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PROCESS, PRODUCT AND PRODUCTION SYSTEM – TRENDS IN THE DEVELOPMENT OF PRODUCTION DESIGN AND ORGANIZATION OF WORK WITHIN THE SWEDISH AUTOMOTIVE INDUSTRY

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ABSTRACT

During the 1970s, several innovations were introduced in the ways of organizing work and production within the Swedish automotive industry. New methods of arranging material flows and layouts, emerged new transport systems and new work organizations, based on the principle of semi-autonomous group-work, were developed. What have been the experiences of these changes and what are the trends of today?

This report attempts to document the state of the art, or in other words, to document the different organizational alternatives in existence and their distribution throughout the different production components and within the production systems for different types of vehicles. Social, technical and economic restrictions to alternative production systems are analyzed, especially in the final assembly of passenger cars.

The report is based on studies conducted within the sub-project "Future Production Systems". Different production systems within the Swedish automotive industry have been investigated by means of interviews and observations at a number of plants (cf Berggren, 1983). Quantitative studies on equipment needs in various systems and on characteristic features of the suppliers of components have also been conducted.

Other studies linked with the project have examined some of the restrictions which are seen in this report as central to the design of the assembly systems, i.e., the design of basic objects and material flows (see Engström, 1983). The main finding here is that it is possible to change both product design and production systems in such a way as to make possible the matching of a new system to a new design. Using such a method, attractive alternative production systems can be developed for the final assembly of commercial as well as personal transports.

STATE OF THE ART IN THE DESIGN OF PRODUCTION SYSTEM AND WORK ORGANIZATION

It is possible to identify three patterns for designing layouts and jobs within the Swedish automotive industry today. They are found in their most elaborate forms in the final assembly. The three patterns differ from one another in several or all of the following respects:
- degree and type of control over production process;
- character of the layout;
- contents of the work and skill requirements;
- degrees and forms of joint action by workers and,
- technical/administrative autonomy at shop level.

The three alternatives are:

1. The conventional line-model with its distinct series layout, centralized control, and low-qualified and fixed production positions.

2. Modified line-model. The layout here is also usually of the series types, with some cases of the series-parallel type, but with bufferts between separate stations and/or subdivisions, and more flexible job roles.

3. A complete departure from the line model of organizing flows and jobs.

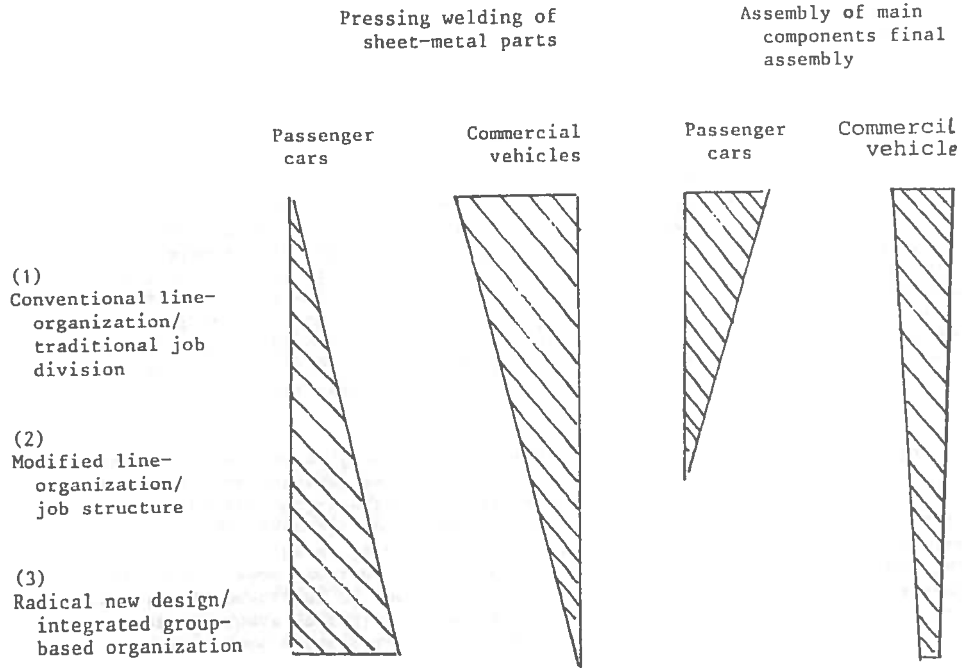
Over the past 10 years, studies have pointed out several ways in which the line-system is ineffective. (See e.g. Wild, 1974.) Nevertheless this model enjoys the support of the production management in many companies. The most important reasons for this are that:
- The line gives the production management immediate control over the flow and pace. The workers are subjugated to the coercive rythm of the conveyor belt. This gives management an illusion of reliability:"the line is any case predictable".
- The line allows for a simple material supply. Articles needed in assembly, etc are delivered at few - or only one - separate stations.
- The line is a system of administration which follows proved scientific management principles: detailed division of labour; high-grade specification; prior determination of work tasks and strict line-hierarchy.

With the modified line, Model 2, an attempt is made to increase the effectiveness of the production system and its ability to absorb disruptions without altering the fundamental principles of design. This usually implies that the control of the system continues to be centralized, and that the content of the work is expanded only horizontally, but without more than a marginal rise in the level of qualification. At the same time, these changes often imply greatly enchanced demands on the intensity of the work.

Much more has happened with Model 3. Some if not all of the following features are typical:
- The absence of series connection. The layout can be totally parallel, or it can have parallel short flows, or it can have other combinations of series and parallel connections.
- The absence of mechanized rate determination or other centralized control, the workers regulate their own work pace (technological autonomy).
- Institutionalized collaboration between the workers, usually in the form of group organization in order to achieve self-regulation in other areas too (administrative autonomy).
- Significant expansion of the contents of the work, greatly increased work cycles and/or integration of tasks with other skill requirements.
- Simplified production administration, fewer reciprocal flows, reduced waiting and adjustment times, decentralized responsibility.

The distribution of the three organizational alternatives varies for the different production components. There are also differences between production systems for different kinds of vehicles. A schematic representation is given in the figure.

Distribution of different organizational alternatives in two main processes of Swedish automotive manufacture. Schematic representation.



In the production component pressing the sheet-metal parts, there is a positive correlation between the degree of automation and new work forms. It was first when the principal part of the highly repetitive machine operation was eliminated that it became possible to introduce qualitative organizational changes. The degree of mechanization interplays with the volume. For that reason, the manufacture of passenger cars has come further than that of commercial vehicles in the transformation of work forms in this production component. One example of this is Volvo Olofström. The operations in the mechanized press lines here are built upon integrated work teams. They are responsible for the supervision of the process, the replacement of equipment as well as for the remaining manual moments, primarily removal, inspection and packing of processed parts. The new work organization has also meant a substantial rise in the qualification demands compared with the machine operation at an earlier phase in the development.

However, there is no unequivocal correlation between automation and new work organizations. There are other examples of plants where mechanization of the press-lines is not accompanied by any changes in the traditional job hierarchy and management. In some instances even individual piecework has been retained.

In the next production component, that of the welding of constituents/parts, one can find examples of far-reaching mechanization within car-body as well as truck-cabin production. But the proportion of manual operations is still high here compared with that found in sheet-metal pressing. Thus the supply and removal of materials as well as completion and adjustment of the weldings to a large extent have remained manual functions. Short-cycled and fragmented work which is restrained by machinery or conveyor, therefore, still dominates this sphere. Little room for choice of organizational design is left: in practice, those plants which have come furthest, have not achieved much more than modifying the conventional systems. Examples of such measures are the installation of buffers, U-formed flows, parallelling of specific stations, as well as job rotation within production groups.

The basic stages in the construction of car bodies have been mechanized to a great degree in the manufacture of passenger cars. There are also examples here of advanced work organizations of the third type. One example is the tacking line for car bodies at Trollhättan. In order to divide up the monotonous as well as the qualified work and at the same time ensure a high level of competence, the workers and foremen took the initiative for a matrix organization. In this type of organization, the various subgroups have their own area of specialization:

- robot maintenance including programming;
- adjustments;
- quality control; and,
- upkeep of tacking fixtures.

Within each subgroup, workers shift between production work (mainly fixed-position loading jobs) and work within the group's speciality. Moreover, the subgroups attend to the section's administrative activities one month at a time.

A hindrance when increasing the level of qualification in the system is found in the fact that a large part of the qualified work is a kind of maintenance work which falls within the realm of an entirely separate organization.

Even here there is a wide margin for different solutions. Saab chose to introduce a parallelled layout with a group-based organization in the middle of the 1970s (documented by Karlsson, 1979). Volvo has retained traditional line-organization in the manufacture of personal autos, but has begun to test new approaches. One instance of this new approach is a design which entails a strong emphasis on technical and administrative autonomy, job enlargement, job rotation and up-grading. The main part of the work - welding, fitting, etc - is performed in parallel two-man stations. A minor part of the work, above all material loading, is performed "on-line", which means a more short-cycled and fixed-position work. Similar production systems exist in the manufacture of truck cabins (Volvo Umeverken).

Assembly functions continue primarily to be performed manually. The fundamental technical changes are few and far between because of the built-in resistance to mechanization in the assembly work. Such resistance is found in the complexity of the material flow, the need to use a series of different fastening techniques, the great importance of the inspection functions due to the proximity of assembly to the market and the special difficulties in automating these inspection functions.

Today, huge efforts are being made in the manufacture of passenger cars to overcome these obstacles to mechanization of the assembly. There are, for example, automatizing of specific, critical operations, of certain sub-assemblies, and of some sections of the heavy component assembly. The most important feature here is the division of the gasoline engine assembly inte a mechanized internal basic assembly and a manual external assembly which is nearing realization. The precondition for this division is that the variant dispersal is limited to the external assembly even in the future. Final assembly of cars, however, is not being faced with any leaps in mechanization at all at this point.

Thus, in final assembly the development of particular tools and the tightening up of production standards still constitute main elements in the rationalization process (here we leave aside the process of production accomodation of the product design). Great gains could in many cases be made through radically altered work organization. Despite this fact, there are not any true departure from the line model to be find in final assembly of passenger cars. Volvo Kalmarverken, which after all is an example of a modified line system (an elastic line), did not pave the way for new assembly designs in this sphere. It was not until 1982 when Saab began to redesign its final assembly in Trollhättan that a successor to Kalmarverken appeared. The new design in Trollhättan however is even more conventional than the Kalmar system.

Impulses for innovation in the final assembly have been greater among the manufacturers of commercial vehicles, bus and truck chassis. Here examples are found of plants where the line has been substituted for parallel flows operated by production groups enjoying administrative autonomy and a substantial up-grading of the assembly work. In those units where this development has gone the furthest, the inherent limits in this kind of work have been reached. It may be long-cycled and freed from any conveyor-belt element, but assembly work in mass production remains a repetitive, predermined work which in itself neither stimulates personal growth nor gives incentives for organizational development.

A long-term qualification of the direct production work in assembly seems to require a much higher level of mechanization. Then, qualitatively new work moments, such as machine supervision and maintenance, could become

Compared with the traditional and modified lines, the alternative production designs result in substantial economic gains, including increased productivity, greater capacity to absorb disruptions and greater availability (production workers feel directly responsible for and are capable of attending to the equipment), lower costs for tying up capital in inventory, mainly through a lower proportion of cars in final adjustment, as well as faster conversions/rebalancing.

A counterweight to the gains is the costs, which are incurred mainly for acquisition of new equipment and sometimes also for obtaining greater space. With the establishment of new units, this is seldom a problem. The situation is worse when changes are to be made in existing plants when it is demanded that the new constructions be so profitable that they finance not only the extra equipment and space requirements but also the sunk costs of the former system.

In addition, some new personnel costs can arise, such as costs for further education and group training.

Changing line-organized assembly - some restrictions

The growing number of variants in final assembly intensifies the demand for uninterrupted sequence. Otherwise, the conventional system for sypplying materials is not functional.

In a line the sequence is fixed and if the material supply functions, the right gear box is paired with right car body which later is fitted with the right wheels, etc.

The exact sequence in which the variants will come off the end of the track is known at the start of the line. But if such a line flow is replaced with series-connected groups having internally free flows (or series-connected modules comprised of groups working in parallel), then the variant sequence at the end of the flow cannot any longer be predicted. Accordingly there is a risk that the right variant article will not be in its correct place.

In changing the existing structures, there are also problems of lack of space. A conventional line demands little room for the assembly itself, but a large section is needed for adjustment work. The problem is the exact opposite for an alternative model, the more or less parallelled design. With a conversion from the line to the parallel system, the decreased system loss will free space in the adjustment section that can be used for assembly stations. The problem is that this freed space is a result of the new system, and only comes into existence after the new system is introduced.

Naturally, many of these difficulties can be solved. The sequence problem disappears in a system with many variant-specialized flows. Or through the use of spacious assembly fixtures which are loaded with basic objects as well as with heavier variant-specific articles. Or simply by drastically shortening the flows to 2-3 groups in the series with 6 assemblers in each group for the final assembly of a passenger car. In such a case, the sequence problem would be insignificant.

SPECIAL STUDIES

Hand tools in the assembly and repair work

A detailed, quantitative analysis of the sets of hand tools in some production systems for trucks and passenger cars have been conducted (see Kilbo, Kluge & Nevén, 1983). For the same product different operations (assembly, adjustment and, for trucks, also repair) have been investigated.

A general finding of the study is that higher frequence (shorter specific-time) necessitates greater numbers of hand tools. In addition, the following observations were made concerning the different types of operations and production systems:

1. There are well-defined tasks and therewith a well-defined need for the tools in the final assembly department. The need for surplus tools for problem-solving is minimal.

2. The cycle-time in the passenger car assembly department is short (2 minutes). At the same time many of the assembly functions involve working at inconvenient angles with blind spots. The result is a need for a large number of special tools and compressed-air driven machines.

3. Truck assembly has a long cycle-time (34-37 minutes). Due to the design of a truck, with a supporting frame, the assembly positions are relatively easy accessible. Therefore few special tools are needed and a lesser number of compressed-air driven machines are used than for personal cars.

4. In the global adjustment section all tools for each model are needed. In this process there is also a great need for problem-solving. The tools at the conveyor belt can only be used in a fixed sequence. By contrast, the adjustment worker requires tools which are not restricted by any such sequences.

5. The tools used during repair are quite similar to those used during adjustment, although the former process requires straightening tools and a greater number of processing tools.

In a somewhat generalized analysis, the following marks could be made:

- The qualitative differences between adjustment and assembly are reflected in the number and types of tools at the respective stations. Adjustment work contains features of various different work types, both craft skills and a demand for technical sensibility. The assembly work is excessively standardized and as such is a disincentive to development of different skills. At this point we can refer to the previous reasoning about the positive aspects of automating standardized and repetitive work from a work-content perspective.

- The level of mechanization generally tends to follow the frequence, either because high frequence makes mechanization profitable, or because high frequence creates a problematic work situation from an ergonomic point of view. But behind the recorded high-frequence, there is often in its turn a more or less concious social choice. If a parallelled flow was chosen instead of a line-layout, then the frequence would be another - as would be the interest in mechanization.

Automotive component production - some features of small and medium-sized subcontractors

An essential part of the automotive industry production is performed by the various subcontractors working with sheet-metal processing, plactics manufacture, rubber work and so on. If the goal is to achieve an overall picture of the automotive industry's work structures this section must not be overlooked. Therefore a minor study of the relationship between product design, production technology and the organization of work among component suppliers has been made (see Erixon et al, 1983). The main results of this study which is based on investigations of six subcontractors representing different specialities can be summarized in the following way.

The proportion of white collar employees generallys is much lower than within automobile companies, and the total work content is often thin and externally circumscribed. The main part of the production work in these plants could be characterized as repetitive and fragmented labour, which often takes the form of operating semi-automated machinery. There have been few attempts at renovating work structures by introducing group-work or raising skill requirements, for example. The organizational structures in the large as well as in the small component manufacturing firms seems to be overwhelmingly conventional as is seen in their usually strict line hierarchy and functional differentiation.

However, worker autonomy and job content vary considerably between the larger and the smaller subcontractors. The larger companies (one hundred employees or more) are often highly bureaucraticized with many hierarchical levels. One example from the above study is a manufacturer of rubber parts with 500 employees and 7 hierarchical levels.

The production work in these larger companies usually is broken down and divided to a great degree, which results in operator jobs with low or very low skill requirements. The small subcontractors are forced to have flat organizations and a more flexible and competent personnel due to cost considerations. As a result the diffusion of product and process knowledge among the workers is sometimes substantial. Thus, workers in small firms are likely to have greater possibilities of quitting and starting a firm of their own. However, these features do not in turn signify any departure from conventional forms of work organization.

Generally seen, the possibilities of developing higher forms of work organization have been substantially greater to this point within the larger production systems in the automotive industry's core companies. Nothing indicates that this situation is likely to change.

CONCLUSION

There is a general tendency within the passenger car production for the development of new work organizations to have come the furthest in the "middle" of the production chain. The restrictions against designing alternative production systems nevertheless look different if you compare the first component of the production process, the subcontractors, with the final component, the final assembly. The work patterns found among the subcontractors are closely associated with their structurally subordinate position in the total production process. The final assembly, on the other hand, is the flow's nerve center at the same time that it is a dust bin for the mistakes of all of the other production departments. All of the problems are gathered here, and it is here that production management feels the greatest need to control and supervise. And in the final analysis, these are the decisive reasons for the low level of organizational innovation in the final assembly department.

Of all the units for final assembly of personal car and truck chassis in Sweden, there is only one to date where the line-model has been entirely abandoned, namely, at Volvo Tuvefabrik where Volvo's heavy trucks are produced. Even here it is technically possible to return to a pure line-control.

An important conclusion reached in the project "Future Production Systems", therefore, is that there is an intimate relationship between the technical and social dimensions of such production.

In a short or medium-length time-perspective, the technical as well as the social restrictions of innovation are strong, because it is a question of modifying existing designs of car and truck types and renovating existing physical structures. In a longer perspective which takes into account new generations of car models the number of degrees of freedom will become greater, and here it is important not to be bound by existing practices and restrictions. To outline a series of alternative systems and to visualize them in such a way that it becomes possible to systematically confront current practices with a series of radical alternatives is an important task for future research.

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