ECRs are handled, they are first divided into five different cases depending on where they are in the development process and whether the bill of material (BOM) must be changed. Due to the rarity of the 5th case, it was decided prior to this project start that ECRs relating to the 5th case would not be a part of this thesis. All cases also require the input of three different roles to be completed. The roles are as follows:

- Change author
- Bom engineer
- Module team approver (MTA).

The change author is the person responsible for initializing and writing the changes introduced in the ECRs. The actual occupation of the individuals who can assume the role of change author can differ greatly at the company. Often the individual is a computer-aided designer (CAD designer) however that is far from a requirement. A product's BOM is a list consisting of raw materials, assemblies, components, and the quantity of each to produce the product. The BOM engineer is responsible to make sure that the change author has written the BOM in the correct format. At Zeekr Technology different work teams exist that are each responsible for a different part of the car. In these teams, the team leader is generally responsible for approving the technical changes in the ECR, sometimes though these responsibilities are delegated to other members of the team. The person responsible for this job is known as the module team approver.

2. Theoretical framework

To determine which case should be utilized to handle an ECR the flowchart in Figure 2.1 can be utilized. As can be read from the flowchart, if a BOM change is required the ECR should be handled with the work steps described in cases 3 or 4. To determine which of the two methods should be utilized you then need to determine if a PCR is required or not. With the help of these two questions, you can decipher which of the four cases four cases must be applied.

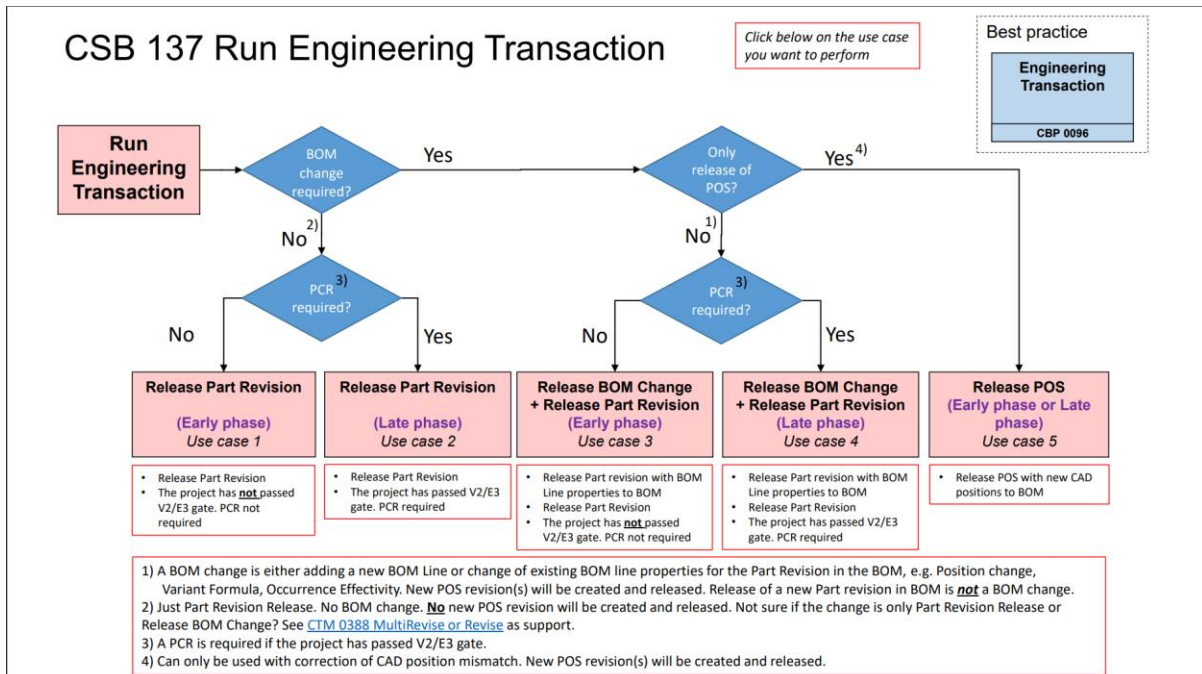


Figure 2.1: Flowchart to help determine which case an ECR belongs to and what work should be done

2.3 Box plot

The Box plot is a graphical tool to represent data and its primary use is comparing different sets of data. The box plot among many things provides a visual representation of the data and its variation. One of the main strengths of the box plot is that with this tool it is possible to visualize a lot of different information in only one contained and easily understood image (McGill, Tukey, & Larsen, 1978). The box plot can be seen as a two-dimensional box with a line going through, dividing it into two boxes. It also has one whisker on each side of two opposing ends of the box. The whisker lay at a 90°-degree angle to the line dividing the box into two, to help visualize see Figure 2.2.

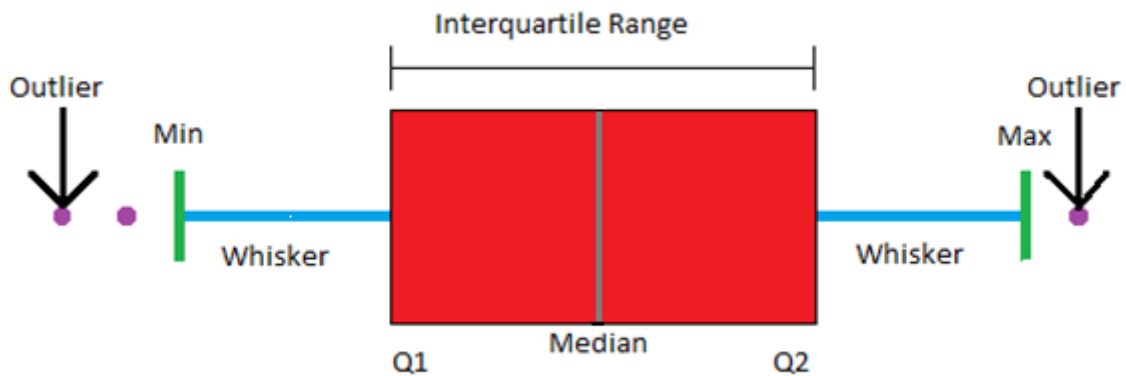


Figure 2.2: *Visual representation of a box plot.*

The box plot has multiple defining elements which are as follows (Byjus, n.d.).

- **Minimum value (min):** The min value is the lowest in the data set excluding outliers. On the Box plot, this value can be found at the end of one of the whiskers. If the box plot is standing vertically the whisker can be found at the bottom of the box plot and if it is laying horizontally, it can be found on the left side.
- **First Quartile(Q1):** The first quartile is an indication on the box plot which indicates that 25% of all values in the data set have a number that exists before the marker. On the box plot, the Q1 marker is one of the sides that make up the box plot, it is the side that lays right next to the start of the whisker connect to the min value.
- **Median:** The line dividing the boxes into two is the line representing the median of the data values. Half the values of the data set exist up to and before the line. The other half exists from the line and after.
- **Mean:** The mean value is the average value of the data set. It however does not have a visual representation on the box but can be found in the exact middle of it.
- **Third Quartile(Q3):** The third quartile is the indication on the box plot which says that 75% of the data exists before the marker and 25% after. The quartile can be found at the box at the end opposing the lower quartile. The quartile also exists right next to the beginning of the other whisker.
- **Maximum Score (Max):** The max value is the highest in the data set excluding outliers. On the box plot, it can be found at the end of the whisker sitting at the opposite end of the box to the whisker describing the min value.
- **Interquartile range (IQR):** Interquartile range is where the range of values that exist between Q1 and Q3 can be found. This range is what visually makes up the box.

Boxplot also has the capabilities of showing if the normal distribution is skewed, this is the case if the median line is not in the middle of the box. If the line sits to the left, it's a positive skew and opposite is a negative skew. Outliers can also be found above the third Quartile and below the lower first quartile ($Q1 - 1.5 * IQR$ or $Q3 + 1.5 * IQR$)

2.4 Bottlenecks

Bottlenecks exist in every production where they act as limiters to the production's capacity. Since the bottlenecks act as limiters a removal or widening of the neck will increase a production system's capabilities to produce. However, to do so a bottleneck must first be found, and even when a bottleneck is found it may not be the most efficient place to perform improvement since there may be other more important bottlenecks. The size of the bottleneck and the cost of improvement must be considered before making improvements. Another point to consider is that the size and places where they exist in the production flow may change depending on the time and type of product going through the production system. Generally, in a production system, the machine with the slowest processing time is the bottleneck. However, if for example, a machine tends to break down and stop the entire flow it then creates a temporary bottleneck whenever that happens. The time and cost loss during these types of breakdowns may in turn be worse than the slowest machine and thus is of greater importance to treat. Whenever a bottleneck is removed a new one presents itself, like in the example of the machine with the slowest processing time. The new one in that case is likely the machine with the then-second slowest processing time and thus now making it the slowest (LeanProduction.com, n.d.).

Not only do bottlenecks put a limiter on a system it also introduces problems in other processes such as a blocked or starved process. A blocked process occurs when there is no more room in the buffer situated after the blocked process and before the bottleneck. This means that the blocked process can no longer send products forward and must wait for the bottleneck to finish. This in turn leads to a total stop in that process, this means that because of the bottleneck you will be forced to underutilize the process occurring before it. A chain reaction due to the bottleneck may also occur where multiple or all the processes before the bottleneck will be blocked. A starved process is situated after the bottleneck and occurs when there is no buffer left before the starved process and after the bottleneck. This means that the starved process must wait for the bottleneck to finish to receive further products. This in turn leads to a total stop in that process, this means that because of the bottleneck you will be forced to underutilize the process occurring after it. A chain reaction due to the bottleneck may also occur where multiple or all the processes after the bottleneck will be blocked (LeanManufacture.net, 2023; Sepasoft, n.d.).

3 Method

This section describes the methods used to investigate the data in the PLM system. The chapter ends with a description of what processes were used to analyze the data and how it was done.

3.1 Project upstart

Because of the sheer size of the PLM system utilized by Zeekr Technology and the uncertainty of what value could be extracted from it, it was decided that the analysis should be performed on only a small part of the system. The area decided upon was the release process, the reason this specific part was chosen was that the project team responsible for this part was also the team most in contact with the thesis writer. The steps required to go through to complete an ECR can be seen in Figure 3.1. However, this is only for case 1 the remaining 3 cases can be seen in Appendix A. To provide the author of this thesis with a better understanding of the system they were provided with an introductory course in Teamcenter (the PLM system utilized by Zeekr Technology). Person-on-person guidance with the BOM engineers from the project team was then also provided to further support their understanding of the PLM system.

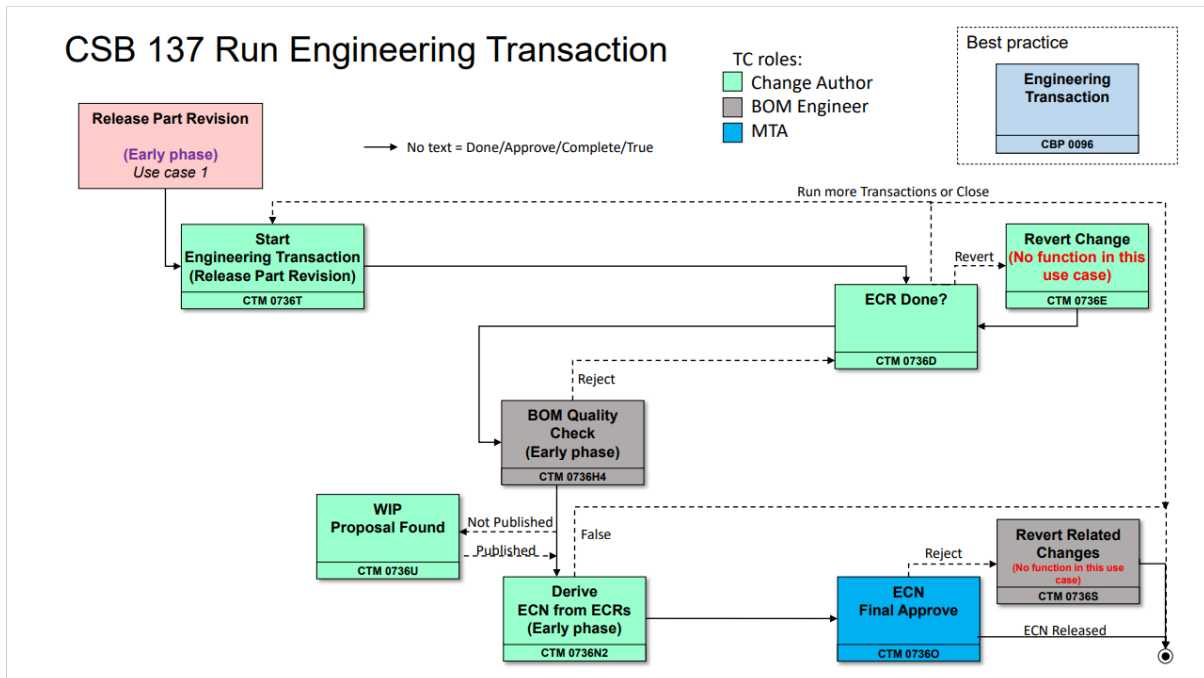


Figure 3.1: A flowchart showcasing the steps required to perform to complete case 1

3.2 Data gathering

This section describes how and what data was gathered that would later be analyzed

3.2.1 Acquisition of cases

To analyze the data a significant amount of ECRs from the PLM system had to be retrieved. They also had to fit into one of the four cases displayed in Section 2.2. The initial idea was to retrieve previously finished ECRs handled only by the team in most contact with the writer and cases only belonging to one and the same project. However, while ECRs had individual IDs registered they rarely came with project IDs. So, a large Excel sheet consisting of ECR ID numbers was retrieved which did not have an identifier describing the project they were a part of. The ECRs did have identifiers describing who worked on which task. This did make it possible to personally contact the individuals or project team the person was working on the ECR with. However, due to time limitations, it was not reasonable to reach out to each individual person concerning every single ECR since each ECR then had to manually be retrieved from Teamcenter utilizing the ID numbers from the sheet.

The retrieval process consisted of sorting the ECRs into one of the four cases, filtering out incomplete (abandoned/scraped) ECRs. This was done by opening excel files linked through Teamcenter and comparing the steps completed with the case descriptions described in section 2.2. Then documentation the initiation date, elapsed time, and completion date for all the different tasks detailed in the ECRs into a new Excel sheet. These three date/time descriptions will from now on be referred to as “recorded timesteps”. With the help of the ID numbers, it was possible to look up the ECRs in Teamcenter. This then made it possible to figure out which ECR fell into which case description. The main case determining factors were whether a PCR and or BOM change was required for the ECR. And If a PCR is required, if it were the acronym PCR would be included in the title of the ECR in Teamcenter, and if a BOM change was required a red marker with a white an M symbol would signify it. Finally, a complete ECR would be signified with a flag at the end of its title. Examples of the above descriptions and what it looks like in Teamcenter can be seen in Figure 3.2.

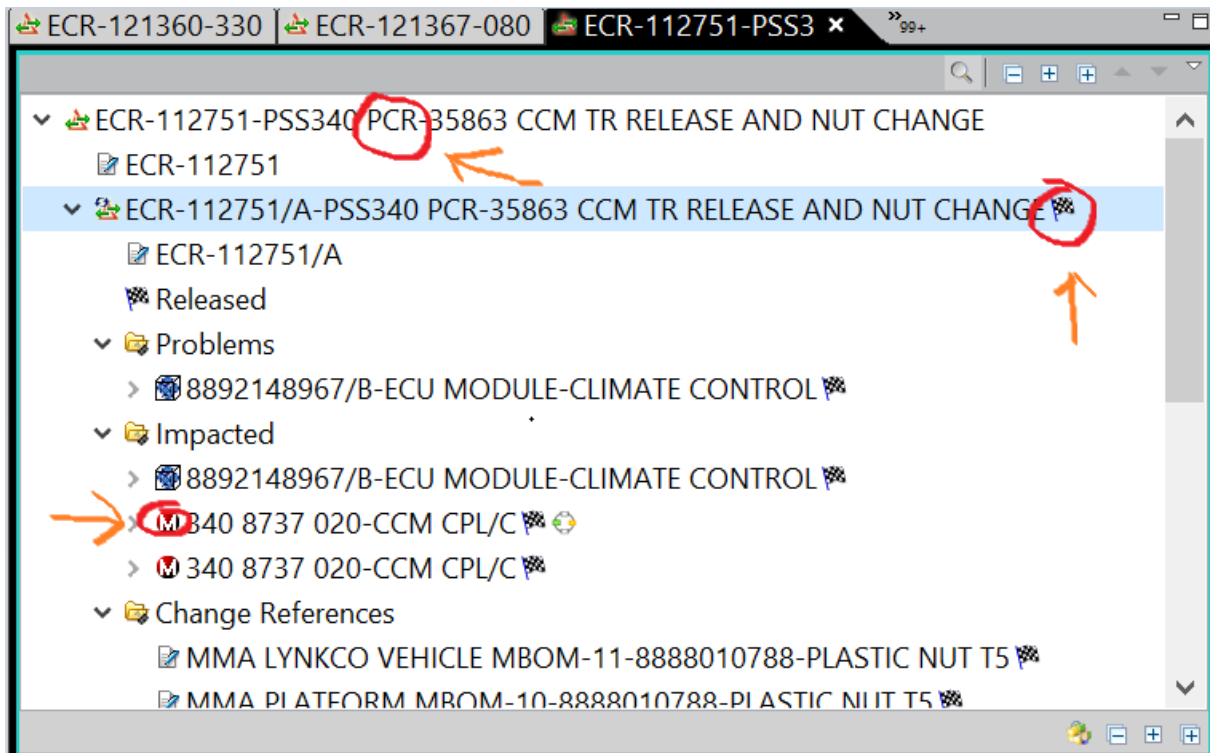


Figure 3.2: Image showcasing an ECR in Teamcenter with points of interest circled, description in text above.

3.3 Step mapping

While the flowcharts seen in Figure 3.1 and Appendix A did give an overview of the tasks recorded in the ECRs they did not entirely match the timestep recordings found in the ECRs. Because of this, a remapping of each case had to be done based on found timestamps. The excel sheets were filled with tasks and timestep recordings documenting each step from the initialization of an ECR till its completion in minutes elapsed. The tasks and timestamps ranged in the hundreds however, most of the steps had a recording of zero minutes and on multiple occasions, steps occurred within the same timeframe. The reason behind these occurrences ranged from certain steps being sub-steps to others and short-time recordings being rounded down to zero minutes. Each ECR also had one timeframe recording consisting of the total timeframe of the ECR. Provided with that a mapping of all the unique timeframe recordings was made and duplicates were ignored. This decision was made to avoid presenting an active work time of above 100% and instead only presenting the unique work time.

While many of the steps were similar between the four cases a unique mapping was still required for each unique case. Additionally, in some ECRs certain steps had repeat occurrences with unique time recordings. It was decided that these occurrences were to be recorded separately to analyze their impact. Furthermore, not all steps were discovered in the initial mapping of each case and backtracking had to be done when new ones were discovered to ensure the quality of the data.

3. Method

To get a better picture of which segments were more straining regarding ECR work the mapping was strengthened with a description of which of the three roles described in Section 2.2 was responsible for each task. This was determined through interviews with some of the people working with ECRs at the company. Table 3.1 showcases a color coded new mapping of case 1, the others can be found in Appendix B

Case 1a	ECR Done	BOM Quality Check	WIP Proposal Found	Derive ECN From ECRs	Publish Derive ECN	ECN Final Approve	Notify Stakeholders
Case 1b	ECR Done	BOM Quality Check	WIP Proposal Found	Derive ECN From ECRs	Publish Derive ECN	ECN Final Approve	Notify Stakeholders

Table 3.1: Image showcasing new color-coded mapping of case 1. Green color indicates that the step was handled by Change author, grey Bom engineer, blue MTA and pink is an indication of a step that was automatic.

3.3.1 Data filtering

While the flag marker described in Section 3.2.1 helped in filtering out incomplete cases a second screening had to be done in the Excel sheet to ensure that they were indeed complete. Furthermore, some of the ECRs in the four case scenarios had additional steps that were not part of the initial mapping. However, due to their frequency or infrequency case by case decisions were made to either include or ignore those steps. The reason for ignoring some of them was simply that they were not frequent enough to provide enough data to draw any conclusions. Instead, they were more likely to muddy the data and make it harder to analyse.

On occasion, certain ECRs had one or multiple steps repeating with their individual unique timesteps. This occurred when an ECR handled multiple articles and thus required some of the steps to be performed on each article. It also occurred when mistakes occurred, and certain steps had to be reworked. It was not possible to decipher which of the reasons were behind the occurrence of the multiple occurring steps and thus they had to be counted together. Cases with multiple articles were also not filtered out due to a lack of knowledge at the project start that ECRs did on occasion handle multiple articles.

3.4 Data analysis

Within each ECR a task named “Engineering Transaction” existed, this task was the sum of all tasks contained within an ECR. The task itself had a timestamp starting at the initiation of an ECR and concluding at its end. To help determine the quality of the data from the ECRs all the other timestamps, excluding the Engineering transaction step, were to be summed up and compared to that step. The reason behind this decision was to help determine the loss in accuracy that occurred since data was recorded in minutes and thus had rounding errors existed, as described in section 3.2.2.

Finally, to get a better understanding of how demanding the different roles described in section 2.2 were. An investigation was done to determine which role was responsible for which activity in the case mapping made in section 3.2.2. This was done through interviews with the project team. Furthermore, activities that were performed automatically, but recorded by the system were documented as a separate role. Table 3.1 and appendix B showcases this to further analyze the data the cases were compared against each other in box plot format to highlight various data, such as various in total time, how common repetition was and more. A similar approach was used to compare the time steps with the different cases to each other. More in-depth presentation exists

3. Method

in the result section complimented with the appendix

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4 Results

This chapter presents the results of the project, gathered and analysed.

4.1 Results from data gathering

This section presents general data and information that was collected through the data gathering step.

4.1.1 Results from Acquisition of cases

The data gathering resulted in an accumulation of 166 ECRs being analyzed. The data was divided into the four cases described in Section 2.2 depending on which they belonged to. The result of this division was 44 cases describing case 1, 41 describing case 2, 43 describing case 3 and 38 describing case 4. Since some of the ECRs had repeating tasks the four cases were divided into two sets each. One handling no repeating tasks referred to as 1a-4a, and a second one which does and is referred to as 1b-4b. The total time data describing the initialization and end of an ECR for the four cases were summed up and presented in Box plot format in Figure 4.1. Due to the low amount of b cases the decision was made to present their data combined with the a cases when comparing the cases against each other.

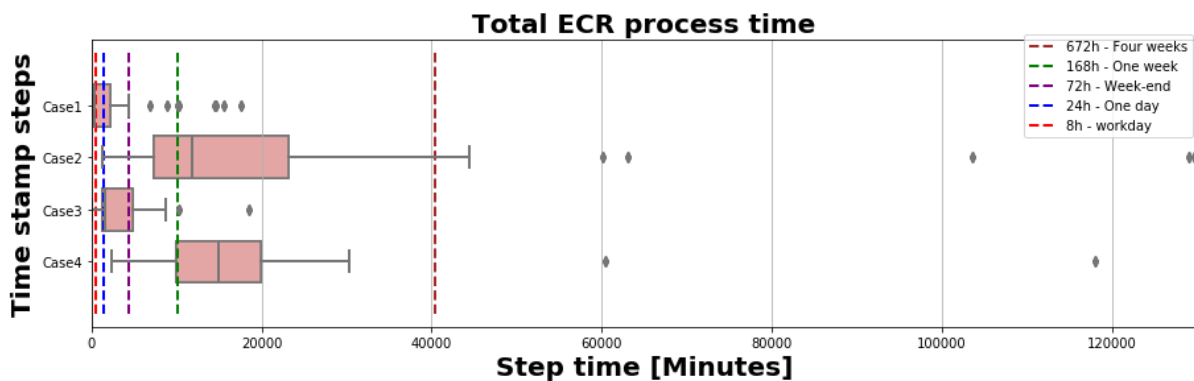


Figure 4.1: Data illustration for the different cases in the form of box plots presented in minutes. The data is further aided with differently colored dotted lines to indicate different increments of time. The grey/black rhombuses appearing in the graph are visual representations of outliers calculated using the formula described in section 2.3.1. For a more detailed, but less visualised representation of the numbers presented in the box plot see Appendix C

The illustration clearly shows that the PCR-dependent cases two and four tend to take several times longer to perform than cases one and four. Furthermore, by observing the range of the boxes the stability to perform the ECRs within similar timeframes is much

4. Results

worse for the PCR cases. A description of the functionalities of Box plots can be seen in section 2.3.

4.1.2 Results from case mapping

The result of the mapping of the four cases made it possible to present which steps were shared among the cases and which were unique in Table 4.1. The more complex cases such as two and three were made up of a noticeably higher number of steps than case one. Furthermore, case four, the most complex case was made up of the greatest number of steps. Furthermore, by noting down the frequency of a step's occurrence and the frequency of its time recording being zero it helped illustrate the impact of the different steps. The "WIP Proposal Found" step for example was a rare occurrence in the different cases, but in its occurrences, it always showed a number higher than zero.

Case	Statistics	Create BL Form	Update BL Info Forms	ECR Done	Modify Effectivities and Variant	Change Author Review	WIP Proposal Found	BOM Quality Check	Change Author Final Review	OK To Publish	Publish pos 1	Change Author Final Approve	Published Proposed Parts	Verify Approved Introduction	Edit BOM/Validity	Derive ECN From ECRs	Publish POS 2	Generate ECN Report for MTA	ECN Final Approve	Release all	Generate ECN Report(Final)	Distribute ECN Report	Notify Stakeholders	Quick Loop BOM Engineer	Change Author Review 2	Publish Derive ECN
Case 4	Empty [%]	87	0	0	0	0	76	0	0	0	0	0	76	0	0	0	0	0	0	0	0	0	0	0	0	0
	'0' [%]	0	0	24	11	11	0	0	3	3	97	0	0	0	5	71	97	5	0	90	0	5	95	0	0	0
Case 3	Empty [%]	65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	'0' [%]	5	0	49	16	33	0	0	0	0	0	0	0	0	63	0	0	0	0	0	0	0	0	5	9	2
Case 2	Empty [%]	0	0	0	0	0	47	0	0	0	0	0	58	0	0	0	0	0	0	0	0	0	0	0	0	0
	'0' [%]	0	0	0	0	0	0	0	0	0	0	3	0	0	3	0	11	0	92	0	3	100	0	0	0	0
Case 1	Empty [%]	0	0	0	0	0	70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	'0' [%]	14	0	0	0	0	0	0	0	0	0	0	0	0	26	0	0	0	0	0	0	0	0	0	0	0

Table 4.1: Illustration of the steps, their frequency of occurrence, and frequency of timestep being zero for the different cases. All numbers in the illustration is presented in percentage form.

The table provides statistics on how frequently different steps which are optional in the cases occur. The rows highlighting the frequency of steps occurring are done so under the name of "Empty". The data here is presented in percentages of how frequently a step does not occur for a specific case. The remaining rows are the ones describing the frequency of a step having a time recording of zero and this data is also presented in percentages. In the scenarios when there are no numbers describing a specific step and case combination, it is done so because the step does not occur for that specific case.

Each timestep for every case was also illustrated in Appendix D. The data points gathered there highlights how frequent timesteps occurred in each case and the duration of them.

4.2 Results from data analysis

This section presents results from the analysis of the four different cases, the data is

4. Results

presented in different graphs and tables with descriptions explaining the reason behind it and how to read them.

4.2.1 Box plot

Due to its ability to provide a lot of analytical data box plots were made on each individual step for each case incorporating steps mapped in the mapping segment of the project. The box plots allow for the analysis of the different steps' mean value, total range of values, outliers, and more. For further information on the possibility of boxplots see section 2.3.1. The box plots of the different cases can be seen in Figure 4.2 to figure 4.9.

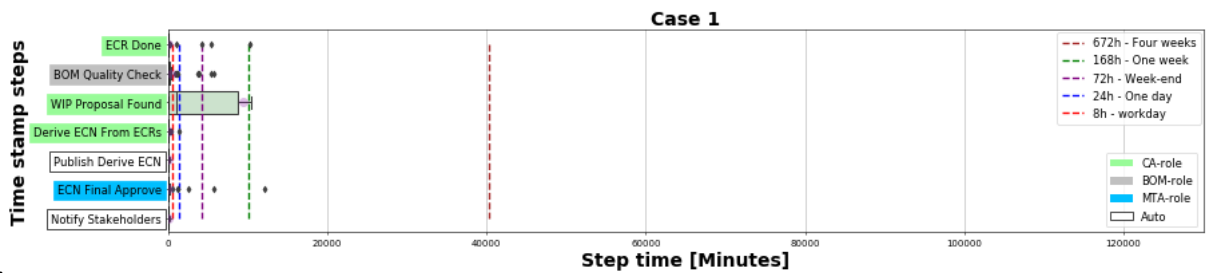


Figure 4.2: Data illustration of case 1 in the form of box plots presented in minutes describing the different steps incorporated in case 1. The Y-axis ranges from 0 minutes to 13 000 minutes. The data is further aided with dotted lines to indicate different increments of time. The grey/black dots appearing in the graph are visual representations of outliers. Furthermore, the purple circles are representations of occurrences when iterative work took place. The steps are divided into four categories describing who is responsible for the tasks, the division is based on the information described in section 2.2.

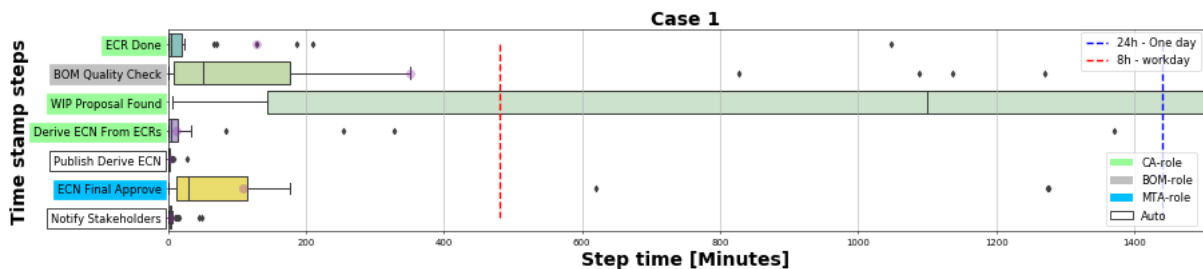


Figure 4.3: Same data illustration as Figure 4.2, but a lower range in the Y-axis to increase the readability of the graph. The range in the Y-axis is from 0 minutes up to 1500 minutes.

In regards to case 1 from the graphs, it can be seen that the “WIP Proposal Found” task is the noticeably longest task to complete. It can also be seen that manual tasks have a noticeably longer process time than automatic ones.

4. Results

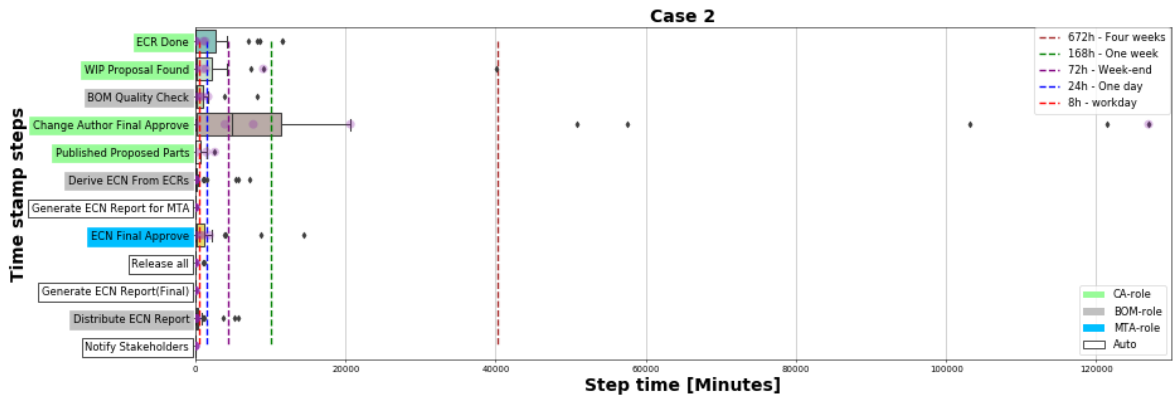


Figure 4.4: Data illustration of case 2 in the form of box plots presented in minutes describing the different steps incorporated in case 2. The Y-axis ranges from 0 minutes to 13 000 minutes. The data is further aided with dotted lines to indicate different increments of time. The grey/black dots appearing in the graph are visual representations of outliers. Furthermore, the purple circles are representations of occurrences when iterative work took place. The steps are divided into four categories describing who is responsible for the tasks, the division is based on the information described in section 2.2.

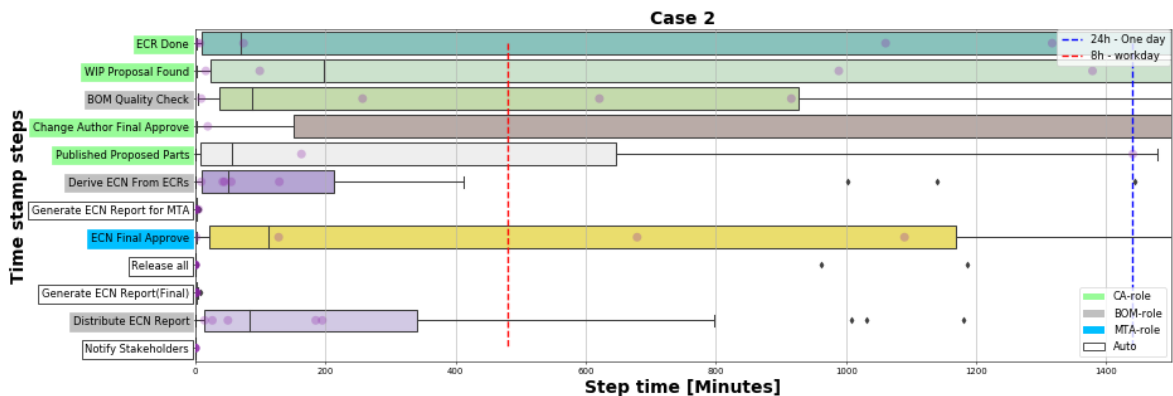


Figure 4.5: Same data illustration as Figure 4.4, but a lower range in the Y-axis to increase the readability of the graph. The range in the Y-axis is from 0 minutes up to 1500 minutes.

For case 2 the graphs again illustrates that the “WIP Proposal Found” task is the noticeably longest task to complete. It can also be seen that manual tasks have a noticeably longer process time than automatic ones.

4. Results

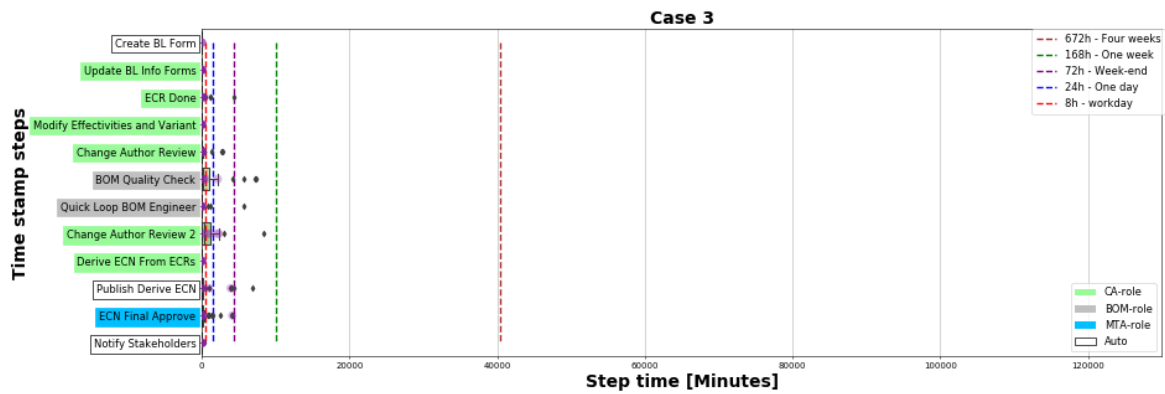


Figure 4.6: Data illustration of case 3 in the form of box plots presented in minutes describing the different steps incorporated in case 3. The Y-axis ranges from 0 minutes to 13 000 minutes. The data is further aided with dotted lines to indicate different increments of time. The grey/black dots appearing in the graph are visual representations of outliers. Furthermore, the purple circles are representations of occurrences when iterative work took place. The steps are divided into four categories describing who is responsible for the tasks, the division is based on the information described in section 2.2.

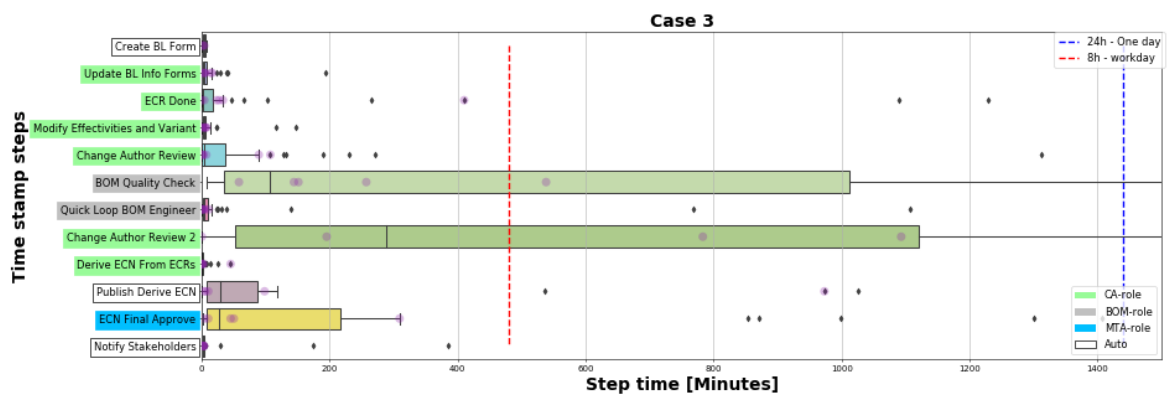


Figure 4.7: Same data illustration as Figure 4.6, but a lower range in the Y-axis to increase the readability of the graph. The range in the Y-axis is from 0 minutes up to 1500 minutes.

For the 3rd case it can be seen that the “BOM Quality Check” and “Change Author Review 2” tasks are tasks that have noticeably the longest process time. It can also be seen that manual tasks have a noticeably longer process time than automatic ones with the exception of the “Publish Derive ECN” task.

4. Results

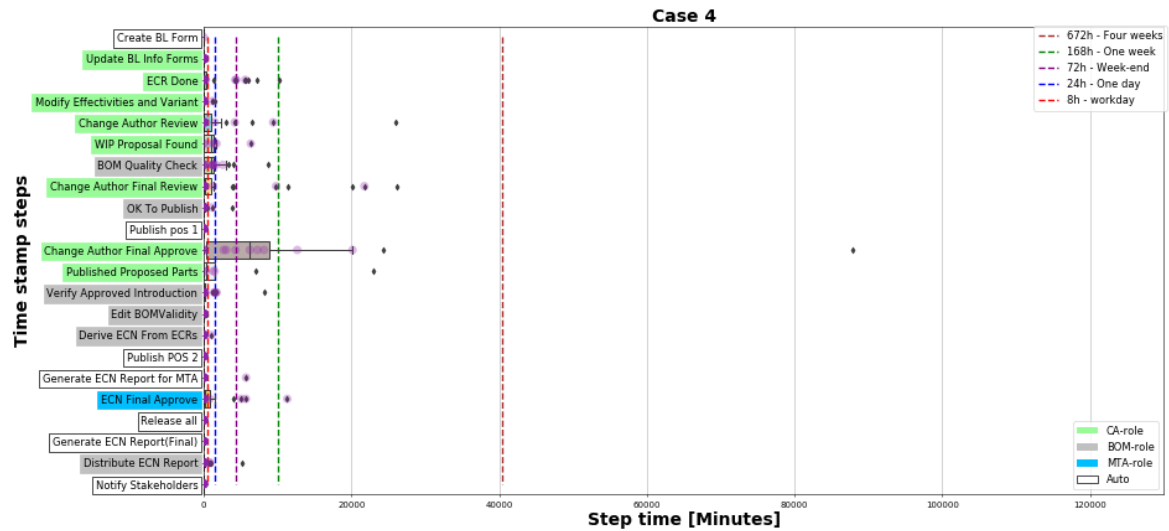


Figure 4.8: Data illustration of case 4 in the form of box plots presented in minutes describing the different steps incorporated in case 4. The Y-axis ranges from 0 minutes to 13 000 minutes. The data is further aided with dotted lines to indicate different increments of time. The grey/black dots appearing in the graph are visual representations of outliers. Furthermore, the purple circles are representations of occurrences when iterative work took place. The steps are divided into four categories describing who is responsible for the tasks, the division is based on the information described in section 2.2.

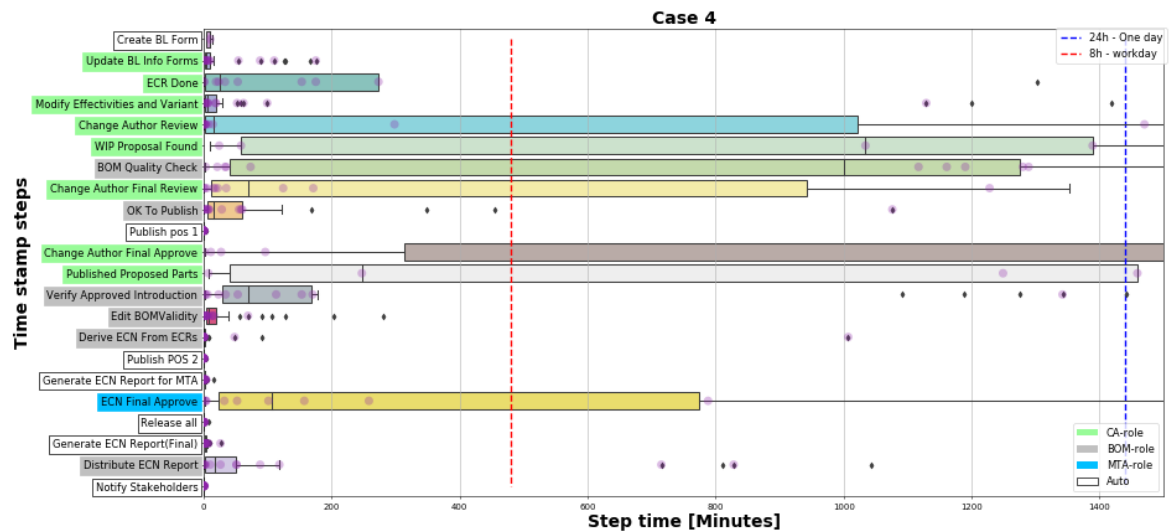


Figure 4.9: Same data illustration as Figure 4.8, but a lower range in the Y-axis to increase the readability of the graph. The range in the Y-axis is from 0 minutes up to 1500 minutes.

In the 4th case it can be seen that the “Change Author Final Approve” task is the noticeably longest task to complete. It can also be seen that manual tasks have a noticeably longer process time than automatic ones.

4.2.2 Iterative work

As described in section 3.2.3 the ECRs sometimes had multiple timestamps for the same time step. This occurred when multiple articles were handled, or errors occurred which required work to be repeated. In this section the frequency of this occurring is described and for which steps in each case. Since there is no way to decipher between rework and work handling multiple articles, it is all instead referred to as iterative work.

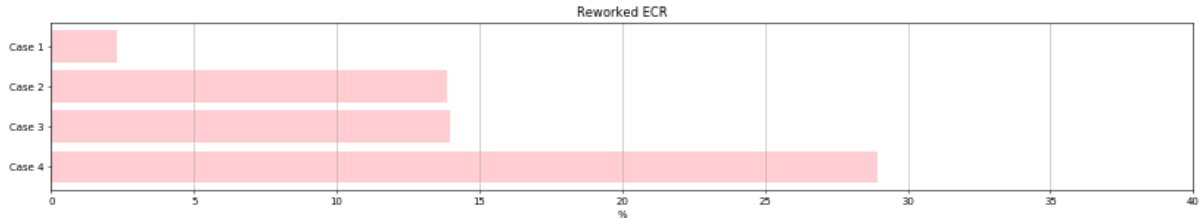


Figure 4.10: Illustration of rework occurrences in between the four cases. The bar describes the statistical occurrence of rework in the form of percentages.

For the respective four cases, there were 44,41,43, and 38 ECRs processed in the data. With this knowledge and the graph above it can be seen that iterative work only occurred once. While for cases two and three iterative work occurred five and six times. Finally, for Case four iterative work occurred twelve times.

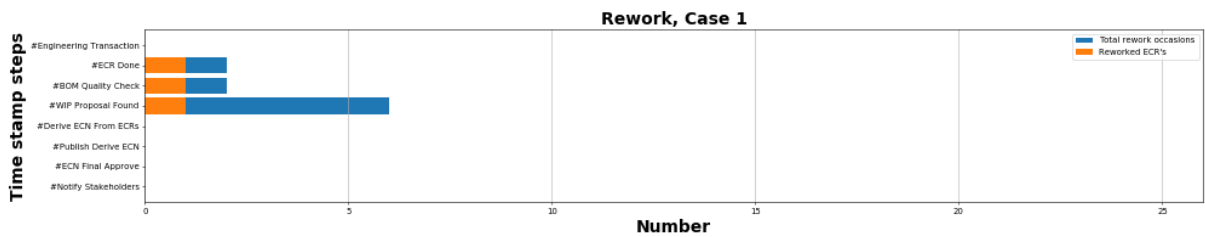
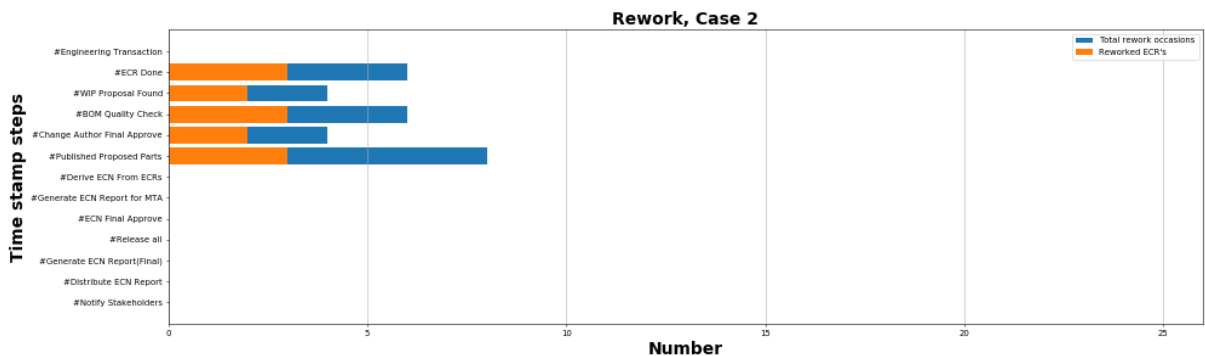


Figure 4.11: Illustration of rework occurrences in Case 1 for each individual time step. The orange bar describes the statistical occurrence of rework in the form of percentages.

In case 1 iterative work only occurred in three different timesteps. Aided with the knowledge that iterative work only occurred once described in the segment above it can be determined that the iterative work that occurred required the three timesteps to be completed. However, it should be noted that the “WIP Proposal Found” step had more than one multiple occurrences in the one ECR where iterative work was required.



4. Results

Figure 4.12: Illustration of rework occurrences in Case 2 for each individual time step. The orange bar describes the statistical occurrence of rework in the form of percentages.

In case 2 the occurrence of iterative work was higher than in case one as was the number of steps iterative work occurred within. It should also be noted that when iterative work occurred it was not always for the same steps as can be determined using the percentage values seen in the Figure above and the figure describing the four different cases at the beginning of this section.

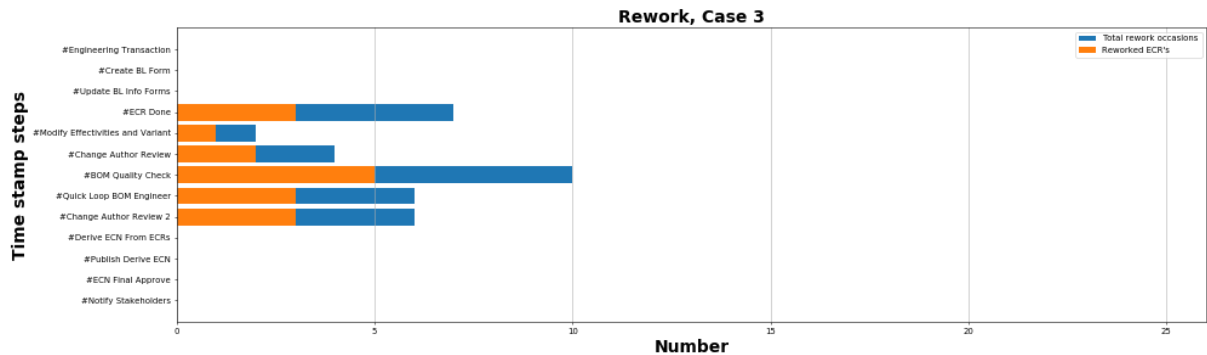


Figure 4.13: Illustration of rework occurrences in Case 3 for each individual time step. The orange bar describes the statistical occurrence of rework in the form of percentages.

In case 3 the occurrence of iterative work was higher than in case two as was the number of steps iterative work occurred within. It should also be noted that when iterative work occurred it was not always for the same steps as can be determined using the percentage values seen in the figure above and the figure describing the four different cases at the beginning of this section. Furthermore, it should be noted that of the steps where iterative work occurred the “Modify Effectivities and Variant” step seemed to occur noticeably less frequently than the others.

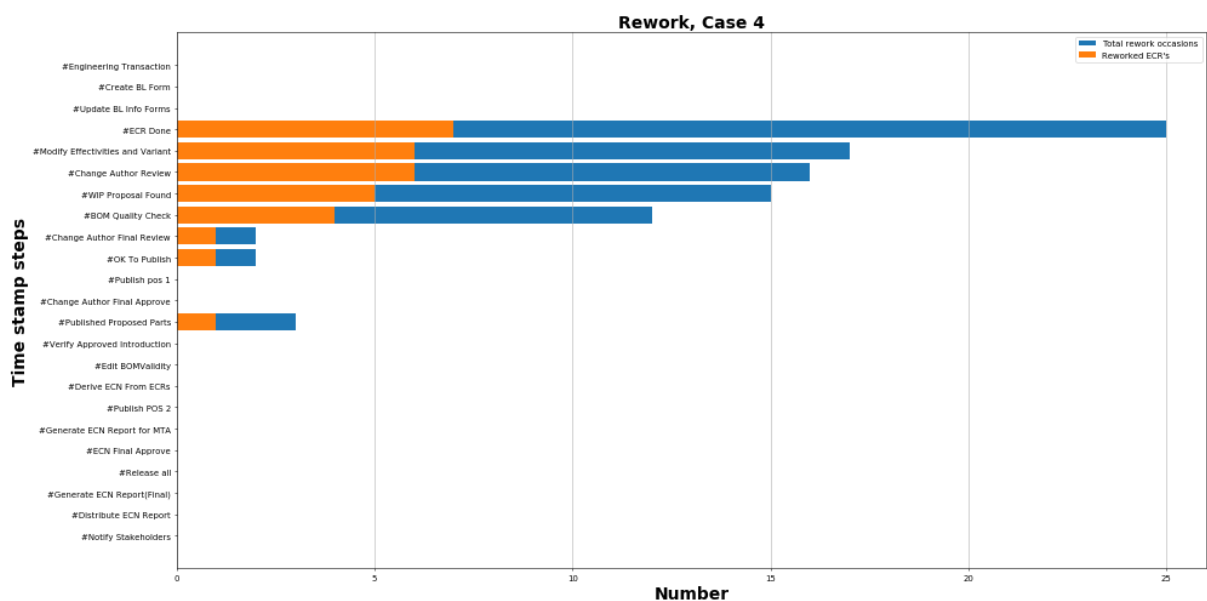


Figure 4.14: Illustration of rework occurrences in Case 4 for each individual time step. The orange bar describes the statistical occurrence of rework in the form of percentages.

percentages.

In case 4 the occurrence of iterative work was the highest as was the number of steps iterative work occurred within. It should also be noted that when iterative work occurred it was not always for the same steps as can be determined using the percentage values seen in the figure above and the figure describing the four different cases at the beginning of this section. Furthermore, it should be noted that of the steps where iterative work occurred the “Change Author Final Review”, “ok to publish” and “Published Proposed Parts” steps seemed to occur noticeably less frequently than the others. The “ECR Done” while not having an appearance that was noticeably more frequent than others should be noted that when it appeared it often had more individual timestamps for its step.

4.2.3 Outliers

A further benefit of the boxplot was its potential to highlight Outliers. Thus, we were then able to look at and try to analyze outliers for each step in the different cases. For more information regarding the possibilities and usefulness of boxplots see section 2.3.1. Figure 4.15 provides data regarding the frequency of the outliers.

Case	Engineering Transaction	Create BL Form	Update BL Info Forms	ECR Done	Modify Effectivities and Variant	Change Author Review	WIP Proposal Found	BOM Quality Check	Change Author Final Review	OK To Publish	Publish pos 1	Change Author Final Approve	Published Proposed Parts	Verify Approved Introduction	Edit BOM Validity	Derive ECN From ECRs	Publish POS 2	Generate ECN Report for MTA	ECN Final Approve	Release all	Generate ECN Report(Final)	Distribute ECN Report	Notify Stakeholders	Quick Loop BOM Engineer	Change Author Review 2	Publish Derive ECN	
Case 4	5	0	18	24	18	13	3	8	18	13	3	5	5	21	18	18	3	13	11	11	11	13	5				
Case 3	5	0	12	19	9	21		9											19				12	19	5	19	
Case 2	14			17			8	6				14	3					36	11	8	3	17	0				
Case 1	19			21			0	19											14				14			16	

Figure 4.15: Illustration of outlier occurrences in all 4 cases for each individual time step. The numbers describe the frequency of occurrences in amounts.

The frequency of the outliers differed a lot between time steps, another thing of note is that certain steps are unique to some cases, and thus only data for those cases exist. In comparing the shared time steps, it varies a lot regarding which case had the most frequent outliers between the timesteps and can likely be explained due to the limited sample of cases. However, the engineering transaction step the step which described the total elapsed time of an ECR had a fairly large difference in the frequency of outliers between cases 1,2 compared to 3 and 4. This then suggests that the cases without a BOM change were more volatile in their time frame than those with.

Another thing of interest is that while cases 2 and 4 (cases containing a PCR) did not show a direct pattern of increased frequency of outliers, they did contain the largest outliers. Examples of this can be seen in Figure 4.4 from section 4.2.1. Looking at that figure we can see 2 outliers surpassing 100,000 minutes.

4.2.4 Time credibility

In section 3.2.2 the documentation and analysis of the combined time of the timesteps in comparison to the Engineering transaction steps was described. The analysis was done

4. Results

to determine the impact of rounding errors in the ECRs. However, through closer inspection, the errors were not limited to rounding errors. It was discovered that at different points in the some ECRs recordings of time simply did not exist. To determine the cause of these inconsistencies', interviews were conducted with the project team, however, no conclusions were found to the underlying cause. In most ECRs the degree of error was around half a percent, in some, there was none, and in a few they exceeded twenty percent. The ones with extremely high and low accuracy were most found in ECRs with a short duration from its initiation until its completion.

5 Discussion

5.1 On data gathering

The data-gathering process was filled with hills and hurdles to overcome which strongly limited what was possible to do with the data. For one the initial idea was to acquire ECRs from the same project and project group. However, due to the infrequency of this information being recorded in the ECRs. It was not possible to gather a large enough set of data to look at. This would have allowed for a clearer understanding of how differently draining the case scenarios are. In the current state because the data is from different projects and project groups the data is likely skewed. Since it is likely that the demand, difficulty, and competence in different projects and project groups differ it is also likely that those factors may impact the reliability of the data. However, due to how the data is registered in the system it was not possible to filter these things while collecting the data.

Another issue with the gathering process was the sheer volume. Initially, the idea was to automatically print a large part of the data into a combined document. Instead of manually typing and checking each step for every ECR as well as manually performing the sorting into cases. Because everything had to be done manually most of the time was spent on transcribing the data point and ensure that the cases did fit into the mapped patterns. Had the process been automatic more data could have been analysed to increase the reliability of the analysis. However, an advantage to the manual process was the spotting of odd data points. This allowed for a quick way to track down and possibly uncover some of the issues in the system.

5.2 Regarding data analysis

When comparing the four cases it can be quickly noted that there is a big discrepancy in process time, whereas cases two and four noticeably have a much longer process time. It should also be noted that the range of the box plots is vastly larger in cases two and four, which means that the timeframe to complete those cases differs greatly from ECR to ECR. The reason for this occurrence ranges from increased complexity in the steps and increased wait time between them and an increase in the number of optional steps in the cases. The increased wait time occurs due to the requirement of a PCR in cases two and four. The wait time due to the PCR can occur midway through an ECR where the next step can't be completed until the PCR is further developed and thus the ECR is placed on hold. The elapsed process time for the ECR continues while the actual work is put on hold this wait time can on occasion range from days to months. It should also be noted that case one has a processing time that is noticeably shorter than the others and this is because the steps are fewer and simpler to complete than the ones occurring in the other cases. While increased process time generally seemed to occur with an increased amount of process steps case two being longer than four breaks this pattern. However, the discrepancy between two and four is not that large and due to the impact of wait time from PCRs, the reason behind this occurrence is likely due to a small sample size.

5. Discussion

As was mentioned in the previous segment, wait time occurs between steps. This wait time is not registered, but instead occurs as work time. This means that when one step is completed the next one begins according to the system, but the actual work may not always start immediately. This can be seen in the box plots describing the steps for the individual cases. If one were to look at the ranges and outliers at the box plots one should be able to derive from the data that a lot of outliers occur around the 24, and 72-hour mark. What happens is that one task is completed at the end of a workday or workweek, and another is initialized but not touched until the next day or the beginning of the next week. The system continuously counts the elapsed time and thus does not register the downtime. Another interesting thing to note is the pattern of when these steps occur, they rarely occur at the beginning of the ECR, but instead often occur when the ECR changes handler. For example, the steps “BOM Quality Check” and “ECN Final Approve” hold a decent number of outliers in all four cases and tends to have a fairly long process time in comparison to most of the other steps. Another thing to consider for the outliers is what was mentioned in the previous segment regarding the wait for PCRs. Depending on which step is being worked on in an ECR regarding cases two and four it may have to be put on hold while waiting for the PCR to mature. This may also lead to a bottleneck since when the PCR is ready another more important ECR may be of priority and thus more time goes recorded and wasted at least according to the system. Similarly, the argument can be turned around and an ECR can be considered starved from the system and time recording aspect when it is waiting on a PCR. Finally, another explanation for the process time are steps that can, but do not always occur such as “WIP Proposal Found”. These steps sometimes seem to take longer to complete than the regular ones, the explanation behind this however is not entirely certain.

If we once again compare the cases against each other an interesting point of interest is the iterative work/rework occurrence. It is very clear that the more steps introduced in the cases the bigger the risk of iterative work. In case one rework rarely occurs, for cases two and three the occurrence lies around 15% and in case four it is double that of the previous two. Through conversations with the project group, it was also discovered that sometimes the iterative work was due to multiple articles going through the same step. Though it did not seem like it was the explanation for all the occurrences. Regardless of which the iterative work did not have a major impact on the overall time required to complete and ECR, this could be different if a larger sample sized had been used or if less of the total time composed of idle time.

Another interesting thing to look at is the occurrence of outliers between the cases. Cases one and one only sit at 5% but cases two and one sit at 14% and 19% respectively. The reason for case one can often easily be explained by looking at graph xx which shows that outliers start occurring already at the 72-hour mark. The reason for this is that the processing time for that specific case is generally quite quick so the box plot is much more sensitive than the others. This means that when an ECR for that specific case is initiated before a weekend, but not completed the wait time alone will lead to an outlier. Similarly, if someone is on sick leave for a couple of days or on vacation for a week this ECR will count as an outlier. Because this case is simply much more sensitive than the other. So, outliers in this case scenario are often due to worker wait time and not necessarily because any actual significant amount of more work was required to complete it or spent on it.

When looking at the outliers for the individual steps the numbers are quite high, often

5. Discussion

going above 10% and quite a few above 20%. It should however be noted that in most scenarios the percentage of outliers in steps that occur in multiple cases lie quite close to each other apart from case one where outliers are a bit more common. Since we are now comparing steps between cases and not cases the reason for this occurrence cannot be explained similarly as was explained in the segment regarding outliers between cases. Where the reason for the occurrence was due to the increased sensitivity in case one, where simply work left over a weekend became an outlier.

When looking at steps that occur in multiple cases time may vary greatly, such as the “ECN Final Approve” step. Looking at this specific step, the median and average time required to complete the task is several times higher in case four than in case one. Now, this could be explained if the actual task work differed greatly between the cases, however when discussed with the ECR workers this was said to not be so. According to the workers the job was roughly the same but according to them what instead could be the explanation was the PCR. In cases two and four the requirement of a PCR is introduced and depending on which step you are working on you are required to have the PCR to continue the task. A good example of when this is often the case is the “Change Author Final Approve” step in cases two and four. What often happens here is that the PCR has not reached a mature enough status for the cases to continue so thus the work must temporarily stop and wait for the PCR to be further developed. The problem with this explanation however is that it does not explain why there is such a big discrepancy between cases one and three regarding certain steps such as the “ECN Final Approve” step. In these cases, there is no PCR required and the work is supposed to be roughly the same between the cases, but the discrepancy is still several times higher in case three compared to one. The explanation for this could possibly be the limited number of ECRs analyzed. However, it does seem unlikely that this would result in such a massive difference between the median and average time between the cases.

Comparing the automatic steps to the manual it can be clearly seen that the automatic steps are a lot quicker. This makes a lot of sense since the speed is dependent on the server and system. Another point to consider is that the automatic steps do not have to consider weekends and time off work since when they are started, they are continuously worked on until completion. However, an important thing to note is the large range of the box plot and the outliers. One would think the automatic steps should generally be performed within a similar timeframe, but this is not always the case. One of the reasons for this is simply that the size of the content varies from ECR to ECR and thus requires more time to be analyzed and registered by the system. Based on talks with workers at the Zeekr Technology the main reason for this outlier seems to be server problems. Occasionally the server goes offline and thus the ECR cannot be completed. However, there may be other reasons for the outlier but since there is no way to see in the ECRs if the outlier occurred because of an outlier or not it was not possible to pursue this issue further.

5.3 Answers on research questions

- **Is the data retrieved from the PLM system representative of the actual work?**

Answer: The PLM system currently records the work done in minutes which does mean

5. Discussion

that tasks performed too quickly will not be recorded. However, when you consider that ECRs can take several weeks to complete this makes it a negligible factor. The decision to record all time even time that is not spent actively working on the ECRs does weaken its ability to represent actual work. Furthermore, the inability to distinguish between repeat work and iterative work in ECRs also harms the ability to interpret actual work done from the data and analyze it. With these points and the thesis as a basis, it is probably fair to say that the data is not representative of the actual work.

- **How can the data be used to improve the efficiency of the release in BOM process?**

Answer: The company can investigate the more frequent and large outliers and see if there are actual issues there or if it is just unreliable data, such as recordings of offline time along with active time.

- **What are the major types of waste in the system?**

Answer: The largest waste recorded in the system is undoubtedly the wait time, however it is not necessarily waste since sometimes other work takes priority or the ECR is simply waiting for a PCR to develop further. The repetition of the same tasks within the ECRs could also be an indication of waste if it is indeed reworked. However, this is not known since it cannot be separated for other occurrences when a task is performed multiple times.

6 Conclusion

The project has studied the time data contained within a PLM system. Four cases, hundreds of ECRs and thousands of data points were collected and analyzed. The results of the project were extracted through a deep dive into information that was often not seen and hidden behind a system and thus not fully understood. The data points in this system were also illustrated in various ways to present and showcase as much information as possible. The illustrations showcase that a lot of time is being committed to the ECRs, however it is not clear what is idle and what is active time. This in turn makes it hard to see when issues have occurred since there is no differential between a delay occurrence by mistakes, system failure or simply idle time spent away from work.

This in turn has presented the possibility for further studies to fully understand what is being done and when. It should also be noted that since all datapoints had to be transcribed manually there is a chance of human errors in the data. The inability to access ECRs for chosen projects also decreased the potential of data analysis. Had it been possible a comparison between projects could have been made. In conclusion this indicates that there is great possibility for improvements If further development in this area is decided upon. The company can acquire a better understanding of their system which in turn can lead to a reduction in waste and improved efficiency in work tasks. The first step I would recommend the company to take is to set better descriptors of the ECRs. Setting project indicators for each ECR would drastically help if comparisons between projects want to be made. Since extracting the data points from the ECRs was the most time-consuming task, automating it would greatly increase the possibility of data collection and thus increase confidence in further analysis. Another recommendation is a more in-depth dive into each timestep to understand exactly what takes place at each timestamp. A separation of active work and time where work cannot take place, such as holidays and weekends, would also make it easier to analyze the outliers and understand the more time demanding tasks. Separating the recording of work done when errors occur, and rework must be done from occasions when multiple articles are handled would further increase the value of data. There is great potential for understanding and thus likely improvements in the data and it's up to the company to decide if further development is warranted.

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A

Appendix A

Case flowcharts

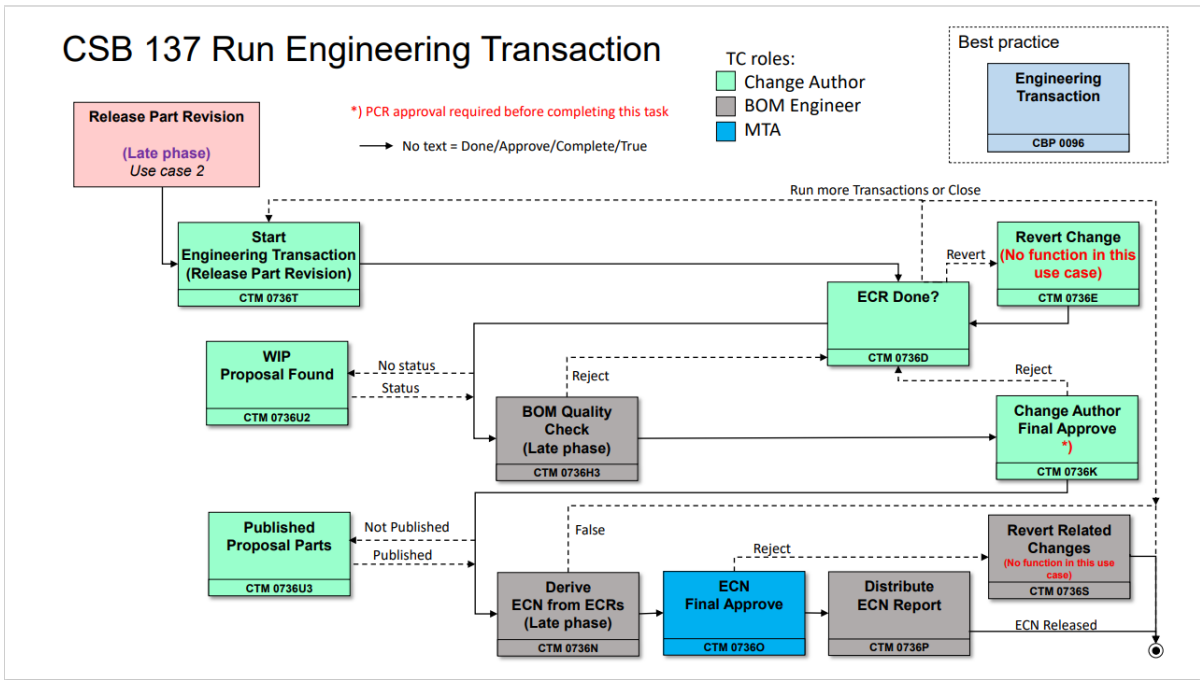


Figure A.1: A flowchart showcasing the steps required to perform to complete case 2

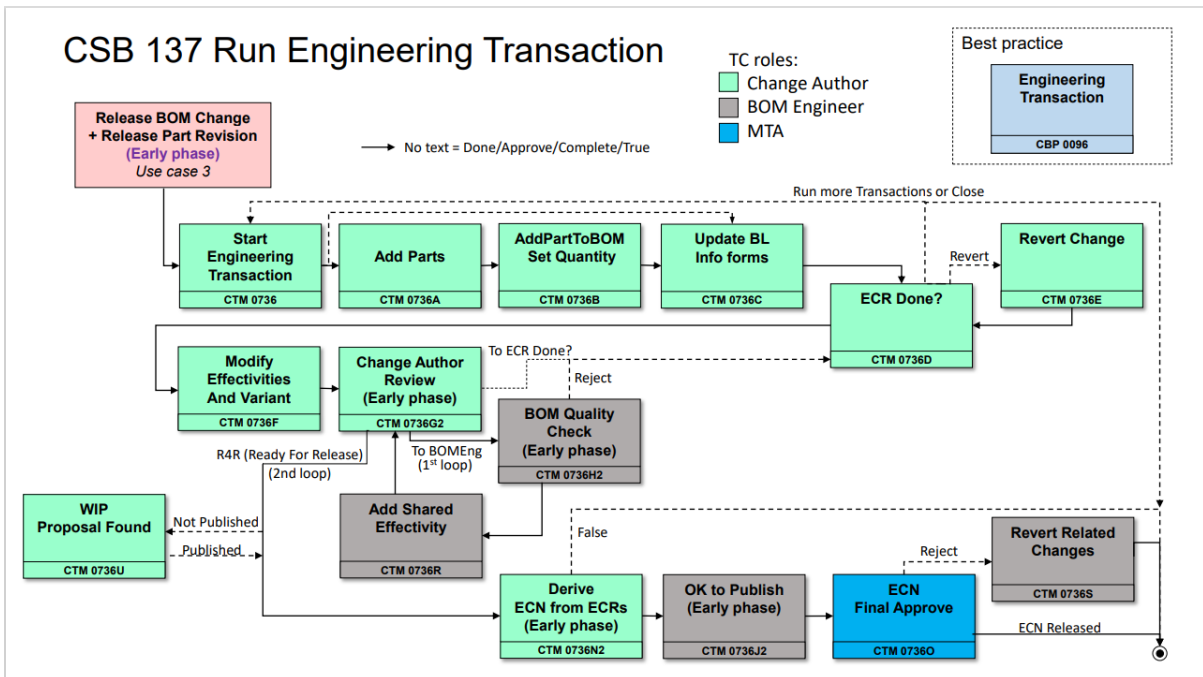


Figure A.2: A flowchart showcasing the steps required to perform to complete case 3

B

Appendix B

New case mapping

Case 2a	Case 2b
ECR Done	ECR Done
WIP Proposal Found	WIP Proposal Found
BOM Quality Check	BOM Quality Check
Change Author Final Approve	Change Author Final Approve
Published Proposed Parts	Published Proposed Parts
Derive ECN From ECRs	Derive ECN From ECRs
Generate ECN Report for MTA	Generate ECN Report for MTA
ECN Final Approve	ECN Final Approve
Release all	Release all
Generate ECN Report(Final)	Generate ECN Report(Final)
Distribute ECN Report	Distribute ECN Report
Notify Stakeholders	Notify Stakeholders

Table B.1: Image showcasing new color-coded mapping of case 2. Green color indicates that the step was handled by Change author, grey Bom engineer, blue MTA and pink is an indication of a step that was automatic.

Case 3a	Case 3b
Create BL Form	Create BL Form
Update BL Info Forms	Update BL Info Forms
ECR Done	ECR Done
Modify Effectivities and Variant	Revert Related Changes
Change Author Review	Modify Effectivities and Variant
BOM Quality Check	Change Author Review
Quick Loop BOM Engineer	BOM Quality Check
Change Author Review 2	Quick Loop BOM Engineer
Derive ECN From ECRs	Change Author Review 2
Publish Derive ECN	Derive ECN From ECRs
ECN Final Approve	Publish Derive ECN
Notify Stakeholders	ECN Final Approve
	Notify Stakeholders

Table B.2: Image showcasing new color-coded mapping of case 3. Green color indicates that the step was handled by Change author, grey Bom engineer, blue MTA and pink is an indication of a step that was automatic.

Case 4a	Case 4b
Create BL Form	Create BL Form
Update BL Info Forms	Update BL Info Forms
ECR Done	ECR Done
Modify Effectivities and Variant	Revert Related Changes
Change Author Review	Modify Effectivities and Variant
WIP Proposal Found	Change Author Review
BOM Quality Check	WIP Proposal Found
Change Author Final Review	BOM Quality Check
OK To Publish	Change Author Final Review
Publish pos 1	OK To Publish
Change Author Final Approve	Publish pos 1
Published Proposed Parts	Change Author Final Approve
Verify Approved Introduction	Published Proposed Parts
Edit BOMValidity	Verify Approved Introduction
Derive ECN From ECRs	Edit BOMValidity
Publish POS 2	Derive ECN From ECRs
Generate ECN Report for MTA	Publish POS 2
ECN Final Approve	Generate ECN Report for MTA
Release all	ECN Final Approve
Generate ECN Report(Final)	Release all
Distribute ECN Report	Generate ECN Report(Final)
Notify Stakeholders	Distribute ECN Report
	Notify Stakeholders

Table B.3: Image showcasing new color-coded mapping of case 4. Green color indicates that the step was handled by Change author, grey Bom engineer, blue MTA and pink is an indication of a step that was automatic.

C

Appendix C

General ECR statistics by case

CASE 1	Engineering Transaction	ECR Done	BOM Quality Check	WIP Proposal Found	Derive ECN From ECRs	Publish Derive ECN	ECN Final Approve	Notify Stakeholders
count	44	44	44	13	44	44	44	44
mean	2851,91	507,26	584,81	3676,54	54,19	2,63	582,86	5,60
std	4922,41	1841,47	1397,64	4357,80	214,81	4,38	2030,76	10,04
min	12	0	1	6	0	1	1	1
25%	82,00	1,50	8,50	144,00	0,50	1,00	12,50	2,00
50%	262,00	5,00	51,00	1101,00	4,00	1,00	29,00	2,00
75%	2125,00	20,50	177,00	8729,00	15,00	2,00	114,00	4,00
max	17621	10245	5696	10476	1371	28	12056	50

Table C.1: A Table of statistics that make up the boxplot of Case 1. All numbers are presented in minutes except the “count” row. That row indicates how many ECRs make up the case

CASE 2	Engineering Transaction	ECR Done	WIP Proposal Found	BOM Quality Check	Change Author Final Approve	Published Proposed Parts	Derive ECN From ECRs	Generate ECN Report for MTA	ECN Final Approve	Release all	Generate ECN Report(Final)	Distribute ECN Report	Notify Stakeholders
count	41	41	19	41	41	15	41	41	41	41	41	41	41
mean	24973,64	2086,39	3586,95	665,53	17359,92	485,93	664,06	1,31	1272,75	59,69	1,69	597,58	0,00
std	32952,93	3492,51	9203,64	1487,80	33148,94	783,08	1696,23	1,01	2814,95	250,95	1,09	1368,31	0,00
min	1173	1	2	3	2	0	0	0	1	0	1	0	0
25%	7233,75	10,50	22,50	36,75	150,50	7,00	9,75	1,00	21,75	0,00	1,00	13,50	0,00
50%	11781,50	69,00	197,00	88,00	4828,00	57,00	50,00	1,00	111,50	0,00	1,50	83,50	0,00
75%	23133,50	2736,75	2225,50	927,75	11475,50	646,50	212,00	1,25	1168,75	0,00	2,00	341,25	0,00
max	129628	11552	40015	8184	126985	2592	7187	5	14434	1187	7	5722	0

Table C.2: A Table of statistics that make up the boxplot of Case 2. All numbers are presented in minutes except the “count” row. That row indicates how many ECRs make up the case

CASE 3	Engineering Transaction	Create BL Form	Update BL Info Forms	ECR Done	Modify Effectivities and Variant	Change Author Review	BOM Quality Check	Quick Loop BOM Engineer	Change Author Review 2	Derive ECN From ECRs	Publish Derive ECN	ECN Final Approve	Notify Stakeholders
count	43	15	43	43	43	43	43	43	43	43	43	43	43
mean	3367,81	3,67	11,33	178,91	9,86	190,47	922,37	182,79	796,21	2,67	622,49	420,56	16,05
std	3574,62	2,77	30,06	699,12	27,84	611,70	1788,45	871,43	1398,77	7,94	1545,54	960,45	63,21
min	58	0	1	0	0	0	8	0	0	0	0	1	1
25%	1271,00	1,50	1,00	0,00	1,00	0,00	35,00	1,00	52,50	0,00	7,00	7,00	2,00
50%	1638,00	4,00	3,00	1,00	3,00	3,00	107,00	3,00	288,00	0,00	29,00	27,00	2,00
75%	4826,50	6,50	8,00	18,00	6,00	37,00	1011,50	9,50	1119,50	1,00	86,50	216,00	3,00
max	18426	8	194	4353	147	2883	7282	5612	8426	45	6916	4133	384

Table C.3: *A Table of statistics that make up the boxplot of Case 3. All numbers are presented in minutes except the “count” row. That row indicates how many ECRs make up the case*

CASE 4	Engineering Transaction	Create BL Form	Update BL Info Forms	ECR Done	Modify Effectivities and Variant	Change Author Review	WIP Proposal Found	BOM Quality Check	Change Author Final Review	OK To Publish	Publish pos 1	Change Author Final Approve	Published Proposed Parts	Verify Approved Introduction	Edit BOMValidity
count	38	5	38	38	38	38	9	38	38	38	38	38	9	38	38
mean	18183,97	8,20	26,00	1317,13	110,66	1542,29	1316,56	1133,97	2727,39	180,29	0,11	8012,79	3663,56	524,37	31,16
std	19610,90	4,60	48,87	2581,25	340,22	4526,54	2003,33	1602,37	6448,84	643,80	0,65	14444,03	7551,16	1380,80	59,46
min	2323	3	1	0	0	0	9	1	0	0	0	1	7	2	0
25%	9931,75	4,00	2,25	1,25	2,25	2,25	58,00	40,50	12,25	6,00	0,00	314,00	40,00	29,00	3,00
50%	14892,50	10,00	4,00	25,50	5,50	16,00	1034,00	1000,00	69,00	15,50	0,00	6185,50	247,00	68,50	7,50
75%	19907,00	10,00	9,00	272,75	18,75	1020,75	1389,00	1274,25	942,75	59,50	0,00	8925,50	1459,00	167,50	19,00
max	118003	14	175	10289	1419	26035	6356	8677	26204	3872	4	87950	22909	8182	281

Derive ECN From ECRs	Publish POS 2	Generate ECN Report for MTA	ECN Final Approve	Release all	Generate ECN Report(Final)	Distribute ECN Report	Notify Stakeholders
38	38	38	38	38	38	38	38
30,84	0,08	152,32	939,34	0,37	3,66	246,45	0,05
163,46	0,49	926,45	2190,07	1,40	4,32	870,91	0,23
0	0	0	2	0	1	0	0
0,00	0,00	1,00	23,00	0,00	2,00	2,25	0,00
0,00	0,00	1,00	107,00	0,00	2,00	16,50	0,00
1,00	0,00	2,00	773,75	0,00	3,75	51,00	0,00
1007	3	5713	11296	8	26	5233	1

Table C.4: A Table of statistics that make up the boxplot of Case 4. All numbers are presented in minutes except the “count” row. That row indicates how many ECRs make up the case

D

Appendix D

Timesteps in histograms

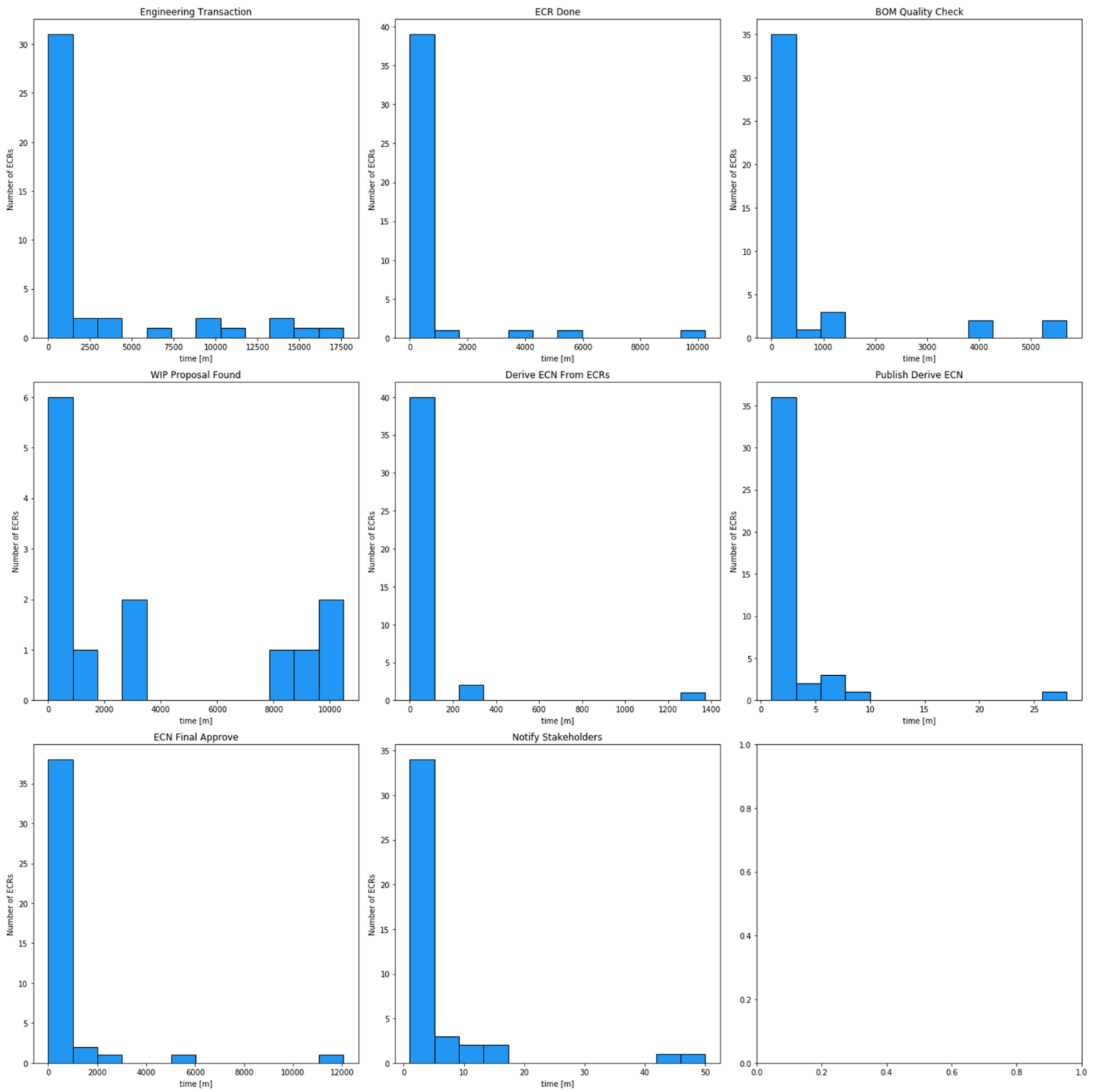


Figure D.1: A collection of histograms highlighting the total count of a timesteps appearance in case 1 on the X-axis. The Y-axis shows the timeframes (in minutes) in which the timesteps were completed.

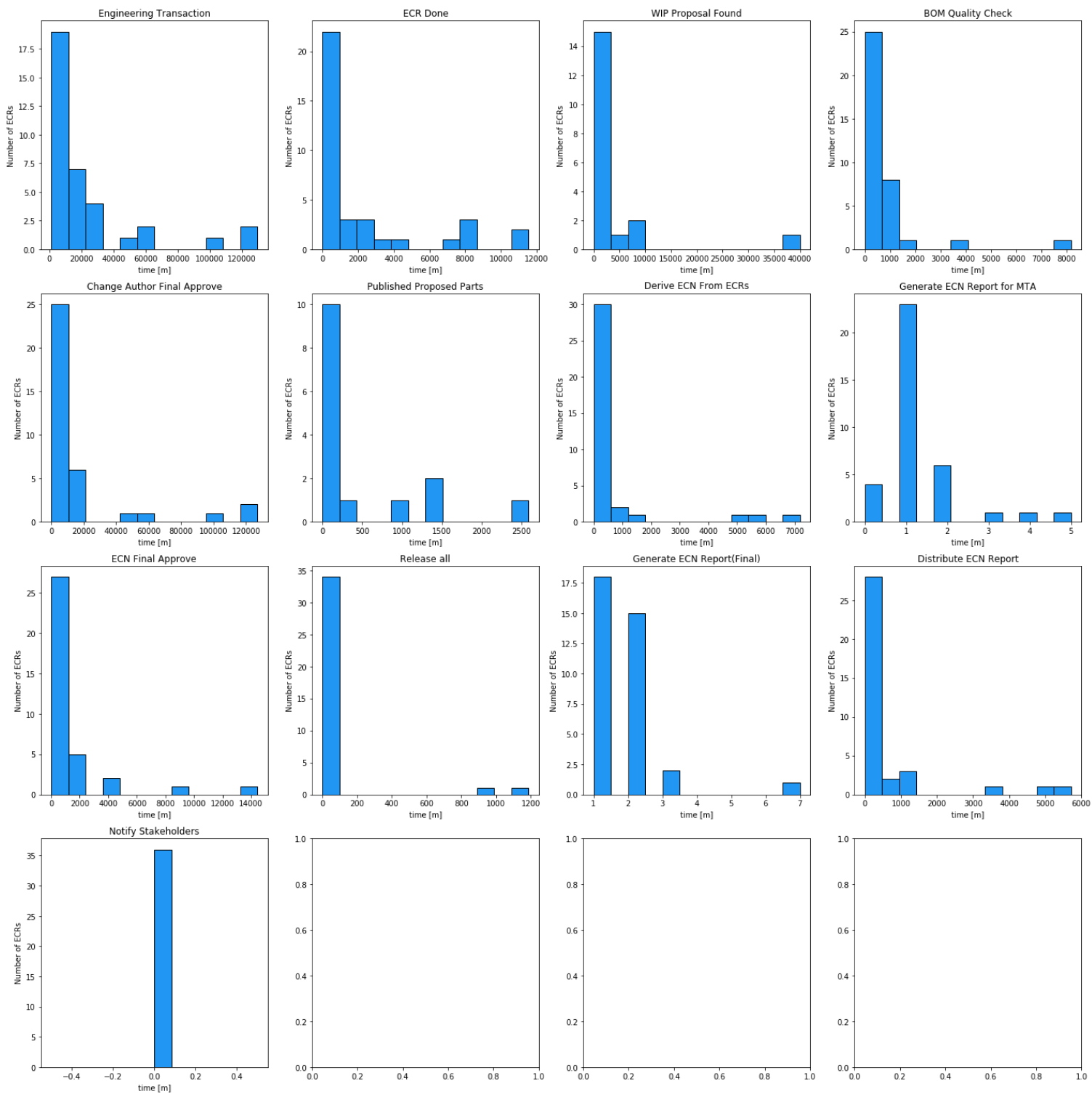


Figure D.2: A collection of histograms highlighting the total count of a timesteps appearance in case 2 on the X-axis. The Y-axis shows the timeframes (in minutes) in which the timesteps were completed.

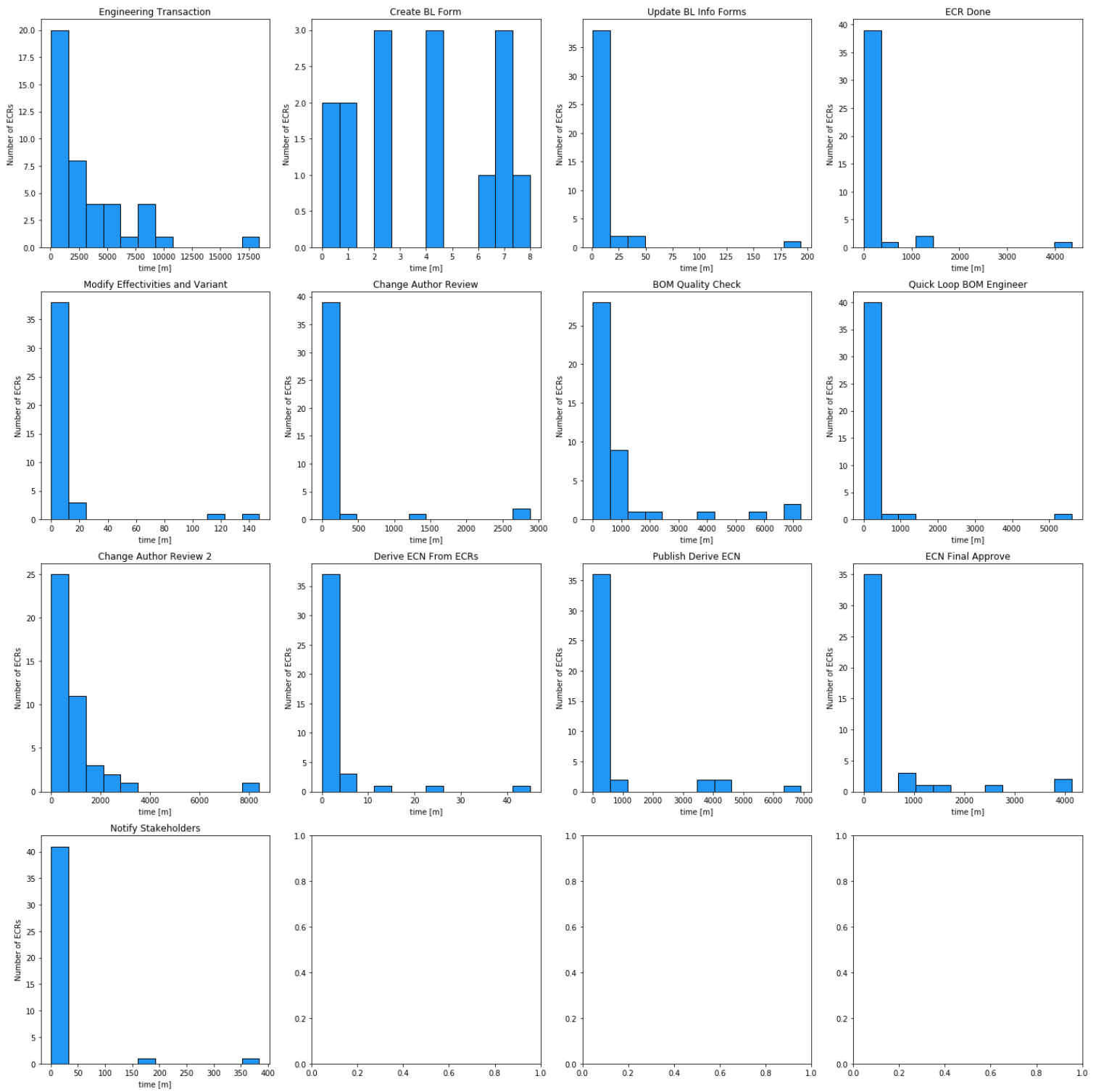


Figure D.3: A collection of histograms highlighting the total count of a timesteps appearance in case 3 on the X-axis. The Y-axis shows the timeframes (in minutes) in which the timesteps were completed.

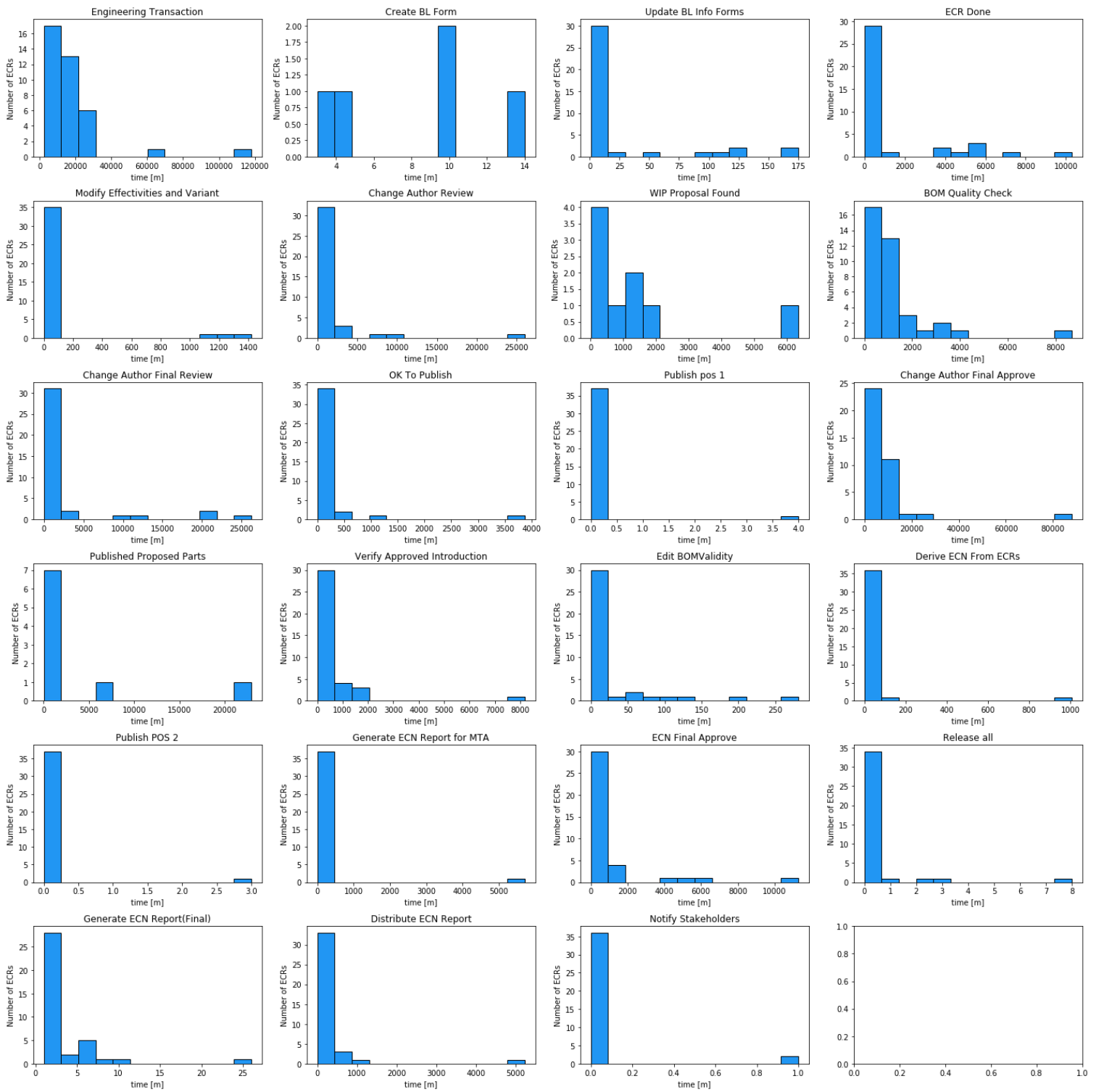


Figure D.4: A collection of histograms highlighting the total count of a timesteps appearance in case 4 on the X-axis. The Y-axis shows the timeframes (in minutes) in which the timesteps were completed

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