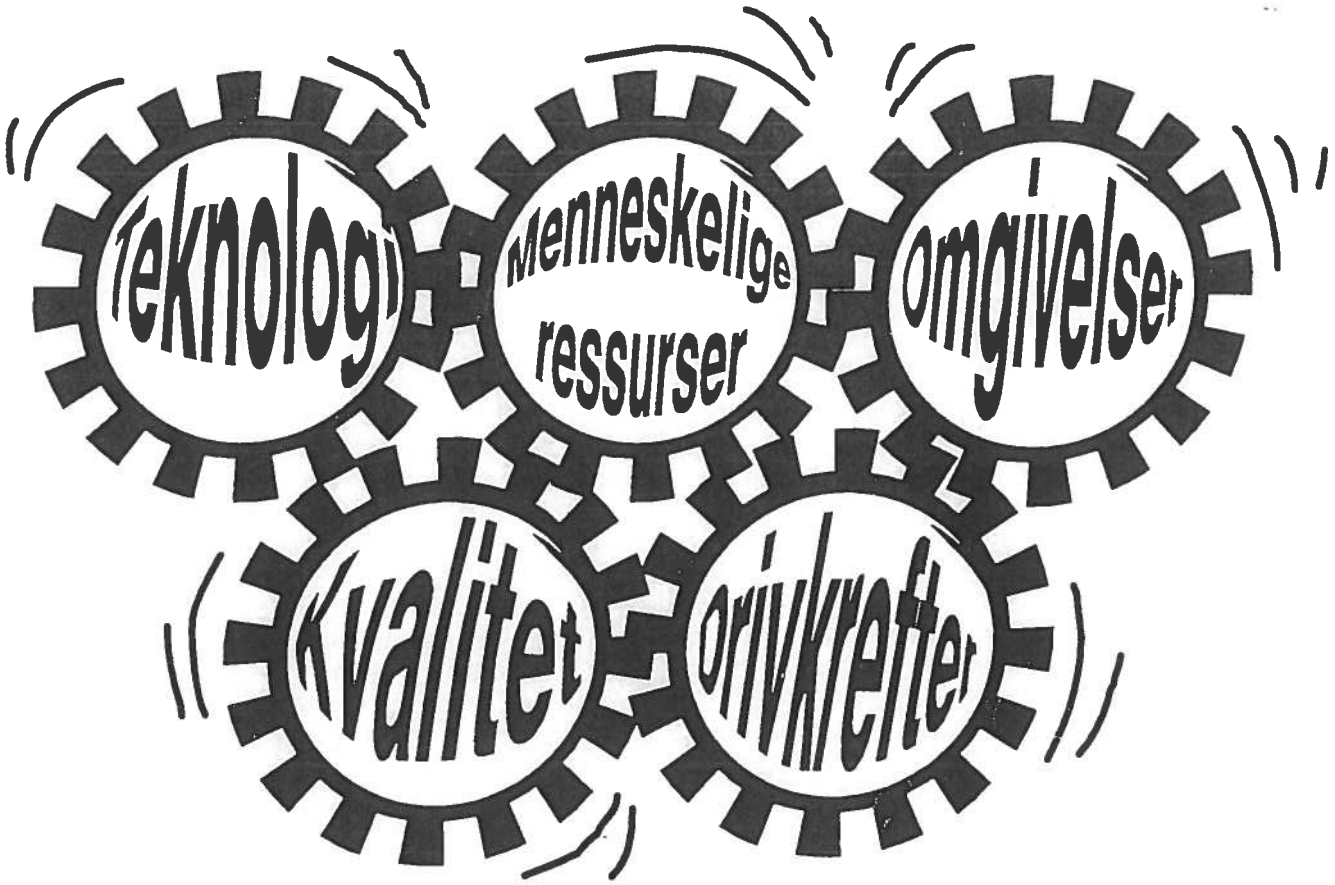

MENNESKET OG OMGIVELSENE - I TAKT ?

23-25 SEPTEMBER 1992
Lillehammer Hotel

6.1.27

NORDISKA ERGONOMISÄLLSKAPET
NORSK ERGONOMIFORENING

Principles and Promises of Reflective Production

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1 Background

As discussed earlier [1], traditional mass production as found in the motor vehicle industry is based on a rigid and extensive division of labour and a serial production flow, usually implemented by means of a paced assembly line. Line assembly appears rational in that material flows are well-defined, a familiar material feeding technique is available etc. During the last decade, the traditional assembly line production has been strongly criticized, however. To a greater extent than is generally recognized, considerable productivity losses are inherent in line assembly. This is mainly due to the natural human variation in working pace, the sensitivity to disruptions, the difficulty of balancing the work operations, and the need for extensive inspection and adjustment of the objects assembled [2].

In traditional line assembly work, the individual's working pace is controlled by the movement of the assembly line, and the work is fragmented – the main reason for the latter being, of course, the line itself, but also in some Swedish cases the way of describing the product and organizing the pre-production work, which has led to inadequate perceptions of the product. (It was thougt to be far too complex and contain too many components to be possible to assemble by one work team [3].) These working conditions on the shop floor have led to high levels of employee turnover and absenteeism, and have undermined the sense of responsibility for product quality.

Internationally, the pre-dominating trend has been to refine line assembly to address some of these problems. Some common techniques for improving line assembly are Kanban, Kaizen, visual control, quality circles, team work, standardized work, product standardization, extended subassemblies, etc. The expression lean production, originally coined by Krafcik [4, 5], was used by Jones et al. [6] to refer to a production form incorporating such improvements on traditional mass production and possible to characterize in terms of main concept, flow pattern, human aspects and division of labour.

Lean production is similar to traditional mass production in that it includes bureaucracy and Taylorism. Lean production systems have developed these work organizations methods further and are mainly focused on creating participation rather than autonomy. These production systems have highly formalized and standardized organizations designed to support effective learning and innovation, where the workers participate in developing the rules that govern their work. An important element is that standardization/formalization facilitates innovation on the shop floor, since the production process itself becomes possible to understand [8]. To motivate the workers in such production systems it is essential that the authority is subordinated to common predefined clearly formulated goals and rules.

In this case the serial flow represents a technical restriction that generates productivity losses, implying the need for "standardized humans" and restriction regarding technical autonomy.

However in Sweden technical autonomy has proved to be one important factor for achieving efficient true team work, since under suitable conditions it enables a correspondingly increased administrative autonomy, providing an important incentive for shouldering increased responsibility.

2 Reflective production as an emerging production form

In order to nuance the debate around lean production we have introduced reflective production as a new alternative production form (not to be viewed as merely a "social experiment"). Two main examples of reflective production in the motor vehicle industry so far are Volvo Car Corporation's facility for final assembly of automobiles in

Uddevalla (the last case in Table 1) and Volvo Truck Corporation's Tuve experimental facility for final assembly of complete trucks in a team (not shown in Table 1).

	Team size	Cycle time (min)	Number of Parallel flows	Work stations in sequence	Material handling of bodies and feeding	Workers per object
Automobiles	1	2	1	250	Line and fork-lift truck	500
Automobiles	15-20	20	1-5	17	Autocarrier and fork-lift truck	50-500
Trucks	10-15	240	1	2	Aircushion and fork-lift truck	10-15
Busses	9-10	120-180	4	3	Aircushion and fork-lift truck	10-20
Trucks	4-9	40	2	4	Autocarrier and fork-lift truck	20-30
Automobiles	8-10	120-480	48	1	Taxi autocarrier and kitting	2-10

Table 1. Examples of Swedish production systems for final assembly of vehicles.

Technically, a reflective production system for final assembly is based on the idea of highly parallelized flows that enable autonomous work teams to assemble objects independently. As a concomitant of this parallelization, the work tasks assigned to teams and individuals will comprise a larger number of work operations. This means longer work cycles in the final assembly, requiring extended competence in order to fully utilize the potential. On the other hand, new types of competences are also generated by the extended work content. The work teams are given responsibilities so that they can meet demands on, e.g., quantity and quality.

It should be emphasized that reflective production does not endorse humanization of work at the expense of economic and technical efficiency – quite on the contrary! As discussed further in [1], reflective production systems for final assembly are as technically and economically efficient as lean production systems and in addition more "socially efficient".

Reflective production also includes the same important values as lean production – thoroughness, consistency and steady, incremental improvement with perfection as the ultimate goal. The problem-solving approach is to identify and eliminate the cause of the problem rather than to rely on a quick fix.

	Mass production	Lean production	Reflective production
Main concept	- Roots in the early industrial society ("technical reductionism")	- Refined traditional concept ("technical holism")	- Technical solutions subordinated to human preconditions ("intellectual holism")
Flow pattern	- Serial flow, implying productivity losses and paced work	- Refined serial flow, paced work and individual work with collective responsibility	- Parallel flows with individual and collective technical autonomy
Human aspects	- Exchangeable worker, fragmented work and information	- Individuals appraised in a collective context	- Co-operative work and individual appraisal
Principles for learning and division of labour	- Additive learning where the required time determines the work content	- Learning of detailed standardized work patterns (one "correct method")	- Holistic learning with many different work patterns and methods based on a common material grouping

Table 2. Summary of different productions forms as they apply to the final assembly of vehicles.

4 Aspects on autonomy

The development in the final assembly of automobiles and trucks is in Sweden moving from production systems with short repetitive tasks which are controlled outside the work process, towards more connected, complex tasks. This requires advanced material feeding techniques where the objects to assemble are standing still during the total assembly process while the workers are moving around performing assembly, materials handling, control and adjustment work. The lack of material feeding techniques was earlier a restriction for parallel flow, but this does not today imply for example that the auto-carrier system is the key innovation of the Volvo Car Corporation Uddevalla factory, although this is often emphasized both by the company and their visitors [9].

The introduction of parallelized final assembly with extremely long work cycles changes the work content from being controlled from outside the work process, towards team controlled flows connected to more complex tasks. To make this possible in reflective production during the projection of new Swedish factories, it was necessary to totally reorganize the assembly work on the basis of formalized knowledge derived from the shop floor. A knowledge summarized by a common material grouping (a so-called "assembly geographical atlas") which describes the product from an assembly point of view), in Uddevalla ultimately manifested by the material kitting fixtures. Final assembly with considerably longer work cycles can by this means contain true technical and administrative autonomy.

5 Conclusions

In the lean production approach, products, production resources and production environments are adapted to a given production system, specifically the paced assembly line. This means, e.g., an emphasis on design for manufacturability, use of heavy equipment and automation wherever useful, extensive use of pre-assembled parts, a highly selected workforce, high work intensity, and a corporate culture stressing loyalty to the company, rigid adherence to rules and continuous improvement of production processes.

In reflective production, by contrast, the overall approach is to adapt the production system to the given products, human preconditions, production resources and production environment. This means designing a flexible production system, capable of efficient production of even low volume products which might have a low degree of design, accommodating variations with regard to products and worker performance, taking advantage of human intellectual capabilities present in a workforce representative of the general population – its skills, level of fitness, needs, values, etc.

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