Comparison of Management Practices between Sweden and Japan
Programme

Seminar in Osaka, Japan, 22 – 25 November 2000

Osaka University of Economics, Faculty of Information Management

22nd (Wednesday)

9:30～12:00 Visit to Daihatu Ikeda Plant
– Light Passenger Car Assembly Line and Midjet Atelier

Opening of the Seminar

14:00 Introduction: Local Organizer

14:30～16:00 Issue I

Tetsuro Nakaoka (Osaka University of Economics)
"Skill Formation in Japanese Automobile Manufacturing Lines"

Lennart Nilsson (Göteborg University)
"Learning Strategies in order to support Production Concept and create Competence in relation to Different Kind of Work Organization on the Production Line"

- - Coffee Break (30 min.) - -

16:30～18:00 Issue II

Tomas Engström and Lars Medbo (Chalmers University of Technology)
"Summarizing Merits and Malfunctions of Parallel Flow Assembly Systems – Some experiences from substitution of assembly line"

Hikaru Nohara (Hiroshima University)
"Convergence and Divergence between Japanese Model and Swedish Model"

18:30～ Welcome Party

23rd (Thursday)

9:30～11：00 Issue III

Tomas Engström (Chalmers University of Technology) and Lennart Nilsson (Göteborg University)
"Explaining and Reporting on Learning and Assembly Performance in Parallel Flow Assembly Systems –Practical and theoretical frames of references"

Mikael Wickelgren (Göteborg University)
"The Role of Emotionality in Product-development in the Car-industry"

- - Coffee Break (30 min.) - -

11:30～13:00 Issue IV

Lars Medbo (Chalmers University of Technology)
"Material Supply, Product and Product Descriptions for Assembly System Design – Experiences from design and operation of some Swedish assembly systems"

Koichi Shimizu (Okayama University)
"New Simultaneous Engineering and Skill Formation at Assembly Shops"

- - Lunch (1 hour and half) - -

EXPLAINING AND REPORTING ON PERFORMANCE IN PARALLEL PRODUCT FLOW ASSEMBLY SYSTEMS – THEORETICAL AND EMPIRICAL FRAMES OF REFERENCES

Main topic: Work Organisation on the Production Line

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Abstracts:

This paper explains and reports on established theoretical frames of references concerning learning, i.e. the learning curve model and various established concepts of learning. This have, in the paper been focused on industrial learning and summarised as contrasting an encounter between holistic learning principles and the reorganisation of assembly work, which is explained as opposing the so-called mechanistic contra the so-called organic descriptive method.

This two descriptive methods are discussed and illuminated by some examples from the authors involvement in various industrial projects aiming at designing assembly systems utilising long cycle time assembly work within the Swedish automotive industry.

Effects of the implementations of the organic descriptive method for long cycle time assembly work are illustrated by three examples. There, e.g. one example shows the self-rated assembly competence for long cycle time assembly work based on a questionnaire survey performed at the defunct Volvo Uddevalla plant showing assembly.

The assembly competence was in the Volvo Uddevalla case impressive compared to the corresponding competence among assembly line operators, and also compared to what has been believed to be possible to learn according to the learning curve model. One the other example concerns a brief example on the method used for assembly system design at the AutoNova plant (i.e. the reopening of the Volvo Uddevalla plant in 1995) and for restructuring of the information system at the Scania diesel engine assembly line in 1998 using the same method. Thereby illuminating the generality of the method. Two other examples also draws conclusions on learning aspects based the authors questionnaire data from the defunct Volvo Uddevalla plant.

1 THE ENCOUNTER BETWEEN HOLISTIC LEARNING PRINCIPLES AND THE REORGANISATION OF ASSEMBLY WORK

One of the main arguments restricting the introduction of parallel product flow, long cycle time assembly systems, regards the assumption that it is impossible to learn long cycle time assembly work. Consequently, it is of importance to outline the context of industrial learning.

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In industrial engineering, the learning curve model by Wright (1936) is used to establish the need of resources for manufacturing. The time or cost is assumed to decrease as the number of a manufactured product increases. This learning curve model makes it possible to evaluate organisational learning through gathering relevant data, and has been widely spread (Shtub et al. 1993).

Another aspect of industrial learning is the application of the learning curve model focus on repetitive work (De Jong 1964; Hancock and Bayha 1992). The conception of short cycle time learning through learning curves means that learning is mainly regarded as a mathematical problem and, for example, every time the number of cycles is doubled, the time per cycle decreases by a fixed percentage.

However, it should be noted that the learning curve model does not contain the "conditioned learning time", i.e. the time required for the operator to learn during the initial time period when he or she barely knows how to perform the work. This time period is often long since trial-and-error learning is most often practised in the manufacturing industry (Hancock and Bayha 1992).

Boucher (1987) discusses short series and batch production on assembly lines, resulting in a significant production volume during the early period of learning. The assembly line balancing becomes a trade-off between production losses (i.e. balancing losses and materials handling increase with shorter cycle times, due to more workstations) and cycle time length (i.e. a longer cycle time increases the learning time). Increased cycle time, often synonymous with job enlargement, is thereby claimed to reduce the number of repetitions, which in turn decreases the productivity gained, according to the learning curve model (De Jong 1957).

Chakravarty and Shtub (1988) discuss the effect on the learning curve model of a parallel product flow, assembly system with long cycle times. They claim that reduced learning should be balanced against reduction in absenteeism and turnover as a result of increased satisfaction due to work enlargement. The design of, for example, the assembly system is therefore a question of optimising the short cycle time assembly work

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Cross-disciplinary, applied research, influenced by psychology within the field of cognitive engineering focuses on learning by means of improving human perception. Cognitive engineering is mainly concerned with the design of computer-based information systems to support work in complex, socio-technical systems (Vicente 1999). Extensive research, especially concerning the design of control and safety systems for industrial process plants, has been carried out. Rasmussen (1986) developed a framework for "cognitive task analysis" describing decision tasks in terms of information processes. The framework consists of five classes of behaviour shaping constraints (Vicente 1999), based on the assumption that all possible tasks cannot be anticipated and therefore not trained.

A number of design principles have emerged from Rasmussen´s research as, for example, ecological interface design, which facilitates operators' flexibility to adapt to unanticipated events. It is based on "work domain constraints" rather than on a task analysis which defines 'one right way' to perform anticipated tasks (Vicente and Rasmussen 1992).

Jones (1995) observes that cognitive engineering research has focused on the study of humans supervising complex, dynamic, highly automated systems. In these systems the human supervises highly automated processes rather than participating in continuous direct control of a process.

Example 1:

> Figure 1 shows self-rated assembly competence (i.e., how large part of an automobile an assembly operators can assemble single-handedly) as a function of time of employment at the Volvo Uddevalla plant. There was a positive correlation between time of employment and assembly competence in the wide sense (r=0.31), and a weaker correlation (r=0.21) between time of employment and full pace assembly competence. On the other hand, figure 1 also shows that the individual variation in assembly competence. Only 5 percent of the variation in full pace competence, respectively 10 percent of the variation in assembly competence in a broad sense was accounted for by the variation in time of employment.
>
> While the assembly competence is impressive compared to the corresponding competence among assembly line operators, and also compared to what has been believed to be possible to learn, we would not draw any conclusions about the potential for learning from the data in figure 1. These data, we believe, do not primarily reflect the potential for learning long cycle time, assembly work but the requirements and incentives for learning in the Volvo Uddevalla plant. Based on previous research as summarised above and our

observations we believe the potential for learning to be greater than what is suggested by figure 1.

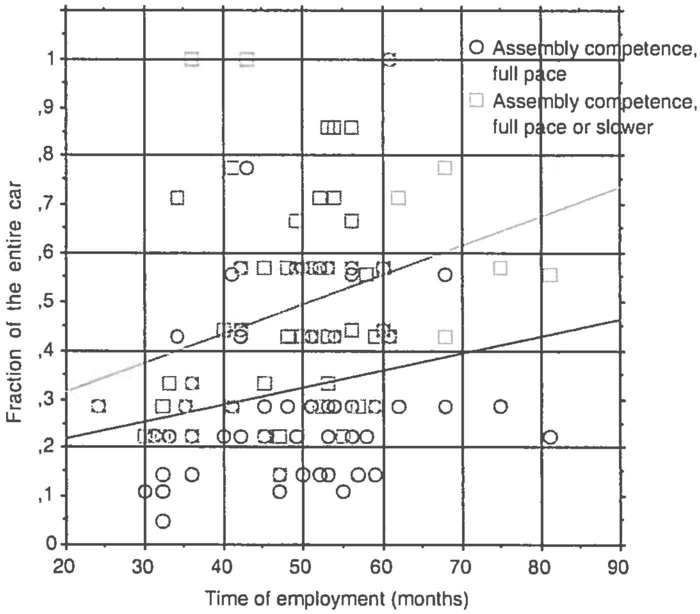

Figure 1: Relationship between time of employment and assembly competence. Assembly operators, n=68. Source of data: the closing-down survey according to Engström, Jonsson and Medbo 1996).

From learning research several perspectives concerning different types of knowledge have been crystallised, and as a consequence if this different kinds of learning strategies has been developed in order to support creation of various types of knowledge.

Marton (1970) stresses the importance for the human being of creating an internal, mental representation – a structure – to facilitate learning. It is especially important to construct a mental structure ("building up an internal representation as a structure") in the initial phase of the learning, leading to higher performance in later phases. Complex knowledge cannot be composed out of small pieces.

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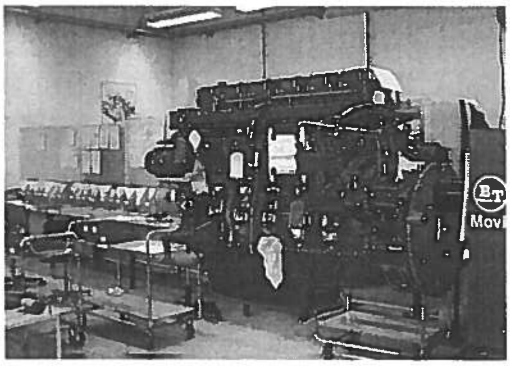
In the light of recent developments in the international automotive industry, as well as the authors experiences from of parallel product flow, long cycle time assembly systems within the Swedish automotive industry during the last 25 years have crystallised into two lines of development with regard to assembly system design. That is: (1) Refining repetitive, short cycle time assembly work, in serial flow assembly systems (assembly lines), drawing inspiration from Japanese success cases. – Or (2) developing unorthodox long cycle time assembly work in parallel product flow assembly systems, which might be recognised as a new manufacturing paradigm, drawing inspiration from Swedish experiences.

These two extreme assembly system designs could from a learning aspects be generalised an encounter between holistic learning principles and the reorganisation of technological and administrative preconditions (i.e. reforming product information, product flow patter, materials feeding techniques, etc.).Which in turn are derived from two qualitatively different perspectives, below denoted as the mechanistic contra the organic descriptive method (see Nilsson 1994).

Example 2:

> Disassembly of physical products and reorganisation of the physical components have been one of the authors means for applying holistic learning principles, i.e. to define the organic descriptive method. Engström, Johnsson and Medbo (2000) explain the method used for assembly system design more in detail. That is the mechanism used for reorganising of the technological and administrative precondition taking advantage of the readably available product information. In figure 2 this procedure for design of assembly systems and for the necessary restructuring of an information system respectively in shown by a disassembled automobile (Volvo 800-model) from the design procedure of the AutoNova plant in 1995. While to the right in figure 2 the photograph of a diesel engine, disassembled at the Scania engine assembly plant in 1998 shows a similar procedure. In principle, these disassemblies constituted an additional development of analyses done for the design procedure of the Volvo Uddevalla plant more than ten years earlier. For example the removed components were organised according to so-called work modules in the AutoNova case as well as according to the individual operators' assembly work at a specific workstations along the existing assembly line in the Scania case. In both cases the components were separated by means of wooden lathes. Thus the method for assembly systems design are generally applicable even to serial product flow assembly systems.

Disassembly at AutoNova (in Uddevalla) in 1995 for design of assembly systems.



Disassembly at Scania (in Södertälje) in 1998 for restructuring of the information system.

Figure 2: Disassembly of physical products aimed at implementing holistic learning principles in the automotive industry, i.e. to define the organic descriptive method for two different reasons. That is the design of an assembly system including design materials feeding techniques comprising i.a. materials kits (AutoNova plant and the Volvo Uddevalla plant for long cycle time, assembly work), see Medbo (1999). While the other reason is: improvement of work instructions and product variants codification, as well as handles the organisation of introducing product design change orders (the Scania diesel engine assembly system using a serial product flow assembly system which short cycle time (traditional assembly line). See Portolomeos and Schoonderwal (1998).

2 THE MECHANISTIC CONTRA THE ORGANIC DESCRIPTIVE METHOD

As stated above, there are two qualitatively different ways to describe assembly work and learning; the predominating mechanistic descriptive method and the organic descriptive method. Let us take a closer look at some important dimensions in each.

In the predominating mechanistic descriptive method the basic/underlying assumption is that "the final result is the sum total of all components". This perspective demands an overall standardisation implying an administrative rationality, which for various reasons, results in replacing meaningful names on components, assembly positions, product variants, etc. by codes adapted to computers (i.e. part numbers and cryptic variant codes or various abbreviations). Thereby the physical components are thus assigned a mainly numerical code, suited for the information systems. For this reason, and through there being many product variants and a, the number of components for combinatorial reasons seems enormous for the practitioners working as e.g. manufacturing engineers administrating. Whom for example are responsible for implementations product design change order or distributing the assembly work tasks along the workstations along an serial product flow in order to maximise the utilisation of the human and to create a smooth flow of products.

According to the authors experiences, the information systems used within the Swedish automotive industry are based on the product design departments work (i.e. the traditional design-oriented product structures) in general designed to "keep track of all the components" (i.e. used for materials feeding on intra and inter plant level, bills-of materials). In most respects severely restricting a richly varied reality perception of product and assembly work. Thereby learning based on the humans perception of the components' appearance – qualities such as colour, shape, size, weight and fragility disappear totally. The description of the physical product (components, product variants, tools, etc.) is in fact reduced to a string of figures, sometimes supplemented with an abbreviated names or codes. This increases, expands, the perceived complexity.

Note that this phenomenon is not, however, caused by the components themselves but rather by the way the administrative support functions to the operator on the shop floor organise the physical components and the product information. In form of e.g. supplying them en masse in materials containers and forming assembly instructions and product variant specifications.

Phenomenon that the human experience as complex is understandably easily associated with the components themselves. However, it is not the components in themselves that are complex. For example, the act of picking the components from a materials container during assembly work is not complex in itself. Neither is assembly work fitting the components especially complex in terms of materials structuring and other preparatory work. The experiences becomes complex through making it complex.

Thus the difficulty lies in trying to find meaning in unconnected information based on strings of numbers and abbreviations which lack a significant context. When phenomenon are made complex in this way, the notion quickly arises that the human must be addressed a restricted work content in order to cope with "their fragment". These artificial difficulties thus become arguments for perpetuating an extreme division of labour (short cycle time).

When the predominating mechanistic descriptive method are computerised this perspective is made permanent when it in fact ought to be substituted. The potentials of computer technology, which earlier was one explanation for the fragmentation of the product information (i.e. the restricted computer capacity and limited space for accommodating e.g. complete denominations) has today turned into a possibility in no respect at all prospected.[1]

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[1] In the case of the defunct Volvo Uddevalla plant there where, apart from a correct component denomination also, in some relevant cases, a complementary nickname assigned.

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The organic descriptive method is based on (functional and integrated) wholes. Formulated in an abstract way, the wholes which contains a number of phenomena, which fill various functions such as that qualities characteristics and mutual relationships (as well the quality of the relationships) of a large number of different "parts" constitutes both functions and categories. This is an essential precondition for the whole and the phenomena contained in it.

Transferring this abstract principle to materials handling and assembly work, the basis must be the physical product and its components as a whole and various functions must be sought in the product. This is important for the operator on the shop floor but even more so for the materials handlers, who in their practical role must be professionals at choosing the correct materials. This is especially important if the materials are delivered as materials kits as is necessary for long cycle time assembly work there the materials kit functions as a structured puzzle guiding the operators assembly work.

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The product functions in the physical product perceived on the shop floor are normally constituted through composing a number of physical components being related to each other (fitted) with predetermined quality (precision) and fixed to e.g. an automobile body or in relation to it. The point is that it is possible to describe a vehicle in terms of functional materials groupings, which are related to assembly (i.e. an assembly-oriented product structure in contrast to the traditional design-oriented product structure, see Engström and Medbo (1993) for a more detailed explanation of these product structures).

This means that function, assembly, and the position of the material, to give a few examples, can be taken into consideration at the same time, i.e. a qualitatively (multidimensional) fundamental dimensions in perception is created. The “parts” are arranged into "families" and these are in turn arranged into larger groups, "kin". The “parts” now become clearer, through their being assigned a descriptive identity. They are given a recognisable name (besides the part number), membership of a family and kin; i.e. they are part of an assembly-functional group (family) which in turn is part of an assembly-oriented product structure (kin), which also reflect the "creation process" of the product.

The vehicles path through the assembly process can thus be described as a “growth pattern” – instead as merely an addition of components defined by cryptic alphanumerical codes. The assembly process can be viewed as an organic dynamic process – rather than as an isolated mechanistic addition of “parts”.

This means that functions, patterns, contexts, processes and descriptions in terms of colour, shape, size and fragility are important aspects from the point of view of learning. These aspects vitalise people's intellectual and emotional life, while the mechanistic, numerically oriented, linguistically restricted descriptive method, which at present dominates work performed on the shop floor in most assembly systems, has proved to hidden the possibilities for an industrial development.

That is, the possibility of extensive development the individual and collective skills of the human are severely restricted, but this is also true incentives and insight to reform an established industrial context. This even though the holistic learning principle will be, and are, a fundamental precondition of the working life of the future.

Example 3:

> As an example of analysis of some of the authors data, we have in figure 3 illustrated the assembly competence in the different product workshops at the defunct Volvo Uddevalla plant. The diagram is based on wage-related personnel statistics, which divided the assembly work into four steps 29 – 40%, 40 – 60%, 60 – 80% and 80 – 100% of an automobile. To summarise this data, 64% of the operators learnt to assemble at least 60% of an automobile at full pace, and 4% were even able to assemble complete automobiles single-handedly at full pace, which they proved by performing a special test. Note that in this case, we only report on the competence according to how the assembly operators mastered the different types of assembly work. We have therefore called it "assembly competence". We do not consider other vital aspects of competence, some of which were included in the wage system, for example social competence in introducing new members to the work groups. The wage system was quite advanced and it was constantly being reviewed and debated during the plant's total life. The high assembly competence in the plant may to a large extent depend on the pre-structuring of the components needed for assembly in materials kitting fixtures, which formed complete kits of the materials required for one single automobile. The relationship between the vehicles being assembled and the materials kitting fixtures supported a holistic learning process.

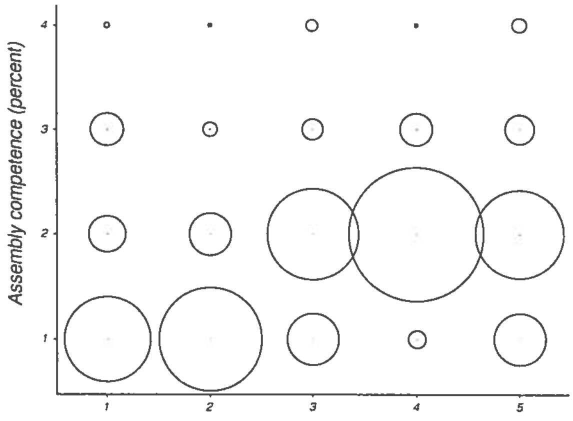

Figure 3. Distribution of blue-collar assembly competence in the different product workshops based on personal statistics. Note that step 4 in the diagram equals the ability to assemble complete automobiles, i.e. 100% (Source of data: Volvo personal files according to Engström, Jonsson and Medbo 1994).

All orientation is related to the fundamental dimension in perception of time and space. This means that those phenomena that we wish to treat must be described with regard to their position and spread in both time and space. The assembly process orientation, "left-right, over-under, front-back" etc. is similar to the geographical orientation of "West-East, North-South". In this context, it is important to point out that a vehicle, like e.g. an automobile, displays symmetries, just like many other products, both mechanical and biological. These symmetries facilitate the descriptions to a considerable degree by forming a base for an appropriate overview. The position of the phenomena in the fundamental space dimension is therefore important in the context of orientation. For the assembly operator assembling e.g. an automobile, it is principally the relation of the materials to the automobile body that gives a relevant description in space. Materials' handling demands a greater precision in the orientation pattern, since the complete vehicles are usually not perceived.

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Another fundamental dimension is time, i.e. before and after in relation to the present so that work is not experienced as consisting of a number of "small presents". Reflection, consideration, and forethought assume that the individual is also oriented in the fundamental dimension of time.

How a human being experiences time is connected with the emotional and intellectual content of the activities he performs during a given time period. The experience of time is closely related to the experience of the purpose and meaningfulness of what he does. The tasks that the individual performs should contain certain qualities that contribute to the creation of meaningfulness from the individual's point of view.

The difficulty lies in the fact that people for various reasons have different time perspectives. Some people have a very short, while others have a longer perspective. As far as is known (Nilsson 1981) that people's time perspectives can be changed provided that they are allowed to perform work tasks they can see a purpose in, and have a good chance to master the complexity of the works tasks. It is also important that they experience themselves as competent human beings. Their time perspective is then expanded and possibilities are created for seeing a purpose in things that lie "further ahead in time".

Consciousness in relations to planning, doing and drawing conclusions concerning work consequences are unique for the human being and ought to be prospected in the design of the assembly work.

The surrounding work structure (i.e. technological and administrative preconditions) must therefore be so designed that these qualities are rewarded and possible for the individual to attain. Conditions are thereby created for him or her to acquire an expanded time perspective. It is important in this context that the technological and administrative preconditions are designed in order to contribute for “handling” the complexity of the work and to be successful at this “handling”.

Example 3:

> The authors data illuminates that the assembly work at the Volvo Uddevala plant was not perceived as extremely demanding either manually or intellectually (Engström, Jonsson and Medbo 1996). These findings are in agreement with our previous argument that short cycle time assembly is learnt by an mechanistic learning process, whereas long cycle time assembly is learnt through a qualitatively different learning process.

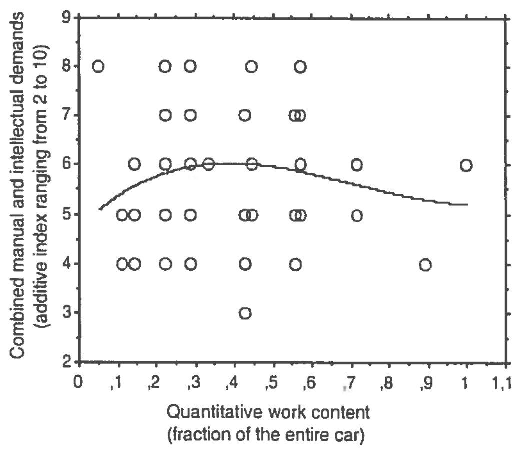

Figure 4. Observed relationship between quantitative work content and self-estimated manual and intellectual competence requirements. Non-linear regression (third degree polynomial). Assembly operators, n=68. Source of data: the closing-down survey of the Volvo Uddevalla plant according to Engström Jonsson and Medbo 1996).

3 SUMMARY

Let us summaries, the encounters between the holistic learning principles and the reorganisation of the technological and administrative preconditions for assembly work results in the organic description method. A description method which in turn, in industrialised assembly work, corresponds to various means such as utilising an assembly-oriented product structure, which complements or substitutes the traditional design-oriented product structure. In practice, one of the consequences of this means that assembly operators and materials handlers become "owners" of a multidimensional verbal and visual network connected to the assembly work based on e.g. the reformed product information which constitutes wholes, for instance by means of materials kits.

Thereby explicitly and implicitly explaining relationships between "parts" and wholes in depth, height and breadth, and which also reflects both the vertical and horizontal spread in various products. It is then possible to handle the predictable and also the unpredictable aspects in the assembly work. By taking advantage of this type of description method suddenly it is a value in the initially illogical relationship between one's own assembly work. This is qualitatively different from the predomination mechanistic descriptive method.

Nuances and precision in the mental world and in the reality receive a explanatory value – a meaning from the human perception point of view, i.e. the reality will be enriched which consequently also demands a multidimensional descriptive system. One effect of the organic descriptive method is that it also provides the opportunity to successively formalise one's own experience and set it in relation to earlier knowledge as well as linking individual competencies to collective. The technological structures, which previously dictated the restrictions for developing the assembly work, are hereby seen to be possible to influence.

One important conclusion drawn from our analyses and experiences within the automotive industry is that it is product flow patterns on the shop floor, predominating mechanistic description method and existing work organisation that have generated most of the unpredictability, digitalisation and additive thinking.

Or to put it in another way; the assembly work itself possesses an inner logic provided it is described with a reformed product information and the physical product as the basis. The vehicle is in fact deterministic, it is defined in detail during the design and pre-production stages, i.e. the product information is readably available but need to be reorganised according to a the organic descriptive method explained above. This, since among other things, physical products with similar assembly should consequently be similar in materials handling and descriptive aspects, not as regards details but certainly as regards categories and in relation to prevailing symmetries.

An overview which comprise also details on various descriptive levels of the complete "creation process" of the vehicle makes it possible to organise the assembly work in accordance to the underlying principles of long cycle time. The design principles and methods of an assembly system follows as a natural consequence. As is briefly sketched and illustrated above.

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