MANAGEMENT AND NEW PRODUCTION SYSTEMS

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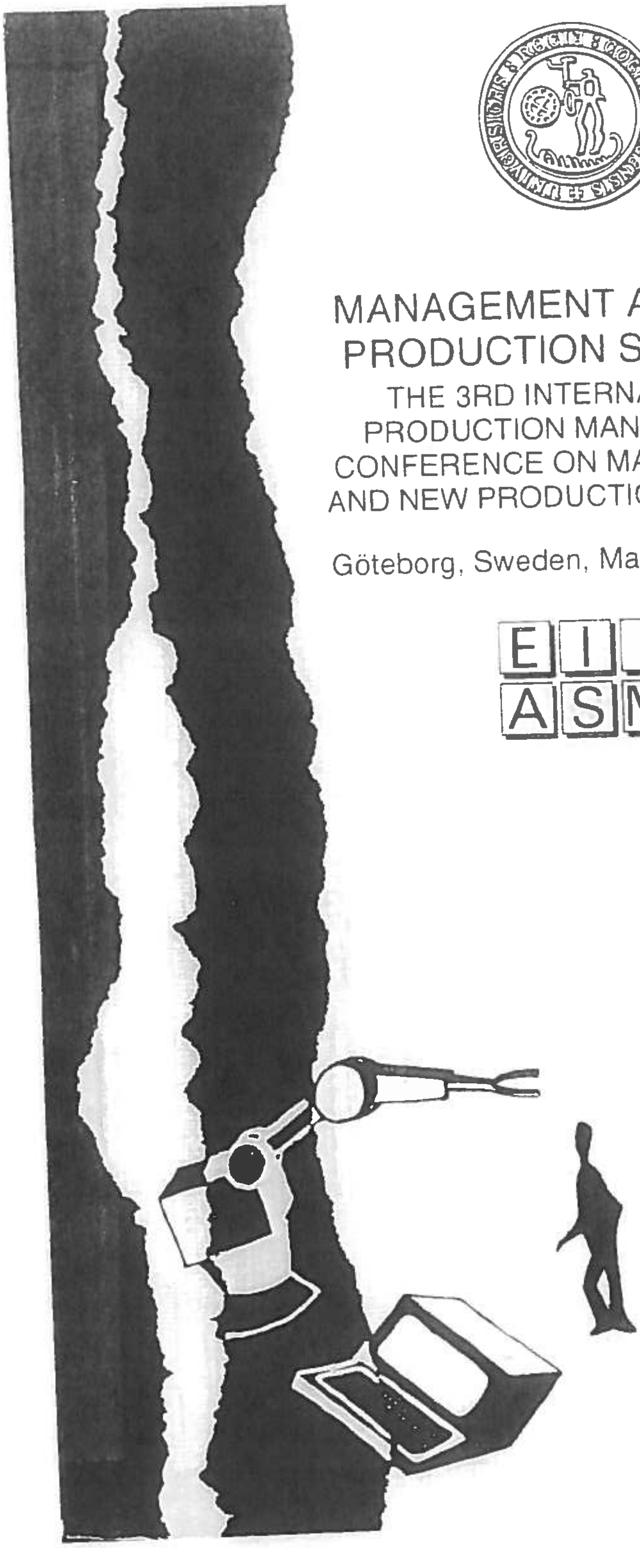

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MANAGEMENT AND PRE-CONDITIONS FOR LONG CYCLE TIME ASSEMBLY SOME FINDINGS

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1 Introduction

Earlier research in Sweden had shown that the combination of high production flow, a multitude of material to supply and assembly of medium or large sized products would have been impossible without line assembly. The use of parallel material supply is problematic because of the need for space for the material containers at the work station, which means extra cost for transportation, buildings and capital tied up in material. Furthermore it had been found that the design of the product was a very important dimension - and in some cases the only determining factor for the way in which the material supply and work operation were organized (ref. 3).

We have shown that the formulation of detailed production system specifications requires the participation not only of labour but of production engineers as well, and it is then perfectly possible to combine higher productivity with meaningful work content. Experience from such system changes has been communicated at the international level only to a limited extent. The uniqueness of each system makes transfer of experience difficult. There have been several failures when transferring experience from one system to another, usually because the local conditions have not been taken in account (ref. 5 and 6).

A possible conclusion is that production systems which are very similar to each other are probably not optimized since the products have proved to be so very different. The reason for keeping unmodified, "simpler" systems may be ignorance about the content of "the technology shelf" or the inability to establish the close cooperation needed for refinement of the system. The long tradition of close cooperation between management and labour in Sweden has greatly facilitated experiments with new production systems and work organization (ref. 9).

To some extent the limited production volumes (compared to those of many competitors) have improved flexibility in the Swedish production systems. our experience has shown that it is extremely important to specify exactly the performance requirements of the new systems. In order to understand and be able to meet these requirements, it is necessary to describe clearly and communicate the overall goals among the parties involved.

The overall goal of series production of automobiles and trucks has for a long time been to produce a given design at the lowest possible cost. The production engineer has been reasonably independent when setting up his part of the production system. Similarly the vehicle designer has retained considerable freedom when implementing re-designs based on the feed-back from the production system.

If line assembly is to be replaced for reasons of efficiency and to satisfy demands for humanization of the work, the management and pre-conditions will have to be radically changed. Moreover, a wide range of variants, in combination with a large number of direct deliveries of complete pre-assembled components, leads to unrealistic solutions for materials supply to the assembly line. The growing differences between production systems, central pre-production procedures, and designers' product description method, mean increasing amounts of information need to be transferred if local pre-production is limited. If considerably greater work content is to be achieved this information has to be reorganized using formalized knowledge on the local factory floor as a base. This reorganization must be based on the product itself and its variation.

2 Additive and functional characterization of the work

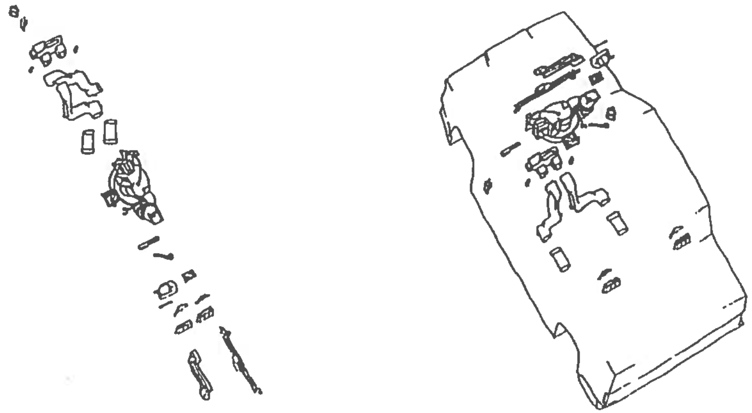
There are essentially two different ways of forming a mental picture of the work task by means of "inner maps". The work is viewed either additively, each element being added to those already mastered, or functionally, so that details are a consequence of wholes. Individual work elements are through interpolation out of a generally current descriptive structure instead of being extrapolated out of a number of tasks.

This means that the material, in the form of components to be assembled and which for the beginner initially only describe how the work is to be performed, at a later stage for the skilled operator, have been transformed into "inner maps", representing the actual assembly reality. This then means that the assembly reality is in agreement with the skilled operator's mental picture of it. The work itself has then been integrated into the operator's professional skill.

One of the basic principles in long-cycle assembly work is that there must be agreement between how to carry out the work, how to display the materials and how to describe the work. It must be possible to visualize the product and the work in advance, but the problems then arise of how to determine if the wrong materials or the wrong description have been supplied, or if there is uncertainty in respect of how to carry out the work - otherwise the worker is forced to test-fit the materials, with the consequential risk of being forced to dismantle.[1]

One conclusion that we draw from our research is that up to the present time it is the flow pattern on the shop floor, the descriptive systems used by

the company and the existing work organization which have generated most of the unforeseeability, digitalization and additive thinking in the final assembly of automobiles. Neither has the need to create new, rational thought patterns in the vehicle industry been a prominent issue before .



Components for a climate control unit placed in assembly order.

Components for a climate controll unite placed according to their position in an automobile.[2]

Figure 1: Above is illustrated the difference between describing the work as a sequence of steps contra viewing it functionally. In the latter case it is an aid to understanding how the climate control unit in the figure functions in reality.

3 Explorative studies, action research and experiments to find an operationalization theory established on thorough empirical data

In order to implement occupational learning theory and to convince practioners of, for example, the possibility to supply materials, the Volvo Uddevalla project employed researchers (ref. 11, 14, 15 and 16). These were given access to an experimental workshop ("The Red Shed") and the company's products (including structural information from the administrative systems). The researchers worked together with assembly workers and production engineers in the training workshop that was set up before the Uddevalla plant was completed. Both established and newly developed knowledge could in this way be articulated in terms of "nuts and bolts". It was necessary to depart from an evaluating "label research", whereby researchers try only to describe and classify that which already exists. This type of research does not lead to any breakthrough as regards knowledge.[3]

One of the aims of the work in the "Red Shed" was to create instruments which would allow the workers to check their own work and maintain production quality and the quantitative planning of the production volume[4]. The knowledge developed was then transferred to routines and documents which facilitated the broadened assembly work.

Experience from the periodicized assembly work [5] in the training workshop with different layouts and results in the form of, for example, revised work instructions and checklists, indicated the preconditions for the assembly work according to stipulated principles.

The formalization of both the structure of the product from the point of view of final assembly and the assembly work itself allowed that times fixed by central pre-production could be made available for more variants than were built at the time in question. These times then formed the basis of our calculations of production capacity for different layouts. Decisions regarding assembly concept were also on these times.

The existing structural information systems for the product were primarily designed to steer material to a material address along a line, but the smallest unit in the information systems is not synonymous with the smallest unit in the assembly reality, which is why parts such as loudspeaker grilles are found in one position in the overall design structure but in four positions in parallelized assembly where each work group assembles the doors as integrated subassemblies (one grille for each door).

Since we were endeavouring to develop a new structure that would support long cycle time work it was necessary for us to dismantle a number of products. As an aid and for registration, data printouts and reduced photocopies of production engineering information were laid out on tables. In this way we were able to understand both the real products and their current administrative description.

This work was carried out in stages over a number of years, in order to find the new groupings and ascertain the principles valid for them.

We first had to understand a single product, which was a variant of with a simple design. This was identical with the first fifty automobile assembled in the training workshop. Then followed the dismantling of a number of extensively equipped variants.

When this work had been completed we had learned enough to be able to perform both paper and computer-based analyses. For three years all the components remained laid out on the floor, marked with structure information, to enable us to check when we felt uncertain. Another reason for keeping the components for so long was that during this period we also produced visual illustrations which described the new structure of the

products. To help us with the illustrations we employed an architectural research student specializing in visualization techniques.

Alongside the work of assembly and dismantling empirical manual explorative studies were made with scissors, glue, paper, copying machines, a word processor and pens. All results were purely manual to begin with, i.e. written by hand or on a machine, drawn or cut and pasted. As the project progressed a certain amount of computer support was made available and collaboration with practitioners, who willingly put resources at our disposal, intensified. An important feature was, therefore, that manual explorative studies led to heuristic models which were further elaborated by means of computer support and finally led to formalized data models and computer systems (ref. 16).

4 Stages in our method during the first two years of research

The stages in our method for developing principles for naturally grouped work are illustrated in the figure below. We first tried to find distinguishing groups of material for a particular automobile. Then a number of support systems were built, designed among other reasons to maintain the new groupings (these could, for example, consist of various types of index, often alphabetical).

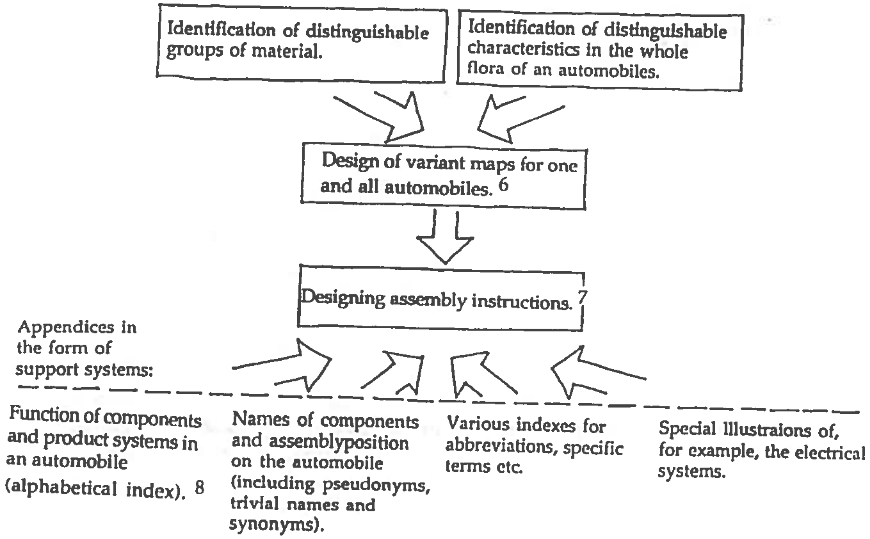


Figure 2: Stages in our method of developing naturally grouped work.

From the beginning these support systems were the analytical instruments of the researchers. Identification of distinguishing characteristics in the the whole flora of automobiles followed, which in turn gave "variant maps" with new variant specifications. It was only then that it was possible to begin the work of developing work instructions for the operators. In the figure below the method stages have been numbered according to the order in which they were performed. As is shown, the research work did not start directly with developing the work instructions, but these were instead a consequence of the following stages. It would have been impossible to start by producing instructions.

5 Functional characterization and its relationship to additive assembly sequences

Expressed in a few words, the research has developed and implemented a verbal and visual network for a final assembly plant, which makes it possible, without exception, to relate individual parts to different wholes. This network of texts, words and pictures is named "the assembly-geographical atlas" (interrelated maps). This atlas is based on characteristics always present in all vehicles. There are certain generic characteristics, built-in hereditary factors which we have used to obtain a new description that is resistant over time and between different products irrespective of whether these vehicles are automobiles or trucks, (ref. 17). We have carried out a similar analysis for Volvo Truck Corp. and the results are today in the process of being applied.

The description of the final assembly of the automobiles exploits symmetries in real objects and variations around these symmetries, i.e. the point of departure is that distinguishing characteristics which are always found in all automobiles must be used (for example if a right hand part exists then there must also exist a corresponding left hand part, if central locking is fitted then mechanical locks are not fitted etc). The guiding principle, as stated earlier, is that there must be agreement between the way of working, the material display and the description of the work, where the description of the work is based on a number of "basic maps", so-called Final Assembly Functional Groups, of the product and the consequent assembly work. These "maps" are at the same time both verbal and visual, and are based on the fact that the automobiles' variation is an asset and describes the product and the assembly work in a way that maintains stable relationships between the description of a specific automobile and all possible individual variants. [9] The assembly geographical atlas constitutes rational thought patterns and "inner maps".

The figure below presents results of our research in the form of exploded views which illustrate the final assembly functional groups. In order to provide an overview of the product and thereby the whole final assembly process a system of stable illustrations has been developed, in which the body is viewed at an angle from above and behind. The illustrations are

grouped according to level so that they range from one automobile to all automobiles and from a complete automobile to an individual part. These illustrations are available in different forms with a varying degree of schematization, i.e. both realistic and symbolic pictures. [10]

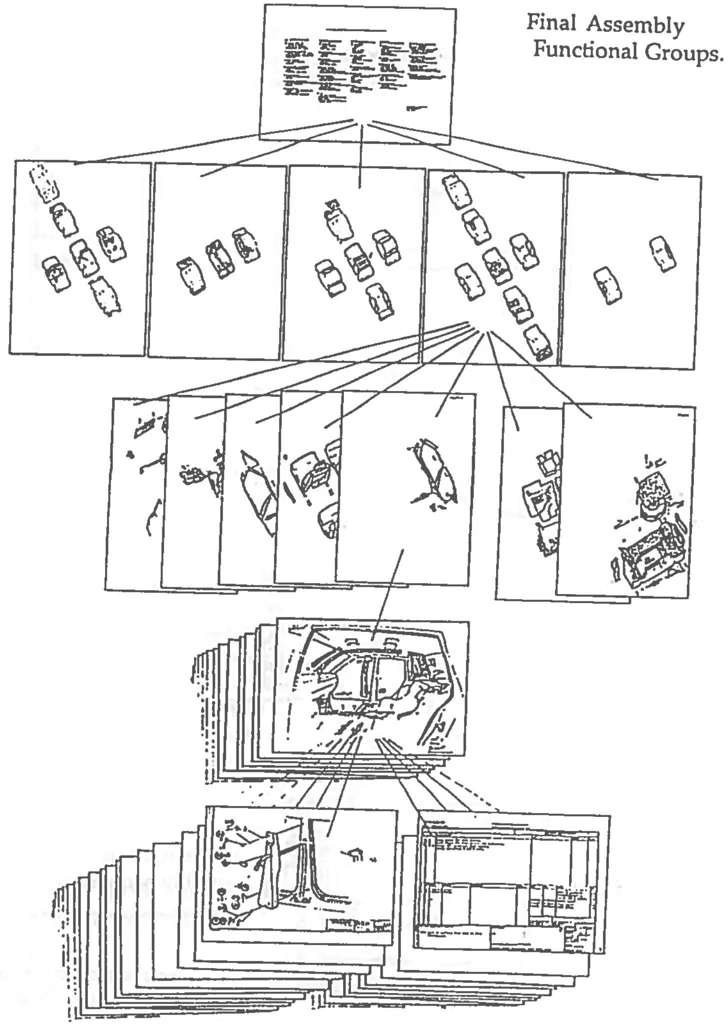


Figure 3: Examples of exploded views which illustrate the Final Assembly Functional Groups.

The Final Assembly Functional Groups are used as a starting point for assembly instructions which consist of various assembly sequences. These sequences can be derived and developed, according to the production system employed. This is achieved by means of the work distribution which consists of so-called assembly phases (a section of the assembly sequence) and the worker positions in a work team, illustrated schematically as a "compass card", which occurs again in the introductory overview to each section of the assembly sequences. The assembly phases are described in increasing levels of detail, as shown in the figure below. [11]

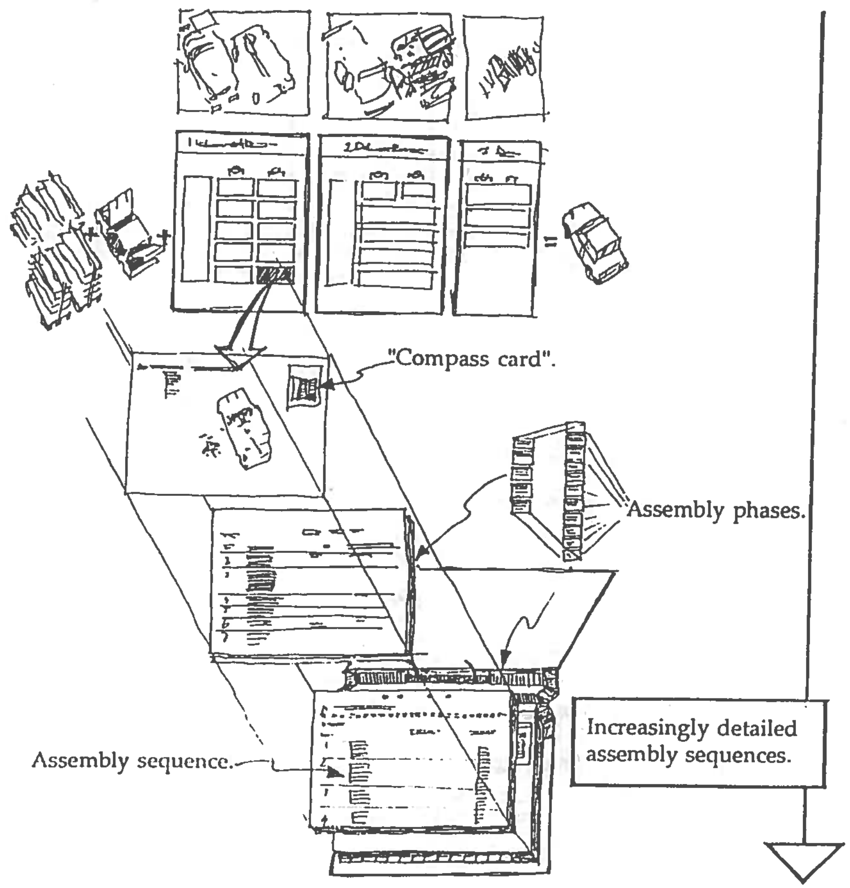


Figure 4: **Above is illustrated how it is possible to shift between The Final Assembly Functional Groups and assembly sequence for an individual automobile (consisting of different so-called assembly phases which are normally different for different production systems).**

These levels are linked by indexing, gridlines of varying length and thickness, ancillary tasks are described in italics etc. These assembly instructions also serve as a communication instrument between the various departments who collaborate in the final assembly. It is possible, for example, to order material when shortages occur, by means of the assembly instructions. The production engineering aspect of the local pre-production of the automobile is also carried out by organizing production engineering in accordance with the Final assembly functional groups. This has allowed the implementation time for large product changes to be considerably shortened.

Since the Final Assembly Functional Groups are based on the components, one and the same database can contain all the components and form the basis of all the administrative support systems within the factory , i.e. picking lists, assembly instructions and time analyses etc are different aspects of the same reality.

6 Some implications for local factory management of the new characterization

In contrast to short cycle work, the application of occupational learning principles in long cycles in final assembly systems with a high degree of parallelization, has necessitated the development of a system of concepts and a language to facilitate communication, the building of experience, and orientation in assembly reality.

This language allows production engineering and pre-production activities to be transferred to a more qualified personnel than is normal in today's Swedish factories, namely to the spearhead competence on the factory floor (such spearhead competence is in use abroad, ref. 10). It becomes possible to create natural work.Through the components being given a meaning by linking them to a language, it also becomes possible to regard assembly work as a meaningful occupation. It then becomes a job to which it is possible to have an intellectual relationship, thereby enabling the learning of an ever larger work content. This transfer of work tasks to the factory floor is necessary in order to create a profession in the assembly industries of the future.

Reality in the form of the components and their design, and the verbal and visual representation of this reality are therefore intimately linked.

Our experiences indicate that, within the automobile and truck industries, the greatest obstacle to the work of tomorrow (either as an assembly worker or as a designer) is not in the work itself, but is to be found in the work description in use today and the resultant perception of one's own work in relation to the performance of others, the underlying principle being that if my conceptions help me to handle reality, then they are correct. These conceptions can, however, initially be derived from qualities that exist in reality, and later assembled into logically resistant patterns. The need for this kind of rational thought pattern has not previously existed in final assembly, and has therefore never been identified and formalized.

When the workers' tasks are broadened the need for central support functions changes (i. e. those parts of the work that today are performed by central pre-production and planning departments). In order to allow the assembly activity both at individual and group level to receive the autonomy and support needed to be able to accomplish the tasks an organization is required that is based on the production activity to a greater extent than at present.

The need then arises for "flat organizations" in the local factory, with completely new delimitations. These organizations will be specifically distinct, according to the assembly process chosen. The staff in these new production systems will then have new functions to perform, at the same time as certain of their present tasks are transferred to production itself.

One example is material pre-production, which was earlier restricted to the communication of information between supplier and store. Its new task will be to carry forward and ensure that the new language in the production activity has correct names and structural information that makes each individual component uniquely defined both in the company's central and in the local information systems. 12

At the same time the role of management in or connected to assembly will be redirected from problem solving in acute situations to being responsible for long-term maintenance/development of the pre-conditions in production and the internal knowledge profile of their own work groups.

Let us summarize some consequences of long cycle assembly work:

-As long as the Swedish vehicle industry has not recogniced identified the need for assembly-related product structures, in connection with the introduction of the new assembly work, the staff in the local assembly plants, and their support functions, will have to perform a multitude of new rolls, as compared to their traditional ones.

This fragmentizes their activities, since they must be responsible for redesigning the central product structure while supporting the assembly work.

Our conclusion is that this local activity will be considerably simplified and made more efficient if it is based on an assembly-related product description common to the whole company. This will allow local resources to concentrate on supporting the assembly work. At the same time the new product description will mean that details will be derivable in the company hierarchy and exchanges

between different local processes will be simplified. There is also reason to believe that these changes will in the future have considerable influence on the work of the designer too.

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1 It has recently been found, when applying these principles in the final assembly of automobiles, that learning time for a 120-minute cycle-time is 2 weeks for half full pace and has been estimated to be 3 months for full pace. To achieve these times, the systems for describing the work have not, however, been fully developed. These times should be viewed in relation to the conditions relevant for conventional line assembly with additive work elements. Earlier research has shown that 20 minutes is here the maximum cycle time for automobile assembly with a learning time of 3-6 weeks for full pace (ref. 3).

2 To describe the complete final assembly process for an automobile, 28 "maps" with this degree of detail are required. In our example , conventional line assembly requires 1900 process instructions from pre-production each with from 1 to 5 detailed illustrations. These illustrations are not standardized with the result that the assembly process can not be surveyed. The process instructions are spread over approx. 400 additative line stations to enable the final assembly process to be described and performed.

3 In order to influence large industrial systems, research established on thorough empirical data is required, where researchers and practitioners work together in action research projects. Industrial changes occur so quickly that action research is a precondition for my aims to transfer and, together with industry, develop new knowledge and in order to influence ongoing projections in industry.

4 Personal control over other conditions here includes responsibility för basic production data, work functions, understanding of functions, working as instructor etc.

5 Principles which include work rythm, and time distribution ("periodicity") preparatory structuring of material and equipment, and successive development of knowledge in the areas of quality, production volume, and instructor ability, and where assembly capacity has been grouped functionally (ref. 11 and 14).

6 To cover the possible variation for all markets an automobile family is described by means of 77 different areas of characteristics. 28 of these affect the the assembly work. The corresponding figures for all variants for one single main market are 46 and 13.

7 Now that it has been fully developed the information system is able to break out each individual component with the correct central information complemented with process-dependent local information for each particular automobile for any structure week. This information system allows the product to be derived from the perspective of different users, for example assembly instructions for fitters and picking lists for material handlers. It functions also as a protective shield to prevent incomplete or incorrect information from negatively affecting the assembly or material handling work. The descriptive structures used by the whole company is compared and changed to agree with the assembly principles.

8 These comprise, among other things, registers of all concepts required to be able to understand the function of all automobile variants. The total number of concepts is 137. The register includes synonyms and the constituent components of variants, indicated by different printing styles. If the automobile is to fitted with air-conditioning a rectangular rubber plug is fitted in the upper fire wall, with two holes for the AC-leads. If the automobile is not to be equipped with air conditioning, this rubber plug has no holes. The rubber plug is in this case a constituent component for air conditioning. There are also descriptions of how common the systems (functions) in the product are, the components in them and how they work. These descriptions include references to various information sources, such as production details, spares catalogues and service handbooks.

9 The criteria distinguishability and generativity were the bases for producing these maps (ref. 17).

[10] These illustrations are based on a number of reference diagrams of the body and build hierachically various sorts of illustrations from part to whole. They are drawn in milltary perspective so that it is possible to shift around the components without deforming the perspective. The overviews serve as instruments to survey at group level. The automobile is viewed at an angle from above and behind "as a town planner views a town". It is important first of all,in the context of long-cycle work , to be able to see who will be working on the right and on the left and at the front and rear. These illustrations also contain a number of basic views originating from the same diagrams. We have also used the illustrations, together with the fitters, to balance the assembly work for all possible and tested assembly layouts. In the system of illustrations each final assembly function has been assigned its own colour, which makes it easy to perform engineering analyses by using scissors, glue and paper.

[11] The material required to perform the assembly work is supplied to the fitters acording to the same principles applied to the description of the work. This means that the material is displayed by grouping into levels. The material for assembling an automobile is supplied to the fitters in the form of a kit, composed according to the "chosen routes" through The Final Assembly Functional Groups. To supply material to a selected automobile six specially designed kitting racks (1,9 x 0,8 x 1,6 m) with a total volume of 13 m^3 are required in addition to the body. Parts that fit in boxes (0,6 x 0,4 x 0,15 m) that can be handled manually are packed together according to the above principles. Small parts are kitted in bags. These then in themselves form an assembly instruction. This method provides increases the surveyability of the automobile's components. As stated earlier, a complete material kit is made up of 6 kilting racks consisting of 32 boxes and 190 large parts. The boxes contain 410 parts and 90 bags. This makes a total of 690 supply units to the fitters for each automobile. This must be compared to conventional material supply to line for all variants, which entails the display of parts in over 5000 different positions.

[12] A certain screw which occurs in a number of different positions in a certain automobile must be uniquely defined in each case, to provide an efficient administrative image which can support operators and production engineers, facilitate communication and prevent misunderstandings. In today's assembly plants this structure information is not available in the parts' administrative image (the need for this has not been apparent in line production systems).

Compare having only a part number with having complete structure information for a particular component. This complete structure information means that the component is defined via a series of textual concepts relating the individual component to the product as a whole (function, position, sub-asseblies etc). We exemplify this with a component numbered *96 84 64* referred to as *Screw ST4,8'13* which is part of *Lock cylinder, side doors*, which is part of *Lock cylinder kit*, which is part of *Lock/handle*, which is a component of *Automobile type x*. The italics indicate structure information. This is the formalization of the designer's work. This information exploited correctly this is a great advantage in the assembly work.

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