CREATING STRATEGIES FOR GLOBAL ASSEMBLY INSTRUCTIONS – CURRENT STATE ANALYSIS

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Abstract: This paper present result from three global companies regarding strategies for creating global instructions, the studies are from a current state perspective. The result is based from a survey with 65 respondents. The designers are responsible for instructions and are from two different areas; assembly and service market. Furthermore a workshop has been arranged were two of three companies participated. Three main issues towards formulating a strategy will be discussed; (1) Information carrier; the results reveal that the most common information carrier for instructions are, Paper, Personal meetings and Desktops. (2) Who is responsible for quality assurance, most answers were production engineers. (3) Are there any standards concerning instruction at your company today? The respondents answered yes or under development in over 80 % of the cases on the question; if it exist any standards today.
Keywords: Global, Instructions, Strategies, Assembly, Service and after market

1. INTRODUCTION

In order to maintain a sustainable production in an increasingly globalised industry, current traditions for design and usage of automation may not be adaptable to the needs and future challenges that the industry is facing. Rapid changes of demands and requirements, both internal and external, frequently trigger plans for change in different manufacturing areas i.e. lower product and production costs, higher quality and shorter throughput time. This demands a high degree of flexibility (Chryssolouris, Efthymiou, Papakostas, Mourtzis, & Pagoropoulos, 2013; Koren et al., 1999) and more dynamic decision making later in the production chain to answer to a growing complexity (Müller et al., 2011). Flexibility and changeability are key enablers for meeting the challenges of a global market (Wiendahl et al., 2007). A global set-up of production sites and suppliers in an increasingly globalised world provides huge opportunities for companies, such as the development of new markets or the reduction of production costs. In spite of these advantages and the desire of companies to make full use of them, global production has not been fully mastered so far and its potential has not yet been fully tapped. Global production often results in quality issues or unexpectedly high costs (Bernard, Lanza, & Weiler, 2011). Cognitive automation strategies are needed in order to achieve a sustainable and reconfigurable assembly system.

2. AIM AND SCOPE

In order to form a strategy for globalisation of instructions, a current state has to be analysed, the paper aims to discuss three issues that could contribute towards formulating a strategy for global assembly instructions.

2.1 What types of information carriers are used for information and communication handling today?

Results from earlier studies within ten industrial cases show that over 80 % of all tasks are performed with the operators own experience even though the products' complexity and variants has increased (Fast-Berglund, Fässberg, Hellman, Davidsson, & Stahre, 2013; Åsa Fasth & Stahre, 2010), this was mostly based on poor design regarding competence levels and that the instructions were placed away from its need for use. This is in line with earlier studies (G Bäckstrand, De Vin, Högberg, & Case, 2005) which indicate that the personnel do not always use the information system in an appropriate way. ICT tools hold the possibility to save time through quick and effective information flows that synchronizes the work and enables a proactive work setting (Fässberg, Nordin, Fasth, & Stahre, 2010), but the question is if companies choose to invest in these solutions end furthermore, do they have a strategy for such an investment?

2.2 How is the content of information presented?

Operators need to have quality-information and not quantity of information in order to work proactive, which motivates a tailored work instruction (Bruch, 2009). Instructions need to consider amount, timing and presentation of information in order to achieve good quality (G. Bäckstrand, Thorvald, De Vin, Högberg, & Case, 2008). Currently the operators state that too much information is often displayed and the existing work instruction was seldom used. Furthermore the cognitive automation level was found to be too low, which is supported by previous studies at the case company (Åsa Fasth, Stahre, & Dencker, 2010). The previous studies found indications that the information system is not used as intended, causing risk for quality problems and linked this to the level of attention. When reducing the amount of information displayed to the operator, found that different skill and knowledge levels needs to be supported in order not to affect the internal quality negatively (G Bäckstrand, De Vin, Högberg, & Case, 2005; Dencker, Mårtensson, & Fasth, 2010; Fast-Berglund, Fässberg, Hellman, Davidsson, & Stahre, 2013).

2.3 Are there standards for constructing/designing instructions within the companies?

Standards form the core of any infrastructure. Accordingly, much of the research need to focus on standards: their design, diffusion, evolution, and impact (Hanseth & Lyytinen, 2004). This paper aims to investigate if companies introduce or implement standards for assembly instructions and how the employees interpret the word 'standard'. According to (David & Greenstein, 1990) standards could be defined "*as general agreements between producers and users of technology*" form another constitutive element of infrastructure design.

3. THEORY

The following sections will discuss the relevant theory used in the paper;

3.1 Globalisation

Conditions for manufacturing industry have changed, it has become increasingly important to establish and manage a company's position in global production networks (Karlsson, 2003). Technology transfers, replications and relocations are important strategic weapons for firms to remain competitive (Galbraith, 1990). Globalization is transforming the ways in which nations interact. National economies become integrated as the flow of goods and capital across borders expands. In pure sociological terms, Giddens (1996) defined globalization as:" ... the graving international integration of markets for goods, services and capital. It is the process of change towards global economic integration and a world economy characterized by liberation of trade, and rapid diffusion of advanced technologies and consumption patterns" (Aluko, Akinola, & Fatokun, 2004).

3.2 Transfer of production and technology

Transfer of production is a growing phenomenon, and it will become even more important to decrease the risks of transferring production (Fredriksson & Wänström, 2014). Many companies have difficulties meeting their transfer of production cost targets, and they often underestimate the complexity in transfer of production (Wipro council, 2013). Transfer of production is a complex process, especially in an industry like aircraft production (Rasheed & Manarvi, 2008; Siemens, 2013; and Wipro council, 2013). International transfer of production can involve everything from the manufacturing of a standardized part to the manufacturing capability of a complete factory (Minshall, 1999). Production transfer is often transferring of the production system, which includes people, equipment and procedures organized to perform manufacturing operations at a company (Malm, 2013).
Several risks can appear during a transfer, some can be exemplified by (Madsen, 2009; Bengtsson & Dabhilkar, 2009; Malm et al., 2011): full-scale production not reached as planned; difficulty in transferring tacit knowledge; geographically-spread supply chains; and different cultures. Geographical distance will often challenge suppliers and manufacturers with political, financial, cultural and practical differences as well. Financial differences can be exemplified by different currencies and payment systems, which can delay the transfer. Different languages can make communication a challenge; in many cases, the mutual language is none of the parties' mother tongue. Different cultural settings can affect many aspects of a project, since culture follows people. Practical differences can involve for example different time zones. All of these factors can diminish the effectiveness of business processes (Zeng & Rossetti, 2003; Fraering. & Prasad, 1999; Fawcett & Birou, 1992; Levy, 1995; Johansen et al., 2005). Robinson (1998) emphasise that when transfer of technology from one context is implemented to another context is the adaption to use it crucial. The "adaption to use" refers to the knowledge beyond the written

instructions needed to use the technology (Robinson, 1998). The initial transfer of machines, requirements and basic training is only the beginning of the technology transfer (Grönhaug & Kaufman, 1988).

3.2 Cognitive Automation

An increased cognitive LoA (i.e. more decision-making tasks are performed automatically) could improve the operators' work situation and decrease their workload while retaining the same mechanical automation (Fasth and Stahre, 2010). This motivates a shift of focus from mechanical towards cognitive automation (Fasth & Stahre, 2013). Cognitive automation is defined as: "*technical solutions helping the operator, e.g. HOW and WHAT to assemble (Levels 1-4) and situation control (Levels 5-7)*" (Fasth & Stahre, 2013).

Level 1 could be described as when the operator is performing a task solely based on own experience i.e. no help from technology in order to assemble, the higher the level, more technology is used in order to help the operator to have control over the situation. At level 7 machines are performing the task and the operator has a supervision part and has technology as help to have a situation control.

In order to form a detailed strategy for cognitive automation, each level of cognitive automation can be further divided into two different types of information; information carrier and content of information (Fässberg, Fasth, & Stahre, 2012). *Carrier* concerns the medium of information e.g. paper, screens, or PDAs. *Content* concerns the mode of information e.g. text, pictures, sound or movies. Interpreting McLuhan's (McLuhan, 1964) well-known aphorism "the medium is the message," i.e. a medium shapes content in ways that are advantageous to the biases of that medium, as all media have biases. These biases influence not only the content but also the experience of the user (Koltay, 2011).

3.3 Strategies for information sharing

Earlier research shows that there is a need for strategies and standards when dealing with different cultures… In a case study earlier performed at Aeronautics showed that culture differences have a large effect on the project time schedule. People perceive things differently depending on their background; these perceptions can cause confusion, misunderstandings and delays (Malm et. al, 2011 ISMICJ). To achieve a successfully transfer of production, harmonization of production documentation between the recipients and the senders is very important (Malm et. al, 2011 SPS). According to National Commission on Higher Education (NCHE, 1996) report: "Greater flexibility in production design to meet increasingly diverse global consumer needs obtained by using new computer-led technologies and employing more educated labor force in more participatory forms of work organization. These include teamwork, multi-skilling, flattening management structures and quality circles. Micro-economic strategies today are concerned primarily with adding value in production through innovation, by so-called "smart" workers, new technologies, participatory work and continuous deployment of new knowledge".(Aluko et al., 2004)

4. RESULT – INDUSTRIAL CASE STUDIES

In order to get a broad view over the field of cognitive strategies i.e. development and evolution of instruction for operators, four different methods have been used; two web based surveys (n= 65), semi-structured interviews (n=8), SWOT analysis (n=8) and key-word mingling (n=7). The web-based survey were done in order to get a broad view, which is in line with (Denscombe, 2000), who talks about surveys in in favour for width, which was the aim as a first step. Theses survey is also easier to answer in relation to surveys done by phone or post.

Table 1 Company descriptions

	Product	**Global/National**	**Context**	**Participants**
Case A	Trucks	Global	Assembly	35
Case B	Airplanes	National	Assembly	10
Case C	Trucks	Global	Service market	20

In Case A an investigation were conducted to understand how and by whom an assembly instruction was created, and to understand what content it contains. In total 35 respondents answered the questionnaire that was digital sent out to the target group, which up to 89 % consisted of production engineers. The majority of the target group had had their current position up to five years (82 %). 60 % of the target group had been employed up to 5 years 29 % of the respondents had been employed between 11-20 years. No direct conclusions can be drawn between relatively new employees and senior employees.

In Case B the resent evolution going from using paper-based 2D CAD or blue-prints towards using computer-based 3D as assembly instructions has been studied. Furthermore, going from Swedish to English as a global strategy is also studied. A total of 10 participants were answering the survey, 80 % were production engineers and 20 % method developer. 70 % of the respondents have been working within the company over 20 years and as production engineers over 10 years.

In Case C the survey focused on content and production of instructions for a global service market. Several roles are involved in the production of instructions: method engineers, technical writers, and technical illustrators. All these roles are represented in the survey. Half of the target group had been employed at the company for more than five years, and 28% had had their positions for more than five years.

4.1 Information carrier and Information content

This section will discuss the two first issues i.e. *What types of information carriers are used for information and communication handling today?* and *How is the content of information presented?*

Table 2 reveal the answers regarding the current use of information carrier and information content and how the information is presented.

Table 2 Carrier and content of information – current state

	Information Carrier **(WITH WHAT)*** (Top 3 of 13 alternatives)		Information Content **(WHAT TYPE)*** (Top 3 of 9 alternatives)		Information design **(HOW)*** (Top 3 of 6 alternatives)	
Case A N= 35	Paper Personal meetings Screens (prod. info), Phone	86 % 76 % 59 %	Assembly instructions Blueprints 2D Maintenance instructions	100% 34 % 34 %	Text Photo Animations (3D)	80 % 51 % 9 %
Case B N= 10	Computer desktop Computer laptop Paper	90 % 60 % 50 %	Blueprint 3D Assembly instructions Tacit knowledge (Experts)	100 % 80 % 50 %	Text Animations (3D) Photo	80 % 70 % 60 %
Case C N= 20	Computer desktop Computer laptop Paper	90 % 85 % 80 %	Assembly instructions Blueprints 2D Maintenance instructions	70 % 70 % 65 %	Text Line-drawing Animations (3D)	90 % 85 % 80 %

**Could answer more than one alternative*

Following sections will describe the result in more detail, case by case, seen from the industrial point of view.

Case A

The study showed that personal meetings, telephone calls, computer systems, computer screens, barcodes are heavily used to transform assembly information to the operators. The most common type of assembly information used was assembly instructions, but blueprints, machine instructions and maintenance information were also used. Regarding how well the ICT tools works, and how good the information works in the instructions, a majority of 71 % answers “good”, only 6 % of the respondents answers “bad”. The conclusion to be drawn is that the production engineers believe that current situation is in satisfaction. The comments given by the respondents are that an overflow of information for the operator may occur, and could be complex for the operator when new variants are introduced. Almost all respondents (83%) indicate that pictures are used to complement the text instructions. Despite this given answer, it is not clear in to what extent this really is done.

A variety of ICT tools enabling transformation of production information to the shop floor, were indicated to be used. Among the most popular ICT tools were papers, personal meetings, screens and telephones. This diversity indicates that fully digital information flow integration is not available or not to be considered to be optimal for the current business. As indicated in the survey, almost half of the respondents indicated that tacit knowledge is somehow used. The reason tacit knowledge is widely used is important to analyse and understand since that bad form of knowledge is not desirable in the long run since it is operator dependent. It might also reflect the reason why the diversity of ICT tools is so broad.

Case B

The result in Table 2 show that the three most applied information carriers are computer desktop (27%), computer laptop (19%) and paper (15%). These three in total is 61%, which indicates that the spread in different information carriers is wide. The information content is mainly blueprint 3D (37%) and an estimated percent of 18 is connected to tacit knowledge (Experts) 18 %.

These results are in line with the implementation of Model Based Definition that is ongoing within Aeronautics. The introduction time has been long and it is still a long way to go. Model based definition (MBD) can be explained by the application of 3D digital data within 3D Computer Aided Design (CAD) software to provide specifications for individual components and product assemblies. A CAD-model is a 3D-model that includes information earlier communicated through 2D-drawings (Alemanni et. al., 2011; Quintana et. al., 2010). A MBD dataset contains the 3D geometry and 3D annotations of the product’s dimensions, tolerances and

parts/notes lists for a complete product definition (Quintana et. al., 2010). The data is created once then re-used; the product structure is less hierarchical and the digital mock-up is on everyone's desk. Aerospace industries apply the MBD concept to compose, detail and annotate views of 3D models for downstream application, such as manufacturing, planning, product services and procurement (Versprille, 2008). After introducing MBD, the product requirements are within the design models. It is possible to review the production technique and methodology within the digital models before the actual production starts. Dimensions and regulations are directly connected to the solid model, and product and requirement documentations are stored in a data base. This provides an opportunity for reuse of design between projects and products. The introduction of MBD implies that methodology and working tools have to be further developed. MBD provides easier access to perform simulations and visualizations; this gives opportunities to see the whole picture in process flows. However, simulations cannot show the the interaction between the operators and how they apply the work instructions.
The large amount of tacit knowledge (18%) is an expected result. This indicates that the assemblies are complex and that the knowledge is connected to the operators. Today Aeronautics applies extensive mentor-novice programs (up to several years) with different authority levels to catch this type of knowledge. Tacit knowledge will always exist in assembly of Gripen aircraft, the assembly process is complex, the manufacturing rate is low and the learning time to be a certified assembly operator is extensive (5-10 years). Updated production documentation, simulations, better visualizations etc. could decrease the amount of tacit knowledge. In Table 2, the information design is quite evenly spread by text (38%), 3D-animations (33%) and Picture-Photo (29%). This also indicates the ongoing implementation; over time will the amount of text decrease a bit more. The implementation of MBD is not yet complete; it would be interesting to follow the development of the three measured factors.

Case C
In Case C instructions are created using a diversity of IT-systems, both standard tools like the Microsoft Office and frame maker as well as internally developed systems. Information flow is mainly supported by computers, paper, and personal meetings. A majority, 83%, indicates that there are standards available, and one third says that standards are under development. The answers indicate that the existing standards are not complete and/or not satisfactory. On the overall, the satisfaction level is above average (3, 5 of 5).
Instructions mostly consist of text and illustrations (line drawings), and there is currently a shift towards even more illustration based instructions. Also, methods for using 3D illustrations and animations are developed.

4.2 Are there standards for constructing/designing instructions today?
Results from the survey is illustrated in table 3, were three questions regarding standards has been collected.

Table 3 Standardisation – current state

	Standards		**Responsibility for right quality**		**Where (software)**
Case A	Yes No Under develop.	89 % 4 % 11 %	Production engineers Me Operators	96 % 54 % 21 %	Avix, MSExcel, MSWord, Own internal systems (SPRINT)
Case B	Yes No Under develop	70 % 20 % 40 %	Production engineers Quality Operators, IT-department	100 % 20 % 10 %	CATIA, DELMIA, 3DVia, WKC, ERP, Own internal systems (MBD)
Case C	Yes No Under develop.	65 % 20 % 20 %	Technique informer Method engineer Me	45 % 25 % 20 %	Catia, Delmia, FrameMaker, Office, PhotoShop, Own internal system (WINGS)

Following sections will describe the result in more detail, case by case, seen from the industrial point of view.

Case A, Standardisation strategies
A majority of the respondents (63 %) indicates that the instructions are often created in an ordinary office suite, while 40 % indicates that internal systems and applications are used. Only 22 % of the respondents indicated that CAD software is used. In this question multiple answers were allowed.
In total, 86 % of the respondents argue that standards are followed when creating instructions, and only 14 % states that no standards exist or standards are under development.
Bad handled diversity could indicate that standardization is not implemented to its full potential. It was also indicated that different ways of present information is used; text, pictures, movies and animations. A majority of the respondents indicate text and pictures to be more common. The survey did not reveal into what extent each form is used.
A common system used when preparing a truck for production is the SPRINT system. SPRINT is a manufacturing resource planning system and fetches material data from the PDM system (KOLA). The SPRINT

system contains material flows, operator instructions, tool data, factory structure, operator structure and makes it possible to have a global overview of production data. Data is stored and updated by manufacturing engineers before serial production starts.
A majority of the respondents uses traditional office suites for creating instructions. A follow up question would be needed to bring clarity in to what extent the creational process is structured. Reflecting comments in the survey results, one specific comment was protruding. It has always been a discussion regarding the assembly instructions usage in practice. Some people argue that the instructions are not followed. What is more important in this topic is to understand (i) what kind of information an instruction should contain, (ii) the amount of information, (iii) the structure of an instruction and (iv) how shall the instruction be used. Having these four points clear and agreed upon, form the basic conditions for high quality assembly work.
As a final comment the respondents were asked what is most important when creating assembly instructions, the most comments were; user friendliness, trust to information and easy to make right. In order to establish conditions for fulfilling the four factors previously mentioned, there is a need of more research in this area to be able to understand prerequisites and create global standards.

Case B, Standardisation strategies
Globalisation within the aircraft industry is closely connected to offset business; offset is involved in practically every large international agreement in defence-related industries. The buyer often wants this collaboration to support long-term local industrial development, with for example transfer of production from the selling organisation (Ahlström, 2000). Governments are increasingly applying offset conditions on the procurement of both commercial aircraft and define items from various suppliers. For example, the Boeing 787 is being built by a consortium of local companies to fulfil Japanese government orders. Boeing thinks of themselves as large-scale system integrators rather than airplane manufacturers (Wipro council, 2013)..
SAAB Aeronautics is an aircraft industry company. The aircraft industry can be a representative example of a global industry (Porter, 1986:1990; Yip, 1992). The aircraft manufacturing industry is regulated by strict national and international standards as well as comprehensive configuration management (Rasheed & Manarvi, 2008). The aircraft industry is known for its dedication to quality thinking, as failures in an aircraft may have severe consequences. Much focus is placed on security, safety and reliability requirements. Specifications, standards and work instructions build up a complex, hierarchical and interrelated system. The complexity is needed to always maintain traceability, at the same time is the complexity creating complicated structures on the individual product-level (Armbrust et al., 2009).

Five interviews were performed with different roles i.e. tool construction, detail construction, CAS, assembly and preparation method work. The interviews showed that different roles had different perspectives of what is important when designing the instructions. When asked what is most important when designing instructions it was most important that the information was correct and that the product quality was as high as possible. It was also important that the instruction was easy to learn and that it represents reality.

The results in Table 3 illustrate the implementation of MBD, not all standards are yet up to date, and the results for column 1 are not as severe as it may appear.
Regarding the answer for responsibility for right quality: the results indicate the importance of production engineers. However, it has to be taken under consideration that no quality personnel have been interviewed.

Delmia is primarily a tool for the Manufacturing Engineer in the work of defining the manufacturing bill of material (MBOM) from the engineering bill of material. Delmia is master for the MBOM. Delmia is integrated with the ERP system. The projects and programs that uses Delmia for process planning has the possibility to define the majority of the process planning in Delmia. WKC, or Work Instruction Composer, is an integrated application of Delmia Process WKC is used to create and store Work Instructions in light weight format. 3DVIA is the player for showing work instructions at the shop floor and reads light weight 3D-models from WKC. The work instruction is visualized in a 3DVIA player imbedded in an Internet Explorer template. This template enables the information from the design definition to easier be found by the shop floor worker.
However, there is no standardized visualization approach of assembly instruction in use at Aeronautics today. The production engineers visualise the models from their best ability based on agreed guidelines, this can end up with visualised work instructions that are company-unique.
When transfer of production is performed or a new supplier or partner is contracted can differences occur in how these visualizations are performed. By identifying a standardized way-of-working for 3D work instructions can the instructions be more easy-to-understand. A standardized way of working can include standardized test symbols, language, colours, views of the model etc.

Case C, Standardisation strategies

The survey results indicate that a majority of people involved with creating instructions agree that there are standards to follow, but that these are not fully satisfactory. Standards can hold for several different areas, such as the instruction format, the language and terminology used in texts, and how repair methods are developed and described in steps. Unfortunately, the survey did not include specifics of where these standards are described. A further investigation is therefore needed in order to find out if there are a general standard.

5. FUTURE WORK –WORK SHOP-POST-IT MINGLING

The post-it mingling for synergies effects together with previous case results showed different areas of interest: *Design, use, information handling* and *teaching*. *Design* was the most discussed area including: *Preparation, standards, pictures/symbols* and *language translators*. *Preparation* regards what guidelines there are to make instructions today and for instance how ICT tools are chosen. *Standards* are an important aspect was the project will study further what standard exist today regarding for instance colours and symbols. *Pictures and symbols* find a method that could test how pictures and language concepts are perceived in different countries and cultures, differences for symbols and colours at a global perspective. An investigation of *language translators* is important since companies want to spread and share information and want to make sure that the information is correct. Further on, *use* regards how instructions are used today, *information handling* how information should be stored and how it can be flexible. *Teaching* regards how, when and where the instructions should be taught.

6. CONCLUSION

The results from the survey and the interviews shows that advanced ICT tools are not used for instructions today; paper, personal meetings and desktops are the three top used information carriers.

How the instruction is presented is often text-based, together with pictures of some sort. It is common to develop internal company specific 'standards' and the software used is often MSoffice (word and excel).

In service market, it is more common to use more advanced software then in assembly instruction design. All case companies uses internal systems for instructions (SPRINT, MBD and WINGS), these systems will be investigated further in terms of global perspective and if it is possible to extend globally.

The three companies are united when it comes to how information strategies are seen and used at a national level. Future research will examine if it is the same at a global level and how the instructions will be developed in order to reach a global standard, in Case A the survey will be sent out to sites at all continents, to see if they have a common view and if the standard are centralised or de-centralised in terms of decisions and development of instructions. In Case B the globalisation strategy has already started when implementing the MBD i.e. going from 2D-to-3D and from Swedish to English, this will be further investigated at a global perspective when implementing this at an international site. Case C will be further investigated in terms of national and international level and the survey might be used in the same way as in Case A.

ACKNOWLEDGEMENT

The authors like to thank the academia and companies involved in the research project GAIS, without the companies there will be a smaller world to explore. The work has been carried out within the Production Area of Advance at Chalmers and sponsored by FFI-VINNOVA. This support is gratefully acknowledged.

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