TRILOG EUROPE
Göteborg meeting

DEPARTMENT OF TRANSPORTATION AND LOGISTICS
CHALMERS UNIVERSITY OF TECHNOLOGY
GÖTEBORG 21-22 JUNE 1999

This is a short information about the meeting in Göteborg the 21-22 of June. We will not be in the department since there are no suitable meeting facilities there. Instead we will be at a place called Entrés hylla, which is at the Chalmers premises, see attached map over Chalmers. The meeting begins at 10:00 the 21st of June and ends 16:00 the 22nd. Please send me a confirmation on your participation no later than the 16th of June so that I can take care of all administrative issues. The hotel is called Panorama hotel and you can call our secretary for the booking for a better price.

Please confirm your participation before the 16th of June, by sending an E-mail to jowa@mot.chalmers.se

Time: 21-22 May 1999
Place: Entrés Hylla, Sven Hultins gata 4 Chalmers, Göteborg
Send confirmation to: Jonas Waidringer,
jowa@mot.chalmers.se or fax: +46-31-772 1337
For booking of hotel please contact our secretary Rosemarie Olivebring
rool@mot.chalmers.se or +46-31-772 1323, hotel Panorama

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IMPLICATIONS OF THE DESIGN OF MATERIALS FLOW SUBSYSTEMS: SOME ILLUSTRATIONS

CONTENTS:

IMPLICATIONS OF THE DESIGN OF MATERIALS FLOW SUBSYSTEMS: SOME ILLUSTRATIONS

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1 INTRODUCTION

The biological or ecological foundations of social life are increasingly being recognised. It is by now well understood that changes in ecological systems may have far-reaching social and economic implications. For example, economic growth may in the long run lead to detrimental ecological changes that prevent further economic growth; hence the concept of "sustainable growth". Thus, so-called environmental issues are redefined as issues concerning life conditions.

It is a basic tenet of this paper that some issues that seem to concern only the technical means to achieve production goals and which are generally seen as technical issues of interest only for manufacturing engineers. Namely the design of materials flow subsystems within the industrial network (production and logistics systems including supply chains) are in reality issues with far-reaching social and economic implications.

This is of course not a new type of insight; the implications of the "mode of production" for socio-economic conditions are a central theme in Marxist thought. Yet, along with the demise of Marxism, this old insight seems to have been vanished. As a consequence of lack of insight that "technicalities" in the design of industrial network may impact socio-economic conditions is in general not fully recognised, questions how these "technicalities" impact socio-economic conditions have been insufficiently explored. This paper attempts to shred some light on this problem.

Below, we shall first consider three "technicalities" pertaining to materials flow subsystems, namely exchangeability of products, accessibility of products in buffers and materials flow patterns. In each case, two alternatives are described, namely administrative exchangeability versus non-exchangeability, restricted versus non-restricted buffer access and serial flow versus parallel flow patterns.

We then turn the implications of choices between these alternatives for the design of internal (i.e. inside a plant) as well as external (i.e. outside an plant) materials flow subsystems, that is materials flows within a single plant and materials flows in supply chains, respectively. Finally, we sketch social and economic implications of the two lines of development discussed. As noted above, this is an area where further research is needed, but we can offer some data and some speculations. The data is inserted as discrete examples in the text to illustrate various aspects debated.

2 ADMINISTRATIVE AND PHYSICAL EXCHANGEABILITY OF PRODUCTS IN MATERIALS FLOW SUBSYSTEM

The introduction of the assembly line at the beginning of the twentieth century is commonly viewed as a breakthrough for efficient mass production. Less publicly recognised but just as important was the concomitant introduction of standardised, exchangeable components. This meant e.g. that any XYZ-screw fitted any XYZ-nut. This possibility to exchange components is today a matter of course, but was at the turn of the century a great step forward. On closer analysis it becomes evident that the possibility to exchange components, as well as products, is somewhat limited even today. It is in fact in some respects even diminishing due to the accelerating number of product variants, which calls for more different variants on the component level.

The international trend towards external subassemblies by component manufacturers or special companies has in many cases increased the number of component types assembled. For combinatorial reasons, the number of product variants tends to increase with the size of the subassembly. In order to remedy this situation the subassemblies are often treated as administratively non-exchangeable though they are in fact physically possible to substitute for one another.

A representative example showing that administrative exchangeability is usually more restricted than the physical is the sequence bound components delivered to a final assembly plant. Sequence deliveries mean that the supplier assigns component individuals to specific product individuals. Two different components, which are physically identical and thereby physically exchangeable, but from the production scheduling point of view designated for different product individuals, will therefore, be treated as non-exchangeable.

Exchangeability of objects in the materials flow subsystems takes several different forms, e.g:

1 Exchangeability of components vis-à-vis other components, e.g. exchangeability of individual nuts vis-à-vis individual bolts or exchangeability of individual bolts vis-à-vis individual nuts.

2 Exchangeability of components vis-à-vis products, e.g. exchangeability of individual engines vis-à-vis individual automobiles.

3 Exchangeability of components or products vis-à-vis production resources or production loci, as when different product individuals can be assigned to a specific workstation.

4 Exchangeability of products with regard to customers, as when there is a choice of which one of several exchangeable product individuals to deliver to a specific customer.

Underlying these different forms of exchangeability, however, is a common "logic of exchangeability" illustrated in Figure 1.

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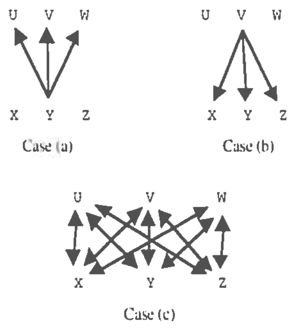

Figure 1. Schematisation of logic of exchangeability, in case (a), Y is exchangeable vis-à-vis U, V and W; in case (b), V is exchangeable vis-à-vis X, Y and Z; in case (c), X, Y and Z are exchangeable vis-à-vis U, V and W and conversely.

As noted above, the recent trend within industries such as the automotive industry has been to deliberately reduce administrative exchangeability of objects in the materials flow subsystems beneath the level determined by the extent of of physical exchangeability. Nevertheless, the benefits of exchangeability remain, and are much the same as experienced in early industrial development. Abstractly, the principle of maximal (administrative) exchangeability of objects in materials flows implies a principle of delayed (or, to use a popular phrase, "just-in-time") commitment of materials. For example delayed commitment of components to other components, delayed commitment of components to products, delayed commitment of components or products to production resources or production loci, or delayed commitment of products to customers.

3 RESTRICTED VERSUS NON-RESTRICTED BUFFER ACCESS IN MATERIALS FLOWS

Briefly described there are two diverging opinions on the use of buffers. According to one opinion, buffers are wasteful and represent efficiency potentials if removed or reduced, due to reduction work in progress, the revealing of manufacturing discrepancies, etc. According to the second view, buffers are consciously positioned and dimensioned to smooth out process and product variations in order to increase efficiency and to form autonomous workgroups with merits such as reduced number of planning points, creation of required operator cohesion, etc (Engström 1983).

Buffers can be classified according to various criteria. However, if we connect to the discussion in section 2 and the empirical examples presented below, it is evident that to capitalise on the distinction between administrative and physical exchangeability calls for a refined perception of buffer functions. If a product is prioritised due to shifting between physically exchangeable products it must also be physically prioritised in the buffer. Thus a buffer could be said to comprise two mechanisms for absorbing variations, (1) to accumulate materials or products and (2) to sort the materials or products (se figure 2). This mechanism might be denoted restricted and non-restricted buffer functions.

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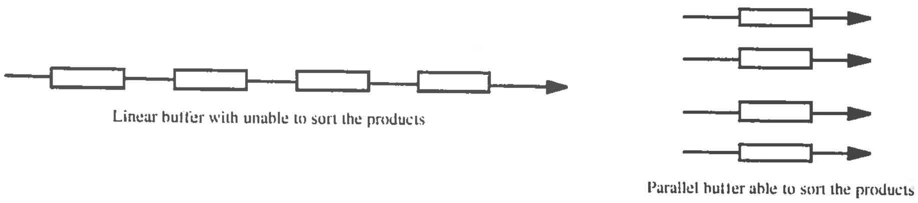

Figure 2. Buffers with restricted versus non-restricted access to buffered objects (sorting versus non-sorting buffers).

4 SERIAL VERSUS PARALLEL PRODUCT FLOW PATTERNS

In the light of recent developments in the international automotive industry, as well as experiences from alternatives to the assembly line featuring so-called autonomous workgroups in the Swedish automotive industry during the last 20 years, two lines of development with regard to assembly system design have crystallised:

1 Refining repetitive, short cycle time work, in serial product flow assembly systems (assembly lines), drawing inspiration from Japanese success cases.

2 Developing unorthodox long cycle time work in parallel product flow assembly systems, which might be recognised as a new manufacturing paradigm, drawing inspiration from Swedish experiences.

In a serial product flow system, the product being assembled passes all workstations along the flow. The cycle time is short. In a parallel product flow system, on the other hand, the product passes only one workstation or workstation system, and the work is less repetitive due to the increased cycle time. If operators co-operate on one or more products collectively we have a special type of working denoted collective working in a defined subsystem of workstations and workers, i.e. workstation systems.

The parallel product flow alternative has been assumed to be contradictory to traditional production engineering practice, striving for reduced manufacturing costs and using mechanisation and standardised work as important means towards this goal. Instead, this new alternative has been supported by the argument that, due to humanisation, sick leave and turnover would decrease, and this would compensate, for increased manufacturing cost in unorthodox assembly systems. The fact is, however, that parallel product flow assembly does, correctly designed, simultaneously achieve increased efficiency and a more humane work compared to the assembly line (e.g. Karlsson 1979; Engström et al. 1995 and 1999).

5 ALTERNATIVE LINES OF DEVELOPMENT IN THE DESIGN OF MATERIALS FLOW SUBSYSTEMS

The three design dimensions defined by the "technicalities" pertaining to materials flow subsystems (i.e. administrative versus physical exchangeability, buffers with restricted versus non-restricted access and serial versus parallel product flow patterns) discussed above are clearly interrelated. For example, if access to buffers is restricted, products in such buffers are not exchangeable vis-à-vis downstream destinations. Also, as will be discussed in Section 6, parallel product flow assembly systems require components and products to be exchangeable vis-à-vis parallel workstations if potential efficiency gains are to be realised.

It is in fact possible to discern two alternative lines of development with respect to the design of internal as well as external materials flow subsystems:

- A trajectory involving (1) early coupling of customers to the product individuals, product individuals to production resources and component individuals to product individuals (2) restricted access buffers (non-sorting buffers) and (3) serial product flow patterns as in line assembly. In this approach, the administrative exchangeability between product and components in the internal and external materials flow subsystems is deliberately reduced.

- Another trajectory calling for (1) administrative exchangeability of products and components at the level of physical exchangeability mainly aimed at improving flexibility, (2) unrestricted access buffers (sorting buffers) to improve administrative exchangeability, and (3) parallel flow patterns as in some innovative production systems (e.g. the Volvo Uddevalla plant discussed below).

While the dominating trend in the automotive industry has been the first alternative, there are some examples of applications of the second one in other industries and also in "experimental" production (so-called pilot plants) facilities in the automotive industry. In addition, the second line of development is sufficiently promising to merit attention as an alternative to traditional materials flow subsystems design.

6 INTERNAL FLOW IMPLICATIONS ILLUSTRATED: ASSEMBLY VARIANTS AND PRODUCTION SCHEDULING

To capitalise on physical exchangeability in internal materials flow subsystem in parallel-flow assembly systems we have developed the concept of so-called assembly variants This concept groups product variants into clusters according to how a specific product variant impacts the assembly work (Engström and Medbo 1992).

The concept of assembly variants means that product individuals belonging to the same assembly variant will thereby be both administratively and physically exchangeable from an assembly point of view. The identification has its origin in the categorisation of the characteristics of the products. The basic idea of the categorisation is that different examples of the same assembly variant will be exchangeable vis-à-vis a number of parallel workstation systems. That is, a particular product could be assembled at any one of several workstations by the team located at that workstation system, and a particular team at a particular workstation could assemble any one of several products scheduled for assembly.

There are three principal categorisation criteria:

- Competence requirements.
- Assembly time.
- Tool and equipment needs.

There may be further demands, related to specific assembly systems (for example, low frequency variants), or if the concept is applied outside the chosen assembly system.

Because product variants differ considerably, all products cannot be assembled at all workstations, limiting the exchangeability of products vis-à-vis workstations. We distinguished several levels of exchangeability based on different degrees of similarity of products and assembly tasks.

> Level 1: The same assembly work, but with different components, for example panels of different colours.
>
> Level 2: The assembly work is marginally different. Different components but relatively "obvious" regarding assembly; a gearstick boot, for example.
>
> Level 3: Assembly tasks that it has been decided that all workers must be able to manage both in respect of knowledge and equipment. For example, all the characteristics of the doors can be placed here. The doors can then be used as balancing pre-assembly in a team work pattern.
>
> Level 4: Assembly differences dependent on competence, assembly time or equipment. It is characteristics on this level that make assembly difference and thereby define the majority of the different assembly variants. Low frequency variants on this level must in practice be treated separately.

Having thus established the physical exchangeability of products, the logical next step is to devise a product codification system in which exchangeable products are coded identically, allowing administrative exchangeability to increase to the level of physical exchangeability. This is a coding complementary to the traditional one using so-called product numbers to specify complete individual product variants trough the manufacturing process. (In e.g. Volvo his product number comprise 25 alphanumerical characters accompanying each individual vehicle or vehicle-to-be during product ordering, product planning, product assembly. product storage and product delivery phases.)

The number of different assembly variants is considerably smaller than indicated by the traditional way of codifying product variants by means of product numbers. When the frequency of the different assembly variants is known, it is possible to optimise the materials flow within a specific assembly system.

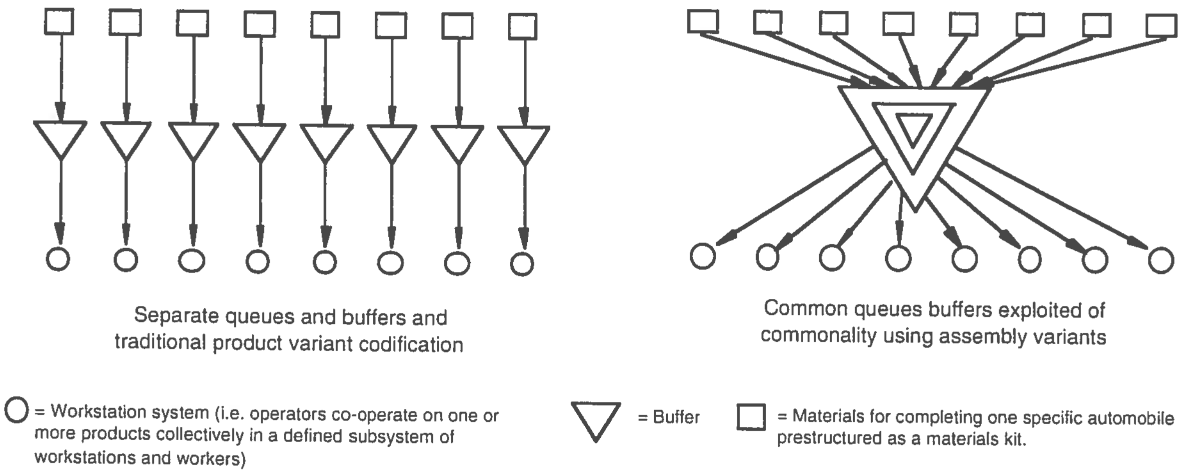

Figure 3. Schematisation demonstrating the difference between using and not using assembly variants at the Volvo Uddevalla plant comprising 48 separate queues for each workstation systems

(only eight shown in the figure). The consequence is that buffer volumes are either exploited for reasons of commonality (sorting buffer) or develop their own separate queues (non-sorting buffers).

Figure 3 shows a simplified example with different assembly variants. The difference in function between the buffers is shown schematically in both cases. The large triangle to t right indicates that the grouping of the assembly variants gives the automobiles different degrees of exchangeability depending on the frequency of each assembly variant (shown by the smaller, inserted triangles). The highest frequency ones will automatically be exchangeable and thus form a common buffer for all queues to parallel workstations systems concerned. The significance of this is that there will be degrees of exploitation of commonality ranging from the highest frequency to the extremely low frequency assembly variants. Such low frequency variants must always be treated separately.

7 EXTERNAL FLOW IMPLICATIONS ILLUSTRATED: THE AUTOMOTIVE INDUSTRY VERSUS THE PERSONAL COMPUTER INDUSTRY

As indicated above, the two lines of development introduced in section 5 apply to external as well as internal materials flow subsystem. There is furthermore a connection and parallel between internal and external subsystems. For example, internal materials flow subsystem in the automotive industry tend to be characterised by restrictions on exchangeability of components and products, restricted access to buffer and serial flow patterns, and the situation with regard to external materials flow subsystem is similar.

In this industry, the companies and plants responsible for the assembly operation at tend to be large, while most of the suppliers positioned in the lower in the supplier pyramid are small. For example, we find at the top of the pyramid companies like GM, Ford and Toyota, while at the bottom of the supplier pyramid a number of garage enterprises are located. The industrial network constitutes by the manufactures of automobiles and personal computers have resemblance's that mirrors or congruencies the product's hierarchical structures.

In the automobile industry, an increasing part of the topmost tier of the supplier pyramid is tied to the assembler by means of sequence-bound deliveries of components, in effect creating an invisible assembly line that extends into the suppliers' plants (see e.g. Smitka 1991). This industrial structure is not universal, however. For example, in the consumer electronics industry, the situation is quite different. The PC industry is a pertinent case.

In the personal computer industry, by contrast to the automobile industry, many suppliers operate at an extreme large scale, while the enterprises assembling the personal computers may be small. The giants in the industry are suppliers such as Intel, which develops and manufactures microprocessors, and Microsoft, which among other things supplies the Windows operating system. For example Intel might sell microprocessors to a manufacturer of so-called mother cards, which in turn trades those cards to the ”box makers” who afterwards supplies these to a company which compose "systems" of personal computers, peripheral equipment and cables. The customer then buys these “systems”. There is thus a pattern of parallel assembly of PCs or integration of PC-based ”systems” being performed in many parallel facilities or shops.

The automotive industry suppliers pyramid is thus in most respect turned on its head within the personal computer industry.

Figure 4. Schematisation of the supplier pyramids within the automotive respectively the personal computer industries.

Yet another difference between the two industries is that the components and the interface between various components are more standardised in the personal computer industry than in the automobile industry, meaning that components are more exchangeable in the PC industry.

It may be that the differences between the structure of supply chains in the two industries can partly be attributed to differences between their respective products. There are in fact significant differences with regard to size and weight between the products, which may influence the degree of geographically centralised component manufacturing in the supply chain. For example, the fact that it is much less costly to transport microprocessors than engine blocks can help to explain the differences between the two types of supply chains.

On the other hand, some of the differences in the industrial structures can be seen as consequences of design decisions concerning internal and external materials flow subsystems involving choices between the "technical" alternatives discussed in sections 2 – 4.

It should be noted that a buffer allowing non-restricted access may be used as a "time machine" that moves the future into the present, in a sense allowing a component to be consumed by an in-house process before it is delivered from an upstream process. In reality, what happens is that a particular component in an in-house free access buffer is used instead of an exchangeable component to be delivered later.

If the "time-machine" is taken away by either removing the in-house buffer or imposing buffer access restrictions as in sequence-bound delivery, time becomes scarce. As a response to this, assemblers typically strive to cut supplier-to-assembler lead times. Such lead-time cutting usually involves measures to reduce transportation times, which in turn usually involves moving first-tier suppliers close to the assembler, as in "Toyota City" style supplier villages.

We come to the conclusion that structures of entire supply chains – and social and economical implications of these structures – are influenced by "technicalities" such as those discussed in this paper.

8 CONCLUSIONS

With regard to internal materials flow subsystem, as we have seen, some of the highlights of the two lines of development sketched above are:

- The parallel product flow results in efficiency and flexibility implying low-scale manufacturing premises by means of extremely competent individuals (i.e. in the most extreme case comprising only one workstation system). This contrasts with high volume manufacturing by means of high-division of labour by operators, who today in the western world are either low qualified or multipurpose.

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- The new product variant codification implied by the assembly variants results in flexibility making it possible to prioritise the internal work of materials handlers and operators involved in the direct manufacturing – in contrast to the demand for total synchronisation of materials handling and direct manufacturing.

In fact the new product variant codification implied reformed product descriptions results complementing the concept of base product descriptions and production scheduling on component numbers and alphanumerical characters. Instead it has, in the case of the Volvo Uddevalla experiences proved necessary by means of introducing a nomenclature recreating the logic the product on the shop floor. Thus forming a "semantic and spatial network" giving a holistic perception of product and work, closely coupled to the product – a network which in fact could be derived from the designers nomenclature (Engström, Jonsson and Medbo 1997). The "semantic and spatial network" in turn creates increased operators competencies that enable operators to control their work and perform administrative work such as creating work instructions, dealing with product change orders, earlier inevitably done by white collar personal. This contrasts with traditional fragmented product descriptions generated from a distant design department, which inevitably gives excessive administrative work at the local plant.

In the first case the training and education is constituted by the technical preconditions for work, i.e. the implicit technical structure promotes and demands qualified operators (for materials handling, assembly, administrative work, etc.). In fact the training and learning might be performed from the direction of a whole to the details and not the opposite. The learning can therefore be regarded as holistic (hierarchical integration of knowledge) instead of atomistic (focusing on details), see e.g. Marton and Both (1997). This leads to a work which utilises the specific human capabilities as a valuable complement to the technology of the future.

These effects could be transposed the external materials flow subsystem and thereby affect the external industrial network, creating two contrasting scenarios:

- There is a trend of outscoring by means of engaging external suppliers resulting in reduced manpower requirements at the local assembly plant. If the trend continues, the plant will ultimately consist of a marriage-point, which is ether fully automated or prepared for increased automation. This contrast with industrial networks composed of a number of small plants, forming larger "virtual plants".

- There is a trend of standardising the local plants' assembly process forming industrial networks of carbon copy plants. This stands in contrast to a heterogeneous structure of plant designs adapted to the local preconditions, custom barriers, local suppliers specialities, etc.

- There is a trend of differentiation of suppliers according to level of responsibility in respect of product development, thus forming national as well as an international network of high volume, specialised, independent suppliers, while at the same time the dependent suppliers are categorised into class A, B and C-supplier. This may be contrasted to industrial networks where the nodes take other functions. The industrial network can not be perceived as a number of predefined, rectilinear, materials flow subsystems starting upstream at the suppliers and ending downstream at the customer. Instead the industrial network turns into multidimensional matrix comprising a number of materials and handling information-handling processes.

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