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## Managing production complexity by empowering workers: six cases

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### Abstract

To manage high product variety many companies empower their operators. Reaching the benefits of that is connected to successfully distributing role allotments and work tasks in the complex context. The characteristic of empowerment is studied in six cases where the focus is work tasks and power to affect the company. Results indicate that the workers are, in general, responsible for more than 30% of the tasks connected to the production but that they do not always have the power to make decisions that influence the organization directly. This could increase the companies' attractiveness as a future employer and its competitiveness.

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### 1. Introduction – the role of complexity

Increased complexity is one of the biggest challenges in manufacturing today [1]. Amongst the challenges is mass-customization forcing manufacturing systems to manage high flexibility, small batch sizes, small product volume and a high number of variants [2] at a low cost [3, 4]. In a complex production settings the human role is increasingly important [5] since humans are flexible and can handle the complex and dynamic context [6-8]. Therefore, managing complexity and thereby product variety is connected to improving the operator performance i.e. to decrease process errors, achieve high quality, achieve good working conditions, fast processes, quick change-overs and to decrease cost [2-4, 9]. Although complex systems are unpredictable, it is possible to find strategies to manage complexity i.e. reduce risk, handle uncertainty, control the system and catch benefits of having such a system [1, 10]. Producing companies also has demands regarding social sustainability that makes it important for them to be attractive to a workforce with varying age, skills and health issues [11, 12].

To manage complexity many companies have started empowering their workers. However, knowing how to empower and to implement empowerment is difficult [13]. Therefore it is important to study empowered operators and how their work in real life cases is characterized. For instance, a study of 2000 Canadian motor vehicle workers showed that they were not seen as empowered. The reasons were: they did not have the power to change their work, vary the work pace or to leave their workspaces (performing other tasks, like planning) [14]. Today this is especially interesting since many companies have a policy to empower their operators. Ahanotu stated also that in order to fully incorporate empowerment the workers also need to be part of the innovative work and fundamental change done at a company [15].

If the worker's role can be increased to include innovation and other work tasks this might increase the competitiveness of production companies.

### 1.1. Production complexity

Complexity in a system can be defined as something that is “difficult to understand, describe, predict or control” [16]. Weaver stated that complexity in a system is, given the systems parts, the difficulty in predicting the system properties [17]. Although complexity has been studied there is no common approach and many models are theoretical [18-21]. Chryssolouris et al. [21] state that in order to manage and consider a complex system the system needs to be quantifiable. However, since existing quantitative methods e.g. the entropy model [20], the operator choice complexity [22, 23] often assess objective aspects of complexity e.g. number of components and tools it is important to consider the subjective aspects. Studying subjective aspects means to study how different people perceive the complexity e.g. opinions. Personnel working with the assembly system may perceive an objectively simple system as very complex e.g. although a car has few and similar parts it can still be complicated to assemble [24]. Studying how the employees perceive their work is crucial in order to successfully manage and design the system [25-27]. Based on interviews with different roles in three producing companies production complexity was defined as: “the interrelations between product variants, work content, layout, tools and support tools, and work instructions” [28]. The aspects in the definition will be seen as focus areas, which contributes to that a station is perceived as complex. This definition will be used throughout the paper.

The management of complexity has been considered by different approaches e.g. by [29-31]. The word manage suggests that it is not evident that production complexity should be removed. This, since many times it is not possible to reduce the complexity due to market demands. Suggested ways to manage complexity are to *prevent* or *avoid* it [29, 30] and Wiendahl and Scholtissek [31] stated that complexity should be *reduced* and *simplified*.

### 1.2. Empowerment

Bowen & Lawler stated that the following features should be included for a worker to be empowered [13]:

- *Sharing information* on the organization’s performance,
- *Base rewards on that performance*
- *Provide knowledge* that make it possible for employees to contribute to that performance
- *Give the employees power* to make decisions that influence the organization performance directly

Wilkinson wrote about the following features: *information sharing, upward problem solving* (to both work and to choose which problems needs solving), *task autonomy, attitudinal shaping and self-management* [32]. A system should be managed in close collaboration with the workers [26, 33]. Grote stated that a systematic approach is needed to manage uncertainties and that it is important to include different organizational domains [33]. And although Taylor proposed efficiency which can be seen as disempowering [15] he stated: “...these foremen and super-intendants know, better than

anyone else, that their own knowledge and personal skill falls far short of the combined knowledge and dexterity of all the workmen under them” (Taylor, 1911, p. 30).

In real life practices the empowerment level of workers depends on companies need, knowledge and time. How the personnel manage the problems with complexity can depend on individual factors for example previous experience, knowledge, training, personality type, background and mind-set. These variations between individuals need to be regarded as well as the work tasks being performed. To grasp the perceived production complexity it is therefore necessary to gain an increased understanding of different functions and their needs in the organization [34].

### 1.3. Purpose and scope

This paper studies how companies have empowered their workers in six case studies. The goal is to describe the empowerment levels according to work tasks to highlight similarities and differences between the cases. The complexity level in the cases is assessed for a better understanding of the worker context. The organization, company vision and planned future work are excluded. Below follows a description of the cases.

## 2. Case studies

Six cases in six stations have been studied in four companies. The companies are all large to medium large with production facilities in Sweden. The products they work with range from medical equipment to machine tools. In several of the cases the operators work with machining or processing of products, while operators in case B and D work with final assembly.

The cases are derived from the project the Operator of the Future\* where they have different scopes (decided together with the companies). The aims of case A, B and D is to empower the operators while in case C and F the aim is to make information more accessible (for instance in order to perform better maintenance but also to some extent to empower the operators. Case E has the aim to increase the maintenance efficiency.

The cases have been classified in Table 1 according to their different contexts. It is a classification of the companies according to: number of product variants, batch sizes and the expertise level of the operators.

Table 1. Classification of companies

Case	Product variants	Batch size	Operators expertise
Case A	Many	Small	Mix, many Experts
Case B	Many	Small	Experts
Case C	Few	Large	Mix
Case D	Medium	Medium	Mix
Case E	Many	Medium	Mix many new
Case F	Few	Large	Experts

\* <http://www.vinnova.se/sv/Resultat/Projekt/Effekta/Framtidsoperatoren1/>

The operator work is described in general for each of the cases below:

Case A: The operators within this department cooperate with many things even though their work rotation does not work that well anymore. The operators work and plan their work mostly by their own knowledge, though, instructions are available they are usually not needed. These operators are also encouraged to develop the production as well as the company culture.

Case B: The operators are working with special customer orders in a self-sufficient way, which other operators in the company neither have the time nor the knowledge to handle. The managers and the ones already working there handpick the operators working here.

Case C: The operators in this case are working at two stations rather isolated from the other operators in the production line they are all connected to. They plan their work to the extent that they chose whom to work where but they do not have any control regarding the products.

Case D: The work here is both tending to machines and assembling the products after they have been machined. The station manages its work with the support of supply chain personnel planning the orders and what to be produced.

Case E: At this station the work is conducted around a large process. Most of the operators were hired from a similar process in an old factory a few years earlier when the new recently had been set up. Due to many issues during the start-up phase the operator tasks are still evolving.

Case F: The operators in this case were chosen for their level of knowledge and drive before the station even existed. The operators joined the team as it was installed and developed their own way of working.

### 2.1. Production complexity

To describe the complexity levels at each case a method called the Complexity Index (CXI) was used (for details see [35, 36]). The CXI gives an index on the station stating how complex it is regarding a few focus areas. The method follows the definition of production complexity studying the interrelations between the areas: product variants, work content, layout, tools and support tools and work instructions.

The method is a survey with 26 questions and shows how urgent the problem areas are ranging from:

- $0 < CXI < 2$ : green (no change needed)
- $2 \leq CXI < 3$ : yellow (need to change)
- $3 \leq CXI$ : red (urgent need to change)

The method has been used as a current state tool (see [28, 35, 37]).

It was seen that most of the areas in most of the cases are thought to be somewhat complex, CXI 2-3, to complex, CXI  $\geq$  3. The CXI measurement is presented in Fig. 1 (CXI for each station is presented in the last row of the table).

In comparison with earlier studies made with the same method, see [35, 38], the operators rated the work as more complex (CXI<sub>average</sub>=3.75 compared to CXI<sub>average</sub>=3.49

where more yellow and green areas could be seen). Additional background data can be seen in Table 2.

Area/ station	Case A	Case B	Case C	Case D	Case E	Case F
Product/variant	4,42	4,18	4,00	4,86	4,00	4,33
Work content	2,17	2,55	2,40	2,43	3,00	2,33
Layout	1,67	3,36	2,75	2,57	2,80	3,50
Tools and support tools	1,58	3,50	2,20	2,43	2,87	2,11
Work instructions	2,25	3,05	2,10	2,07	2,90	2,00
General view of station	2,75	3,55	3,22	3,14	3,23	2,75
<b>CXI</b>	<b>3,31</b>	<b>4,32</b>	<b>3,58</b>	<b>3,71</b>	<b>3,95</b>	<b>3,63</b>

Fig. 1. Results from the Complexity Index measurement

Table 2. Background data on comparison of production complexity at the studied cases<sup>a</sup>

	CXI average value	Number of companies studied	Number of respondents	Number of stations investigated
Presented cases	3.75	4	76	11
Comparison cases	3.49	3	30	14

### 2.2. Empowerment

Interviews were performed to investigate the empowerment of the operators. As a basis for the interviews a concept model to evaluated role allotment was used to evaluate how much control the operator has (both in terms of proactive and actual work [39]). The model is a combination of Sheridan's five operator roles [40]: Plan, Teach (programming), Perform, Intervene, and Learn and work tasks in an automatic assembly system (presented in [41]). The model has shown relevant results in fifteen industrial cases [42] and is presented in Table 3. The input to the concept model is based on interviews (based out of the 17 points in the table, Table 3). The output is divided into three categories: operators only, partly operators and others [42].

Table 3. Role allotment

Roles	Type of tasks
Plan	Process planning and production engineering Long time planning (>2 weeks) Short time planning (1-2 weeks)
Teach	Programming for a new product Material handling Order handling Set up
Monitor/perform	Manual assembling Manual assembling Monitoring machines Maintenance
Intervene	Disturbance handling - Lack of material - Small disturbances - Large disturbances
Learn	Quality check of product and system Continuous improvements Learning new working tasks Teaching new operators

### 3. Results

The shares of tasks conducted by the workers were large in several of the cases compared to other companies. The workers were in general responsible for over 30% of the tasks. The aggregated results from the role allotment model can be seen in Fig. 2. In a study by Fast-Berglund & Stahre, operators were responsible for on average 19% of the tasks [43]. Results show that operators with the widest responsibility level, cases A, B and D, conducted more than 40% of the tasks themselves.

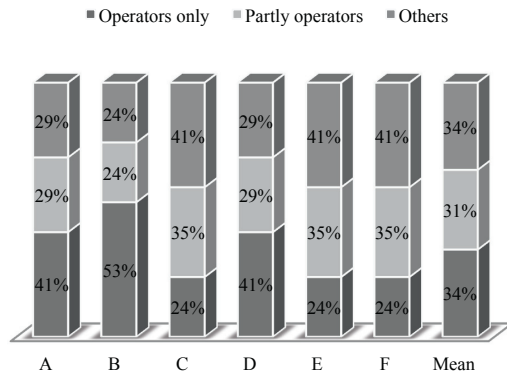


Fig. 2. Results from the Role allotment analysis

The cases were compared according to the empowerment features suggested by Bowen & Lawler [13] and Wilkinson [32]. *Information sharing* was in many cases carried out in the companies. In all cases information was daily given to the operators regarding the performance in their own area. Information about the whole company or factory was given more seldom. Bonuses *based on the performance* were sometimes given to the operators. In case B the operators got a bonus if they were able to produce the products without any major stops. *Basic knowledge* on how to affect the performance is usually provided by the company. Often experience is built from within the team while companies provide basic training. All companies have to some extent given the workers power to make decisions. For cases C, D and E this decision-making is somewhat limited, one of their typical decisions regards division of tasks within the shift. *Attitudinal shaping* was partly seen in case A. Here the workers were part of creating their own company values instead of receiving them from the managers. The operators were not participating in attitudinal shaping in any of the other cases.

How much the operators were able to effect different parts of the company is seen in Table 4. Bowen & Lawler [13] suggested that the level of empowerment ranges from production line, suggestion involvement, some involvement to high involvement. The level of empowerment was divided further into station, line, other line, factory and organization (see Table 4). X denotes that the operators have possibility to effect and O that there was some possibility to effect the company. Station relates to the station or cell the operators were working at, line relates to the line to which the operator and the products he processes belongs, other line are those the operator does not belong to but are in the vicinity. The possibility to influence varied between the cases. Occasionally

the operators had possibility to effect decisions at factory level, often because they are put forth as good examples.

Table 4. The level of effect the workers had on different dimensions of the company

Case	A	B	C	D	E	F
Station	X	X	X	X	X	X
Line	X	X	O	O	O	O
Other Line	O	N/A		O		
Factory	O	O				
Organization						

During the studies it was noted how the managers speak about their employees. It was common that the knowledge the operator has is well respected and the managers trust it when making decisions. At a few places, case A, B and F the managers also described their operators as experts and some of the best. These operators also got much responsibility for the work.

When asked what they thought was the best with the work approximately half of the operators, from most cases, told it was the empowerment, problem solving and the possibility to structure their work. In two of the cases, A and D, the operators stated that it was good to have defined roles were others had responsibility for certain tasks as planning. Thus, there was no desire to have additional tasks and responsibilities.

### 4. Discussion

#### 4.1. Production complexity

Production complexity could be managed through *preventing* or *avoiding* [29, 30], *reducing* or *simplifying* complexity [31]. This is done instead of removing complexity, which is in many cases not possible due to market demands. One way to do this is to empower operators i.e. increase their level of experience and decision power. This could help *prevent* uncertain outcome, *avoid* product errors, *reduce* the number of unknown problems, and planning done by the team leader. This could thereby *simplify* the production planning since the operators in a sense plan their work themselves.

The operators are all working in complex production where giving workers power is crucial in managing complexity. This was seen studying the CXI measurements done at the companies. The measurement was based on the definition of production complexity where focus areas included product variants, work content, layout, tools and support tools, work instructions and the general view of the station.

#### 4.2. Empowerment

The cases have shown characteristics of empowerment where work tasks, workers view and the managers view gives an input on how complexity can be managed.

Studying role allotments gave an interesting view of what additional work the operator performs. However, the aggregated description of the operator tasks (Role allotment analysis) did not give detailed enough information to judge the operators level of empowerment. Specific tasks need to be studied to understand the responsibility level and possibility to affect the work. None of the operators perform the long time



planning but the operators in case A and B, though together with manager in A, perform the short time planning on which orders to start when. Most of the operators work with continuous improvements to some extent. However, at the interviews the level of encouragement to the operators was different and was highest in case A, E and F. At these stations the operators were encouraged to develop the work, decide which tasks to perform when and why. The reason behind this result could be that the stations in case E and F were recently created and routines and work tasks had to evolve as the stations did.

In the cases where the operators performed the largest share of the tasks themselves, case A, B and D, workers could also influence not only their own station but also their line and to some extent the factory (*give employees power*). In case A management tries to create a strong engagement and commitment from the operators and many do have a strong commitment and wishes to improve the processes.

Based on the empowering features [13] the workers in all the cases are empowered since they are given *decision-making power* (to various extents). The degree of how they can affect the organization differs. However, workers in the case companies still miss features for the operators to be fully empowered. These features could be important to attract new personnel, which is a big challenge connected to managing the complexity. Having a work where you are an expert is important, but it is equally important to be able to control and be a part of *attitudinal shaping* and for instance *knowledge development* [13, 15, 32]. Frederick Winslow Taylor believed that humans could be seen as resources that should work under maximum efficiency according to the natural abilities that fit the person [25, 26] In order to do that, he stressed that the person should receive training and be developed so that he or she could learn to do his work in the best possible way. Taylor also stated that the workers knows most about the work which is in line with what was seen in the case companies, especially in cases A, B and F.

To what extent the workers should be empowered could be connected to the general managerial style and company culture. For instance in case A the sick leave is very low and the average year of being employed is 29. Even though this could be due to that the company is situated where there are not many other employers, it is also a success story of how workers could be empowered. This is true also since operators are seen as experts, *attitudinal shaping* is continuously developed and workers are happy to be empowered. The same is seen in case B, where the workers have a big freedom.

The Role allotment model combined with the level of effect the workers have on different dimensions of the company (Table 4) were useful tools for studying the empowerment of the companies.

## 5. Conclusion

This paper shows the empowerment levels of six case studies. It was seen that the workers were all working in complex contexts and that they had differences in the amount of tasks the operators are performing, in the decisions they can make and knowledge they receive. Compared to other case

studies they are in general responsible for more than 30% of the tasks. However, they do not always have the *power to make decisions* that influence the organization. By increasing the level of *attitudinal shaping* and for instance *self-management* production companies could better empower their operators. To fully empower the workers this could include innovative work and fundamental changes. In addition, this could increase the companies' attractiveness as a future employer and its competitiveness.

The paper gives an interesting perspective of how managers perceive their workers and how the worker perceives the work. In addition, it explores how empowerment can be assessed by using a Role allotment model complemented with the level of effect the worker have on different dimensions of the company.

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