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NOTES

Work Environment and Production Development in Swedish Manufacturing Industry

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Swedish manufacturing industry has previous held a leading position regarding the development of attractive industrial work environments, but increasing market competition has changed the possibilities to maintain the position. The purpose of this literature study is therefore to describe and analyze how Swedish manufacturing industry manages work environment and production development in the new millennium. The description and analysis is based on recently reported Swedish research and development. The gathered picture of how production systems generally are developed in Sweden strongly contrasts against the idealized theoretical and legal view of how production systems should be developed. Even if some of the researchers' and authorities' ambitions and demands may seem unrealistically high today, there still is a very large potential for improving the processes and tools for designing production systems and work environment.

work environment production development manufacturing Sweden

1. INTRODUCTION

Swedish manufacturing industry has previous held a position as a precursor regarding the development of attractive industrial work environments. Well-known are, e.g., Volvo's assembly factories in Uddevalla and Kalmar (Sweden) that were developed during the 1980s and 1990s [1, 2, 3, 4]. These factories replaced traditional assembly lines with assembly work in groups, so-called reflective production. The physical design of the plants was also supporting the new way to organize work.

The situation in Swedish manufacturing industry has changed today and there is a clear and general trend to return to serial line-based production from more sociotechnically concepts [5]. The task to develop attractive and health-promoting work environments at the same time as developing competitive production systems is very difficult today, especially regarding that the Swedish manufacturing industry competes with industry in low-salary countries on a global market where working conditions differ very much and this directly influences the cost competitiveness. The economic prerequisites for maintaining and developing attractive work environments in Swedish manufacturing industry are not optimal. It is therefore interesting to try to describe and analyze how the development of the work environment and production in Sweden has been performed over the last decade.

2. PURPOSE

The purpose of this study is to describe and analyze how Swedish manufacturing industry has managed work environment and production development in the new millennium.

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3. METHODS

A broad literature study has been performed using digital databases and search engines. Both literature in Swedish and English has been searched. Key words used in different combinations have been manufacturing, industry, factory, production, assembly, development, work environment, health, safety and work organization. Search with the first six key words resulted in many hits but when search was combined with the final four words the number of references was reduced. Relevant literature has also been identified from reference lists in articles and handbooks. Finally 49 references have been used in this paper. The description and analysis is mainly based on recently reported Swedish research and development.

4. RESULTS

The results of the literature survey are presented as three pictures, first a theoretical one, secondly a picture of present production and work environment development in practice, and finally a picture of the future.

4.1. Production and Work Environment Development in Theory

The development of industrial production and the work environment is an extensive and complex field, which is why few researchers have tried to grasp it in its entirety. Instead most researchers have chosen to limit and deepen their research within already established smaller fields. There are however some bold exceptions.

4.1.1. Holistic thinking, context and production strategy

Bellgran and Säfsten presented a general theoretical framework for developing production systems and work environment where holistic thinking and context were central together with basic production strategy [6]. They regarded production strategy to be a "handrail" for production development. They stressed the importance of knowing how to work in three major phases: planning, design and realization. These phases were related to the current context where the context and performance demands formed the basis for development. The theoretical framework required a local adaptation and it was considered best if every company gradually created its own company-adjusted way of production development. Tangen, von Axelson, Dencker, et al. also focused on strategies and production development and, to some degree, discussed work environment design [7]. They outlined ways to base the production system design on business strategy and expected to publish more precise methods for detailed design. The importance of and correlation between production strategy and ergonomics was especially discussed and stressed by Neuman and Winkel and colleagues in a number of articles [8, 9, 10, 11, 12, 13].

4.1.2. Specification of demands—important in designing and evaluating the work environment

The idea of providing guidelines and specified demands for production design engineers or teams has been kept alive both by researchers and practitioners. For example, Berggren, Ellegård and Holmgren published a proposal for a check list for The Good Car Factory, where they specified demands and presented ways to realize work environment and organization goals [14]. More recently Lindelöf presented a proposal for a general and flexible tool for integrating work environment factors during production design in an international context [15]. Lindelöf's tool covers the different phases; concept, prototype, implementation and running project. For each stage the tool specifies demands and important questions on three levels; regulatory, culture/branch and company specific. Bellgran and Säfsten also clearly stressed the importance of specifying the demands, both for guiding the production design and for evaluating solutions, e.g., regarding workplace design and ergonomics, in early as well as late design stages [6].

4.1.3. Layouts and work organizations are interrelated—a holistic view is important

Layouts and work with layouts are central for production logistics, production technology, production economy, but also for work organization and the work environment. Bellgran and Säfsten gave clear recommendations how work organization and the work environment should be dealt with when choosing technology level and automation [6]. Work organization should be designed parallel and integrated with the technical system, since the choice of layout controlled and limited the choice of work organization. The design of work organization was strongly related to both the physical and psychosocial work environment.

Ranhagen stressed the importance of strategic holistic physical planning and design of industrial sites, buildings and workplaces to achieve attractive, well-functioning and sustainable results [16]. Early participation from the intended work force was crucial according to Ranhagen. Instead of speeding up initial planning and design phases it was better to extend these phases. With thorough initial planning and design the execution of plans would be smoother, quicker, cheaper and less problematic. Ranhagen recommended a holistic, cyclic and iterative design process with a successively more detailed design work.

4.1.4. SWEA's demands on workplace design and systematic work environment management

The physical design of factory halls, premises and work equipment is crucial for both the physical and psychosocial work environment. The Swedish Work Environment Authority's (Arbetsmiljöverket) (SWEA) provision AFS 2000:42 applies to all types of business [17]. This provision specifies numerous general demands on the physical design of the workplace. SWEA's general advice regarding the application of AFS 2000:42 clearly explains the importance of considering the work environment already in the early design stages. Despite this emphasis and insight the authority has chosen to focus on developing the work environment in existing workplaces. The development of the work environment in workplaces in production is primarily regulated by the provisions of AFS 2001:1 [18] and AFS 2003:4 [19], which are the most important general work environment provisions in Sweden. They point out the importance of preventive actions, co-operation between management and labor, participation of all employees and continuous improvement. The basic improvement process is not prescribed in detail and has to be adapted to the needs in specific businesses or industries [18, 19, 20].

4.2. Development of Production and the Work Environment in Practice

Theory is one thing and practice is another. This raises the question of the practice of the development of production and the work environment in Sweden.

Swedish industry management is strongly influenced by both theory and the current international management context; Johansson and Abrahamsson call the result of this influence a "Swedish dialect" [21]. There are also a number of relatively recent reported case studies that show how development work has been carried out in both new and existing production systems [22, 23, 24, 25, 26]. Most of the studied companies had 100–200 employees and were assembling medium-sized and complex products. Still these studies only gave a limited view on how problems of the work environment were managed during production development, since the work environment was not a prime study object. Andersson, Hägg and Rosén revealed the type of strategies, methods and practices for work environment management used in Sweden in 2004 [20]. They did not however present any strategies, methods or practices for work environment management in connection with the development of new production systems. Instead focus was set on developing the work environment in already existing production systems.

4.2.1. The Swedish management dialect

Johansson and Abrahamsson described how a Swedish version of present international management concepts developed into what they called the Swedish dialect with its four clear features [21]:

- rational flows in traditional assembly lines or in product groups linked in a flow;
- integrated product groups with work organization based on flows or processes;
- flat organization with more decentralized decision-making and more delegation of tasks and responsibilities;
- learning at work, competence development to manage rapid changes of demands.

These features are characteristic for the development work in many Swedish industry companies, together with the idea of "lean" production, which dominates among present management philosophies. The Swedish dialect has a clear and conscious balance between demands on rationality/productivity and good work conditions.

4.2.2. Constant change and the reasons for change

In a study of 11 companies representing the average within Swedish manufacturing industry, Christmansson and Rönnäng found that all those companies were executing major changes or had recently completed such changes [24]. The study indicated that constant change had become the norm in companies.

Bellgran and Säfsten came to the conclusion that the development of Swedish production systems in practice was influenced by many factors, which could be grouped under three headings [6]:

- external influences;
- strategies and basic values among present designers and decision-makers;
- relevant alternatives/choices during the development of production systems.

The most common reason for changing a production system was that new products and new versions of products were introduced and that the present manufacturing system could not produce them. Other common and attributing reasons for change were the need to improve capacity, flows and work organization, but also the need to improve the work environment and ergonomics. External influences often dominated together with some internal reasons when radical changes were made. For more limited changes internal reasons dominated [6]. There was also a great diversity regarding the goals of and needs for change, development practices and methods. The goals presented mainly improved economy; increased capacity, production volume, quality, the work environment and ergonomics; but also reduced lead times and cycle times. When production systems were designed different assumptions, limitations and demands were regarded, e.g., variations in production volume, expected production capacity, demands on adjustment time. More seldom were the personnel's needs specified regarding work content, working hours, etc. [24].

4.2.3. Company culture, design process and project leaders have a great influence

Bellgran stressed that the importance of the company culture should not be underestimated when it came to how production systems were developed [23]. The company culture was a carrier of the silent knowledge that was accumulated among the employees.

The system design was heavily influenced by the way design work was carried out (the process) and by the persons joining and steering the project group. The members of the project group however did not regard the actual design process as a tool to create the best solutions. The design process was therefore not emphasized and this resulted in a lack of structure and system in the design work. Much of the performed work was intuitive and was characterized by ad hoc solutions. There were however a few companies that used a more structured and goal-oriented approach to work, with clearer objectives and more expected deliveries. Participation of workers/operators was usually limited to the opportunity to comment on different conceptual solutions, often layout

drawings. Labor union power and influence was in general low in the studied companies [6].

The project leaders, the system designers, had a key role in the design process. They were often chosen with regard to the expected technology level in the new assembly system. The members of the project group (typically 2–4 persons) were usually recruited from a function/department for production technology, where they worked as production engineers or technicians [22, 23]. When some other type of competence was needed other internal specialists were engaged, e.g., health and safety experts. External competence was seldom used.

4.2.4. Layouts were central, much was copied and little was simulated

Factory layouts were often central in the practical redesign work that was carried out. Layouts were the basis for discussions and work with new solutions. A standard procedure was to sketch a number of alternative solutions and thereafter, also quite quickly, pick one concept for further development in detail. Decisions were made after discussions and evaluations among the members of the design group. The evaluations were often intuitive and unsystematic. In a few cases demands were specified and used for evaluating conceptual solutions. The main argument for not using specified demands was that such demands were needed only when expensive and complex equipment was to be bought from external suppliers. It was also quite common to copy old solutions when it came both to technology and work organization [6].

No numerical simulations were performed in the 25 companies studied by Bellgran and Säfsten [6]. Instead they used two-dimensional drawings of factory halls, machines and equipment (in scale). Drawings of machines and fittings where cut out to test and intuitively evaluate different layout alternatives. Christmansson and Rönnäng reported a study of 11 companies consisting of two main groups [24]. The smaller group had used different simulation and visualization tools during production development work, while the larger one had hardly used such tools.

4.2.5. Suppliers were chosen first—production system later

Bellgran and Säfsten showed that when the companies used machine or system suppliers to design the most suitable solutions they often aimed at finding the best supplier rather than finding the best technical solution [6]. Reference companies, where similar solutions were used, were often visited. Impressions from such visits were often crucial for the choice of supplier. Important aspects were the supplier's general reputation, service and continuity. Some companies went so far that they first of all decided on the supplier before they developed and discussed any conceptual solutions.

4.2.6. Systematic evaluation of outcome was unusual

It was unusual to systematically evaluate the effects of an accomplished change. Bellgran and Öhrström analyzed 10 companies [22]. No thorough systematic evaluations of the built assembly systems were carried out in those companies. Often there was no specification of demands or goals to base a systematic evaluation on. Instead management was satisfied with the daily feedback they received from the running systems.

4.2.7. Obvious shortcomings in the development work

Christmansson and Rönnäng pointed out five obvious shortcomings in the development work in the 11 companies they studied [24]:

- few companies had a clear structure for their development processes;
- there were no routines for competence development and transfer of experience;
- the development methods did not function in a satisfying way;
- the new assembly systems were seldom evaluated;
- the development processes were not evaluated at all.

Those shortcomings surprised Christmansson and Rönnäng, especially considering the high

costs of production development. Lack of time, lack of knowledge and lack of tools for evaluation were the reason for no evaluation.

4.2.8. Big companies have their own work environment design processes and tools

Many big companies have their own design processes and tools for assuring proper ergonomic design, e.g., Volvo [27, 28, 29, 30] and SAAB [31, 32, 33]. The car industry has the most developed tools and programmes. Participation and ergonomics expertise are key factors for success, but participation can also be very resource-demanding and require support from the management and the trade unions [30]. However few companies see good ergonomics as an important part of the overall business strategy. In most cases ergonomics programmes are regarded as pure health and safety matters [27], although several studies have shown that investments in work environment improvements are profitable and increase quality [34, 35, 36].

Dukic, Rönnäng and Christmansson showed that computer manikins were useful tools in verifying ergonomics in product design and assembly early in the development process. However, there was a large potential for improving both software and work processes of those tools [37]. Their case study at Volvo Car Corporation also showed the need for knowledge on virtual simulations when it came to analyzing and interpretating results. Laitila reported similar results [38]. A major criticism of computer manikins was that simulation and analysis with their use were very time consuming [38, 39] and thereby also very expensive.

4.2.9. Work environment management in companies

An evaluation of the work environment management activities in Sweden in 2004 produced a summary of strategies, methods and practices for work environment management [20]. Research in this field mostly focuses on smaller businesses with little research on larger companies. Many facts indicate that work environment management activities in large companies are still to a high degree performed outside the normal organization, in spite of the clear demand by SWEA that the work environment should be managed within the companies' regular organization [18, 19].

Systematic work environment management is clearly more used in larger companies than in smaller ones (Table 1). Large industrial companies with a dangerous physical work environment conform best [20, 40].

Relatively few Swedish companies (147 in 2007) are certified according to the voluntary standard OHSAS 18001[1] for work environment management [41]. SWEA does not approve of this standard because it differs from the compulsory provision in a number of ways, e.g., regarding distribution of tasks, demands on co-operation and documentation [20].

Laring and Christmansson stated that the internationalization of the manufacturing industry influenced how the work environment was managed in Sweden [42]. Major decisions were

TABLE 1. Application of Systematic Work Environment Management (SWEM) in Swedish Companies According to the Number of Employees (in 2004) [41]

	Companies (%)						
SWEM	**≤4**	**5–9**	**10–19**	**20–49**	**50–99**	**100–499**	**>500**
Not introduced	45	25	25	20	18	13	11
Introduced	40	39	31	33	31	35	34
Applied	15	36	43	47	50	52	55

[1] British Standards Institution (BSI). Occupational health and safety management systems—specification (Occupational health and safety assessment series No. OHSAS 18001:1999/2007). London. UK: BSI; 1999/2007.

made in the central offices of international concerns, far away from the factories in Sweden. This situation diminished the possibilities for employee participation in decision-making and in having insight in the decisions that shaped the work environment. Also Andersson et al. [20] pointed at problems caused by some foreign ownership. Lacking respect for employees and traditional Swedish employee participation in decision-making caused deterioration of the psychosocial work environment. Frostberg stated that concerns were not employers in legal terms and therefore they had no legal responsibility for the work environment within the companies in the concern [43]. This responsibility was instead placed on the companies who had to cope with demands from both concern management and the authorities.

4.3. Production and Work Environment Development in the Future

A clear global industrial structural trend is of great future importance for Swedish manufacturing companies. There is already a significant outsourcing to other countries and a great uncertainty about further development. It is obvious that outsourcing decreases the demand for simple low-wage jobs in Sweden and increases the demand for more qualified and better-paid ones [44].

Experts who participated in the Swedish Technology Foresight 2003 project described a number of fields that would be crucial for the Swedish manufacturing industry in 15–20 years' time [45]:

- large volumes of products adapted to individual customers;
- individuals and companies acting globally but existing locally;
- products developed and produced in networks;
- new possibilities created by selling functions;
- intellectual capital being the most important competitive factor.

Säfsten and Aresu also described the development of future production; they asked representatives from 15 companies to describe their future production system [25]. The common denominators were as follows:

- line layouts, assembly lines;
- clear distinctions between subassembly and final assembly;
- sequential assembly;
- modularization of product and process.

A further feature was a decreased need for mechanization in final assembly, thanks to a better design of the products. Automatic and complex assembly systems were unnecessary because of prior experiences of such systems (low availability). Instead companies wanted simplicity in production, which was in line with lean production.

4.3.1. Lean production and work environment

A continued and strong development of lean production can be regarded as a concept for the future since many companies so far have only tried limited parts of the successful lean concept (mostly reduction of waste in processes). According to Liker this stood for U.S. companies [46] but Bellgran and Säfsten believed that the situation in Sweden was similar [6].

The influence of lean production on the work environment is disputed. Research did not give a clear picture except that the opinions and conclusions about the effects could be divided into two groups [47]:

- lean production was by definition positive for the work environment because a waste of human resources (poor conditions, injuries, etc) would be gradually eliminated;
- lean production had a negative effect on the work environment, health and attitudes.

Berglund concluded that lean development gave great opportunities both for a good work environment and high efficiency, but it did not happen automatically and it required great awareness and a will to make the possibilities come through [47].

Johansson and Abrahamsson [21] described the massive impact of lean production on

Swedish industry and showed both pitfalls and possibilities for what they call The Good Work, a Swedish trade vision from 1985 [48]. They also presented an alternative called The New Good Work, which had five main features:

- the group as the lowest planning level;
- learning that included general/generic knowledge;
- integrated operator maintenance;
- affirmative action for under-represented groups;
- systematic work environment management efforts.

This alternative was suggested to be implemented in a lean context, where employers were expected to be against the alternative. The future of The New Good Work was therefore still to be decided.

4.3.2. Proactive assembly systems—assembly systems of the future

The present development of Swedish production has a clearly reactive character where actions are responses to changed external demands [6, 49]. Dencker, Stahre, Gröndahl, et al. [49] also saw great opportunities to instead develop so-called proactive assembly systems, characterized by "knowledge workers", extensive information and automation. An emphasis on human resources was also a typical sign of the system. The possibility to dynamically distribute tasks between humans and the technical system, whenever needed, was another sign. Dencker et al. [49] suggested that proactivity was strongly influenced by the levels of automation, information and competence among operators.

Neuman and Winkel [8, 12] concluded that the process of developing a production system was changing from a reactive to a proactive approach. They found support for this in their own studies at Volvo Powertrain where they studied how ergonomics could and should be integrated in a company's daily development work. On the basis of the research results some practical recommendations were stipulated. The recommendations were addressed to persons who were working with practical production development and who wanted to create competitive systems with good ergonomics. Neuman and Winkel stressed the importance of having a company management that supported the idea of a sustainable production system where production and ergonomics were co-optimized.

5. DISCUSSION AND CONCLUSIONS

The gathered picture of how production systems are generally developed in Sweden strongly contrasts with the idealized view of how production systems should be developed. Even if some researchers' level of ambition may seem unrealistically high today, there is still a great potential for improving the processes and tools for designing production systems and work environments.

It is obvious that work environment issues today in practice are low in priority and that the development of the work environment is often separated from production development. It is also obvious that aspects of the work environment are often dealt with late in the production development process and thereby also have become less cost and result efficient. Probably this is so because the designers do not know how to, in a reasonable way, bring in the work environment aspects early in the processes. Here human work sciences face great challenges and possibilities.

Big companies like Volvo use modern computer technology to virtually model and simulate their production before anything is physically built in their factories, but too few of the small and medium-sized companies use this modern technology. Here a change must take place and computer-aided design technology is an excellent tool for improving personnel participation. It is also important that the software for ergonomic simulation becomes less time-consuming and expensive, more user-friendly and provide reliable results.

Looking at the Swedish Work Environment Authority's actions one can question why the authority does not emphasize AFS 2000:42 [17] more than they actually do. Instead the authority

has chosen to focus on AFS 2001:1 [18] which mainly deals with continuous improvements in small steps. If workplaces are given a poor design from the start it will be very hard and expensive to improve the situation by continuous improvements in small steps. This speaks for more focus on AFS 2000:42.

Regarding AFS 2001:1, there are big differences between legal compulsory demands and common practice [18]. The differences are especially large in small companies. Also here the major reason for this might be that managers and others do not know how to carry out the compulsory tasks in a reasonable way. SWEA ought to improve and extend their efforts and guide small and medium companies to find well-functioning solutions.

A special problem for SWEA is that industrial concerns in practice have a major influence by setting business demands, goals and restrictions for the companies that are included in the concern. This has great impact on how work environment management is performed and what this work results in. The legislation ought to be revised so that also concerns are given a clear and reasonable responsibility for the work environment. This is an important task for the Swedish government and parliament (Riksdag) to decide on.

How shall the manufacturing companies in Sweden be able to survive and at the same time sustain developing good work environments? The most obvious, but not simple way, is that Swedish companies must become significantly better in developing production and work environment and use that competence as an effective tool for market competition. The companies already seem to be in a state of constant transition and especially then they cannot afford inefficient and expensive change processes. They also cannot afford to mismanage the probably most important competitive factor in the future, which is the flexible and highly competent workforce. A more proactive attitude and a continued concentration on the operator's high competence and good general work conditions might be parts of the solutions for the future. Here the Swedish universities have a very large responsibility when they plan and decide on education programmes for future production developers.

Last but not least, it is important that production designers and developers must adopt a critical attitude to the presently dominating lean philosophy. It is obvious that this philosophy contains elements that can create unacceptable work conditions and such elements must not be ignored. Also here the universities have a very large responsibility when it comes to the content of the education programmes and implementing critical thinking among engineering students, future production designers, developers and managers.

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