Assembly Work Settings Enabling Proactivity – Information Requirements

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Abstract

Information is a critical factor to support a proactive behaviour of operators in complex work settings characterized by flexible levels of automation and need for knowledge-based decision making. In this conceptual paper the authors define proactive behaviour as the ability of operators to control a situation by taking action in advance. Information requirements that enable proactivity and different control behaviour are identified. Moreover, several demands on the information support system are outlined. Further, the paper presents some implications for management as a result of the new work role of the operator regarding decision making, planning, and control.

Keywords:

Uncertainty; Proactive behaviour; Information support

1 INTRODUCTION

Turbulent markets and powerful customers require assembly systems to deal with frequent changes in the market demand as well as to adapt quickly to new products and variants. Managing the dynamics of the market requires decreased response time in the assembly system in order to remain competitive. To be able to act quicker it is important to reduce the complexity of the control system.

Fleig and Schneider [1] claim that the implementation of automated systems has failed to integrate planning and control tasks effectively and efficiently. The implementer of automated systems did not recognize the importance to distribute planning and control tasks to human operators on the shop floor, who ‘experience’ the production process at first hand and influence it by their actions [1]. Moreover, since real preplanning is only possible in a few exceptional cases [1] it is important to take care of appropriate human participation during planning and assembling. If a company provides a satisfying education and facilitates life-long learning for their employees, they will be the most flexible resource of the company [2].

In working situations characterized by uncertainty, need for knowledge-based behaviour and work role aspects that cannot be formalized, proactive behaviour can contribute to competitive advantages (e.g. [3], [4], [5], [6], [7]). Thus, assembly work settings enabling proactivity with a focus on active participation of the human operators may be favourable to achieve flexibility, reconfigurability, changeability and evolvability of the assembly system. The combination of a need for knowledge-based behaviour, information and automation characterize proactive assembly systems. Hence, levels of automation, information and operators’ competence were identified as three main drivers in a proactive assembly system in the ProAct project within which this paper was written [8]. ProAct is a collaborative effort involving six Swedish manufacturing businesses and three Swedish technical universities.

In this paper we define proactive behaviour as the ability of operators to control a situation by taking action and effectuating changes of the work situation in advance in order to create a favourable outcome. Necessary planning and decisions are made by the operators and they have the authority and autonomy to perform needed actions.

The system behaviour of a proactive work setting should thus have the ability to act before a situation becomes a source of confrontation or crisis. Systems with proactivity can to some extent foresee and adapt to dynamic changing environments in real time. In doing so, sustainable proactivity necessitates two different time perspectives; one concerning acting proactively during operation and the other concerning maintaining the proactive ability over time.

Such an assembly work setting needs improved information exchange and more acting operators who are able to make decisions previously associated with middle management level. This implies that proactive assembly work settings require operators that are able to exercise their own judgement, take own initiatives and anticipate future problems in order to avoid exceptional situations in production or work. It is not any longer sufficient for the operators to perform a narrow assembly task satisfyingly. Work instruction sheets cannot represent all possible situations operators will face. Furthermore, the actual activity performed by the operator in real work situations will vary from the prescribed task according to activity analysis theory [9].

Therefore, operators need to have a certain degree of freedom in a proactive assembly work setting to contribute to effectiveness in uncertain situations. Proactive behaviour of the operators will support both short and long range development of proactive assembly systems. As Crant, describes, “Proactive behaviour can be a high-leverage concept rather than just another management fad, and can result in increased organizational effectiveness” [5, p. 435]

The benefit of proactive work behaviour of the operators may be for example that the operators will develop knowledge about a future need for change in assembly and they will identify an alternative route of action. Operators who will obtain information about upcoming production demands will have the time needed to collect more information, think about the best alternative and choose the right method to assemble.

The paper is conceptual, and aims at clarifying the role of information in a proactive assembly work setting. The literature study conducted is the basis for further research at the different case companies in order to empirically establish and validate the attributes of a proactive assembly work setting.

In this paper we identify information requirements that enable the proactive behaviour of the operators. We also present different demands on the information support system. Further, the paper outlines some implications for management as results of the new work role of the proactive operators regarding decision making, planning and control.

2 THEORETICAL BACKGROUND

2.1 Information requirements

The term "information" has been defined in many ways. In this paper information is defined as "the collection of data, which, when presented in a particular manner at an appropriate time, improves the knowledge of the person receiving it in such a way that he/she is better able to undertake a particular activity or make a particular decision" [10, p.4].

If workers on the shop floor are responsible of tasks including planning, control and execution of assembly they need adequate information. Each activity needs information, or collection of data, requirements that must be fulfilled to be able to complete the activity [11]. These information requirements as well as the value of information are also affected by contextual (when is it used and in which situation) and personal (who uses it) characteristics [12], [13]. If information requirements may be either informative or irrelevant to a user depends on both the performed activity as well as the individual cognitive processes [10]. Thus, the perception of "right information" is of importance with respect to the performance of the operators.

The information presented to operators should inform them about a reliable up to date picture of the situation but also present future production demands. In line with Byström [12] and Fjällström [13] information is understood in the role of an abstract tool that enables, or is initiated to enable the fulfilment of activities. Thus, information is viewed from the operators' perspective.

Information that supports event handling of the operators has to be pragmatic [13], [14]. Pragmatic information, which consists of two complementary dimensions: novelty (Erstmaligkeit), and confirmation (Bestätigung) [14], adds knowledge to the operators. Pragmatic information will support the operators action since it will make a difference to what the operators already know (by novelty) but at the same time also include pre-knowledge of the matter (confirmation) [14]. Neither 100% novelty nor 100% confirmation will make any different to the operators knowledge. 100% novelty does not contribute to understanding since the operators are not able to relate the information to any meaning and 100% confirmation does not comprise any new information at all for operators. Further, for information to effectively fulfil the users needs there are six qualitative criteria that are required if information should be useful: relevance, timeliness, accuracy, accessibility, comprehensiveness and format [15].

However, there exists differences between less experienced and experienced operators (e.g. [16], [17]). Thunberg [17] claims that the operators' level of expertise controls the information processed and the experienced workload. Both the type and the amount of information perceived differ between less experienced and experienced operators [17]. The skill and expertise of the operator affect the human behaviour, which can be categorised in Rasmussen's three levels of performance: skill, rule-, and knowledge-based (SRK) behaviour [16]. Each level of the SRK taxonomy defines different ways of representing the constraints in the environment and thus different level of cognitive control of the operator, see Figure 1. The skill-based behaviour (SBB) takes place without conscious attention or control and consists of smooth, automated, and highly integrated patterns. Rule-based behaviour (RBB) is characterised by pattern matching with stored rules derived from previous successful experiences. At the RBB level people are aware of their cognitive activities, and hence, can express the applied rules. Finally, the knowledge-based behaviour (KBB) is required in unfamiliar situations and demands a conscious, focal attention of the operator. In these situations previous experience is no longer valid and a solution must be improvised by functional reasoning.

The differentiation of human performance in SRK based behaviour means also differences in the way in which workers perceive and interpret information from the environment. To understand the relationship between the level of human performance and the way in which information is interpreted Rasmussen [16] introduced the concepts of signals, signs, and symbols. These three different types of information represent three ways in which workers can interpret information. During SBB, information is typically interpreted as signals. Signals have a strong perceptual basis because they are continuous quantitative indicators of the time–space behaviour of the environment. Signs, on the other hand, refer to the RBB of the operator. Signs are characterized as arbitrary but familiar perceptual cues in the environment. Information has to be perceived as symbols to be meaningful for KBB. Symbols are reasonable formal structures that represent the functional properties of the environment.

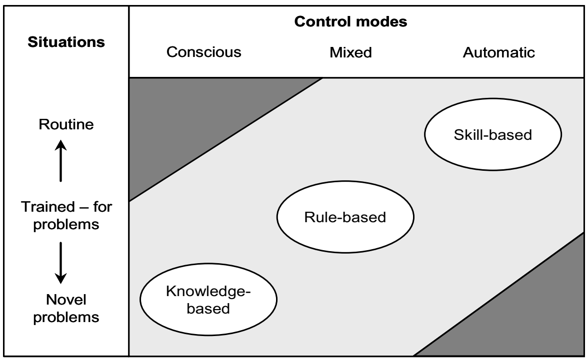

Figure 1: Control modes during different problem situations in production (From Reason and Hobbs [18]).

However, whether information is interpreted as signals, signs, or symbols relies on the context in which information is perceived and not only on the form in which the information is presented according to Rasmussen [16]. This means, that the very same object observed may be interpreted as a signal, sign, or symbol, depending on the intentions, expectations and expertise of the operator.

In order to analyse the information requirements for a range of activities, which mean different difficulties to different operators, it is useful to categorize activities according to the complexity of the activities (Figure 2). The activities that the operators in assembly systems have to handle in a proactive way are of diverse character. The activities needed to be performed by the operators are either planned or unplanned as well as how to handle the activity is either known or unknown. By supporting SBB and RBB in familiar tasks, more cognitive resources may be devoted to KBB. Unknown handling of unplanned activities is not considered to be a relevant option for defining information requirements.

To be able to control a situation the operators need to have knowledge about the cause-effect relationships that can be used for control. That is, in order to act in the right way, the operators not only need to know the result of the action, but rather the operators also have to understand the consequences of their acting. Petersen [19] enhanced the idea of von Wright [20] that it is important to make a distinction between what the operators are doing and what changes they brings about. Usually, the operators will perform control actions in order to bring about the desirable changes in the controlled system. However, the desired system change may just be a consequence of the doing and not the immediate result of action due to causal relations inherent in the controlled system. This means that the action performed by the operators will result in a system change that causes another system change (Figure 3).

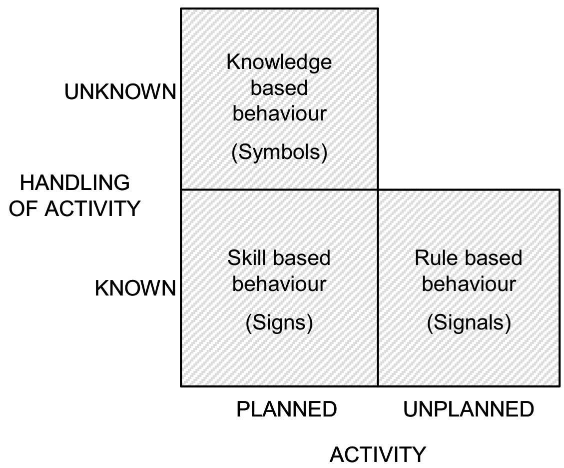

Figure 2: The relationship between complexity and performance (Modified from Fjällström [13]).

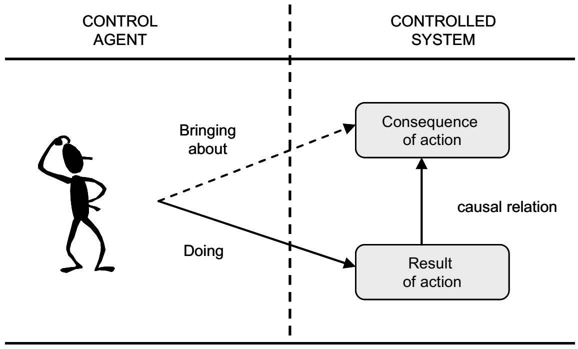

Figure 3: The doing and bringing about aspects of control actions (From Petersen [19]).

In a complex system like a proactive assembly system the potential actions of the operators are specified by constraints. The constraints can be classified as five different layers of constraints, namely: work domain, control tasks, strategies, social organization and cooperation, and worker competencies. These constraints are behaviour shaping [21] because they define the boundaries of possible actions for the operators. By identifying the constraints on operators' actions it is possible to embed them in the information system. Human operators then have the flexibility to improvise their action within the remaining space of action opportunities that are acceptable work strategies (Figure 4). According to Vicente [22] the constraint space will provide the flexibility that is required:

- To handle context-conditioned variability.
- To handle the intrinsic variability.
- To handle individual differences between the operators.

Hence, the approach based on constraints illustrated in Figure 4 helps operators to solve unanticipated situations and to follow their own choices (by choosing the preferred trajectory), while at the same time, fulfil the demands of the activity (by staying within the constraint boundaries) [22]. However, flexibility does not mean that everything goes. Therefore, it is important that the constraints remain identifiable, independent of how the operators choose to act.

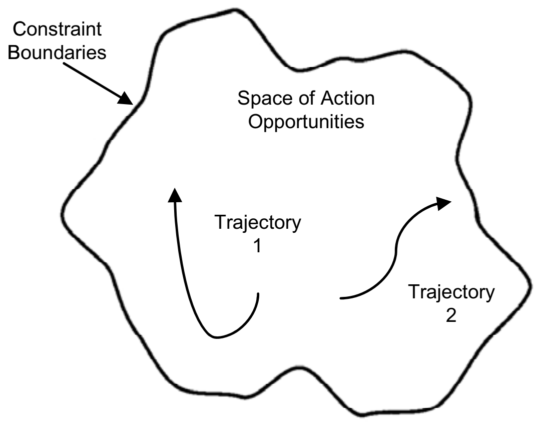

Figure 4: The available opportunities for actions by the operators are specified by behaviour-shaping constraints (Modified from Vicente [22]).

The study of Parker et al. [7] state that if a company wants to have a proactive work behaviour they should support a flexible role orientation (to define one's role broadly so that one feel responsibility for longer term goals), role breadth self efficacy (one's judgement about one's capability to perform particular tasks) and job autonomy of the operators. To facilitate the development of these characteristics, information needs to promote the flexible role orientation, to build employees' self efficacy and to encourage employees learning and development.

Moreover, the processing of information in organizations shall reduce uncertainty and equivocality [23]. The processing of rich information, which changes understanding within a time interval and thus enable debate, clarification and enactment will reduce equivocality. Additionally, organizations have to provide the right amount of information to facilitate a reduction of uncertainty. Yet, the challenge is to process sufficient information, that is not too little or too large amounts of data, in order to avoid frustration, confusion and time consuming activities (e.g. [24], [25]).

In general, the smallest amount of information required for the operators to keep the system stable is defined by Ashby's "Law of Requisite Variability" [26]. This means that to control a situation and to perform according to requirements, the variety of the control responses must as a minimum be as large as the variety of system changes that need to be compensated. Thus, the law of requisite variety has two important consequences:

1. The amount of information available determines the amount of appropriate actions that can be performed.
2. To be able to control a situation the variety of the controller must be equal or greater than the variety in the system being controlled.

Because the performance of the operators is influenced by the utilized information [27] and the information flow in an organization is seen as one of the predominant factors to higher levels performance [28] it is necessary to apply these information requirements in designing a system interface that controls the collecting, evaluating, organizing, and distributing of information. For example information should be organized in such a way that the operators have access to relevant information at the required time.

2.2 Information support system

The information support system is used to provide information and knowledge that supports different work activities [29]. The general aim is to design information support that enable human operators and technologies to work together in a more flexible and mutual control system which in turn functions reliably in complex work environments. Or to put it in the words of Hollnagel [30, p.221], the objective is to "provide the right information at the right time and in the right way".

Providing operators with a complete, accurate, and up to date picture of the situation will be the challenge as the work setting of the operators become more complex and demanding. Kasvi et al. [29] identified four parts of an information support system:

1. A source of information, supporting efficient, good quality, and safe completion of work activities.
2. Support is available on demand, in context with the task supported.
3. Information is accessed spontaneously and the order of access is controlled by the end user of information.
4. In addition to providing information, the system interactively supports the collecting, creation, and synthesis of the experienced-based knowledge of the members of the operative organization.

The actual form and functionality of an information support system depends on the work and people supported [29]. One important challenge is to develop an information system that simultaneously supports the use of existing knowledge and the creation of new knowledge as in proactive work settings. Therefore, the information support system has to include both reader-users (recipient of information) and author-users (ability to change and personalise the content of information) [31].

The SRK framework developed by Rasmussen [16] will support designers to combine information requirements for a system and aspects of human cognition. Designers can apply the SRK framework to determine how information should be presented to the operators to take advantage of their perception and psychomotor abilities [32].

It is important to have a broader functionalist perspective to the development of the support systems. The system does not only consist of the human operators and the machines, it also includes the work domain. It is important to understand that the human operators and the machines are integral parts of the work system (e.g. [31], [33], [34]) The importance of this perspective can be illustrated by Simons [35] parable of the ant. To understand the underlying rationality of the behaviour of the ant and its path along a beach it is necessary to see the path in the context of the beach. When the ant's path, on the other hand, is considered isolated from the beach it appears complex and the underlying rationality is not obvious. In consequence, if we want to learn about the ant's behaviour we need a description that recognizes the constraint arising from both the beach and the ant.

The interaction between human operators and their work has to be the focus in the design process. For the design of support systems, the above mentioned constraints, which define the boundaries of action opportunities, have to be analysed [22, 36]. The operators then should have the possibility to choose from different alternatives as well as the operators have different ways to gather information to make more informed choices. Moreover, the information system should support the operators to handle the limits of local decision making. That is, it should control that operators will only make decisions within the outer boundaries [22].

Information should furthermore help to avoid sub optimization of the proactive behaviour because operators are only parts of the system and need to cooperate. In interdependent systems, the behaviour of the individual has an impact not only on the effectiveness of that individual, but also in the effectiveness of others, including groups, teams, and the organization as a whole [3]

2.3 Implications for management

Since work in assembly systems is based on standardization, proactive behaviour implies to deviate from the standardized processes. Moreover, the opportunities of proactive behaviour of the operators may be limited due to little autonomy and control. Thus, to support proactive behaviour of the operators, organizations and individuals need to change. The traditional view of the operator as someone who is exposed to decisions by production management must be redefined towards a view of the operator as an actor and as a learning and collaborating individual. This poses problems of organizational solutions like raising the authority of the operators and the needed support from the organization. It also puts new demands on the technical solutions of the production system and the information system [37].

When operators have to make decisions on their own, it has to be considered how to handle the relation between local decision making of the operators and decision making provided by production management. The concept of proactivity always bears the risk of unexpected and unpredicted (and unwanted) outcomes because of the independent judgement and initiative of the employees [4]. As demanded, employees may go beyond given task descriptions.

Moreover, other organizational factors have to be considered when developing a proactive workforce. First operators need to adopt a more customer-strategic focused orientation since it will not be enough for shop floor employees to restrict their efforts to maximizing volume [38]. Organizations have to develop initiatives that enhance the understanding of modern principles (like increasing flexibility, continuous improvement, etc.). This will help employees to understand and create acceptance for principles that derive from broader strategic objectives.

Second, Freese and Fay [6] defines that employees need the right knowledge and skills, know when it is better to “give up”, and the degrees of autonomy have to have limits. Cambbell [4] suggest four strategies of which only the first three are in line to our concept in order to avoid the so called ‘initiative paradox’ (employees are expected to use independent judgement and initiative, and simultaneously expected to think and act like their bosses):

1. Goal alignment requires substantial alignment between the goals and interests of the organization and the goals and interests of the individual; the alignment of interests minimizes the likelihood of undesired, unexpected results.
2. Communication of boundaries, careful communication of the kind of initiative desired, and the limits surrounding these, initiative and judgement are encouraged only in circumscribed job or work situations.
3. Information sharing, minimizing unshared expectations by providing trusted employees with the same information and frame of reference that the managers use in running the work unit.

This is in line to Bateman and Crant [39] and Vicente [22] who suggest that the organization should make the core activities clear and define the outer constraints. After that, it is important to give the operators considerable degrees of freedom for decision-making.

Furthermore, research on control behaviour suggests that human control requires perception of being in control. A high degree of autonomy will increase the controllability of the task [7]. This is in line with Karasek’s demand and control model [40]. High demands will contribute to a proactive workforce only if combined with high levels of job control and social support. Thus, facilitating proactivity may require structural changes that devolve authority to the people on the shop floor – changes that can be quite difficult to achieve.

3 SUMMARY

It is widely accepted that a proactive behaviour is advantageous in today’s workplaces. Yet, operators need information that enables them to anticipate and plan for expected changes. This paper sought to address information requirements in a work setting enabling proactivity, by examining demands on information, the information support system and management.

Our findings are that there is a need to develop an appropriate information support system that considers both the operators’ cognitive abilities and demands on information. Since in the end, the ability to present meaning, rather than information is the most important factor to the operators. Moreover, we have shown that operators proactivity will not only put demands on information and the information support system but also on how to handle a much more delegated decision making and still avoiding sub optimization.

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