Use of Assembly Information in Global Production Networks

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ABSTRACT

The competitive world market has forced manufacturers worldwide towards higher quality and performance targets in production systems. Therefore, the manufacturers need to be more cost efficient in their processes. Due to the rapid changes in technology and market demands the assembly operators meet a high amount of product variants every day. Earlier research has shown that depending on how information is presented to the assembly operator the quality on produced items varies. Therefore, a case study has been performed to understand how assembly information is treated at different productions sites in different countries within one production network. The case study has been carried out through a web survey addressed to 12 different production sites in seven countries. The case study is also compared with a previous case study addressed to production sites in Sweden. Since the study is focused on Global Production Networks the focus of the study is put on how diversity appears within a production network. The case study shows that diversity may not be perceived just between countries and different production sites, it can also be perceived within one production site.

1. INTRODUCTION

Both global and national companies are forced to be more cost efficient due to the dynamic global economy. The paradigm shift from mass production to mass customization has provided the market with the choice of customization and variation [1] [2]. The consuming trends leave a high demand on customized products at a high pace. Therefore, assembly operators meet high level of product variation every day. Due to the narrow margins in the economy the demand on lower product and production costs creates a need for an effective model for providing high quality at low cost. The globalization has given companies the possibility for rapid growth on a global market. A disadvantage of the globalization effect could be the difficultness to create and maintain an efficient Global Production Network, GPN. This study follows a national study [3] performed during the spring of 2014 within the same GPN where the focus was to identify used information carriers for information and communication handling in assembly, identify how information was designed and if standards were used in practice. The aim for the previous study was a first step in the process of performing a current state analysis enabling the creation of strategies for global assembly instructions. This study goes further for analysing the current state on a global basis. For this study the focus is on manual assembly of heavy vehicles. The hypothesis for this study is that there is diversity in the process of creating assembly information for the assembly operator. Process diversity prevents the possibilities for establish efficiency and stability within a GPN.

Therefore, the research aim for this paper is to answer the following research question;

- *Can diversity be perceived in the development and use of assembly information within a global production network and in what forms?*

The result from the national study has shown the presence of diversity in the way of working. Therefore it was essential to find out whether the diversity is national or global phenomenon within the industry. There are several myths on how companies misinterpret the concept of standardization and how it reduces process diversity [4]. Such myths may disrupt an efficient way of working and interferes with the ambition of continuously improve processes. In the analysis and discussion a comparison is made between this study and data collected from Case A in the national study.

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2. THEORY

The following subsections describe theory used in this paper;

2.1. GLOBALIZATION

According to Porter [5] "*an industry can be defined as global if there is some competitive advantage to integrating activities on a worldwide basis"* (p. 19). In Oxford dictionary of English globalization is defined as "*The process by which businesses or other organizations develop international influence or start operating on an international scale*" [6]. According to Ram, globalization has enabled knowledge spread and capital flow in the world. Further on, Ram states that due to globalization the integration of countries and people has dramatically increased [7]. The significant drop in transportation costs can be seen as an enabler of the globalization [8]. Liberalization, competition and the quick development and spread of IT can be seen as three additional drivers for globalization and the beginning of global production networks [9]. To be able to be competitive on the global market, a global company is forced to improve its standards in terms of cost, quality and productivity. One of the risks for companies that globalize their business is the ability to manage their diversified operations world-wide. The diversity might have negative influence on the overall performance in the company [10].

2.2 .GLOBAL PRODUCTION NETWORKS

Original Equipment Manufacturers, OEMs, are often organized in networks where both development and production of components in high degree are outsourced to global suppliers [11]. According to Håkansson and Snehota [12], a business network can be seen as structure of different actors where the inter-connections can be seen as relationships. Ernst and Kim [9] describe the purpose of a Global Production Network, GPN as "*provide the flagship with quick and low-cost access to resources, capabilities and knowledge that are complementary to its core competencies"* (p.1420), where the flagship is considered the main contributor in the network. The actors within a GPN have different roles and have different conditions fulfilling their targets. Ferdows [13] has identified six different roles that appear in GPNs. The different roles are described in Table 1. Ferdows claims that a GPN is more robust if it contains many of the strategic roles (e.g. lead factory, contributor factory and source factory). Better knowledge and more competence make the factories more competitive.

Table 1: Description of the six roles in a GPN

Type of Factory/Role	Description
Offshore Factory	Specific products/components at low cost. Minor engineering is carried out on site.
Contributor Factory	Serves a specific market/region. Engineering is highly carried out on site.
Source Factory	Low-cost production. Great competition potentials.
Outpost Factory	In regions where high value knowledge and experience can be found.
Server Factory	Supplies a certain market/region for overcoming taxes, tariffs or other barriers
Lead Factory	Serves the GPN with product and production development and have main responsibilities.

2.3. STANDARDIZATION

Dennis [14] defines a standard as "*clear image of a desired condition*" (p.28). Liker and Meier [4] state that continuous improvements begin at the standardization. Further on, standardization defines the best available process and visualizes it. Standardization is also the basis for process stability [4] [15]. Ortiz [16] claims that standardization in the work process is "*the best, most efficient, safest, and most practical way of doing work*" (p. 38). Furthermore, systematic process improvements are not possible until the process itself has been standardized [4]. Manrodt and Vitasek [17] argue that one of the benefits for standardization in processes is the ability to efficiently handle downtime in production and keep up with the current product demand levels on the global market by being able to move production within the GPN. They also claim that the main difficultness for the companies is the balance between keeping global standards and still be able to meet local requirements. However, Ferdows [13] argues that a robust GPN will gain less from shifting production between actors within the network. According to Claesson [18] a higher amount

of standards within the work process tends to increase the amount of psychological stress for the operator, but when achieving high quality standards the increase seams much smaller. It is therefore important to focus on quality when implementing standardized work processes. The lack of standardization causes diversity. Berger [19] emphasizes that the operator must rely on its own skills to interpret available assembly information when no standards are available.

3. METHOD

The aim of this study was to get a perception of how the GPN is working with assembly information in practice. A questionnaire was constructed as a web questionnaire made available in Dutch, English, French, Japanese, Portuguese, Russian and Swedish. As Bethlehem and Biffignandi [20] states, web surveys are convenient in such way that they are great tools that during a limited time period can collect data from a wider target group. It can, and in this case, provides data which become the starting point for interesting reflections and thoughts concerning the hypotheses behind the questionnaire [21].

The questionnaire was sent out to 40 production engineers, 9 team leaders and 9 assembly operators. The term "team leader" considers the blue collar coordinator of a group of assembly operators who coordinates the work of the group. The production engineers were the main target for the study, but together with the answers from the team leaders and the assembly operators the result also includes a wider view on the questions asked. In the study 13 production sites were contacted and 12 of them participated in the questionnaire that was created. The division of product types, sites and countries can be seen in Table 2. In this study powertrain is always considered as another site although it is located in the same geographical area as sites for other product types. The selection of production sites was made based on the globalization criteria. It was also judged that the result would better represent the GPN compared to only study a couple of production sites abroad. The questionnaire was web based and the respondents answered the questions during a limited period of time.

Table 2: An overview of production sites, locations and product types

Type of Product(s)	Type of Production	Location	Country
Cab/Truck	Assembly	Site A	Australia
Truck	Assembly	Site B	Belgium
Cab/Truck	Assembly	Site C	Brazil
Powertrain	Assembly	Site D	Brazil
Cab	Assembly	Site E	France
Powertrain	Assembly	Site F	France
Truck	Assembly	Site G	France
Cab/Truck	Assembly	Site H	Japan
Powertrain	Assembly	Site I	Japan
Cab/Truck	Assembly	Site J	Russia
Cab/Truck	Assembly	Site K	USA
Cab/Truck	Assembly	Site L	USA

The questionnaire consisted of 23 questions, of which the first seven questions were of demographic matter. The 16 following questions focused on the kind of ICT tools that are used, what content and what content design that are used today. Some of the questions were created as ratings from 1-5 where 1 represented low score and 5 represented high score. The purpose of the rating questions was to get an understanding of how well certain tools and information design works, but also to get an overview of the use of standards in the work process.

4. RESULT

Among the respondents 43 % have been working at any of the group companies for up to 5 years, 36 % have been working at any of the group companies between 6-10 years, and the rest for more than 10 years at any of the group companies. When it comes to current position a majority of the respondents have had their position for up to five years,

22 % between 6-10 years and 5 % more than 10 years. The operators that participated have an average employment time between 0-5 years. When it comes to the team leaders 56 % have been employed for up to 10 years and the rest have been employed for 11 years or more, but their current position has only been held for up to 5 years as an average value. When it comes to the production engineers 32 % have been employed for up to 5 years while the rest have been employed for six years or more. About 68 % of the production engineers have held their position for up to 5 years while 30 % had held their position between 6-10 years. Only one production engineer had had the current position between 11-20 years.

A majority of the respondents (86 %) state that the operators are involved when creating assembly instruction and 7 of 9 operators agree to this statement. Four production engineers state that operators are not involved in the process. Regarding responsibility for correctness of information in information carriers, 31 out of 40 production engineers state that the role as production engineer have this responsibility, but only 16 of the 31 production engineers indicate that they actually have this responsibility. The total amount of the production engineers that states that they have this responsibility are 24 individuals, but only 16 of those agree to that the role as production engineer have this responsibility. Looking into what the other 9 production engineers that did not agree to the majority, 8 of the 9 production engineers stated that they have this correctness responsibility. When the question was asked to the operators and team leaders at the sites 14 of 18 individuals state that the production engineers have the responsibility for correctness of information.

One production engineer states that operators together with the engineers are responsible for the correctness in the assembly instructions, but only one operator of the five operators participating from the same production site agrees to that statement. On basis of the collected data there are obvious evidences that the responsibility have not been clearly delegated and/or communicated in the local organization. What effect that might have for the operational work is discussed in the discussion section of this paper.

The study has proven diversity in the use of information carriers, information content and information design. In Table 3 the diversity is shown for each type of information carrier, information content and information design and multiple choices were allowed. When it comes to information carriers the main choices were personal meetings, paper based information, telephone and computers. When it came to other information carrier the scatter was larger. The main information content was assembly instructions, Drawings in 2D and shift/Personnel information. When it came to other information contents the diversity was significant. The most of the respondents agreed upon that text and pictures are the most common information design used for assembly information, but also films, animations and sounds/voices are present sources. In the next section the use of information design, information content and information carriers will be discussed on basis of diversity in GPNs.

Table 3: Diversity in use of information carriers, information content and information design based on all 58 respondents

Information Carrier Multiple choices allowed		**Information Content** Multiple choices allowed		**Information Design** Multiple choices allowed	
Personal meeting	88%	Assembly instruction	93 %	Text	97 %
Computer	76 %	Drawing 2D	59 %	Picture	88 %
Paper	69 %	Shift/Personnel information	45 %	Film	14 %
Telephone	59 %	One-point-lesson (Best practice)	38 %	Animation	10 %
Whiteboard	33 %	CAD 3D	31 %	Voice	2 %
Barcodes	31 %	Machine instruction	28 %		
Monitor/Screen	31 %	Tacit knowledge	28 %		
Pick-to-Light	14 %	Maintenance instruction	24 %		
State lamps	10 %	Sprint Tickets (internal)	2 %		
QR code	5 %				
RFID	3 %				

Three questions were asked regarding how well information carriers work, how well the information is presented and the capability of an inexperienced operator to execute according presented information. In Figure 1 the result of all respondents is presented. Among the 40 production engineers their average value on how well the information carriers work is 3,7. When it comes to how well the information is presented for the operator the average value is slightly lower

(3,6) and regarding the capability of an inexperienced operator to perform his/her work the average value was only 3,1. To sum up the ratings of the production engineers their score is slightly lower and will be further discussed. When the operators and team leaders are asked to do the same rating their average result is slightly higher than the production engineers'. Their average ratings on information carriers and presented information is 4 and the capability of the inexperienced operator is 3,6.

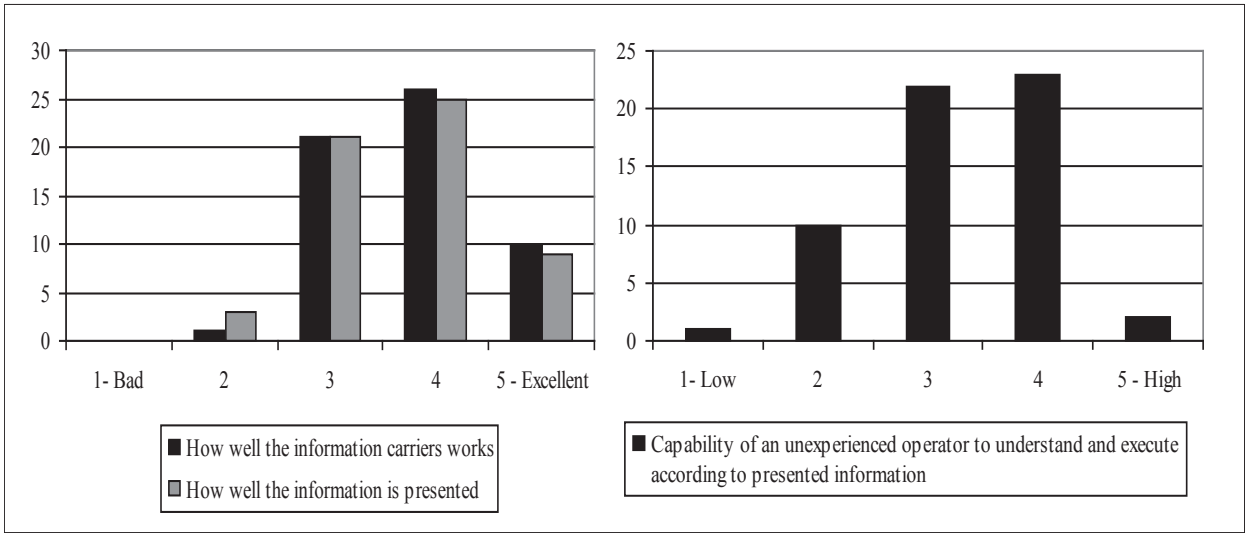

Figure 1: The diagram on the left-hand side shows the rating of how well the information carriers work and how well the information is presented. The diagram on the right-hand side shows the rating of the capability of an unexperienced operator to follow presented assembly information

To get an understanding of the level of diversity the respondents were also asked to state what systems and/or applications are used for creating assembly instructions. The main used systems was MS Office Suite (55 %), internal business systems (33 %) and one specific system (29 %) heavily used within the GPN.

To get an understanding of mind sets when creating assembly instructions the respondents were asked about which factor is considered the most important when creating assembly instructions. Simplicity and easy to do right was equally important and stands for 57 % of the respondents followed by trust in information, decrease workload and competence (skills of operator).

Since this paper reflects the usage of assembly information in GPNs, standardization and collaboration are important factors. Among the respondents 28 of 40 production engineers states that there are standards available for creating instructions and 5 production engineers state that work is carried out for implementing standards in their process. Almost all operators and team leaders (14 of 18) in this study state that standards exist. Only one operator and one team leader indicate lack of standards and on-going work for creating standards. Of the respondents that claim that there are standards for creating assembly instructions their average rating on to what extent the standards are followed was 3,79. Concerning the amount of instruction development work carried out on local sites the average value among the production engineers was 67 % compared to the operators and team leaders 44 %. The amount of collaboration between global and local functions according to the production engineers was 66 % compared to the operators and team leaders 62 %.

5. ANALYSIS

In this analysis a comparison is made between the study presented in this paper and the previous study mentioned in the introduction.

In the national study 60 % of the respondents had been working at any of the group companies for up to 5 years and 82 % of the respondents had had their position for up to 5 years [3]. Comparing the two studies there is no drastic differences in employment time or position. Although, the present study indicates that the majority of the participating operators and team leaders have been working at any of the group companies for up to 5 years and they represent half of the total target group that has been employed for up to 5 years. Only 14 of the 40 in total production engineers has

lower group experience than 5 years. Since a majority of the respondents (73 %) have had their positions for up to 5 years, the following comparisons are based on group experience rather than position experience though it can be assumed that higher amount of group experience might influence the respondents' points of view. The two distinct groups consist of 25 and 33 respondents respectively.

Comparing the two groups regarding available and used information carriers the results generally varies between 0-15 percent compared to the total average. This was expected due to the constellation of the two distinct groups. When it comes to information design there are no significant deviations from the total average. In the comparison of information content there were some distinct differences between the groups comparing machine instructions, 3D CAD, (Computer Aided Design) and maintenance instructions. The group with experience less than 5 years has differences of 10-30 % less than total average comparing with the other group where the differences where about 10 % above total average. There are no certain reasons present in the collected information, but it is interesting that these three types of information contents differ.

When comparing the total averages in this study with the national study one can find out that paper as information carriers are globally lower (69 %) compared to the national study (86 %). How general this difference is can only be discussed, but it is proven that there is diversity in the use of information carriers within the GPN. Diversity is also perceived when it comes to information content in the instructions when comparing the two studies. In the national study the use of 2D drawing was 34 % while the use in the global study was 59 %. The information design also provides evidence of diversity. Globally, text is used 97 % and pictures 88 % while nationally text is used 80 % and pictures 51 %. Diversity is present within the GPN and the consequences of process diversity will be discussed in the following section.

Due to that the global questionnaire was improved and differs from the national study it is not possible to compare the three ratings presented in Figure 1. Additionally to the presented comparison between operators/team leaders and production engineers, a comparison is made between the two groups previously defined in this section. The functionality of the information carriers was rated to 3,7 for the less experienced group and 3,9 for the group with more experience. Regarding presentation of information the result was the same (3,7). When it comes to the capability of an unexperienced operator to act according to the presented information there were some differences between the groups. The less experienced group rated 3,2 in average compared to the more experienced group average on 3,3.

Since this paper is focused on diversity dispersion within the GPN, it is natural to investigate the use of standards, or more precisely, the use of a standardized process when creating assembly information/instructions. Claimed in the result section, a total of 72 % of the respondents think that there are standards for creating assembly instructions. From the group with less experience 60 % of the respondents claim that standards are available while 82 % of the respondents from the more experienced group claim that there are standards for creating assembly instructions. When comparing the score in to what extent the standards are followed the less experienced group (of those who agreed to that standards are available) rated 3,5 compared to 3,9 from the group with more experience. This difference was expected and is referred to the point of view statement in the beginning of the analysis.

6. DISCUSSION

This global study together with the national study has resulted in interesting data in several aspects. Referring to the GPN framework in the theory section each site within the GPN has different purposes and different responsibilities. It is obvious when analysing the collected data that there are differences between different sites, but also within a site. This was the hypothesis for this study already from the beginning. Reasons for this could simply be that organizations that are undergoing an expansion phase which naturally transcend to a shaping phase have hard times creating global standards when product types and brands historically have been different. This is normal when expansion has been made by acquisition of other actors. There is research on concepts that enables global standardization and future research will be focused on how these concepts can contribute to new way of working within a GPN.

It was shown already in the beginning of the data analysis that the question concerning responsibility for correctness in information was special. On basis of the collected data it was obvious that there are divergent views on the responsibility. It is obvious that the responsibility has not been clearly communicated and/or delegated within the local organizations. This has great impact for the individual assembly operator. Incorrect assembly information increases the risks for the operator to make wrong decisions (or correct decision on basis of what information that actually was presented). The lack of standards or the lack of following standards has previously been stated that the operator has to rely on its own skills, experience and knowledge [19].

Within this topic it is important to state that too much information to the operator might also have negative effects on decision making. Bäckstrand [22] and Thorwald [23] have carried out studies on how information design affects the ability of the assembly operator to make correct decisions based on the presented information. It is believed and has been proven by them both that depending on how information is presented and what type of information are presented; the operator can improve its performance.

The spread of used information carriers was expected within the GPN. In the national study the spread was already noteworthy. This paper is not arguing against a diversity of information carriers itself. Instead, it argues on the importance of having a standardized process providing the best possibilities to support adaption to local prerequisites and demands.

The quality ratings performed in the questionnaire cannot be generalized since the sample is too small. Additionally, it would require a much higher operator involvement in the study to get a trustworthy average opinion. Although the numbers of ratings are not enough to make a conclusion, they are extremely interesting since they are diverse along the scale used in this study.

For those respondents who claimed that there are standards for creating assembly instructions the extent of using/following them is extremely interesting. Not following a standardized process might cause confusion, disturbance and quality issues. The reasons behind the respondents' opinions cannot be concluded on basis of the collected data. There are several different factors to consider. One reason why standards are not followed can be their quality and the logic of it, but it can also be related to the interpretation of what is considered as a standard and what is not.

7. CONCLUSION

The study has shown that text and pictures are the most common information design used within the GPN. The study cannot argue in to what extent pictures are used in the assembly instructions, but there are reasons to believe that the extent is very diverse within the GPN. This paper concludes a global study performed via a web questionnaire at 12 production sites in seven different countries within a GPN. The research aim was to proven diversity in development and use of assembly information. It also compares the study with a national study [3] recently made. The study has proven diversity within in the GPN and shows the lack of standardized processes or efficient processes. It has also been shown that responsibility is not clearly communicated or delegated and can be connected to the lack of standardization within the GPN.

On basis of the research question in this paper;

- *Can diversity be perceived in the development and use of assembly information within a global production network and in what forms?*

The answer is yes, the study has provided evidence that there is diversity within the GPN. The diversity can be perceived not only between production sites within the GPN, but also within a production site. The different use of information carriers, information content and information design and systems/tools creating assembly instructions are trustworthy evidences of diversity. In this study, it was believed that there is diversity in how assembly instructions are created within the GPN. The diversity makes it impossible to efficiently share knowledge and experience between the production sites and the diversity contributes to the number of factors that makes it hard to get a holistic overview of the overall GPN production performance.

Future work will focus on investigations of current production preparation processes within the GPN to see how they affect the ability to create high-quality assembly instructions for the operators. The hypothesis for the future work is that the non-standardized production preparation processes within the GPN restrain the possibility to improve assembly information and to improve overall production quality. The two studies already performed and the third study to be conducted will together form a basis for creating strategies for global assembly instructions.

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