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## An Assembly-Oriented Product Description System as a Precondition for Efficient Manufacturing with Long Cycle Time Work

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ABSTRACT:

This paper concerns pre-conditions for long cycle time work in parallelized final assembly of automobiles and trucks. The design-oriented product description system traditionally used in the Swedish motor vehicle industry is presented and some of its shortcomings when applied to assembly work are discussed.

High quality information has proved crucial for efficient manufacturing in highly parallelized final assembly. The paper reports on the methods developed by the researchers in order to create an assembly-oriented logical product structure supporting a holistic perception of the product and the assembly work. This new logical product structure provides the basis for a multi-level verbal and visual product description system which has been partly implemented in two final assembly plants in Sweden.

Finally we spell out some conclusions regarding quality and productivity issues.

KEYWORDS:

Cognitive engineering, final assembly, information preconditions, efficient manufacturing, inter-department communication, long cycle time assembly work, motor vehicle manufacturing, preconditions for quality, product structures, quality of information system.

## INTRODUCTION TO THE PROBLEM AREA

In serial production of motor vehicles in Sweden, the traditional bill of materials based on the central design departments' work is used as one means of communication and coordination between design, central pre-production and local production facilities.

The bill of materials is therefore transformed to support the coordination of materials supply and local manufacturing processes. To put it simply, the perception of the real product is destroyed during this transformation, since the the bill of materials leads to an atomistic perception of the product and the work on the shop floor. This calls for local pre-production and production engineering work to restore the information into a form suitable for the particular assembly system involved in order to get the quality data needed for effective manufacturing.

Our experience from designing production systems for long cycle time final assembly emphasizes the need for a holistic perception different from that generated by the traditional bill of materials. This requires an assembly-oriented logical product structure, emanating from the generic characteristics always present in vehicles on the shop floor. This has been found to be a precondition for non-traditional material feeding techniques and efficient learning on the shop floor in parallelized final assembly, Engström and Medbo (1991a).

A new product structure of this kind has been introduced in a Swedish final assembly plant (Volvo Uddevalla) using parallel product workshops where small teams of operators assemble complete automobiles. The components needed for the assembly work are supplied as kits comprising the materials needed for one complete automobile. The main purpose of the assembly-oriented logical product structure in this context is to structure the components for the operator in order to support long cycle time assembly work, Engström, Jonsson and Karlsson (1992).

## THE TRADITIONAL DESIGN-ORIENTED PRODUCT DESCRIPTION SYSTEM

In this section we outline the product description system traditionally used for design and product specification purposes in the Swedish motor vehicle industry. This description system may be regarded as consisting of the following types of information (coded as in Figure 2):

(a) *Component information*, including a list of part numbers identifying all components occurring in vehicles belonging to the product range.
(b) *A product structuring scheme*, in this case based on a design-oriented logical product structure that provides a hierarchical classification of the product's components. Being design-oriented, the classification scheme is based on product functions analyzed as appropriate for design purposes. On the highest level, the product is divided into seven main function groups, designated 2 000 - 8 000. These groups are then sub-divided on five additional levels (see Figure 3).
(c) *A variant definition scheme*, comprising a set of so-called variant families each of which serves to describe some product function in terms of different variant designations.
(d) *Product variant information*, specifying which selections of variant designations (one for each variant family) that specify a valid product variant (i.e. a unique type of vehicle in the product range).
(e) *Product specification information*, including a file of material control codes, each of which specifies a part number, the lowest level function group to which that component belongs, the number of such components to be fitted into that structural context and a selection of variant designations specifying for which vehicles these components are to be included. This means that if all the variant designations specified in the material control code are applicable to the specific product to be manufactured, then the requisite number of components with the part number specified in the material control code should be fitted into the structural context specified.



It is clear that given a specification of the product in terms of a comprehensive list of variant designations we can generate a selection of material control codes which serve to specify which component should be fitted where (and in what quantities) in a product characterized by that selection of variant designations.

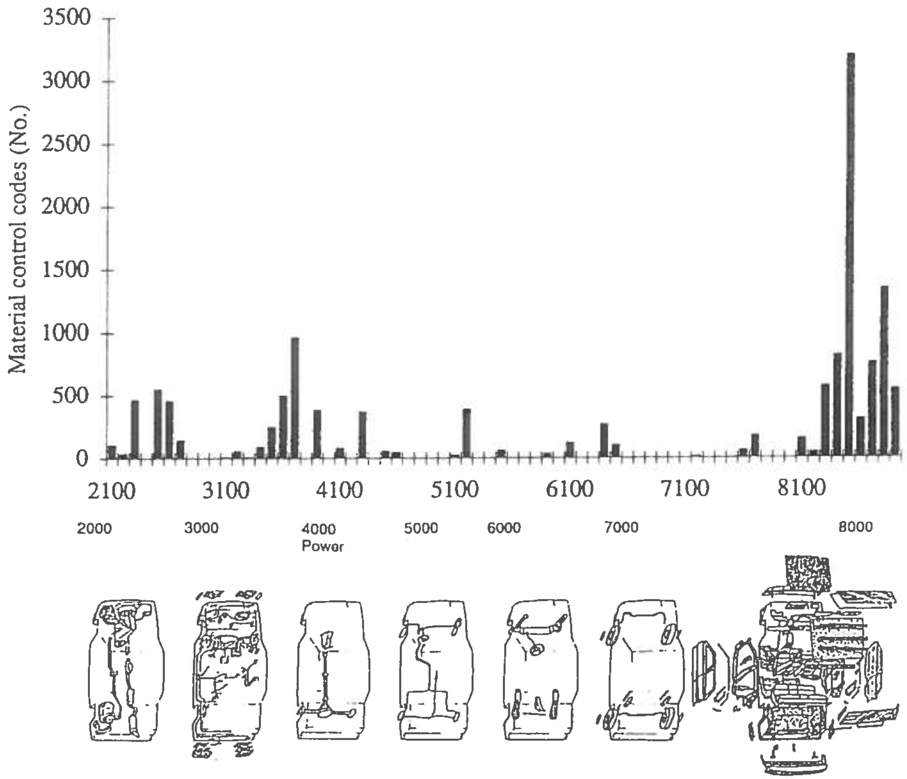



Figure 1. Above are shown the main function groups used for automobile final assembly and the number of material controll codes. The main function groups are 2 000 Engine and equipment, 3 000 Electric power supply and instruments; 4 000 Power transmission; 5 000 Brakes; 6 000 Wheel suspension and steering; 7 000 Frame, springs, damping and wheels; 8 000 Body, cab and upholstery. Note that for reasons discussed later, material control codes, i.e. components, are concentrated in main group 8000.

The product description system consists of a *computer-oriented ("digital") core of alphanumeric codes* supplemented by *descriptive names* for components and function groups. Variant designations, for example "M AIRBAG" (with air bag), and combinations of such variant designations, can moreover be seen as arbitrary *alphanumerical codes* used for material selection or as *meaningful names* of certain product functions appropriate for design purposes. As discussed below, digital elements and interpretations of the traditional product description system are often emphasized when the system is adapted to support shop floor activities.

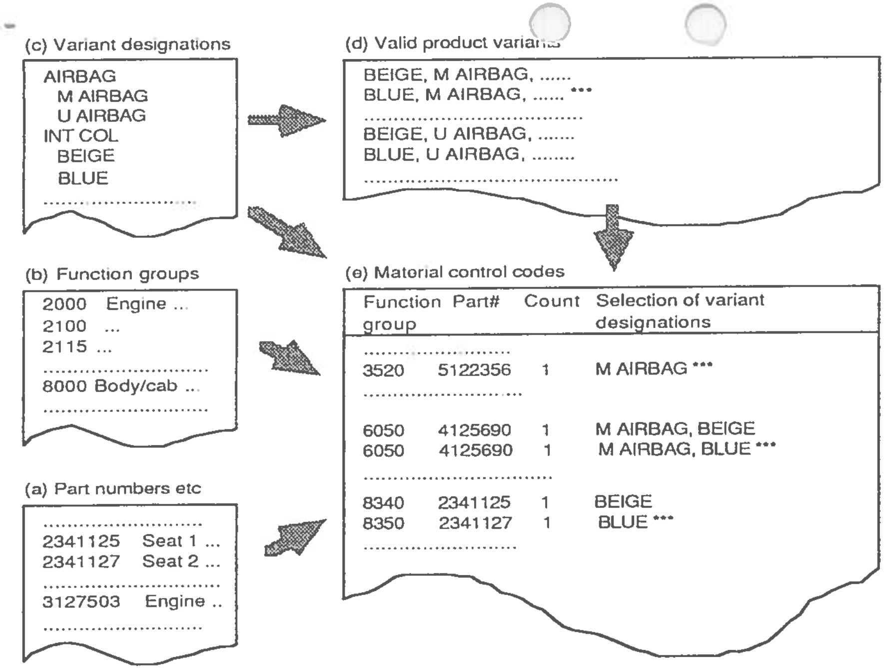



Figure 2. The design-oriented product description system traditionally used for design and product specification purposes (*** indicates one specific product variant).

## THE IMPACT ON THE PERCEPTION OF THE PRODUCT AND ASSEMBLY WORK OF THE TRADITIONAL DESIGN-ORIENTED PRODUCT DESCRIPTION SYSTEM

It is possible, to some extent, to adapt the design-oriented product description system outlined above for use in other departments by adding further information while simultaneously ignoring or deleting other information.

For example, for purchasing purposes one adds prices, names of suppliers etc to the component information, i.e. (a) in Figure 2; the sales function adds market-oriented product specification codes to the product variant information (d); and production adds routing information to the product specification information (e) to support material supply.

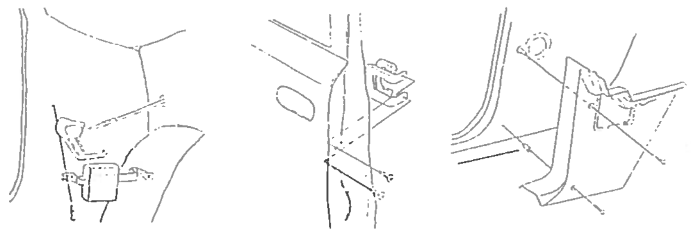
Unfortunately, this approach has led to poor quality of information in some respects and an unnecessarily complex perception of the product. This is particularly evident with regard to the shop floor production activities, which are our main concern here.

The principal cause is that the computer-oriented alphanumeric codes tend to take precedence over name-designations and the higher levels in the logical product structure tend to be ignored, or disappear altogether, as the name-designations are stripped away in the successive steps of the transfer of information from the design department to the shop floor.

Moreover there is no visual or spatial support to describe complete products with the components that comprise them in a way that makes it possible to see individual components. The illustrations that exist are on a much too detailed level and categorized according to function group, which makes it very difficult to find a specific component unless one is very well acquainted with the product and the description system. The illustrations are also inconsistent in that the product is viewed from a number of perspectives without any standardization which would permit illustrations to be combined. Neither is it possible to see correct designations on an illustration, since picture and text are on different pages.

Previously, before the assembly of complete automobiles by parallel small teams had been proved to be a realistic production concept and before the "new assembly work" had been formalized, the flow of information from the design department to the workshop floor had been mainly one-way. This state of affairs meant that assembly work along the traditional assembly line was fragmented and formalization and feed back of assembly experience to the design department was neither "worth the trouble" nor indeed possible. Describing the product in small disjointed units has been regarded as natural.

The need for a reorganisation of the traditional design-oriented product description system is also accentuated by the fact that different assembly plants today have specifically different production systems (as long as line assembly was all-dominating, the central pre-production work was more supportive and more easily accessible to the local final assembly process).



| DESIGN DEPARTMENT INFORMATION | | |
|---|---|---|
| **2710** 40 *147* *968464* | **8340** 10 *110* *968464* | **8512** 10 *621* *968464* |
| **Engine With Mountings** | **Body, Cab And Upholstery** | **Body, Cab And Upholstery** |
| **Engine Control** | **Doors And Lids** | **Interior** |
| **Throttle Control** | **Lock/Handle** | **Trim Panel,Side** |
| **Cruise Control** | **Lock Kit** | **Panel Cowl Side** |
| *Cross Recessed Sems Screw* | *Cross Recessed Sems Screw* | *Cross Recessed Sems Screw* |
| *Bracket Control Unit* | *Lđscylinder, Mrit 1316314* | *Cowl Panel Lh* |

| SHOP FLOOR INFORMATION | | |
|---|---|---|
| *968464* | *968464* | *968464* |
| *Cross Recessed Sems Screw* | *Cross Recessed Sems Screw* | *Cross Recessed Sems Screw* |

| | | | |
|---|---|---|---|
| **XXX** | = Product structuring scheme, function groups, higer levels 1 - 4. | *XXX* | = Product structuring scheme, function groups, lovest level 6. |
| XXX | = Product structuring scheme, function groups, lover level 5. | *XXX* | = Name of component |

Figure 3. Uppermost is shown the verbal information available in the design department for a *"Cross Recessed Sems Screw"*, part number *"96 84 64"*. This particular screw is used, among other purposes, for fitting the bracket for the control unit for the cruise control to the inner firewall, for fitting the locks to the doors and for attaching the trim panel on the side cowl. This screw occurs in different places in the design-oriented logical product structure depending on where it is to be used and is carefully described verbally right at the start. In the lower part of the figure is shown the information which traditionally "stays all the way", albeit in abbreviated form, when the screw is described on the shop floor. As illustrated information which is of value for the assembly process is lost during the tranfer to the shop floor, which leads to an atomitstic perception.

In addition to the problems mentioned above the traditional design-oriented logical product structure does not support a holistic perception of the product and the assembly work (cf Figure 4). There are several reasons for this reasons for this shortcoming.

First, the traditional logical product structure is *design-oriented* and describes product functions from the point of view of the design department.

Second, the product structure is *designed for vehicles in general* (cf. Figure 1). When, for example, it is adapted for an automobile, it causes parts of the hierarchy to disappear.

Finally, the product structure (according to Figure 4) is *out of date,* since it was designed for vehicles of the 50's and 60's. Today, for example, the whole interior is upholstered with panels of plastic or cloth, which is why most of the components are to be found in the last of the seven main groups in the traditional logical product structure.

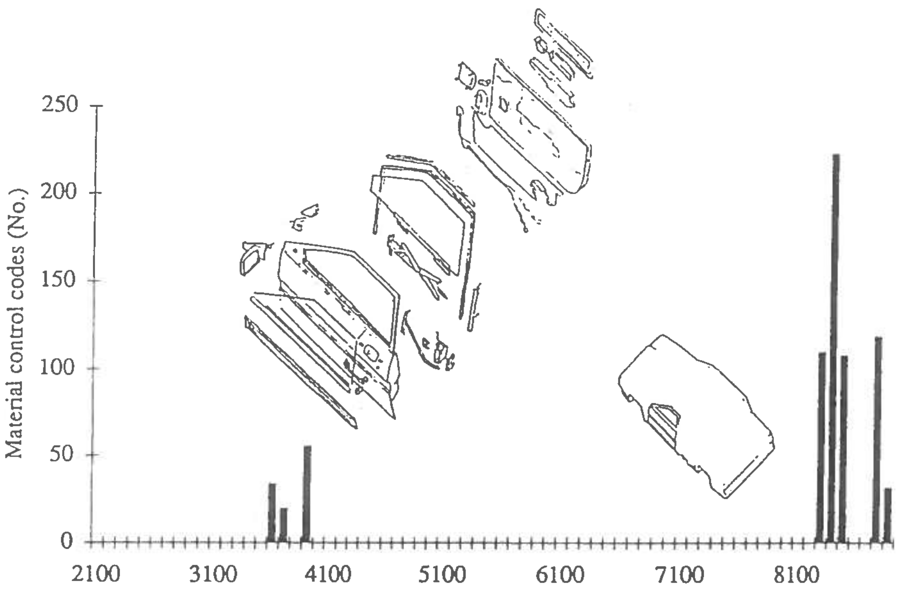



Figure 4. Above is demonstrated by means of the components comprising an automobile door that the traditional design-oriented logical product structure is distorted. Note that the automobile door is spread over several different function groups (those components that belong together in reality do not belong together in the function groups and vice versa).



| | *Characteristics of product description system:* | *Implied product conception:* | *Provides adequate support for:* |
|---|---|---|---|
| *Computer-oriented core and human-oriented extensions* | - Verbal/digital, artificially structured<br>- Incoherent and distorted | - Fragmented<br>- Non-contextual<br>- Non-visual<br>- Distorted | - Computer-controlled material feeding, short cycle time assembly work |
| *Computer-oriented core and reformed human-oriented extensions* | - Multi-level visual/verbal/ digital, naturally structured<br>- Based on single pre-defined point of view | - Restructured<br>- Contextual<br>- Visual<br>- Spatial<br>- Able to accommodate many different points of view | - Computer-supported material supply, long cycle time assembly work |

Figure 5. Summarizing comparison between the traditional design-oriented product description system and an assembly-oriented description system based on final assembly.

## THE METHODS USED TO REFORM THE DESIGN-ORIENTED LOGICAL PRODUCT STRUCTURE

To construct an assembly-oriented logical product structure, we dismantled a number of products seeking guidance from the production documents and assembly instructions that were available. It is significant that in spite of support from the company's experts it was not possible for us to find any simple way of understanding how this dismantling was to be carried out, one of the reasons being the incoherent representation of the real vehicle provided by the traditional design-oriented logical product structure.

First we tried to find distinguishing groups of components for a specific vehicle. A number of support systems (which could, for example, consist of various types of indexes, often alphabetical) were developed in order to compare the real components with information about the product and the assembly work. This was an iterative process – the research work constantly changed between the components laid out on the floor of the experimental shop and production documents and data print-outs placed on large tables.

During this process we marked each component with labels containing complete information from the traditional design-oriented description system. We also sewed down all small components together with the appropriate illustrations on 21 large (220 x 120 cm) white sheets of paper. This method allowed us learn the product and to establish connections between the components and the product structures. These paper sheets were also used by the new operators to learn the assembly work.

We used illustrations reduced in size from those provided by the central pre-production department, but we also constructed a completely new illustrations system as a contextual visual aid. This system contained several interrelated levels and used a standardized outline for normalizing the illustrations: the vehicle is viewed diagonally from behind, as if entering an automobile on the driver's side, Engström, Hedin and Medbo (1992).

Identification of distinguishing characteristics in the the whole flora of automobiles followed, which in turn gave "variant maps" with new variant specifications, Engström and Medbo (1991b).

Figure 6. Interior of "The Red Shed", the experimental workshop where we dismantled various automobiles and trucks in order to be able to compare the products' components with paper print-outs from the traditional design-oriented description system spread out on large tables.

## SOME COMMENTS ON THE NEW ASSEMBLY-ORIENTED LOGICAL PRODUCT STRUCTURE

The guiding principle linking long cycle time assembly work and the product description system is that there must be agreement between the way of working, the material display and the description of the product and the work on the shop floor. In long cycle time assembly work, the description of the product and the work needs to be based on a new assembly-oriented logical product structure.

The logical assembly-oriented product structure used in the Volvo Uddevalla final assembly plant (using highly parallelized flow and long cycle time work) comprises five main so-called final assembly functional groups, Engström (1991). These are simultaneously verbal and visual "maps". They describe 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 (sometimes we talk about an "assembly geographical atlas" defining rational thought patterns and "inner maps").

The distinguishable main groups are: 0 Doors; 1 Leads for electrics, air and water; 2 Drive line; 3 Sealing and decor; and 4 Interior (see Figure 7). This division is designed to categorize the components so that the groups of material, both individually and in interrelation, form contexts and are distinguishable from each other. If for example the interior is to be assembled, this is clear not from a single component but from the individual components being related to a group of components that has been assigned a descriptive Swedish name and belongs to a multi-level verbal and visual/spatial product structure.

In practice, efficient automobile assembly with a minimum cycle time of 120 minutes has proved feasible by using material fixtures based on the assembly-oriented logical product structure illustrated in Figure 7 (some even operators assemble the complete automobile single-handed). For trucks the corresponding cycle time has proved to be 240 minutes.



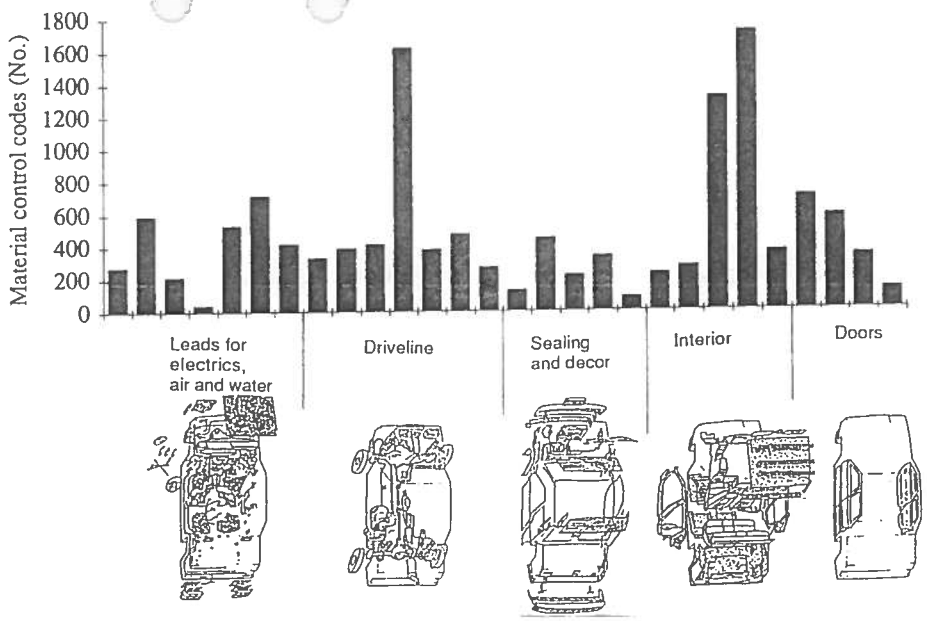



Figure 7. The final assembly-oriented logical product structure and the corresponding number of material control codes on the level below a complete automobile (compare Figure 1 and note that this product structure does not concentrate most of the components into a few groups).

## SOME IMPLICATIONS FOR PRODUCTIVITY AND QUALITY IN FUTURE FINAL ASSEMBLY

Generally speaking, the product description principles discussed in this paper are preconditions for efficient long cycle time final assembly. As discussed elsewhere, Ellegård et al (1991), long cycle time final assembly of motor vehicles is capable of creating superior quality and productivity under suitable preconditions.

But one can also point to specific benefits of using an assembly-oriented logical product structure. It is possible to use this central product structure, in adapted form, in several different production facilities irrespective of where in the world the vehicles are manufactured and regardless of principles of operation. This is important if, as in the Swedish motor vehicle industry of today, different principles of operation are used in different plants.

Furthermore, the hierarchical assembly-oriented logical product structure makes it possible to significantly accelerate the introduction of post-design product changes. Change notices have been found not to have any influence on the higher, more aggregated levels in our new assembly-oriented logical product structure. For example using the new product structure, the Volvo Uddevalla final assembly plant has achieved the shortest introduction times for new model changes within the Volvo group in recent years.

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