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AN ASSEMBLY LINE INFORMATION SYSTEM STUDY

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Abstract

Assembly line information systems are designed to provide assembly workers with appropriate information that allows the assembly of the product in good time and good quality. In this context product quality might be defined relative to the number of internal rejects or products which need some kind of reworking before being in a deliverable condition.

This paper describes a pilot study of a heavy diesel engine assembly line where considerable variety is presented to the assembly workers in the form of engines destined for trucks, buses, marine applications and stationary power generation each of which has to comply with a variety of national and international standards. Internal rejects might for example occur through the fitting of sub-assemblies that are unsuited to the eventual application, and although an extensive information system is currently in place the level of internal rejects is considered to be unsatisfactory. The objectives of the study were to understand how the assembly workers interact with information systems and the impact this has on product quality and productivity. A single line was studied for ten days during which 2600 engines were assembled. At four of the assembly stations the existing information system was changed to reduce the amount of information to be assimilated by the workers, the timing of its presentation and its location. The use of simple colour-coded cards and symbols resulted in the reduction of internal rejects by 40% on two of the assembly stations and to zero on the other two stations. It is believed that changing the information system has changed the workers' behaviour through a reduction in cognitive stress levels. The pilot study has provided useful insights into the basis for modifying information systems and a further study of the final assembly of heavy trucks is planned with an ultimate aim of determining a rationale for the design of information systems for use within the assembly of customised products.

Keywords: Production, Information usability, Cognitive ergonomics, Workplace design, Assembly quality.

1.0 Introduction

Volvo Powertrain in Skovde, Sweden manufactures heavy diesel engines destined for trucks, buses, marine applications and stationary power generation each of which has to comply with a variety of national and international standards. Engines are assembled using mixed-model production where a high volume product is assembled in the main flow but low volume products are also present. To handle this situation a dynamic information system is essential so that it can (for example) refer to parts to be assembled on a specific engine, information regarding how to assemble a particular engine, etc. In the plant studied the information system is implemented as an IT system mounted on the automatic guided vehicles (AGVs) that carry the engines down the assembly line. Earlier work [I] explored the relationships between attention, interpretation, decision-making and acting and how this relates to the information flow based on the idea [2] that the degree to which Active Information Seeking behaviour is supported/triggered has a large influence on the number of internal rejects. As an extreme example, if a trigger is not present or detected, then an active information seeking behaviour will not be present. In other words, the trigger is predecessor to active attention, and active attention is believed to be a state of mind that is crucial for successful use of data and information. If it is not possible to create attention, then it is not possible to start an interpretation, decision-making and acting process. Obviously, there will still be some kind of interpretation, decision-making and acting, and the assembly personnel will continue to assemble engines, but the risk of assembly errors increases if one fails to trigger the personnels' attention [3] at the right time and to the correct data source. "Structured translation of data into action" [4] to reach a specific goal must be the main focus for the assembly personnel. This requires that the information is available at the right time in the right place and that the assembly personnel have identified a need for the specific information. In the assembly environment there is evidence, internal rejects, that the personnel do not use the information system in the most effective way. Studies made on the shop floor have concluded that the support system, from a graphical point-of-view is well, but not perfectly designed, but the users do not use them in a way that was anticipated. Input from ongoing projects indicates that one the main reasons for this is the attention levels among the assembly personnel.

1.1 The Role of Information Triggers

The purpose of any rational action should be to achieve a goal [5, 6]. This should normally create a demand for information, which is triggered in some way. There are four situations regarding information need versus demand: (I) There is a need but no demand. An error will eventually occur, and a solution might be to introduce triggers to create the demand. (ii) There is a need and a demand. This situation is the preferred one with low risk of errors due to lack of information . It is still essential that information matches the need. (iii) There is a demand but no need. This situation can be frustrating for the personnel as they have identified a need and have a demand, but they are not provided with the information they feel they need. (iv) There is no need and no demand.

1.2 Models Relating Action to Information

The OODA loop (Observation, Orientation, Decision, Action) [7] is an example of a model relating the information process to actions. However, some researchers [8] have suggested that "Observe, Orient, Decide and Act" should be redefined to "Observe, Interpret, Decide and Act". This would create a more generic model more suitable for manufacturing purposes, and in this case make it possible to map "Attention, Interpreting, Decision making and Acting" to the OODA model in a better way.

1.3 Attention

Before it is possible to receive information, one must perceive its presence. Aspects of passive and active attention are believed to be major contributors to problems in the work environment [2, 9-11]. Active attention is connected to actively processing information. e.g. during skilled machining operations one actively seeks and processes information. In passive attention, such as a visual inspection task we may register data/information in our surroundings without processing it actively until something unusual happens . The assembly personnel studied seem to be aware of some data, and perform parts of tasks correctly, but at the same time missed other important issues connected to the same task, although all data/information is available in the context of the work station. In other words, attention plays an important role in how data is observed.

1.4 Interpreting

In this case "interpreting" refers to the process of transforming [12] data into information. One way to describe the difference between data and information is that data is "a set of symbols in which the individual symbols have a potential for meaning but may not be meaningful to a given recipient" or "a set of symbols in which the individual symbols are known, but the combination is meaningless " or "understandable symbols rejected by the recipient as being of no interest or value" [12]. Information however can be described as "a message that exists but that is not necessarily sent to, or received by, a given recipient" or "a message sent to a destination or received by a destination, but not evaluated or understood" or "a message understood by the recipient and which changes that person's knowledge base" or "an output of the process of converting received messages, data, signs, or signals into knowledge." [12]. This leads to a conclusion that there is a connection between interpretation, data and information. The definition of information [12] states that it is an output of a process. This output among other things, such as knowledge, is a base for decision-making and acting. From this it is possible to state that information in the assembly plant context could be a message that when **received**, **read, interpreted** by a recipient **creates** knowledge/changes the receiver's knowledge base so that an **action** can be committed by the receiver that is **predicted** by the sender.

1.5 Decision-making and Acting

Although the subject of linking acting to decision making is an interesting topic, within the context of this paper these two topics can be discussed as one. Decision-making can be seen from a process perspective as a "many-to-one mapping of information to responses" [13]. If one considers this visualization together with the "mapping" statement it is easy to see that ·there could be different data/information sources that provide assembly personnel with data/information. This of course can directly affect the decision-making process in a negative way.

1.6 The Importance of Triggers

A trigger is the signal that creates a change of state regarding attention, from passive to active, and preferably, from active to passive. The hypothesis is that on the shop floor much of the attention is focused on the assembly task, and not on gathering data/information. This selective attention [14] is a part of the human nature, so an information system should provide a possibility to focus the assembler's attention to the right place (there is evidence that at the specific plant, the personnel use data/information from non-reliable sources) and at the right time as the trigger and the data must be synchronised.. The information system should support a change of state between active and passive. As "it is the nature of the attention process to generate its own extinction" [15], a trigger must also contribute to the "resurrection" of the information demand. It is important that a trigger is used in a way that really supports the personnel. There is evidence at plant that misuse of quality support systems have created a feeling of irritation leading to misuse.

2.0 Pilot Study

The aim of the pilot study is to find evidence that supports the overall aim of the research which is to find or develop a prototype work method that supports the design of information flow based on product and process demands. Two hypotheses have been formulated: Hypothesis 1 - 'Information Seeking Behaviour' - *The degree to which Active Information Seeking behaviour is supported/triggered has a large influence on the number of internal rejects.* Hypothesis 2 - 'use of evaluation methods' *The use of an evaluation work method in the conceptual as well as in the design phase of an information flow will affect the internal rejects in a positive way.* The pilot study was aimed at gaining practical knowledge regarding how triggers, active attention and passive attention affect the internal reject rate, but it also gave knowledge regarding how the assembly personnel interact with the information flow· present in their work context. It is hoped that the knowledge gained from the pilot will be useful in the next stage of the research which is the creation of a prototype work method.

2.1 Performance Indicator

To evaluate the value of the knowledge obtained it is important to identify a performance indicator. In this case the main performance indicator is the rate of internal rejects for which there is historic data. The historic data covers a period of about 9 months in 2006 and includes approximately 33000 records. This data includes: date and time which can be used to trace the error source, engine family and variant (the data includes data connected to 6, 7, 12, 13 and 16 litre engines). The engine families have different variants (known as "engine types") and approximately 500 variants exist), effect number (a code used for reject causes), part number and free text field (used to describe the cause of rejection - unfortunately not used reliably). The reject historic data process starts with a discovery of a divergence from the order specification. This is done at the end of the line and in the test zones. If a divergence is discovered it is saved in a database and problem is solved in a special reject area. The most common way of subsequently retrieving data from the database is via a Business Objects (BO) question. This data has to be prepared for viewing so that the reject information can be used as the basis of decision-making. In this case the data can be sorted to identify the engine family, the date and time (to establish a weekly reject rate) and the assembly station.

2.2 Experimental Assembly Environment

The actual production environment under norrnal operating conditions was used in the pilot study and was modified by changing the trigger from the screen-based alphanumeric approach. The new triggers were coloured magnetic rubber sheets attached to the Automatic Guided Vehicle (AGV) which is the carrier of the engine (figure I). The sheets have five different colours - blue, pink, orange, green and black to act as triggers for the different situations.

Fig. l. The AGV/carrier and its cargo, a diesel engine.

2.3 Quantitative Data

The results were evaluated by comparing the performance indicator before and after the pilot study. As mentioned earlier, this indicator is a part of the reject handling system and had previously been measured for approximately 9 months during 2006. The data gathered during the pilot study shows that the performance indicator for the period is at a mean level of 1.46% (figure 2). However, depending on the sorting of the reject data two more values with higher means of 2.77% and 3.12% must be considered. The performance indicator with value 1.46% ($H_{\alpha 0}$) includes only rejects with the effect numbers being studied (parts missing or wrong parts assembled). The performance indicator with value 2.77% ($H_{\beta 0}$) includes $H_{\alpha 0}$ and rejects that have a non-assembly related attribute. The performance indicator with value 3.12% ($H_{\gamma 0}$) includes rejects from $H_{\alpha 0}$ and $H_{\beta 0}$ as well as rejects connected to a series of categories that indicate leakage of oil and water. Parts missing or wrong parts assembled can, if not found earlier, lead to a leakage in the final test zone. If this happens the reject registration will not be in the category "parts missing" or "wrong parts assembled" and it will be "leakage" or "deviation from specification". Figure 3 shows the error distribution over the stations within the line during the nine month period before the pilot study. The workstations affected were stations 800 and 1100, and as there are parallel lines this makes a total of four workstations.

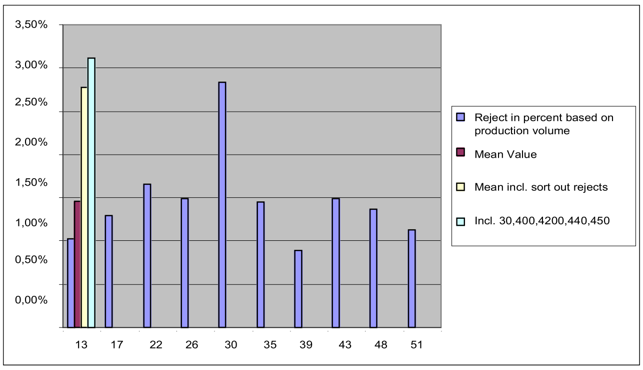

Fig. 2. Performance indicator sorted per week

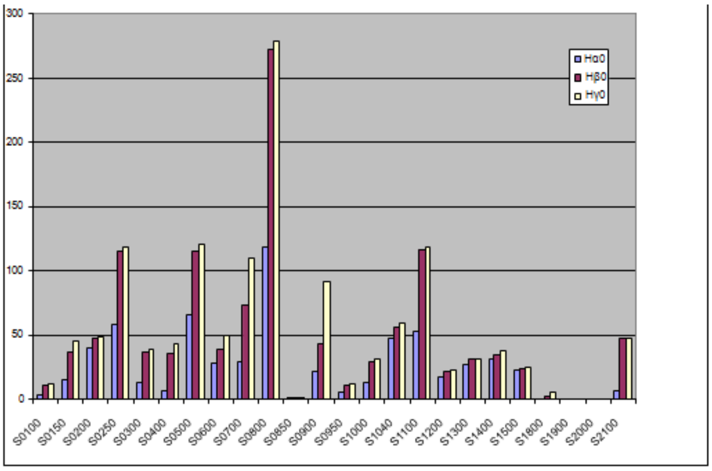

Fig. 3. Performance indicators sorted per assembly station.

2.4 Assembly Process AS-IS

The line studied contains twenty-four assembly stations and is balanced so that every station has approximately eight minutes of assembly time, i.e. the assembly personnel have eight minutes to accomplish the assembly task. The work process starts typically with an AGV/carrier arriving at an assembly station. The onboard information system would typically be displaying up to 19 lines of text to describe the assembly requirements. The subsequent steps in the assembly process are (1) identification of part to assemble. (not necessary where parts are identical on all engines), (2) retrieval of part to assemble (3) assembly of part onto engine . Steps 1 to 3 are repeated until all parts are assembled. (4) Confirmation of task - the personnel confirm via an IT system that they have completed all assigned tasks at the station. (5) Carrier departs from the assembly station to the next station. Step 1, "Identification", involves gathering of data/information. The data/information is presented to the personnel via a computer screen and is visible when the AGV/carrier arrives at that assembly station.

2.5 Assembly Process TO-BE (During the Pilot)

The TO-BE process is in a sense the same as the AS-IS process except in one important respect - that is the trigger. The trigger is a predecessor to "l. Identification of parts. .... ". No special arrangements influencing the production context were made, except for the handling of the triggers (the magnetic sheeting). This is to satisfy the objective of testing the hypotheses in a real assembly environment, and not in a controlled laboratory. **MINITAB** 14 was used to calculate the sample size (number of engine assemblies to be studied). And was calculated to be 2541. This, 2541, is approximately two weeks (ten twenty-four days) production. Therefore the experimental time frame within the production area was set to ten days. It was expected that this time frame would need updating during the experiment due for example to disturbances in production. In all experiments there is a possibility that the experiment itself influences the results. In this pilot three (four) experiment groups were used with the purpose to create an understanding of how this particular pilot might influence the personnel and thereby the results. The different experiment groups are divided by two different variables: A: Interaction: (Al :"High" , A2:"Low"), B: Trigger: (BI:Present or B2:Absent).

3.0 Results

The results can be categorized according to the subject groups. **Control group A2B2:** The results from this group are the historic data from the nine month period in 2006. This results are used as a reference value for the experiment groups. **Experiment group AlBl:** High interaction and trigger present. The experimenter was actively involved (asking questions, starting discussions about the work etc.) with the assembly personnel at their work stations and the new trigger was present. **Experiment group A1B2:** High interaction and trigger absent. As before the experimenter was actively involved with the assembly personnel at their work stations but the new trigger was not used **Experiment group A2Bl:** Low interaction and trigger present. The experimenter was situated in the start of the assembly line and there was no or very little interaction between the experimenter and the assembly personal. The single line was studied for a period of ten days during which 2600 engines were assembled. At four (out of twenty-four) of the assembly stations the existing information system was changed to reduce the amount of information to be assimilated by the workers, the timing of its presentation and its location. The use of simple colour-coded cards and symbols resulted in the reduction of internal rejects by 40% on two of the assembly stations and to zero on the other two stations. On reversion to the original information system the rate of internal rejects rose to equal or surpass those before the study. Full details of the results can be found in [16].

4.0 Conclusions

It is believed that changing the information system changed the workers' behaviour through a reduction in cognitive stress levels. The pilot study has provided useful insights into the basis for modifying information systems and a further study of the final assembly of heavy trucks is planned with an ultimate aim of determining a rationale for the design of information systems for use within the assembly of customised products. The company expects to benefit in the long term through reduced rates of internal rejects brought about by more appropriate information systems that more closely match the assemblers' needs for information.

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