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PARAMETERS AFFECTING QUALITY IN MANUAL ASSEMBLY OF ENGINES

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ABSTRACT

In manufacturing, it is vital that operators and other production personnel have the right information at the right time and right place. But what happens if we overestimate the usability of information for supporting the personnel in their assembly tasks? When does information serve as a quality assurance tool, and when does it become a too large part of the workload, thus reducing the time for core workplace activities, and instead becoming a part of the personnel's workload? This paper reports on work that has been conducted at a heavy diesel engine assembly plant with the aim of finding information usability parameters that can affect the personnel negatively or positively.

The paper presents and describes an evaluation of an existing information system at the plant. The aim of the evaluation was to find out why the assembly personnel, despite the fact that they had “all the information they needed”, did not always assemble the product according to specification and thereby caused an engine reject that had to be re-assembled.

The initial hypothesis was that there would be a strong correlation between the production volume and the number of rejects due to “Information Overload”. However, the study revealed that the personnel do not use the IT system in a way that causes information overload. Instead, the degree to which the IT system supports/triggers different forms of information seeking behaviour is thought to be one of the main factors influencing internal reject.

KEYWORDS: Production, Information usability, Workplace design, HMI, Assembly quality

1. INTRODUCTION

At Volvo Powertrain in Skövde, Sweden the manufactured product is heavy diesel engines used in trucks, excavators, articulated haulers, boats etc. The majority of these engines are assembled in a high volume main flow. In this main flow a high volume product is assembled, but there are elements of low volume products assembled in the same product flow. The presence of these low volume products demands a dynamic information interface and a dynamic information flow concerning information transfer of information for individual engines. The character of this information can be e.g. parts to assembly on the specific engine, but it can also be information regarding how to assemble the engine.

The aim of this study is to find out why the personnel sometimes assemble the wrong parts on an engine when they have “all the information they need” available at the workplace. As a starting point for the evaluation, a hypothesis inspired by [1] was formulated that uses the parameter “Production Volumes” together with "Information Overload":

High production volumes together with Information Overload create a workload that is the main cause for the relatively high number of internal rejects that are due to wrong part assembled or parts missing.

In the evaluation, a passive observation was conducted. The purpose of these observations was to find out how the personnel used the information system, how they used the information and how they responded to the information. A partial Cognitive Work Analysis (CWA) was conducted (three out of five phases) with the purpose of getting a clearer view of how the personnel interacted with the working environment, including the information system [2, 3]. During the evaluation a number of parameters emerged that were not part of the initial scope. These parameters, together with an increase in understanding about Information Overload and how it affects the personnel at the specific assembly plant, created a need for re-formulating the hypothesis. The most important new parameter was “Time” and this parameter is directly connected to the assembly strategy choice for the personnel.

2. CWA (COGNITIVE WORK ANALYSIS)

CWA is one of several approaches to cognitive engineering evaluation of complex sociotechnical systems and is used for analysis, modelling and design of these systems. The aim of CWA is to find situations and strategies for unanticipated events that the human operator may face, and to identify these situations/strategies in the information interface design phase. This makes it possible to design information systems that support the operator better. One fundamental idea behind CWA is that constraints in the work environment and the cognitive competences of the operator shape work activities [3]. This fundamental idea includes seven dimensions; “Work Domain, Task Space”, “Activity Analysis in Domain Terms”, “Decision Analysis in Information Terms”, “Information Processing Strategies”, ” Allocation of Decision Roles”, ” Management Structure”, “Mental Resources, Competency, and Preferences of the Individual Actor” [4]. These dimensions form the five-phased framework of CWA. The five phases are [2, 3]:

- Work Domain Analysis (WDA): Identification of physical and purposive (defines why technical system exists) constraints for the workplace where the activities take place, in this case an assembly station.

-Control Task Analysis (CoTa): Defines what needs to be done within a work domain independently of how the task is to be achieved or by whom.

- Strategies Analysis (SA): Identification of different strategies for accomplishing the task or work defined in the CoTa.
- Social-organizational analysis (SOA): Identifies how the responsibility for the execution of different strategies is divided among humans and between humans and automation.
- Worker Competencies analysis (WCA): Identifies the worker competence needed to accomplish the identified tasks.

There is no hierarchical or strict sequential order between the different dimensions. Therefore, the user need not follow a strict execution order when performing the CWA. Instead, the user can define a path and method suitable for a specific problem [5]. Examples of the use of CWA for the design of user interfaces can be found in domains like nuclear power plants, aviation, the military and medicine [3, 10].

3. INFORMATION OVERLOAD

In the case study, one important part was to observe how the assembly personnel interact with the IT-system and determine whether the information flow created an Information Overload or not. In this evaluation, Wilson's [1] definition of Information Overload was used, that states:

"At the personal level, we can define information overload as: a perception on the part of the individual (or observers of that person) that the flows of information associated with work tasks is greater than can be managed effectively, and a perception that overload in this sense creates a degree of stress for which his or her coping strategies are ineffective."

The hypothesis was that Information Overload could be the reason why the personnel did not always respond to the information that was presented by the IT-system and subsequently assembled the wrong part on the engine.

The IT-system, CMS (Carrier Assembly security System) is mounted on the AGVs (Automated Guided Vehicle) used in the plant, and consists of a computer connected to the intranet by a wireless-LAN, a computer screen and a keyboard (Figure 1). The engine data, task instruction and part number of part to be assembled is transferred to the AGV and presented on the CMS-screen. By looking at the computer screen, the assembly personnel know what part to assemble at the specific workstation. After the assembly task is completed, the AGV moves to the next station and the CMS is updated with information regarding the assembly task at the new station. Meanwhile, a new AGV arrives at the station with a new engine with information regarding that particular engine presented on the computer screen.

Figure 1: AGV with graphical interface, CMS on top of the AGV.

4. CASE STUDY

The evaluation was a qualitative, 21-hour passive observation conducted in a way so that the observers did not interact with the assembly personnel or with objects used at the workstations. It was spread over a two-week period. The material from these observations was analysed within the CWA framework [2].

There were two reasons to conduct a CWA:

- To find indicators that showed if CWA could be used in the pre-design phase for an information system, not from a designer's perspective, but rather from a procurer's perspective.
- To find if it is possible to find and predict tasks, strategies etc. in an existing system and thereby find tasks, strategies that can be helpful for the personnel to adapt to, or in a worst case can create e.g. quality problems.

In the evaluation, production data (volumes) from the years 2003 and 2004 were compared with reject data from the same years.

Three out of five phases in the CWA were conducted (WDA, CoTa and SA). The focus was on workplace and information use, and therefore SOA and WCA were not part of CWA. The reason for leaving out SOA and WCA was a focus on task and strategy identification, rather than on organizational structures and worker competence.

5. CASE STUDY RESULTS

The WDA and the CoTa did not reveal any new knowledge about the work environment, except that the IT/IS-system does not support different skills and knowledge, i.e. the system is not dynamic from a novice/expert perspective and therefore cannot support different strategies or evolutions of strategies. In the SA part of the CWA a parameter that was not revealed by study of the workstation alone was discovered. The parameter was "Time". This parameter together with the parameter "Event" will be explained later in the text.

The result from the CWA showed that CWA could be used to evaluate existing systems if one wanted to find tasks and strategies that were not part of the original scope for the system.

The first reason of the two, i.e.to evaluate if CWA could be used in the pre-design phase, could not be proved. There is some indicator that shows that it could be, but more studies are needed before any conclusions can be drawn.

6. ANALYSIS/DISCUSSION

The analysis focused on four elements: Volume, Time and Event, New Employees, and Information Overload **Volumes**

One part of the hypothesis was that increasing volumes would affect the quality negatively because it created a higher workload for the assembly personnel. Therefore the production data, number of engines/month, was compared with the number of internal rejects/month. The data used was from 2003-2004. The difference in workload caused by volume is an increase of approximately 15%. This increase alone cannot explain the high increase of internal rejects for some part of the period. In some months there is a decrease in production volumes and a very high increase in the internal rejects.

Time and Event

The information system design supports an event-driven perspective, that is, when an AGV arrives at a workstation, the assembly personnel should use the information system to get information regarding the engine variant. The event, see Figure 2 "Strategy B", arrive at station, triggers a direct need for a specific variant part, tied to the engine variant. But, from time to time, there is a delay in the AGV flow. The personnel use this delay (time), see Figure 2 "Strategy A" to prepare in advance for the engine to arrive. These preparations can include e.g. assembly sub-assemblies. The assembly personnel assembles these sub-assemblies from a subjective, by experience, personal prognosis. This action is not part of the assembly strategies that the IT/IS supports. This can cause problems, rejects, if the assembly personnel are not careful when they assembly the sub-assembly onto the engine, i.e. it is important that they use the IT/IS-system at this stage.

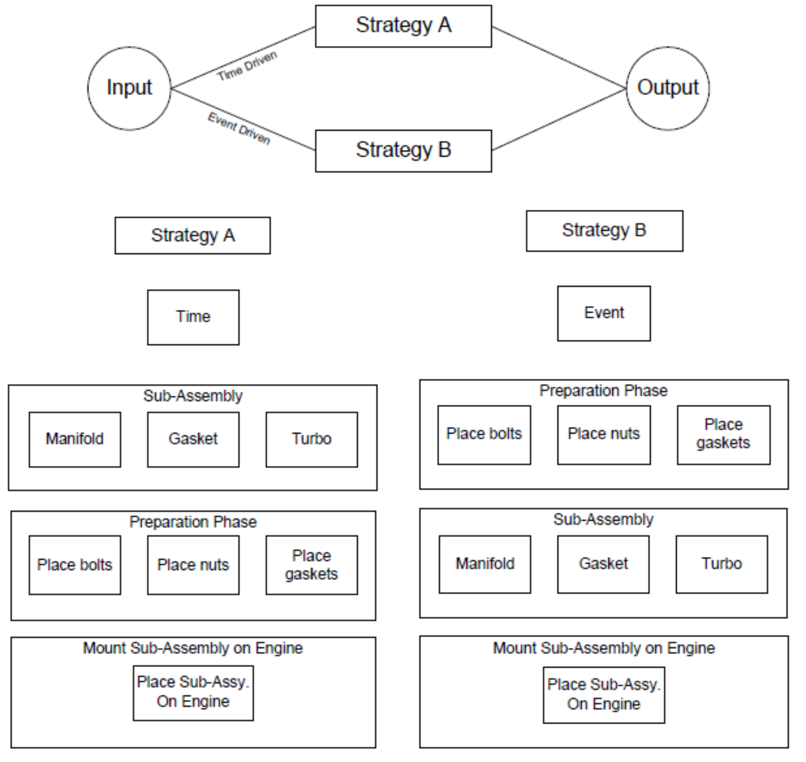


Figure 2: Different assembly strategies.

At this point there is nothing that proves that different strategies causes internal rejects, but it is most likely. This must be more closely investigated and will be in the scope for further research.

New Employees

The parameter, "number of New Employees", was tested because there was no direct connection between the increased volumes and the increase in internal rejects. In some months the volume decreased but at the same time the internal rejects at some parts of the assembly plant increased by over 300%! It is important at this stage to point out that this increase of rejects did not affect the quality of the delivered products.

When comparing the statistics over the number of new employees a correlation between new employees and internal rejects was observed. This correlation can indicate that:

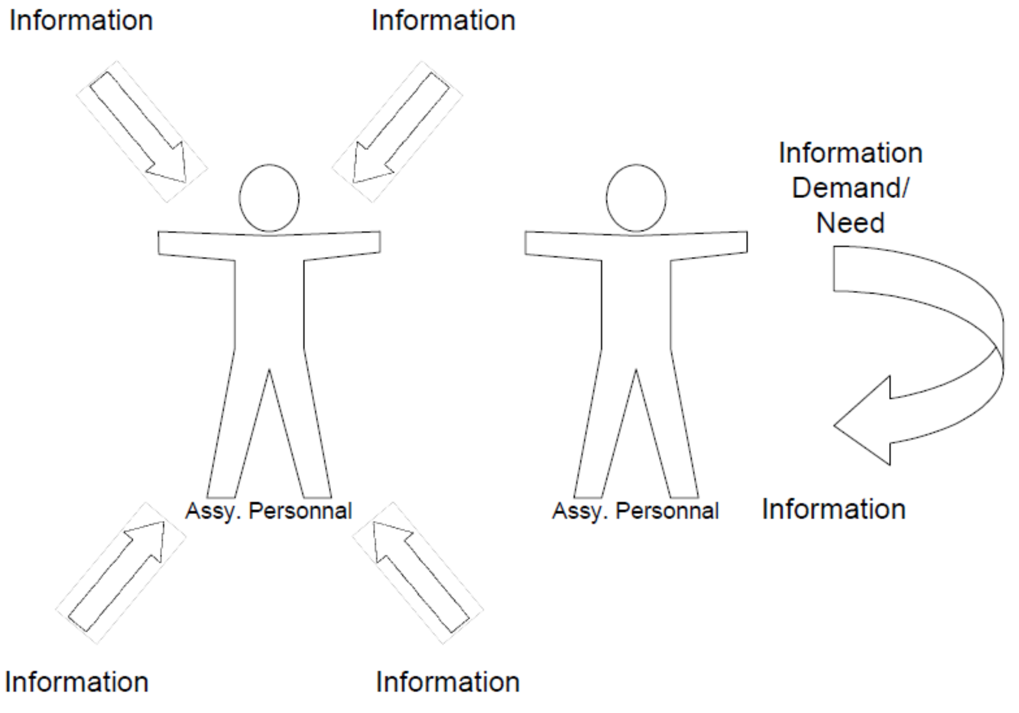
- The training is inadequate.
- The IT/IS-system does not support different personnel skill levels.

Most likely it is a combination of the two and therefore the solution of the problem could also be a combination of the two.

Information Overload

By observing how the personnel interacted with the CMS, the conclusion was drawn that it is unlikely that the IT-system by itself created Information Overload for the personnel. The reason for this conclusion is that the assembly personnel did not use the CMS in a way that could cause Information Overload. When an engine arrives at a station, the personnel should use the CMS to get information regarding the task and parts to assembly. Often they did not use the CMS until it was time to register task completion.

7. CONCLUSIONS AND FUTURE WORK



7.1 Conclusions

Production volume is a parameter that does not affect the existing assembly system in a way that the organization believes. The reason for this can be that:

- The assembly system is underestimated when it comes to product volumes. The maximum production volume for the specific assembly line have not been reached and therefore there is no indication of production volumes affecting the number of internal rejects.
- The product volume is not the main cause for a high number of rejects.

Information Overload due to only the information system is not likely to be the cause for internal rejects. The personnel do not use the IT-system in a way that could cause Information Overload. But it is possible that the information flow together with noise, music/radio, sound sources and other information sources create an overload. If one defines this overload as stress, and argue that a connection between stress and human error exists, then it seems that the information flow is one of many sources that can cause stress and thereby errors in the form of internal rejects [7]. This overload/stress can make it harder for the assembly personnel to efficiently perform an assembly task and thereby make it difficult to maintain a successful assembly strategy [6].

7.2 Future Work

Since the conclusion is that the problems stated in the initial hypothesis are not likely to be the main reasons for internal rejects, the future work will initially focus on formulating and testing new hypotheses. An area of particular interest is the way in which the operator receives information. **Information Delivery Vs. Information demand?**

As mentioned earlier, the design of the IT/IS-system supports the assembly personnel from an event perspective. The event that triggers the delivery of information is the arrival of the AGV at a station, i.e. it is not the personnel that demand the information; they are only the "information receivers". If a person has a need to satisfy a goal, in this case identify the right part to assembly, it is more likely that the information is demanded and utilized/processed at the right time and place [9]. Figure 3 tries to illustrate the difference in the information flow between "Information Delivery" and "Information Demand".

Figure 3: Illustration of the difference between “Information Delivery” and “Information Demand”.

The main conclusion from the evaluation was that the design of the Information system supports not only the event perspective; it also supports Active Information Seeking behaviour in an environment that mainly supports Passive Information Seeking behaviour [8]. A provisional new hypothesis to be tested can be defined as:

The degree to which Active Information Seeking behaviour is supported/triggered has a large influence on the number of internal rejects.

8. ACKNOWLEDGEMENTS

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