# PERSPECTIVES ON CHANGES IN THE SWEDISH MODEL FOR WORK LIFE DEVELOPMENT

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## ABSTRACT

In recent years, assembly lines have been re-introduced in the Swedish automotive industry in many cases, replacing so-called alternative assembly systems with roots in the 1970s. This article reviews and evaluates some explicit reasons given for the return to the assembly line.

It also considers whether the decisions to replace alternative assembly systems with assembly lines may have been driven by other factors and mechanisms than rational decision processes and, if so, what "non-rational" factors could explain the re-introduction of assembly lines. There is also a discussion of which dimensions that should be taken into account when choosing between alternative assembly systems and assembly lines.

Some empirical data are used to shed more light on the issues discussed in the article. The authors report one study that compares automobile assembly in an alternative assembly system with assembly of the same products after introducing an assembly line.

The authors also briefly discuss reasons for and experiences from the recent introduction of alternative assembly systems in the Japanese electronics industry. In this case, so-called cellular assembly systems have replaced assembly lines.

Keywords: Manual assembly, alternative assembly, dock assembly, cellular assembly, assembly line, automotive industry, Swedish industry, Japanese industry.

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# 1 INTRODUCTION: "THE SWEDISH MODEL FOR WORK LIFE DEVELOPMENT"

As a new CEO of Volvo, Pehr G Gyllenhammar in 1973 published a book called "I believe in Sweden", where he wrote:

> But the organization of work, work conditions and work environment are subject to increasing criticism, and the production methods and technology upon which our industrial system has been based must now be reassessed. Demands for what is called work content have increased strongly during recent years. Some see this as a disturbing sign. In my opinion, these demands are sound.
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> /---/
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> If the efforts devoted to so-called work science are directed towards adapting the production to people of today and their demands, it should be possible to develop new solutions in the area of production technology in factories and offices, solutions that combine rational systems with more meaningful work tasks so that the requirements for increased efficiency are satisfied, too. If this succeeds, Sweden will be well positioned industrially.[1]

Gyllenhammar thus makes the point that demands for better working conditions should be welcomed by management and seen as a challenge to organise work in a rational way so that work tasks become more meaningful at the same time as production becomes more efficient.

In "I believe in Sweden", Gyllenhammar deals with the Volvo Automobile Kalmar plant. The design of this plant, initiated during the early 1970s, was guided by the principles brought forward in his book. The Volvo Kalmar plant, and the fifteen years latter initiated Volvo automobile plant in Uddevalla, influenced the development within the Swedish industry even outside Volvo and became famous abroad; they became icons for the "Swedish model for work life development".

These two plants were, however, not the sole examples of bold innovations within the Swedish automotive industry, not even within Volvo. Another initiative within Volvo, but independent of the Volvo Kalmar plants and in fact far more radical, was the temporary workshop in Arendal established by the Volvo Truck Company in the early 1970s. In this case, a small workgroup of nine operators assembled heavy trucks much more efficiently than was done on the assembly line (see Blackler and Brown 1978). The Volvo Kalmar plant and the Volvo Arendal experience were followed by a number of other initiatives, where various types of so-called alternative assembly systems were introduced.[2]

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[1] The authors' translation from the original citation in Swedish.

[2] By alternative assembly systems we mean alternatives to the traditional assembly line. These alternatives may consist of (I) modified assembly lines (product flows) with intermediate buffers between production sections manned by work groups in series, or (II) a number of shorter product flows in parallel, each manned by one work group or (III) semi-parallel product flows manned by workgroups in series which are parallel within some production sections. In the most extreme case (IV) one work group or one operator completes the entire product, thus these workgroups form a number of parallel product flows. These types of alternative assembly systems corresponds to real life plants like the Volvo Tuve plant before the rebuilding in 1993 (type I), the Volvo Umeå

The most interesting of these initiatives were the assembly systems designs that abolished (rather than modified) the assembly line, introducing a new manufacturing paradigm. A traditional mass production system is built around a single product flow, an assembly line, where the product is moved from one operator to another or from one workgroup to another, during the assembly work. The new assembly systems utilise a number of parallel product flows instead. In the extreme application, all assembly work is conducted at the same place (i.e. on one or a few of workstations). In Sweden such stationary assembly work is often referred to as dock assembly: in Japan assembly in parallel product flows is known as cellular assembly.

Furthermore, this new manufacturing paradigm creates preconditions for a new, different work organisation, comprising a more comprehensive and qualitatively different assembly work with increased autonomy in so-called autonomous workgroups. Workgroups, and in some cases single operators, are able to take responsibility for completing a product. Table 1 shows some examples of alternative assembly systems within Volvo; similar initiatives did also occur e.g. in Saab Scania from 1971 (see Karlsson 1979).

The "Swedish model for work life development" was based on domestic experiences and preconditions and theoretically influenced by the socio-technical tradition (see e.g. Emery 1969 or van Eijnatten 1991). Today, the corresponding line of development within the Swedish engineering industry, initiated in the 1970s, has almost been terminated, however. Nowadays, research and development work inspired by visions similar to Gyllenhammar's and frames of references like those in the socio-technical tradition are rare within the Swedish industry.

Presently, CEOs of Swedish companies no longer write books with titles like "I believe in Sweden". Indeed, managements in most of the large Swedish manufacturing companies appear to have lost faith in "the Swedish model for work life development". In particular, a number of examples can be given of alternative assembly systems that have been closed down or replaced by assembly lines.

The Volvo Kalmar plant was closed in 1994, while the Volvo Uddevalla plant stopped manufacturing in 1993. In 1995, production was actually started again in Uddevalla in a rebuilt assembly system with a so-called semi-parallel product flow pattern, where automobiles were moved between workshops with parallel product flows during the assembly work. However, in 2002 this assembly system was rebuilt again and an assembly line was introduced. Also, the dock assembly systems at the Volvo Truck Company in the Tuve plant, which used an assembly systems design quite similar to the temporary Volvo Arendal workshop during 1974 to 1977, was closed down in 2002.

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truck cab (type II), the Autonova Car plant in Uddevalla before rebuilding in 2004 (type III) and the Volvo Uddevalla plant (type IV). Without going into details there are thus several "generations" of alternative assembly systems. As explained in detail elsewhere (see e.g. Medbo 1999) the most "sophisticated" systems call for advanced materials feeding techniques and specific measures to enhance learning of, from the automotive industry point of view, extremely long work cycles.

Table 1. Some examples of alternative assembly systems.

| | The Volvo Arendal workshop | The Volvo Kalmar plant* | The Volvo Uddevalla plant | The assembly docks at the Volvo Tuve plant |
|---|---|---|---|---|
| Products: | Heavy trucks | Automobiles | Automobiles | Heavy trucks |
| Period of operation: | 1974 —1977 | 1974 – 1994 | 1989 – 1993 | 1991 - 2002 |
| Work cycle time: | 240 minutes | 20 minutes | 80 or 100 minutes | 240 minutes |
| Number of operators per workgroup: | 9 | 8 | 7 or 9 | 10 or 9 |
| Number of operators normally working at each product simultaneously: | 3 | 2 | 1.8 (mean value) | 3 or 4 |
| Number of work groups involved in assembly of one product: | 1 | 27 | 1 | 1 |
| Number of product flows: | 1 | 1 | 35 | 6 |
| Integrated sub-assemblies in the workgroup: | Yes | No | Yes | Yes** |
| Materials feeding technique for large components: | Traditional | Traditional | Material kits transported by means of forklift trucks | Traditional |
| Materials feeding technique for semi-large components: | Traditional | Traditional | Material kits transported by means of automated guided vehicles | Material kits transported by means of forklift trucks |
| Materials feeding technique for small components: | Traditional | Traditional | Automated kitting of small components in transparent plastic bags | Traditional |

*) This plant was rebuilt in 1987. The changes included the removal of most of the intermediate buffers and a lengthening of the product flow, but also introduction of parallel product flows in one production section. After this reconstruction it was possible to have a work cycle time of maximum 40 minutes, including the sub-assembly stations.

**) The sub-assembly stations were later removed from the workgroups, and the assembly system was modified to allow the truck chassis to be moved four times during the assembly instead of three.

Yet another example of abolishing alternative assembly systems is the door assembly at the Volvo Torslanda plant which was rebuilt into an assembly line in 2002. The same thing happened at the Volvo Skövde engine plant in the summer of 2002, when the last parallel product flow assembly system in this plant was converted into an assembly line.[3]

Outside the Volvo sphere, as well, alternative assembly systems have been replaced by assembly lines. One case, which has drawn some attention, is the Scania truck cab plant in Oskarshamn, where an assembly line was introduced in connection with an increase of production capacity in 2002 (Janbrink 2002). Similarly, ABB Robotics plant in Västerås was converted into an assembly line in 2002 (Dahlqvist 2003).

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The developments just described raise many questions. Firstly, what are the explicit reasons given for the return to the assembly line in the debates and decision processes preceding these changes? Secondly, are these reasons good reasons? Are the assumptions underlying the arguments for abandoning alternative assembly systems valid; are they based on relevant, solid empirical evidence? Thirdly, could the decisions to replace alternative assembly systems with assembly lines have been driven by other factors and mechanisms than rational decision processes based on the explicit arguments heard? What "non-rational" factors could explain the re-introduction of assembly lines? Fourthly, the comparative assessment of alternative assembly systems and assembly lines in the Swedish automotive industry has been based on a rather narrow set of criteria, most importantly man-hour productivity. Are there other important dimensions that should be taken into account when choosing between alternative assembly systems and assembly lines?

These are questions that need to be addressed not only in order to understand past developments concerning assembly systems but also in order to find a direction for the future, and they will be considered in the remainder of this article. Thus, in section 2 some explicit reasons given for abolishing alternative assembly systems (and by implication re-introducing assembly lines) are examined. In section 3, an empirical comparison of an alternative assembly system and an assembly line manufacturing the same product is presented. This comparison sheds some lights on the argument that man-hour productivity is higher for assembly lines. In section 4, we consider some "non-rational" factors that could help explain the re-introduction of assembly lines in the Swedish automotive industry. In section 5 the re-introduction of assembly lines in Sweden is contrasted against the recent introduction of cellular assembly within the Japanese electronics industry. Finally, in section 6 the most significant advantages of alternative assembly systems are discussed.

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[3] Quite recently it has been decided to convert the Volvo Umeå truck cab plant in the north of Sweden into an assembly line, a decision has caused considerable controversy since this may be the last assembly system representing "the Swedish model for work life development" (see e.g. Aftonbladet 2004, Dagens Nyheter 2003 and Göteborgsposten 2003). In this case the Volvo management sees the reintroduction as a strategic decision, and has actually more or less threatened to move operation abroad. Since opportunities for getting employment in the north of Sweden are scarce, the decision has been forced through. Therefore, 16 small serial product flows comprising six workstations and eleven operators without intermediate buffers will be replaced by a serial product flow of 75 workstations also without any intermediate buffers. The work cycle time of 50 minutes will be changed into three minutes.

# 2 SOME ARGUMENTS AGAINST ALTERNATIVE ASSEMBLY SYSTEMS

Below some frequently heard arguments against alternative assembly systems are presented and commented on – for a more detailed discussion see e.g. Engström, Jonsson and Medbo (1996A) and Medbo (1999).

## 2.1 Man-hour productivity

The assumption that an assembly line leads to superior productivity, compared to alternative assembly systems, has been a key argument for persisting with or reintroducing line assembly. During the early 1990s, the efficiency of the assembly line in contrast to alternative assembly systems such as dock assembly was much debated. This debate was strongly influenced by the management best-seller "The Machine that Changed the World" (Womack, Jones and Roos 1990), in which the expression "lean production" was introduced. This notion of "lean production" reflected line assembly as practiced within the Japanese automotive industry, especially Toyota, during the 1980s, but represented a special, American, interpretation of this Japanese practice.

The authors of this book argued, based on some empirical studies, that Japanese assembly lines (representing "lean production") were far more efficient than both the assembly line and alternative assembly systems. The comparisons brought forward might be questioned from a methodological point of view, however. For example, assembly times for automobiles in various plants were compared, but obviously different automobiles require different amounts of effort to assemble depending on their product architecture etc., and without going into technicalities it can be said that this variable is not controlled for in an adequate way by Womack, Jones and Roos. (for a more detailed argument see Jonsson 1995). Moreover, this book only dealt with plants using assembly lines, i.e. no plant with dock assembly or any other alternative assembly systems was empirically investigated. There may have been good reasons for this choice of focus, but nevertheless it meant that there was no real basis for an empirical comparison of alternative assembly and line assembly with regard to productivity (or anything else).

In contrast to Womack, Jones and Roos. (1990), the present authors have been able to conduct studies where assembly of the same product on assembly lines and in alternative assembly systems is compared empirically. Contradicting claims made in "The Machine that Changed the World", we found that the time required for completing an automobile at the Volvo Uddevalla plant was 2 – 4 hours shorter than for a similar automobile manufactured on the assembly lines at the Volvo Torslanda plant (Engström, Jonsson and Medbo 1996B). In section 3 below we present another empirical study suggesting that assembly in alternative assembly systems is more efficient in terms of man-hour use than line assembly. In addition there are theoretical frames of references explaining the efficiency of alternative assembly (Wild 1975; Rosengren 1981).

## 2.2 Product quality

One argument for the re-introduction of the assembly line sometimes brought forward is that it is not possible to achieve high product quality in alternative assembly systems. However, in most cases the product quality is actually higher in alternative assembly systems. One reason for this is that operators in workgroups have much better possibilities than operators on an assembly line to adjust the components fitted in relation to each other before these finally are torqued down (Engström et al. 1995). It also comparatively easy for a work group in an alternative assembly system to survey and verify correct product functions if the work cycle times are long, especially if advanced materials feeding techniques and specific measures for enhancing learning are utilised.

The improvement of product quality becomes even more pronounced for products with a low "degree of design". Such products are difficult to assemble because little product development and manufacturing engineering time has been spent on preparing them for manufacturing. This is often the case for low volume products with many product variants, such as the heavy trucks assembled in the Volvo Arendal and the Volvo Tuve docks.

At the Volvo Uddevalla plant, the mean product quality, as measured in a standardised manner according to the number and severity of defects observed in quality control audits, was much higher than for similar products built on the assembly line, although it was somewhat uneven between workgroups and automobiles (Volvo Personvagnar AB 1992; Engström, Jonsson and Medbo 1996A). It should be noted that the methods used for dealing with product quality improvement and audit matters in traditional mass production are not fully applicable for assembly systems with parallel product flows.

During the life of the Volvo Uddevalla plant the product quality work was successively adapted to the way of manufacturing there. This work was not completed when the Volvo Uddevalla plant was closed down, but even so the product quality had become higher than in the competing line assembly plants producing similar products.[4]

In conclusion, the experience from the Volvo Uddevalla plant suggests that parallel product flow assembly systems harbour a potential for improved product quality compared to the assembly line, but it is not possible on the basis of presently available knowledge to specify how large this potential is.

## 2.3 Ergonomics

Another argument for re-introducing the assembly line recently brought forward in Sweden is improved ergonomics in comparison to alternative assembly systems. This argument seems to neglect, though, the well known ergonomic problems resulting from repetitive work on an assembly line. Lean production, for example, has been documented to have adverse effects on a range of factors shown to be important in human health including

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[4] This fact was, according to some informant, to some extent considered problematic for the Volvo managers since "professional" customers, or customers with insights, specifically called for automobiles manufactured in Uddevalla. Some manager thus were afraid of having customers wanting automobiles only from the Volvo Uddevalla plant.

musculoskeletal disorders (Landsbergis, Cahill and Schnall. 1999 and Vahtera, Kivimäki and Pentii 1997). The argument also seems to neglect the clear merits from an ergonomic point of view of work in alternative assembly system. Such work is less repetitive due to the increased work cycle time, and the possibilities to vary the work pace within a work cycle as well as during the work day are often much better than on the assembly line. Thus it is possible to follow the natural human work rhythm (Dudley 1968; Whyte 1955). The ergonomic conditions are further improved if non-assembly work tasks in the form of e.g. administrative work tasks and maintenance work are integrated into the assembly work. This is in general both possible and economically profitable in alternative assembly systems. (Some publications discussing ergonomics in parallel product flow assembly systems are Johansson et al. 1993, Kadefors et al. 1996 and Engström, Johansson Hanse and Kadefors 1999).

In some cases, ergonomic problems have occurred in parallel product flow assembly systems due to inadequate maintenance and renewal of tools and other manufacturing equipment. This should not come as a surprise. Appropriate tools, suited for the assembly system where they are used, are of course required to prevent ergonomic and other problems – independently of assembly system design.

Unfortunately, some examples exist where operators working on individual workstations in parallel product flow assembly system has completed their work just after the lunch and then left their work place, which has meant an extreme work pace and consequently also ergonomic problems. This way of working is however not a necessary effect of the assembly system design, but rather due to lack of appropriate norms and rules dealing with the daily work. [5]

## 3 AN EMPIRICAL CASE STUDY OF MAN HOUR USE IN LINE ASSEMBLY AND ALTERNATIVE ASSEMBLY

As noted above, although decisions to replace alternative assembly systems with assembly lines are mostly motivated by efficiency considerations, especially expectations of improved man-hour productivity of assembly lines, empirical studies that actually compare the performance of alternative assembly systems and assembly lines are rare. Such studies are greatly facilitated when one type of assembly system is replaced by another in which the same product is manufactured, offering a so-called natural experiment. The authors have been able to collect data from several such natural experiments, one of which is reported here. This illustrative case serves two purposes here: firstly, it provides data relevant for a comparison of the man-hour productivity of alternative assembly systems and assembly lines, and secondly it illustrates the research procedure as well as the type of data required to make correct empirical comparisons between different assembly systems.

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[5] On the other hand is extreme working up with ergonomic problems as a consequence not only to found in parallel product flows assembly systems. The short serial product flows of earlier used at the Volvo truck axle assembly in the closed down Volvo Lundby plant was an example of extreme collective working up (Johansson et al. 1993).

This study is based on the authors' own video recordings of the assembly of the same product, in this case Volvo C70 cabriolets, in a parallel product flow assembly system and on an assembly line from September 2001 and December 2002, respectively. The original assembly system consisted of two sequential parallel product flow assembly subsystems in two separate workshops. The products are now assembled on an assembly line. The work cycle time on the assembly line is 10 minutes instead of 90 and 150 minutes in the two workshops with parallel product flows. The total man hour requirement for one product is approximately 900 minutes.

Note also that the parallel product flow assembly system used materials kits containing the components required for the assembly work. These materials kits contained a stack of materials containers for the small and medium sized components and materials racks with shelves for the large components, see figure 2 to the right. Each of these materials kits contained exactly the components required for one specific automobile. On the other hand, on the assembly line which practises line stocking, the operators have to walk along the assembly line to fetch the components.

As noted, the products assembled was the same in both assembly systems and the assembly work analysed in the video recordings was also similar, i.e. the same components were assembled in both cases. The work tasks analysed were representative for assembly work on this type of automobile. From each assembly system the analysed video sequences comprised 150 minutes assembly work performed by four operators.

The analysis of the time consumption in the two assembly systems was conducted by means of a computer synchronised video equipment as described by Engström and Medbo (1997). The equipment consists of a video camera, a video tape recorder, a TV-monitor, and a personal computer including self-developed software. The analysis is made by categorization into predefined activities identified on the video tape as shown on the TV-monitor. The analysis is performed by clicking the cursor on "buttons" in windows on the computer screen, where each button corresponds to one activity. The design of the windows on the computer screen is arbitrary and can be made according to the requirements of a specific case in the form of e.g. the number and position of the "buttons".

The analysis by means of the computer synchronised video equipment showed that a larger amount of the operators' working hours was devoted to assembly operations in the parallel product flow assembly system than in the assembly line, where the indirect work tasks required more time. The work pace was found to be approximately the same for both systems. Thus 83% compared with 71% of the time analysed was devoted to direct assembly work; see figure 1 to the left.

It was also found that the time required for indirect work is proportionately twice as long, i.e. 42% versus 21% of the direct assembly work, in the assembly line as in the parallel product flow assembly system, see figure 1 to the right. Principally it was less need of materials handling activities in the parallel product flow assembly system that was the main cause of this difference, see figure 2 to the left. Important is also that the assembly line system generated a considerable amount of walking and waiting time.

As mentioned above, the materials feeding technique practiced in the parallel product flow assembly system utilised materials kits which means that the operators do not have to walk as long as was the case in the assembly line to fetch components, see figure 2 to the right. As shown in figure 2 to the left, it is especially the medium sized components supplied in the materials containers that leads to a considerable time reduction in the parallel product flow case. This depends on the fact that the operators brought the materials container to the assembly position, while in the line assembly, practising line stocking, the operator have to walk along the line to fetch the components.

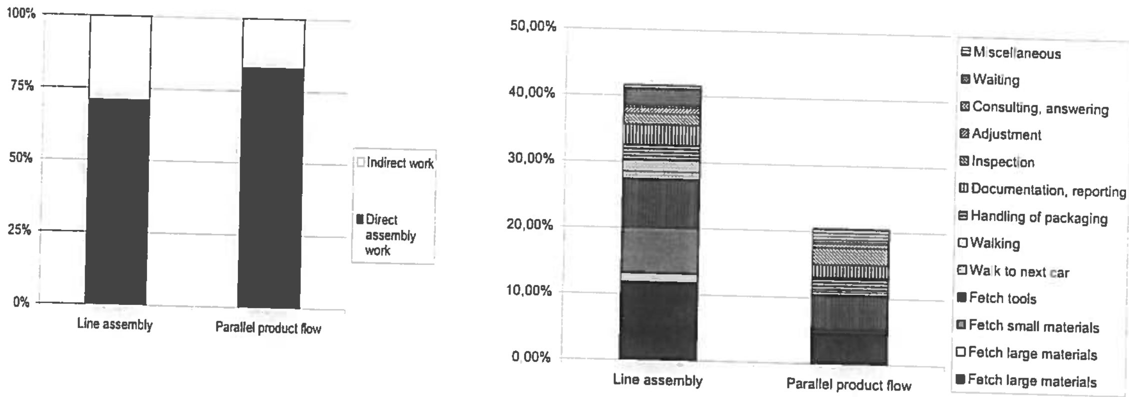


Figure 1.To the left, the operators' distribution of working hours divided into direct assembly work and indirect work according to the video recordings. The indirect work includes all observed work tasks that was non-assembly work. To the right, the detailed observed time consumption of indirect work for the parallel product flow assembly system and the assembly line, as a share of direct assembly work.

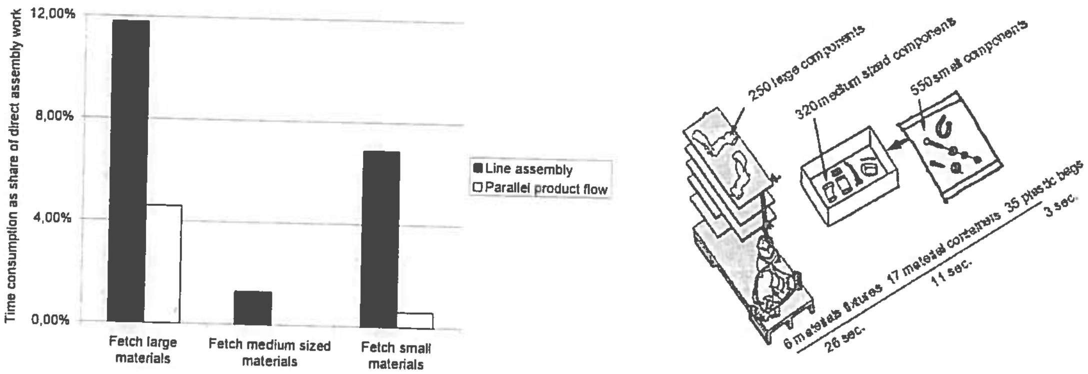


Figure 2.To the left is the time consumption for fetching components as observed in the - parallel product flow assembly system and at the assembly line. The components are divided into three categories and the time consumption is reported as a share of direct assembly work. To the right is the materials kit used in the parallel product flow assembly system shown according to the three categories of components. The number of components and packages for each component category in a specific materials kit are indicated. The order picking times for composing the materials kit according to time studies are also given for each component category.

In conclusion, the fact that 83% of the total observed time could be devoted to direct assembly work in the parallel flow assembly system compared to 71% for the assembly line illustrates the productivity potential of parallel product flow assembly systems, although other aspects such as work pace[6] and resource consumption for materials kitting of course also have to be taken into account in a complete analysis.

## 4 SOME POSSIBLE 'NON-RATIONAL' DRIVING FORCES FOR THE RE-INTRODUCTION OF ASSEMBLY LINES

The arguments for reintroducing the assembly line presented in section 2 do not necessarily tell the whole truth about what has caused this change. Other, more "non-rational", factors may also have contributed to the re-introduction of assembly lines. Some of these possible "non-rational" driving forces will be discussed below.[7] It may be difficult to assess the relative importance, if any, of the factors considered below, and some hypotheses proposed are admittedly difficult to verify directly, but we believe that possible "non-rational" driving forces are nevertheless worth considering.

### 4.1 Internationalisation and standardisation of production systems

In the automobile industry global ownership has increased, and the Swedish automobile companies have became small parts of global companies, while the truck companies are themselves global companies. Global companies often have an ambition to develop standardised production systems, common to all plants in all parts of the world.(Boyer et al. 1998) Given that the assembly line is predominant internationally, the reintroduction of this assembly system in the Swedish automotive industry could be seen as a natural consequence of globalization.

We would argue, however, that assembly lines, while suitable for traditional mass production, are not suitable for product markets with high product differentiation, large fluctuation in demand over-time and relatively short product life cycles. More generally, we would argue that the type of assembly system used should be adapted to the product manufactured, market characteristics, production volumes and product mix characteristics, and so on. Moreover, it would be rational to take advantage of competitive advantages of nations such as, in the case of Sweden, a generally high level of competence and motivation among employees and a tradition of constructive industrial relations when choosing and designing production systems.

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[6] It has been argued that the work pace in parallel product flow assembly systems would be lower than on the assembly line due to the absence of pacing from the assembly line and problems with learning long cycle time assembly work, but according to video recordings from the Volvo Uddevalla plant (Engström, Jonsson and Medbo 1996B) this was not the case.

[7] With regard to the closing of the Volvo Uddevalla plant, Hancke (1994) discussed such 'non-rational' drivers, using the concept 'politics of production'.

## 4.2 Knowledge regarding traditional and alternative assembly systems

The assembly line is well known and established. On the other hand, high-level managers, shop-floor managers and manufacturing engineers in most cases lack knowledge about and experience from alternative assembly systems. In this connection, it should be noted that there is concern in academic circles about the education and competence of manufacturing engineers in the Swedish industry (Kinnander 1993).

The lack of knowledge regarding alternative assembly systems concerns several levels of knowledge. Firstly, there is a lack of knowledge about the potentials inherent in alternative assembly systems, what can be achieved by using such systems. Secondly, there is a lack on theoretical understanding why these potentials exist, for example, the theory of so-called production losses (Wild 1975). Thirdly, alternative assembly systems have often had non-optimal designs, due to a lack of knowledge about design principles applying to such systems. Fourthly, there is also a lack of practical knowledge about how alternative assembly systems should be run in and managed, and which preconditions have to be created in order to make these assembly systems function well.

Often managers and manufacturing engineers state that line assembly is necessary in order to be able to control the production and secure the delivery precision in output. This belief has been reinforced by problems experienced in some alternative assembly systems, but in our opinion these problems are mainly due to insufficient knowledge about how to design and manage such systems. A related argument deals with manufacturing engineering competence. An assembly line is argued to be necessary in order to obtain high manufacturing engineering competence in a company. It is not believed that such competencies can be developed successfully in both workgroups and engineering staffs simultaneously.[8]

Since the manufacturing engineering motives for alternative assembly systems have became unclear, the companies have not been able to take advantage of the alternative assembly systems' full economic potentials. Instead, in some cases the operators have reaped the gains of the more efficient way of manufacturing, while in other cases neither the company nor the employees have been to capitalize on the efficiency potentials. These outcomes have decreased management's interest to implement new or refine existing alternative assembly systems.

## 4.3 Industrial relations: power and cooperation

One should not disregard the fact that alternative assembly systems, where the blue-collar employees' expertise and engagement are of considerable importance for the production results, can change the "balance of power" between employers and employees, as compared to more traditional assembly systems, where the operator performing the manual work on the shop floor has no overview of the manufacturing processes, and where the operator's work is monitored and controlled by the movement of the assembly line or by other means.

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[8] The topic of learning assembly work is important but outside the scope of this article. Principles and practices for facilitating learning of long cycle time assembly work is discussed by e.g. Engström, Medbo and Jonsson (1994) and Nilsson (1992, 2003).

"The Swedish model for work life development" means, according to the authors interpretation, that both employer and employees are willing to cooperate and accept being dependent on each other; that they do not view their relationship solely as a power play. If the employers no longer have this point of departure – if the power play perspective takes precedence for them – it is consequently rational to view alternative assembly systems, with their shifted balance of power, as a threat to their own interests.

In alternative assembly systems some administrative work can be taken over by blue-collar employees, resulting in an overall increased efficiency. Thus, parts of middle management, whose work could be taken over by blue-collar employees, have reason to view their interests as threatened by alternative assembly systems.

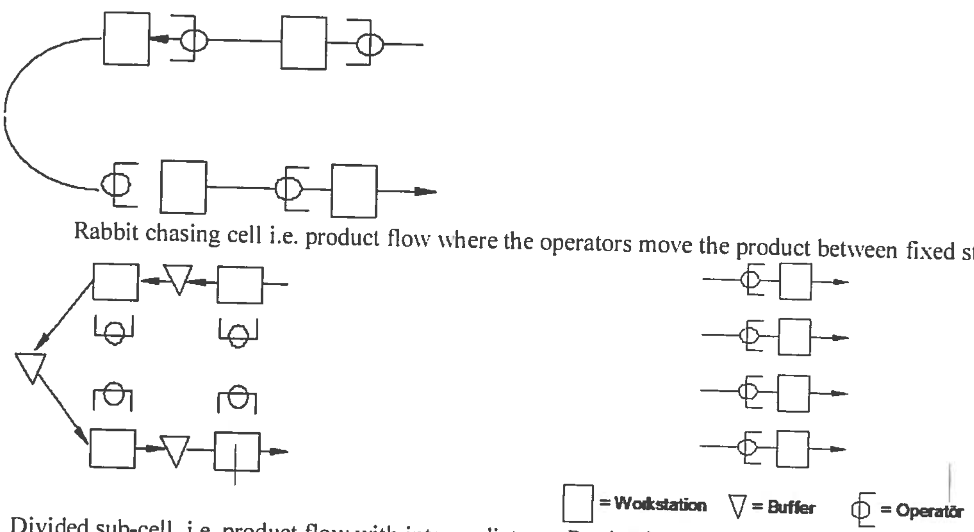
## 4.4 The labour market situation

During the two decades – the 1970s and the 1980s – when alternative assembly systems were introduced in the Swedish automotive industry, the labour market was mostly tight, and there was high turn-over in the automotive industry. This was the case, for example, both in connection with the design of the Volvo Kalmar plant in the beginning of the 1970s and the Volvo Uddevalla plant at the end of the 1980s. There is no doubt that the design of these two plants was influenced by a desire to create attractive work-places to be able to recruit and retain employees (Sandberg 1995)

From the beginning of the 1990s, by contrast, the Swedish labour market has been characterized by unusually high levels of unemployment, and it has been comparatively easy to recruit people to assembly-line work. There is reason to believe that this is also a factor that has contributed to the re-introduction of assembly lines in the Swedish automotive industry.

# 5 SOME RECENT DEVELOPMENTS WITHIN THE JAPANESE ELECTRONICS INDUSTRY

Considering the trend towards re-introduction of assembly lines in Sweden, it is interesting to observe the interest for alternative assembly systems, in the form of so-called <u>cellular assembly</u>, in the Japanese electronics industry. During the last three to four years assembly systems containing so-called assembly cells, where individual operators or groups of 3 – 10 operators assemble complete products, have replaced the assembly lines in many cases. This is especially common for products such as computers, printers, cameras and copying machines (Asao 2001; Nohara 2002).[9] As an illustration, figure 3 contains schematic layouts for different types of assembly cells.




Rabbit chasing cell i.e. product flow where the operators move the product between fixed stations.

Divided sub-cell, i.e. product flow with intermediate buffer between stationary operators.

Production cell with one worker, i.e. a parallel product flow with individual workstations.

Figure 3. Schematic layout of three different types of cellular manufacturing which have been adopted by the Japanese electronic industry according to Asao (2001).

The driving forces in this development are declared to be efficiency and flexibility, foremost through the possibility to handle variation in customer demand, short product life cycles, and many product variants. The principle is to assemble few product variants in each assembly cell. The allocation of product variants to assembly cells, the number of cells and the operating hours of each cell are adapted to current demand for products.

Asao (2001) has reported improved performance in several respects after replacing assembly lines with cellular assembly systems. For example, in a NEC plant for assembly of portable computers, man-hour productivity increased by 30% while the plant space required decreased by 40% and the cost for production equipment decreased by 90%; in a Canon plant for assembly of laser writers man-hour productivity increased by 20% while the plant space required decreased by 50%; and in a Canon plant for assembly of microscopes man-hour productivity increased by 30% while lead-times decreased by 70%.

It is however shorter product life cycles and increased variation in customer demand that has been the prime driving force of the introduction of alternative assembly systems. The now abolished assembly lines resulted in unsold stocks of "obsolete" products. The experience from cellular assembly is that start-up and running-in, so called ramp-up, of new products is done in a shorter time and that it is easier to increase and decrease production volumes than in the previous assembly line systems.

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9 Two of the present authors have recently visited some of these plants and have been able to corroborate Asao's findings.

The small work groups, which are specialized on the assembly of one or a few product variants, can be easily restructured and adapted to modified products, since production equipment and work benches are mobile. Layout changes are usually done each month.

It should be noted that in the Japanese case, production considerations rather than a desire to create more attractive jobs have driven the introduction of alternative assembly systems. Also, the decreased production losses in the new assembly systems have been capitalized on by the companies in the form of increased productivity. These efficiency potentials have apparently not benefited the employees through improved work conditions or less demanding work. In Sweden, by contrast, employees have sometimes been able to reap most of the efficiency potentials of alternative assembly systems in some cases, while in other cases neither employers nor employees have benefited, because the efficiency potentials have been wasted for reasons touched on above.

## 6 THE MOST SIGNIFICANT ADVANTAGES OF ALTERNATIVE ASSEMBLY SYSTEMS

Productivity in assembly work is often regarded as the most important aspect in the choice of assembly system design. However, for automobiles, for example, direct final assembly work corresponds to less than 5% of the total product cost. It is the product development and distribution, including marketing, that involves the large costs. This distribution of costs is similar in other industries.

Therefore, while it is interesting and important to note that alternative assembly systems tend to have higher man-hour productivity than assembly lines, the most significant advantages of alternative assembly systems do not derive from a reduction of man-hours required. Neither do they derive from decreased production costs due e.g. to improved space efficiency (meaning that the number of products manufactured per time unit per space unit increases) or due to the fact that less tools and manufacturing equipment are called for (see e.g. Ellegård et al. 1992).

Instead, the most important reasons for using alternative assembly include those that have driven the introduction of cellular assembly systems in Japan, as described in section 5. It is important to stress the flexibility advantage of alternative assembly systems, that is the possibilities to quickly and efficiently adapt to changes in a dynamic market. For example, in parallel product flow assembly systems, it is easy to adjust the production volume. Each product flow can produce without negatively influence the other product flows, for example by working over-time or working with adjusted manning. It also becomes easier to simultaneously produce different product variants and to introduce product changes or new products. In short, production systems with many parallel product flows provide many ways of achieving flexibility which are simply not available in single flow systems, such as assembly lines, not even “lean production” assembly lines.

The time span from initiating the product development until the product is introduced to the market, the so-called time-to-market, can also be reduced, compared with the assembly line, since the conditions to apply concurrent engineering will be improved. In low-mechanised assembly systems with a parallel product flow assembly system the ramp up time for new products can be reduced compared with assembly lines. It is also important in this context that communication between product design engineers and production people is simplified (Engström, Jonsson and Medbo. 1999).

An assembly line calls for considerable more co-ordination and planning of the assembly work than a parallel product flow assembly system. It is thus more easy to reduce the lead time from customer order to start of assembly in parallel flow assembly systems, i.e. shorter delivery times can be realised in parallel product flow assembly systems. Also, the product throughput-time can be shortened in parallel product flow assembly systems (Medbo 1999).

The assembly line requires extensive product design and manufacturing engineering work to function properly. Assembly in parallel product flow assembly system provides better opportunities than line assembly to manufacture products with a low "degree of design". Note that products with a low "degree of design" should not be confused with low-quality products; we are not talking about low-quality products but the ability to produce low-volume, high-quality products and/or customised products, where the individual product design is dependent on the individual customer order (Engström 1983).[10]

In alternative assembly, where autonomous work groups assemble complete products, the possibilities for direct communication between work groups and customers are radically improved compared to line assembly. This is especially important in business-to-business transactions, for example with authorities, transport companies and logistics companies.

Consequently, alternative assembly will offer opportunities to expand the operations of the companies through increased competitiveness based upon other competitive advantages than just low direct production costs. A dilemma when these types of advantages are discussed is that potential profitability is not as predictable as cost cutting in the budget. On the other hand, the potential profits are much more significant than what is possible to achieve through traditional cost management efforts. This requires, however, bold and innovative strategic thinking by top management; thinking in which the manufacturing strategy is used as to create a critical competitive advantage.

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[10] In fact, the annual model change cost per automobile for the same automobile models in the Volvo Uddevalla and Torslanda plants during 1990, 1991 and 1992 were only some 25 percent of those in the Torslanda plant. Thus, conventional economies-of-scale did not apply in this case (se Engström Jonsson and Medbo 1996A for further details).

# 7 CONCLUSIONS

Some explicit reasons given for re-introducing assembly lines in Sweden are that by doing so man-hour productivity, product quality and ergonomics can be improved. In addition, managers and manufacturing engineers often argue that the assembly line is necessary in order to be able to control the production and secure the delivery precision in output. Based on empirical data presented above, other empirical findings that we have not had space to discuss here and decades of experience from the Swedish automotive industry, we doubt the empirical validity of these arguments.

Furthermore, it may be the case that the re-introduction of assembly lines has not primarily been driven by 'rational' considerations based on arguments such as those just mentioned, but by 'non-rational' driving forces having to do with the internationalisation and standardisation of production systems, lack of knowledge regarding traditional and alternative assembly systems, changing industrial relations and the deteriorating labour market situation.

If the Swedish industry merely copies global production concepts, it will not be possible to take advantage of specific Swedish competitive advantages such as constructive industrial relations or generally highly skilled and motivated employees. Instead the higher man-hour cost will be a decisive drawback. In this way it will be "proved" that assembly cannot be performed profitably in Sweden.

If, on the other hand, alternative assembly is developed further, both working conditions and efficiency can be improved, as envisaged by Gyllenhammar. The man-hour requirements can be reduced, the space utilisation can be improved, and less resources are needed for administrative purposes and for product development (because of less need of high "degree of design").. Even more significant, as noted, are advantages such as increased flexibility (related to production volume and product variation), shorter time to market, shorter delivery time and possibilities of production at local markets close to end consumers. Furthermore, work in alternative assembly systems can become meaningful in a completely different way than at the assembly line, since it is a qualitatively different form of work that engages not only the manual competence of the operator.

Of course, the type of product and choice of product design can facilitate or obstruct the utilization of alternative assembly. Products requiring operations performed by automatic equipment mixed with manual assembly operations can for example prevent the use of parallel product flows.

In conclusion, it should be emphasised, however, that to fully utilize the advantages of alternative assembly, both for employees and companies, an extensive research and development work focusing on technical and human dimensions of assembly has been necessary and continues to be necessary. Alternative assembly does not only provide more opportunity for operators to make full use of their competence but also requires higher competence from people who design and manage assembly systems.

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