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Data and Information Handling in Assembly Information Systems – A Current State Analysis

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Abstract

Products become more complex as the general technology development reaches new levels. These new technologies enable manufacturing companies to offer better products with new functionalities to their customers. Complex products require adequate manufacturing systems to cope with changing product requirements. In general, manufacturing of this type of products entails complex structured and rigid IT systems. Due to the system's complexity and comprehensive structure, it becomes challenging to optimize the information flow. There are improvement potentials in how such systems could be better structured to meet the demands in complex manufacturing situations. This is particularly true for the vehicle manufacturing industry where growth in many cases have occurred through acquisitions, resulting in increased levels of legacy IT systems. Additionally, this industry is characterized by high levels of product variety which contribute to the complexity of the manufacturing processes. In manual assembly of these products, operations are dependent on high quality assembly work instructions to cope with the complex assembly situations. This paper presents a current state analysis of data and information handling in assembly information systems at multiple production sites at a case company manufacturing heavy vehicles. On basis of a certain set of characterizing manual assembly tasks for truck, engine and transmission assembly, this work focuses on identifying what data and information that is made available to operators in terms of assembly work instructions and the importance of such data and information. This work aims to identify gaps in the information flow between manufacturing engineering and shop floor operations.

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1. Introduction

The increasing product complexity and product variety due to product customization have been heavily discussed in recent decades (e.g. [1–6]). This kind of products have evolved in parallel with technology breakthroughs and changed consumer behavior. To better cope with the challenges that arise from increased product complexity and product variety, the manufacturing systems need to be evolved as well.

The automotive industry, heavy vehicle manufacturing included, is characterized by incorporating both automated and manual assembly work. In previous work it has been shown that manual assembly errors are common reasons for quality deviations [6] which also have been shown to have significant positive correlation with the complexity level at the assembly station [7]. Much of the current research is focused on cognitive support to operators in manual assembly with the assumption that high quality assembly work instructions would decrease the level of complexity at the workstations. Such a decrease is suggested to improve production quality as supported by earlier research studies and literature [7,8]. However, there are also complexity factors that lie outside the plant walls which drive production complexity in the plant [9]. Some of those complexity factors are related to the organizational structure and the acquisition history of the manufacturing company. In acquisition research it is stated that even if the driver for acquisitions is to diversify the business of the acquiring company, there are also risks that the business become over-diversified which may lead to poor integration [10–12]. An example of over-diversified business processes was found in an earlier study showing that manufacturing engineering processes and supportive IT systems had become dispersed as a result from large acquisitions in the past [13,14]. As a consequence, there is a risk that these dispersed processes and systems affects the ability to produce high quality assembly work instructions which affects production quality negatively [8]. To be a successful large global manufacturing company with a global production network (GPN) setup, it is important to focus on making processes effective and efficient. With effective and efficient processes the possibility to get use of potential large scale effects increases.

This paper presents a current state analysis of assembly information systems in a case company that manufactures heavy vehicles and heavy vehicle components. The purpose of this analysis is to document what data and information that are made available to the operators as assembly work instructions at manual assembly stations. Following previous studies of manufacturing engineering processes [13,14], this study provides additional knowledge of how data is transformed into information and later used by the operators. The study presents the gap between availability of data and information and the usage of such data and information in current manual assembly processes at the case company. Furthermore, this study is also comparing how operators and manufacturing engineering functions rate the importance of such data and information. This paper is organized as follows: The first section presents an introduction to the research area and the industrial challenges that are vital to solve as moving forward into the digitalization era; the second section presents a theoretical framework capturing different aspects of the research/industrial challenge focusing on DKIW, assembly information systems and cognition theory; the third section presents the methodology used in the study; The fourth section presents the result and analysis of the study; the fifth section presents a discussion of the findings which are connected to the theoretical framework; the sixth and final section presents the main conclusion from this study.

2. Theoretical framework

2.1. Data, information and knowledge

To be able to understand the full meaning of an assembly work instruction in a manufacturing context, there is a need to distinguish between data, information and knowledge. Data can be seen as a representation of properties of any object. After data has been processed giving it a meaning, it becomes information. To reach the state of knowledge, an action of providing know-how by using instructions or extracting it from experience is needed. By adding the skill of judgment, a person can, from their level of knowledge, reach a more permanent state as in wisdom [15,16]. Traditionally, the data–information–knowledge–wisdom hierarchy (DKIW) is used to contextualize the relationship between the entities, suggesting that information is created from data, knowledge comes from the information and from knowledge the wisdom is achieved [17]. By exploring the mechanisms behind the transformations from one level to the next in the DIKW hierarchy, the findings can be applied to the manufacturing engineering process where the assembly work instruction is constructed. As previously stated, information is created by providing a context to data. However, in literature, it is debated whether it is structure or meaning that makes the distinction between data and information. [17]. In industry, the word information is commonly used to define content in assembly work instructions.

2.2. Assembly Information Systems

A manufacturing engineering process can be defined in several different ways and may contain different concepts such as material handling, work measurement, process development, process planning etc. [18]. In this paper, manufacturing engineering is used to define the process of creating assembly work instructions as part of the assembly information system.

The purpose of an information system can be described as “ to get the right information to the right people at the right time in the right amount and in the right format” [16]. An assembly information system is in this paper used as a concept to describe how facts become data and how data becomes information to the operator at the assembly work station. Such a system is used to store, handle and transfer data accordingly to the manufacturing engineering process and eventually to be transformed to the shape of information in an assembly work instruction.

In earlier research, it has been suggested that, in general, the operator most often has the amount of needed information available. Despite this understanding, manual assembly errors are common, especially in high product variety situations [6]. As a solution, it is suggested that the information seeking process of the operator could be improved by presenting information to the operator in such a way that it activates attention [19].

2.3. Cognition

The focus on cognitive support is based upon that better support and information regarding the assembly work to be carried out can decrease the level of complexity at the work station, which would have a positive effect on production quality [7,20]. Within cognition theory there are two particularly interesting topics; automation and ergonomics. Cognitive automation can be seen as skill- rule- and knowledge based behavior [21,22]. When acting upon skills, the human brain is reacting to sensor input such as signals and acts in an automated manner without conscious control. When acting in a more rule based manner, the work situation is familiar and the person acts upon an already known instruction (reacting to a sign). The knowledge based behavior is characterized by acting upon symbols during occasions when know-how is missing. Such symbols are used for analyzing the situation based upon functional properties and the prediction to reach a certain goal [21]. In terms of cognitive ergonomics, two aspects, dependent on each other, are documented in literature, one focused on the human at work and the other on the result of the work task. Furthermore, ergonomics is usually treated from the physical perspective and/or the cognitive perspective distinguishing between quality of working and quality of work. An important factor in terms of cognitive ergonomics is that instead of focusing on how we act, it is focusing on how we think. With such a focus the purpose is to establish better system design in respect to the whole work situation [23].

In the field of cognition, human information processing can be seen as a four stage model covering sensory processing, perception/working memory, decision making and response selection [24,25]. In relation to manual assembly, decision making is essential from a quality perspective. In literature, it has been suggested that the time of the decision-making process can be seen as extended, meaning that it also considers decisions in the past. Furthermore, the decision maker is seen as flexible in choosing the proper strategy to make decisions. Finally, to be able to actually make a decision in the end, the decision maker can restructure available information in order to simplify the problem [26]. The operator is a decision maker that within a limited timeframe needs to find needed information in available assembly work instructions. This information, together with already achieved know-how, is used by the operator to decide on how he or she will perform the requested assembly task. A general belief in terms of decision making is that the more information the operator has about the assembly task, the better decisions he or she will make. However, it is rather the quality of the information that is important for the operator to be able to make good decisions. Such information needs to be accurate, complete, current, timely, relevant and should be communicated through a proper information carrier on a correct detailed level for the intended receiver with a unquestionable clarity [27].

3. Methodology

In previous work, a current state analysis has focused on mapping the manufacturing engineering process in which the assembly work instructions are created. That study found improvement potentials in terms of standardization, by comparing engineering processes between different parts of the case company's organization [13,14]. The study in this paper goes further by exploring how data and information are handled in manufacturing engineering processes and in assembly information systems in the same case company. This study investigates the data and information available to the operators and how these data and information are used by the operators. Furthermore, the study is comparing available data and information with the actual usage of the data and information as well as their importance to the assembly task.

Media routing, clamping, equipment controlled assembly, hole pattern recognition, hidden assembly, console assembly and riveting, which are common assembly activity types within heavy vehicle manufacturing, have been used to identify relevant assembly work stations for this study. In total, 13 assembly and preassembly stations where selected at 3 plants at one manufacturing company with support of the local engineering departments at the plants. The 3 plants represent manual assembly of complete vehicle, engine and transmission. Since the product complexity differs between the plants as well as the assembly station setups, a majority of the participating operators are representing assembly of complete vehicle. In total, 32 operators participated in the study where the majority of them (25) represent complete vehicle assembly. To represent engineering, 7 production technicians participated in the study and additional different engineering roles earlier in the manufacturing engineering process.

Observations have been made at all the sample stations with the purpose of identifying available assembly information to the operators. Furthermore, observations have been made to be able to understand the work content of the assembly stations and to study how operators use the available assembly information in practice. During the observations, some interactions have been made with the operators, asking them to rate available assembly information on basis of usage and importance of such information. The operators marked directly on their current assembly work instructions what information they use and did also rate the importance of the available attributes on the assembly work instructions by rating them from 0 to 5 on a Likert scale.

Additionally, semi-structured interviews have been conducted with the production technicians responsible for the content of the assembly work instructions at the chosen sample stations. The production technicians rated the importance of the available assembly information in the same way as the operators. Semi-structured interviews have also been conducted with manufacturing engineers responsible for different activities in the manufacturing engineering process to be able to address the origin of the attributes' data content in the assembly work instructions.

The data analysis has been conducted by comparing the usage gap and importance gap plant wise, organizational wise, but also comparing the gaps between usage and importance. The qualitative data from the interviews with the production technicians have been used to understand and verify the statistical data.

4. Data and information handling in assembly information systems

The data presented in this paper has focused on the plant and organizational level. To be able to create a current state analysis of data and information handling in assembly information system, the availability and usage of data and information as well as their importance according to operators, technicians and other engineering roles close to production have been measured. During the observations at the sample stations, all kinds of information carriers containing assembly information have been assessed to identify different types of attributes containing data and information. In Table 1, the general information attributes and plant unique information attributes in the available assembly work instructions are listed. The reason to identify these attributes is to understand what type of assembly information that is presented to the operator during the assembly cycle. At the chosen assembly and preassembly stations, assembly information is presented either on printed papers (e.g. physical, SOP *Standard Operating Procedure*), on screens (digital), through other kinds of equipment (Pick-2-Light) or a mix of different information carriers.

Table 1: The table represents general and unique attributes in available assembly work instructions.

General information attributes	Corresponding info. Carriers	Unique information attributes	Corresponding info. carriers
Product ID	Digital/Physical	Product Type	Physical
Procedure	Digital/Physical	Sequence Number	Physical
Part Name	Digital/Physical	Serial Number	Physical
Part Number	Digital/Physical	Assembly Line	Physical
Quantity	Digital/Physical	Instruction ID	Physical
Lamp	Pick-2-Light	Additional Instructions	Physical
Part Number	Pick-2-Light	Packaging	Physical
Part Name	Pick-2-Light	Use point	Physical
Quantity	Pick-2-Light	Cycle time	Physical
SOP	SOP		

In Table 2, availability and usage of data and information are presented as gaps. Furthermore, the importance of the identified information attributes have been rated on a Likert scale from 0 (low importance) to 5 (high importance) by the operators, production technicians and production engineers. The importance is in Table 2 also presented as gaps between operators and engineering functions (technicians and engineers).

Table 2: The table presents gaps of data and information used by the operators as well as the gap in importance of the available data and information rated by operators, production technicians and production engineers. A positive gap in usage indicates that some attributes to not use the data and information content. A positive gap in importance indicates that operators find the contents of the attribute more important than the engineering departments.

		Organization A		Organization B			
		Plant A		Plant B		Plant C	
Attribute	Information carrier	Gap Usage	Gap Importance	Gap Usage	Gap Importance	Gap Usage	Gap Importance
Product ID	Digital/Physical	0,08	-0,32	0,00	**3,80**	**0,67**	**1,13**
Procedure	Digital/Physical	0,24	-0,08	0,00	**1,40**	0,00	**0,73**
Part Name	Digital/Physical	0,08	**3,36**	**0,50**	**0,33**	**1,00**	-2,20
Part Number	Digital/Physical	0,12	-1,04	**0,50**	-0,47	0,33	-0,47
Quantity	Digital/Physical	0,20	**2,32**	0,00	-1,47	**0,67**	-3,07
Lamp	Pick-2-Light	0,00	0,00	0,00	0,00	0,00	0,00
Part Number	Pick-2-Light	0,00	-4,00	0,25	0,00	0,00	**2,00**
Part Name	Pick-2-Light	0,00	**4,00**	0,25	0,00	**0,67**	-0,67
Quantity	Pick-2-Light	0,00	0,00	0,00	-4,00	-	-
SOP	SOP	0,28	0,00	0,00	**2,00**	0,00	-1,67
Product Type	Physical	**0,96**	-0,24	-	-	-	-

		Organization A		Organization B			
		Plant A		Plant B		Plant C	
Attribute	Information carrier	Gap Usage	Gap Importance	Gap Usage	Gap Importance	Gap Usage	Gap Importance
Sequence Number	Physical	**1,00**	0,00	-	-	-	-
Serial Number	Physical	**1,00**	0,00	-	-	-	-
Assembly Line	Physical	**1,00**	0,00	-	-	-	-
Instruction ID	Physical	**1,00**	0,00	-	-	-	-
Additional Instructions	Physical	**0,60**	-0,80	-	-	-	-
Packaging	Physical	**1,00**	0,00	-	-	-	-
Use point	Physical	**1,00**	0,00	-	-	-	-
Cycle time	Physical	0,32	0,00	-	-	-	-

The gap in data and information usage indicates that the data and information are not used by the operator during a normal assembly cycle. The gaps measured are ranging from 0 to 1 where gaps closer to 1 indicate that the data and information are not used. At some of the sample stations, certain attributes in the assembly work instructions are not available, hence the low scoring (e.g. Pick-2-Light at Plant A and Plant B). Gaps equivalent or higher than 0.40 are highlighted in Table 2 since such a scoring suggests that a large amount of the operators are not using that particular parameters in the assembly work instructions. The low scoring of availability and usage of data and information at Plant A for Pick-2-Light is due to that only one out of the 25 operators are performing work in such conditions. For Plant A, there are large amounts of available data and information that are never used in practice. This is also supported by the operators who claimed that there is an information overload in the assembly work instructions. For Plant A, operators stated that the available data and information are useful, but sometimes contain errors or are not updated in time for production. They also stated that the data and information are difficult to interpret for novice operators and are not always well organized in the assembly work instructions. For Plant B and C, the operators suggested that the provided data and information are useful, but not always used due to the prior knowledge of the operators. However, some novice operators would require the *Standard Operating Procedure* (SOP), to get more guidelines for the assembly activity. This view is also supported by the production technicians who are focused on making data and information in the assembly work instructions shorter and more concise. Despite some high usability scoring in Table 2, during the observations it has been found out that operators do not always pay attention to the very details in the assembly work instructions more than checking part numbers when needed. Instead, the operators seem to operate in a know-how manner.

When it comes to importance of the presented data and information in the various assembly work instructions at the sample stations, the result is also presented as gaps. Positive gaps are highlighted in the table and represent that operators (production) finds the data and information content for certain attributes more important than the engineering departments (technicians and engineers). At Plant A, the importance gap is large for the attributes part name, quantity and part name (Pick-2-Light) which suggests that the attributes are neglected by the engineering department. The ratings from Plant B and Plant C suggest that Product ID and Procedure are two attributes that are not given the same attention from engineering as from production. In Plant B, the SOP has a difference in the importance value comparing production with engineering. Part name has slightly lower rating from engineering. In Plant C part number (Pick-2-Light) is scored lower from the engineering side which could be explained by the fact that a lamp in the Pick-2-Light system is lit whenever a part is taken and used. As a summary from the measures of importance, the ratings suggest some gaps which possibly could affect the operators negatively (positive value) in terms of prioritizations. There are also gaps (negative values) which could possibly affect production quality, since operators neglect the importance of the data and information given in their assembly work instructions. Some data and information have been given low ratings of importance of both operators and engineering which match the presented gaps in terms of usage of data and information (e.g. sequence number, part number (Pick2-Light) etc.).

5. Discussion

The assembly of heavy vehicles is complex. Therefore, it is important for operators in manual assembly to have adequate assembly information available to be able to decrease the general complexity level of the assembly station [7,8]. This case study has resulted in interesting facts about how data and information are handled in assembly information systems. On basis of the data collected, several conclusions can be drawn. There are large parts of the data and information content in the provided assembly work instructions that are never or seldom used by the operators. In literature, it has been suggested that by actively stimulating the information seeking process, the interpretation of presented data and information can be improved [19]. However, the large amount of data and information in the assembly work instructions may distract such a process. During the observations, it has been found out that operators do not always pay attention to all details in the assembly work instructions and instead act upon prior knowledge. In previous studies it has been shown that a high amount of reported quality deviations are originated from manual assembly [6,7]. Therefore, it is important that assembly work instructions have a satisfactory level of information quality and are appropriately communicated [27]. It is therefore questionable whether the current assembly work instructions are containing relevant data and information for the assembly activities, or whether they need to be restructured.

Operators and production technicians have stated that assembly work instructions are difficult for novice operators to interpret. As the decision making process includes decisions in the past [26], it becomes more difficult for novice operators to interpret assembly information in current assembly work instructions as they are lacking experience. Therefore, adequate training of the operators is needed before working on the production line. Several attributes in terms of importance have been scored higher by operators than production technicians which may affect operators negatively (i.e. part name and quantity etc.). If the operators' views on importance are not shared by the engineering departments it might hinder improvement work and improvement potential due to prioritizations. This could be explained as suggested by Hollnagel [23], that much focus have been put on how the operator acts rather than on how the operator thinks. To be able to improve production quality, the cognitive aspects needs to be better in focus when designing and producing assembly work instructions in the future [7,20].

By analyzing the compiled data from the three plants, it is clearly evident that no common strategy of what kind of data and information to present to the operators is implemented in practice. Organization A and B use different attributes in their assembly work instructions. In organization B, the plants (B and C) use the same solution for digital assembly work instructions and equipment, but as seen in Table 2, there are still differences in which attributes that are presented to the operators and how these are perceived. The differences of what data and information that is presented to the operators in the different plants may be caused by several factors and have not yet been analyzed in detail. However, as described in previous research [28], there are risks that processes becomes too diversified during heavy acquisitions [10–12] which make it difficult to establish a coherent IT strategy across the acquiring organization. Without a coherent IT strategy it is difficult to make global processes effective and efficient which affect the ability of producing assembly work instructions with high quality [8].

6. Conclusion

In this paper, data and information handling in assembly information systems has been in focus. This study has investigated what data and information that are available and used by the operators in manual assembly. Furthermore, the importance of the available data and information has been rated by the operators and the engineering department using a Likert scale ranging from 1 to 5. The result of this study shows that there is no common strategy of how data and information are handled in the assembly information systems and presented to the operators at either on a plant level, an organizational level or a company level. It has also been found that all available data and information in assembly work instructions are not used by the operators or ranked as important by neither the engineering department nor the operators themselves. By finding a common strategy for handling data and information in one single assembly information system, there is great potential to improve the system and service quality towards the operators. Future work will be focused on assessing information needs in manual assembly and to identify gaps between the current and future state to be able to define design requirements for future assembly information systems.

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