Linking Two Automotive Companies' Organisational Structures to their Materials Flow Systems

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Abstract:

This article deals with cross- and multi-disciplinary evaluation of production systems and the shop floor work by means of amalgamating practitioners' and researchers' goals and perspectives in order to exploit valuable constructive synergies. Three questionnaire studies conducted at the Volvo Car and Truck Companies in the Gothenburg area during 2000 – 2001 form the basis and illustration of this discourse.

At least two methodological key features were important to achieve: synergy in the co-operation between practitioners and researchers and linking of organisational structures to materials flow systems. In this case, the companies' overarching organisational superstructures and the local union's, i.e. Metal Workers' Union Volvo, organisational structure are related to the production system design.

Firstly, there was the use of various intensive co-operation procedures, such as a joint venture construction and prototyping of the questionnaire forms, common reporting, and discussions of the research results.

Secondly, there was the use of department numbers in the questionnaire forms which made it possible to link the questionnaire data to each department. This in turn made it feasible to construct tables comprised of data from each department investigated. On the other hand, the function of each department in turn was understood due to both various forms of schematised layouts, earlier research and development work by one of the authors, by means of study visits at work sites, as well as discussions with various blue-collar and white-collar employees and local union representatives. The constructed tables and various forms of schematised layouts were necessary for e.g. construction of analytical categories to be compared, i.e. clusters of departments with similar functions, similar production systems, similar type of work, etc.

In this article the authors report how this type of analysis and co-operation procedures has been used, i.e. how the relationship between statistical analyses of the questionnaire data and the constructed tables has been dealt with. Two examples are reported comprising various findings on blue-collar employees regarding time of employment, possibilities to fulfil the stipulated production goals, work satisfaction, and future work preferences, thereby exemplifying a more general approach in linking organisational structures to materials flow systems.

Relevance for the industry:

The methods proposed help to link different companies' organisational structures to their materials flow systems and thus also help to relate these systems to various types of shop floor data. To link technical and social dimensions of the shop floor work is of general interest for the industry, especially since e.g. joint venture cooperation between practitioners and researchers are in some problem areas becoming more and more usual.

Key words:

Assembly system design, Customer-oriented work time, Multi-disciplinary research, Socio-technology, Work organisation.

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1 INTRODUCTION AND FRAMES OF REFERENCE

In most cases various intriguing phenomena appearing in large complex organisations have been evaluated from a strictly social, technical or medical science point of view. Thus it may be fair to claim that the understandings of these organisations and phenomena are satisfactory at least from a single-science point of view. However, particularly when viewed from an applied sciences point of view these phenomena sometimes need to be evaluated by a cross- or multi-disciplinary research approach, which may pose additional challenges.

In this context it is usually puzzling to gain an in-depth understanding on how, for example, social and technical dimensions interact on the shop floor at e.g. an automotive plant creating phenomena like psychosocial work conditions, operators' perception of work, incentives systems, etc. Unless various types of organisational structures of companies studied are linked to their materials flow systems, thus also relating these systems to various types of shop floor data, overview and in-depth understanding will be restricted or even sometimes impossible. Such shop floor data may e.g. be obtained by e.g. observations or questionnaire studies.

In this article, the organisational structures dealt with are the companies' overarching organisational superstructures and the local union's organisational structure, i.e. the Metal Workers' Union Volvo (belonging to the Swedish Metalworkers' Union). The materials flow systems dealt with are the product flow patterns, i.e. how the products are manufactured, transported and buffered during their manufacturing. In other words we will explain how to relate two different sorts of organisational structures to the production (assembly) system design.[1]

Since these problem areas are wide and heterogeneous in nature, the authors have in this article focused on two points of departures.

Firstly, in this article the authors discuss an expansion of a cross- and multi-disciplinary research approach by amalgamating different categories of practitioners in the research process. As an illustration the authors use results and experiences from co-operation with local union representatives from two large automotive companies regarding evaluation of the

[1] During the last two decades one of the authors has conducted quite an extensive research utilising a cross- and multi-disciplinary research approach co-operating with researchers from e.g. pedagogy, sociology, psychology, and medicine within the automotive industry, especially regarding specific aspects of production system design and evaluation (e.g. Engström et al. 1995; Johansson Hanse and Engström 1998).

shop floor work and flexible work time scheduling, i.e. 'customer-oriented work time', by means of questionnaire studies (sub-sections 2.2 as well as section 4 with examples 1 and 2).

Secondly, a specific type of analysis procedures is illustrated by data from this co-operation on linking the technical and social dimensions of the shop floor work by means of relating the companies' overarching organisational superstructures and the local union's organisational structure to the materials flow systems by means of constructed tables and various forms of schematised layouts, which are in turn coupled to questionnaire data.

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The table in figure 1 defines and exemplifies combinations of research and development work. The discussions and research results brought forward in this article will specifically deal with field four in the table, i.e. the co-operation between practitioners and researchers with a cross- and multi-disciplinary research approach. Cross-disciplinary science means that the boundary between at least two scientific disciplines is transcended, while in multi-disciplinary science the scientist is specialised within his or her field of knowledge and co-operates with scientists in other fields (Axelsson et al. 1998).

(FIGURE 1)

The practitioners usually deal with everyday problem-solving as an integrated part of established industrial frames of reference. The researchers, on the other hand, belong to a scientific context and look at specific theoretically significant aspects and will usually try to formulate or verify some more general hypotheses about e.g. the shop floor work. Thus the goals of the practitioners and the researchers are not always in agreement.

An especially intriguing situation appears when a 'transcending research approach' is established, which itself comprises both researchers from different disciplines and practitioners in data collection and analysis. If such a research aims at amalgamating practitioners' and researchers' goals and perspectives in order to exploit valuable constructive synergies then a specific way of organisation is called for, a matter only touched upon below. As a result, such a research approach will certainly call for some reflection on research methodology.

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The research presented in this article is connected to the socio-technical research tradition in Gothenburg first developed at Gothenburg University and later on expanded at Chalmers University of Technology. Generally speaking the socio-technical research tradition analysis organisations as open systems since they are seen as interacting with the surrounding environment (Katz and Kahn, 1966). This theory points to the importance of the two sub-systems (one technical and one social) necessarily considered at the same time, known as joint optimisation. Unfortunately, the socio-technical research tradition does not include suitable methods for analysis of technology; for example, guidelines are lacking regarding how the technical sub-system should be changed (e.g. Lindér 1990).

Nevertheless, the debate on merits and malfunctions of the socio-technology is still valid today as will be underlined by the two examples presented in section 4 below. For these reasons socio-technically based methods for design and evaluation of production systems and shop floor work are also of special interest for the practitioners. Owing to this, mutual interests in amalgamating practitioners' and researchers' goals and perspectives are called for.

2 BACKGROUND AND EXPERIENCE FROM CO-OPERATION PROCESSES BETWEEN RESEARCHERS AND PRACTITIONERS

Questionnaires are commonly used for evaluating various aspects of the shop floor work as has also been done in the cases reported here. As a basis for conducting surveys the authors had at their disposal a selection of approximately 150 questions used by different researchers in Sweden. From this selection it was possible to construct prototype questionnaires suited for specific case studies. This procedure was originally carried through for evaluating e.g. the Volvo Uddevalla plant (Engström et al. 1995; Engström, Johansson Hanse and Kadefors 1999). See also e.g. Jonsson and Fredholm (1984), Fredholm (1987) Fredholm and Jonsson (1987 and 1992) who deal with incentives and salary systems. The psychosocial evaluation of the shop floor work is based on Johansson (1994) who in turn refers to Rubenowitz (1992) and Rubenowitz and Schaller (1992).

In most respects these latter questionnaire studies follow the more traditional way of conducting such studies, i.e. in most cases the aim is well defined and the scientist's ambition to achieve an in-depth understanding of the actual work studied is restricted for various reasons; this situation is mainly, according to our experiences, due to impropriate methods. The evaluation of the Volvo Uddevalla plant, on the other hand, was different since it included researchers involved with practitioners during the design, running in and full-scale manufacturing phases. And this fact substantially promoted the interpretation of the statistical analysis of the questionnaire data.

This article will, as an illustration of the co-operation between practitioners and researchers, report on recent findings from three questionnaire studies in two large automotive enterprises in Gothenburg area, the Volvo Car and Volvo Truck Companies, and also a supplier park belonging to the Volvo Car Company.

However, this article will, as mentioned above, only present some selected aspects of the findings since the data available has not yet been fully exploited, nor is the statistical analysis of the questionnaire data fully completed. Furthermore, to avoid overwhelming the reader with data the authors has below in most cases chosen to use the Volvo Tuve plant as an illustration, though similar data collection and analysis has been conducted at the Volvo Torslanda plant and its supplier park.

The questionnaires have been monitored, complemented and further analysed by the use of constructed tables comprised of data from each department investigated (se figure 5), and in most cases also complemented by various forms of schematised layouts[2] which could be either detailed or more aggregated (see figures 6 and 7). In this article the authors will exemplify how these tables and various forms of schematised layouts were constructed and used.

2.1 The background

Briefly recapitulated, the authors' background to the problem areas touched upon above is as follows: By earlier contacts with the local union (i.e. the Metal Workers' Union Volvo) at those companies the authors received an opportunity to conduct a series of surveys at the Volvo Torslanda and Volvo Tuve plants.

These surveys have for three reasons proved to be an opportunity to link earlier research and development work within the Swedish automotive industry by one of the authors to the goals and perspectives of the local union representatives.

[2] By schematic layouts we mean layouts that illuminate the function of e.g. a production system, in contrast to a physical layout that shows the actual (physical) installations such as manufacturing equipment, doors and walls, etc

Firstly, some of the questionnaire variables developed proved to be of common interest. Secondly, methodological aspects were of specific interest to the researchers whereas, on the other hand, the need for more stringent methods and procedures in guiding the local union representatives when conducting their own survey studies in the future was a joint ambition. Thirdly, the local union representatives were concerned that their own previous surveys might not have been sufficiently professional regarding statistical analysis of the questionnaire data, which on the other hand is a field of knowledge mastered by the researchers.[3]

The co-operation with the local union was thus an important opportunity for the authors to get legitimised entrance to conduct these surveys, which were distributed to all blue-collar employees in about 3/4 of the two organisations, but also to get the opportunity to make complementary interviews, make study visits at work sites, etc., as well as receive practical help with various time-consuming details such as e.g. distributing and collecting questionnaire forms. The three questionnaire studies (denoted questionnaire: I, II and III) are overviewed in figure 2 and in the table in figure 3.

(FIGURE 2)

Questionnaire study I was conducted in March through May 2000. This study comprised a stratified selection of 200 operators at the two companies. It included questions concerning work and production, the blue-collar employees' working hours and their perception of working hours, relationships between working and leisure time, wages and perception of wages, etc.

Questionnaires II and III contained questions concerning the blue-collar employees' opinions on a recent reformation of work time scheduling (the introduction of so-called 'customer-oriented work time') as well as e.g. general questions on perception of working hours and the actual working hours of the blue-collar employees.[4]

Questionnaire II was conducted in October – November 2001 at the Volvo Truck Company and included every blue-collar employee with 'customer-oriented work time'. Questionnaire III was carried out at the Volvo Car Company in March – April 2001 and also included all blue-collar employees with 'customer-oriented work time'. The proportion of blue-collar employees, which was affected by the change to 'customer-oriented work time', was approximately 75% of the total work force.

(FIGURE 3)

2.2 Co-operation procedures

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[3] In this context it ought to be noted that today it is difficult to conduct extensive surveys within the automotive industry due to slimmed organisations.

[4] Briefly explained, 'customer-oriented work time' means that the work time is dependent on the company's sales which fluctuate according to customer demands. For example, in the case of the Volvo Truck Company the weekly working time has been extended since 1999 and the blue-collar employees have been compensated with a maximum of seventeen free Fridays in one year. If the management however should want to increase the production capacity due to increased sales it has to demand the use of the 'free Fridays' three weeks in advance. For the curious reader it might be of interest to know something about the findings brought forward by the local union representatives (Fördelaren 2001; Blomquist and Engström 2002). The evaluation of 'customer-oriented work time' brought forward showed e.g. that a majority of the blue-collar employees perceived that the reformed work time had been initiated in order to increase the companies' competitiveness rather than to improve work conditions and job security for the blue-collar employees. Furthermore, a majority of the blue-collar employees working nights and evenings preferred to retain these work times. On the other hand, substantially less of the blue-collar employees working shifts wanted to retain working shifts

Obviously, some sort of procedure to structure the planned co-operation between practitioners and researchers was required. Although, such a structure was implicitly successively established as the co-operation went on. This state of the art is in fact not unusual if the research and development work is carried out more as an open research process. Furthermore the co-operation procedures were intentionally organised to promote overview while at the same time mastering the details, even non-existing details, e.g. future research questions. The reason for this was the fact that the co-operation from the authors' point of view was a direct carry-on of earlier research regarding both methods and procedures.

In figure 4 the various co-operation procedures are schematised. These co-operation procedures comprised e.g. a number of interactive activities:

> (1) 'Preparation for data collection' (B1 in figure 4) comprised e.g. defining the exact number of blue-collar employees at each department. This was somewhat intriguing since the companies' overarching organisational superstructures were not congruent with the local union's organisational structure, combined with the fact that the personnel departments' lists of blue-collar employees work sites were inconsistent due to sick leaves, personnel being off on education or being lent to other work sites as is explained more in detail in section 3 below. In order to control the data collection each department received the exact same number of questionnaire forms corresponding to the assumed number of blue-collar employees.
>
> (2) 'Iterations of diagrams and discussions' (C1 in figure 4) utilising 95 diagrams, which were discussed with the local union representatives who also used these statistics for reporting the findings to e.g. their members. Examples of such diagrams are shown in figures 8 and 9. Moreover in some cases were also special constructed figures comprising selection of questionnaire data combined with various forms of schematised layouts as shown in figures 6 and 7.

Albeit, the frames defined by practitioners (i.e. the evaluation of 'customer-oriented work time' at the two companies) sometimes contrasted with the researchers' specific goals and this instigated a need for (a) discussing, almost negotiating, the exact content and formulation of each question in the questionnaire forms. Furthermore, the researchers first of all had (b) the ambition to cross-refer the findings between questionnaires I, II and III; but then it also proved a necessity to call for a utilisation of the data both in already conducted studies as well as in future ones, especially since extended generalisations between the questionnaire studies were to be considered.

(FIGURE 4)

The reporting of the findings were conducted in different contexts that generated feedback from different categories of practitioners. For example, the results from the questionnaire studies were presented at local union meetings in which the researchers participated. The discussions among the local union members provided the researchers with valuable insights in the ongoing statistical analysis of the questionnaire data.

The discussions and communications carried out with various practitioners during a period of approximately half a year left the researchers with a vast amount of interesting findings and interpretations and also with proposals for future analysis and a complementary data collection.

To conclude, this section illustrates – as most scientists know – the fact that even though the general results from a long-term co-operation between researches and practitioners might seem quite simple it may actually be based on intriguing procedures and insights.

3 ANALYSIS PROCEDURES BY MEANS OF CONSTRUCTION OF TABLES AND VARIOUS FORMS OF SCHEMATISED LAYOUTS IN ORDER TO FORM ANALYTICAL CATEGORIES

As mentioned above surveys I, II and III were complemented by the construction of tables comprised of data from each department investigated. Note that all questionnaires included a question concerning at which department each particular blue-collar employee was working at the moment. By means of these tables, illustrated in figure 5, it was e.g. possible to relate the questionnaire variables to the companies' overarching organisational superstructures and the local union's organisational structure (i.e. the Metal Workers' Union Volvo) as well as to the plant design.

These tables enclose all the departments on the shop floor in the two companies regardless of whether or not they were included in the surveys. Thus it was possible to overview the total function of the manufacturing processes in both companies, which in fact is necessary when e.g. constructing analytical categories to be compared, i.e. clusters of departments with similar functions, similar production systems, similar type of work, etc.

The twenty departments in the constructed table in figure 5 are the same as in the schematised layout in figure 6. These tables were sorted in various ways and used for checking data collected as well as comparing the two companies in various ways. Other variables in the tables that is not shown in the figure were the number of blue-collar employees, the local union committee number and the union representatives contact person. In the table we have inserted blank lines to facilitate the reading. During our use of these tables we also used colour coding. Such tables were constructed both for grasping the companies' overarching organisational superstructures and for the local union's organisational structure as has been mentioned also in sub-section 2.2 regarding 'preparation for data collection'.[5]

(FIGURE 5)

Note that it is important to construct the tables carefully using plain language for e.g. department codification and activities as shown in figure 5, especially so regarding activities in each departments since sometimes are the department name not sufficient for understanding the exact function. This is also important if the data collected are planned to be used for longitudinal or comparative studies since department numbers are for various reasons, not touched upon here, changed constantly.

It is also advisable to have a contact person for each department; by means of the name of the contact person included in the constructed tables it is possible to check up for example discrepancies or lack of insights when performing analysis of data.

There was for example extensive 'detective work' required for the authors to clear out on why and how some department numbers were inconsistent or missing when comparing the questionnaires' data with the tables constructed, in most cases where the contact persons but also other practitioners contacted to clear out these matters. The questionnaire studies had

[5] Note that the department numbers in the first column do not form a coherent hierarchy of figures even though the departments as in this case are situated in series along a part of the serial product flow and that the local union committees might embrace one or many departments, sometimes also splitting a department.

been conducted during different period of times (see figure 2), and sometimes e.g. the department numbers had changed, which became evident when cross-referencing the constructed tables with data from the questionnaire studies.

The analysis procedures by means of forming analytical categories brought forward and briefly explained in this article comprise the following steps: (A) Identifying main and sub-functions within the two companies. In this case the tables created were a necessity since, among other things, the department numbers and codifications were changing constantly in quite an unpredictable way even though the functions of each department may have been similar. Thereby it became possible (B) to define similar and non-similar main and sub-functions relating to the departments and thus to the department numbers. This meant e.g. that the authors could aggregate the departments into analytical categories to be used for various statistical analyses of the questionnaire data.

Two different forms of schematised layouts of some departments at the Volvo Truck Company are shown in figure 6 below. These are the same departments as shown in the constructed table in figure 5 above. In the middle to the left, a symbol of the building premises of the Volvo Tuve plant is inserted (i.e. a more overarching schematised layout). These building premises comprise two interconnected building, i.e. the LA and LB-buildings. Inside the symbol of the building premises are the departments selected marked by ellipsoids. On the top and to the right of this symbol are two 'blow ups' of the departments shown which comprise more detailed schematised layouts and symbols facilitating the understanding o the production system. (Note that some of these departments are discussed below in section 4, example 2).

(FIGURE 6)

The analysis procedures brought forward in this article makes it possible to make comparisons within a specific plant, e.g. comparing different aggregated departments, as has been mentioned above. However it is also possible to conduct comparisons between different companies. In this later case it is necessary to take unique characteristics of different companies in consideration in order to make valid comparisons.

Such considerations may be illustrated by obvious differences between the two companies studied. As mentioned in section 1, it must be understood that Volvo Car Company has both a body shop (so-called A-plant) and a painting shop (so-called B-plant) comprising an extensive number of blue-collar employees, while the Volvo Truck Company do not have similar shops. Instead the truck manufacturing uses fully automated stamping and painting of the frame rails and this work is monitored by relatively few blue-collar employees.

On the other hand, focusing solely on the assembly work (so-called the C-plants) in both companies, the materials flow systems are somewhat differently designed. The Volvo Car Company has one main product flow supplied by e.g. internal sub-assembly departments and an external supplier park, where one of these internal sub-assembly departments is the parallel product flow door assembly as dealt with in example 2 in section 4. The Volvo Truck Company, on the other hand, contains a mix of parallel and serial product flow production (assembly) systems (i.e. so-called docks and assembly lines);[6] that is the so-called chassis and assembly docks and the two main product flows as shown in figure 6. These production systems are also fed by materials from e.g. a number of internal sub-assembly departments.

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[6] To explain the production (assembly) system designs just mentioned; in a serial product flow production system the products are assembled in a serial product flow (i.e. an assembly line), while in a parallel product flow production system, the products are assembled in parallel by individuals or work groups. That is, in a parallel product flow production system the products will in extreme cases only pass one workstation and the assembly work is less repetitive due to increased work cycle time.

All these characteristics must be considered when comparing e.g. questionnaire data from the two companies as is illustrated in example 2 in section 4.

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The aggregation of departments is further exemplified below by an overview of the manning of the various manufacturing processes at the main Volvo Tuve plan prospecting some of the questionnaire data, as is shown in figure 7. In the year 2000 most of the newly employed operators were working at production sections I – III due to the recruitment strategy used.

The most of the long serving blue-collar operators, on the other hand, were employed at the assembly docks or production sections IV – V. For example our interviews revealed that this phenomenon is due to the non-machine paced and qualitatively different work between the assembly docks (please see example 2 for further explanation) and the three first productions sections, where some blue-collar employees which had opportunities has gained work at the two last production sections which has a far less machine-paced work.

(FIGURE 7)

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To conclude, the construction of tables comprised of data from each department investigated served e.g. the purpose of securing a high level of quality data by monitoring the administration of the questionnaire forms and it also provided the opportunity to make cross-references between the original tables and the actual department numbers found in the questionnaire forms. Thus some of the peculiarities which needed to be clarified were illuminated.

While the study visits at the various departments, with e.g. the construction of and use of various forms of schematised layouts, were aimed at understanding the manufacturing process in closer detail the visits also served as an opportunity to establish personal relationships with the blue and white-collar employees. This facilitated the possibility afterwards to check up on some of these peculiarities.

All these measures carried through in co-operation with the local union have allowed the authors to relate the statistical analysis of the questionnaire data to specific characteristics at a single department or to analytical categories.

4 EXAMPLES OF STATISTICAL ANALYSIS OF THE QUESTIONNAIRE DATA COMPLEMENTED BY THE USE OF THE ANALYSIS AND CO-OPERATION PROCEDURES

Below the authors have reported two examples illuminating how this type of analysis and co-operation procedures has been used, i.e. how the relationship between the statistical analysis of the questionnaire data and the constructed tables has been dealt with. As mentioned above, the use of department numbers in the questionnaire forms made it possible to aggregate specific analytical categories at the two companies and this signifies an important analytical potential.

It must be noted that these two examples are more illustrations of the analysis and co-operation procedures, rather than a matter of reporting on basic results as the main topic of a scientific article, although the examples are interesting in themselves.

Example 1 deals with analytical categories used for facilitating the comparisons between companies, and example 2 treat specific analytical categories for facilitating the comparisons between different functions within a specific company such as different production system designs. In this case we also discern and compare these different production system designs within the two companies studied; that is the Volvo Car and Volvo Truck Companies.[7]

4.1 Example 1: Comparisons between two companies distinguishing comparable analytical categories

In order to make relevant comparisons between different companies it is sometimes necessary to define analytical categories which are comparable. As mentioned at the end of section 3 the two companies have quite different organisational structures and materials flow systems which makes comparisons between them intriguing. Therefore, in this example of statistical analysis the authors have only considered blue-collar employees dealing with 'direct production', thus omitting blue-collar employees that e.g. are responsible for materials handling, quality audit, etc.

This means e.g. that the work in the assembly shops at the two companies has been divided into the category 'direct production' comprised of the departments included in (a) serial product flow production systems, (b) parallel product flow assembly systems, and (c) auxiliary direct work. The category 'indirect work' consists of departments dealing with (d) materials handling and supply and (e) auxiliary indirect work. Finally, there is the category of non-relevant departments. Figure 8 compares the blue-collar employees involved in 'direct production' and it shows that both companies follow quite similar patterns.

(FIGURE 8)

One reason for the patterns shown in figure 8 is that quite a number of new personnel were recruited before the 1990s due to the business boom at both companies. Later on, during the recession in the 1990s there was a decrease in the number of newly employed combined with accelerated lay-offs, albeit recruitments increased again in the year 2000. We will not go into details in these matters just state that it is quite a difference between the two companies with regard of recruitment strategies and internal turnover during the last ten years for the blue-collar employees dealing with 'direct production'.

The authors have used these types of diagrams in order to discuss with the local union representatives and, among other things, gain an historical overview of the course of events necessary for an enhanced understanding of the data. For example, it was possible to understand in detail how interaction between introduction of new products and recruitment has functioned over the years at both companies, thus avoiding generalisations by drawing conclusions from the data which hide a far more complex situation. That is, the interpretation of the questionnaire data was facilitated by interviews, constructed tables and various forms of schematised layouts.

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[7] The interesting differences brought forward in the two examples below between blue-collar employees may of course depend on other factors besides the ones touched upon. Factors such as sex and age structure, time of employment, etc., should be studied by means of multivariate analyses of the questionnaire data. This will be developed and reported elsewhere in a future article. This type of analysis and co-operation procedures is facilitated by the extensive data at hand; the questionnaires studies II and III included 1 193 respectively 1 438 persons as is evident in figure 3. These two questionnaire studies were, as mentioned above, also total studies of the companies comprising all the blue-collar employees involved in the 'customer-oriented work time' at the two companies, meaning that all existing departments required for manufacturing were included.

For example, introduction of a new product may on one hand concern only a number of specific departments while on the other hand another introduction might just as well affect all departments. What will happen depends on the type of product, and exactly which departments are affected by the new or revised product architecture. At the Volvo Tuve will e.g. the manual work in the automated manufacturing of the frame rails, which corresponds to the work in the body shop at the Volvo Car Company, hardly be affected by new models.[8]

To conclude, this example illustrates the need for complementary insights beyond what is directly obvious from a questionnaire study. In this case substantial internal turnover combined with extreme variations in recruitment procedures were of vital importance for understanding of the questionnaire data gained.

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The type of analysis illustrated above, with the use of analytical categories which are comparable might be used for international comparisons in the future. As an example it can be mentioned that the researchers have had in their questionnaires similar questions that Japanese researchers had used in studies in automotive industries in Japan (in this case some questions from JAW 1992).

Moreover these analysis and co-operation procedures are also appropriate for studies in various types of other industries since appropriate analytical categories such as non-machine, semi-machine and machine-paced work may also be defined within other branches.

4.2 Example 2: Comparisons between two different production system designs in two companies

As already has been explained it is, with the use of analytical categories, possible to discern different functional units in a factory. In this example we will distinguish two different analytical categories, namely serial and parallel product flow production systems; the Volvo Truck Company's assembly docks at the Volvo Tuve plant and the door assembly, a sub-assembly department at the Volvo Car Company's Torslanda plant (see Engström, Blomquist and Holmström 2004 for further details on the Volvo Tuve plant history and its future).[9]

Both companies had these two different production systems during the period of time when the questionnaire studies were conducted. Questions regarding work satisfaction in a general sense have been included in the questionnaire studies. Figure 9 compares the departments using serial product flow respectively parallel product flow production systems at the two companies regarding whether or not blue-collar employees are satisfied with their work.

(FIGURE 9)

As is evident in figure 9 there are quite extensive differences between the two companies regarding the answers to the question of work satisfaction. According to earlier research (Karlsson 1978) the authors' might have expected an increased work satisfaction at both parallel product flow production systems. This was the case at the Volvo Truck Company

[8] The manufacturing process is fully automated (the changes required are reprogramming a series of machines punching a pattern of holes in the frame rails unique for each product variant). The body shop, however, though heavily automated still has an extensive number of automated or semi-manual workstations, as well as one long welding line. Moreover, compared to the ease of reprogramming the rather small transfer line for manufacturing of the frame rails, the large Volvo Torslanda body shop needs extensive changes involving the manual work.

[9] The assembly docks was successively closed down. The last assembly dock was closed in 2002, and the production volumes (the most complex product variants) were than transferred to the two main product flows. The sub-assembly department for doors was rebuilt into a serial product flow in 2002.

even though the noted differences were not especially large, but in the Volvo Car Company the pattern was reversed.

In this context it must be noted that the expected increased work satisfaction presumes correctly designed parallel product flow production systems, i.e. that e.g. the manufacturing engineering as well as the running in and full pace production has been done according to the principles and practices established for parallel product flow production systems (see e.g. Engström, Jonsson and Medbo 1996).

According to one of the authors' knowledge and insights regarding production system design, based on twenty five years research and development work within the Swedish automotive industry, the production systems in both companies were not correctly designed in some critical respects.

The assembly work at the parallel product flow production system in the Volvo Car Company was in fact not 'true' group work. It was a parallel product flow production system consisting of individual workstations characterised by extreme individual working up, i.e. in some cases the operators individually completed their stipulated work of the day and were able to leave approximately 2 – 4 hours before the working day ends.[10] This situation was partly explained by management practices and ideologies as well as by production system design.

In the Volvo Truck Company, on the other hand, the parallel product flow production system for several reasons represented more of a 'true' group work. The operator cohesions and co-operation were extreme and the working up took place on a collective level. The work groups usually completed their stipulated work approximately 2 – 3 hours earlier if materials were delivered as expected, if the required components were available and if sufficient quality product and assembly information (work instructions and product variant specifications) was at hand, something which however was not all too common. In fact, truck chassis are far more complex and included relatively less product design engineering hours than did the automobile. Somewhat roughly stated it might be considered more or less as a prototype. Thus the assembly work at the Volvo Truck Company was in certain respects far more demanding and the work at the parallel product flow was generally considered as a step forward in the operators' internal career advancement.[11]

In fact these mechanisms were understood by means of the study visits and interviews. The schematised layouts also proved that the assembly work at the door assembly was conducted as a individual work. That is, briefly explained, each operator was able to fetch as much materials as needed and he or she was positioned at an individual workstation working fully independent of the other operators, each operator positioned at their own work station forming shielded compartments. At the assembly docks, on the other hand, cooperation was a necessity, the operators were forced to cooperate, conducting their work within eye distance of each other. Moreover, since the truck chassis may be considered as prototypes, from an assembly point of view, with inferior assembly information, co-operation among operators

[10] A production (assembly) system consisting of a number of workstations in a sequence may fail to accommodate inter-operator and intra-operator variation, product variation etc., thus generating idle operator time and/or need for re-work. In both cases, extra manpower is needed (Wild 1975). Thus a correctly designed parallel product flow production system requires less working hours compared to a serial product flow production system. This is the reason for a higher degree of efficiency and why the operators usually complete their stipulated work ahead of schedule. See e.g. Engström, Jonsson and Medbo (1996) for some empirical data regarding the efficiency of parallel product flow production systems.

[11] In most cases the state of the art sketched above is common for all parallel product flow production systems introduced in Sweden during the last two decades. For a more detailed explanation of the merits and idiosyncrasies of production system designs using autonomous work groups using parallel product flow production systems, see Engström, Jonsson and Johansson (1996); Engström, Jonsson and Medbo (1996) and Medbo (1999).

was necessary. Interpreting the work instructions and product variant specifications, considering the extensive number of product change orders for an enormous number of different product variants, certainly calls for collective efforts and experiences, in a way that was not called for at the door assembly work.

*

To conclude, one of the conveyed merits of this type of analysis and co-operation procedures is the possibility to construct appropriate analytical categories in accordance to the purpose of the analyses at hand. In this example we compared two companies having different production system designs. As is evident above by means of more insights it was actually possible to interpret the noted difference in the questionnaire data.

Later on, the local union representatives helped to arrange for the authors to conduct video recordings of the assembly work at both the assembly docks and at the sub-assembly department for doors. In the future it will be possible to link these data to the findings in the questionnaire studies. These interviews and video recordings supported the conclusions brought forward in this example.

This example underlines the importance of adequate insights concerning the technical aspects for interpreting questionnaire data on shop floor work, and for relating this data to two different sorts of organisational structures and to the production system design.

5 DISCUSSION

The findings and experiences brought forward above illuminate some merits as well as some pitfalls of a 'transcending research approach' with practitioners and researchers in co-operation from a cross- and multi-disciplinary point of view. However, at first the authors will briefly discuss some of the gains from the co-operation which can be divided into two aspects: practical co-operation and analytical synergies.

As mentioned above the local union representatives from the Metal Workers' Union Volvo gave the researchers an opportunity to collect data at the two companies but they also set up an appropriate organisation for distributing and collecting the questionnaires as well as dealing with other practical details of importance, all in a way that would otherwise have been difficult to arrange. This co-operation also facilitated access to all blue-collar employees involved, not only a small sample of employees.

The analytical synergies are of course more complex to evaluate and the authors will elaborate upon this in future publications. However, there are some aspects worth noting in this article that have not been touched upon above, such as the general need for an enhanced systematic discourse regarding various aspects of shop floor work based on 'true shop floor data'. One interesting procedure to be mentioned in this context is the use of the local union's homepage as a future means for reaching blue-collar employees. In that way issues like the findings from the surveys might be debated via e-mail. In this specific case the local union representatives in fact already have an impressive computerised network of communication at hand for fast communication concerning union matters. From an international perspective, this is a communication network which in fact is quite unique for the Metal Workers' Union Volvo.

Some pitfalls to be underlined are e.g. different lines of thought between practitioners and researchers and the variation in conceptualisation as well as verbalisation of phenomena. One of the aspects especially worth noting in the context brought to light above is that a union is in fact an interest organisation, and it might be difficult to co-operate with a party embracing quite specific goals that might be opposed to a scientific point of view striving to be free of value judgements.[12] However, since union values and ideologies are explicit in many respects this makes it possible for practitioners and researchers to define the problem areas of common interest in which co-operation would be valuable.[13]

Finally, detailed knowledge concerning the functions and history of different departments in the companies studied is valuable for an adequate analysis of the questionnaire data. These must be appropriately overviewed and compiled in order to e.g. construct analytical categories. The co-operation procedures between practitioners and researches are of vital importance in this respect.

The analysis and co-operation procedures brought forward in this article is quite hands-on and certainly complements the questionnaire data in a constructive way, as illustrated by e.g. the figures 5 and 6, and also by example 1 and 2. These hands-on characteristics is especially prominent in the use of the various forms of schematised layouts since, among other things, blue-collar employees can orientate themselves and their co-workers in these layouts.

*

It has not been the main purpose in this article to give a downright report on the questionnaire data. The knowledge and insights gained have foremost been used for illustrating and supporting a way of reasoning, i.e. for bringing forward a specific type of analysis and co-operation procedures.

While the findings and experiences reported above are not always possible to generalise and apply to other contexts, the authors nevertheless regard them to be of general interest in a methodological discussion. The analysis and co-operation procedures implied the existence of an iterative research process – co-existing with a more traditional research process – which comprised shifting between various co-operation procedures, analytical categories and sometimes also research questions (see figure 10).

Thus, rather than organising the research according to a straight-line process solely aimed at treating a limited number of research questions to match specific issues and methods within a defined time window, an iterative research process was considered, either as an alternative or as a complement. In the questionnaire studies II and III recapitulated above, both ways of organising were at hand, i.e. the local union representatives obtained the requested evaluations of the 'customer-oriented work time' within a short time span while the researchers were pondering the data collected during a large period of time.

Dealing with hands-on activities will naturally enhance a constructive co-operation between practitioners and researchers since it offers various platforms for true more 'true' co-operations bridging eventual differences in both theoretical perspectives and research approaches, as well as in values and ideologues.

(FIGURE 10)

Thus is may be possible in the future to further prospect by the synergetic effects caused by contrasting or quite different points of departure.[14] Giving prominence to cross- and multi-

[12] It is not uncommon with upcoming conflicts between parties involved in analyse- and co-operation procedures. This might however not be a disadvantage. According to certain research traditions within social-psychology, for example, the human beings' consciousness and capacity to reflect expands when confronted with various conflicting and problematic situations (Mead 1934).

[13] The risk of mixing up the roles between local union representatives and researcher is e.g. underlined several times in a handbook dealing with co-operations with researchers. See LOFO 4 (1983).

[14] The construction of tables comprised of data from each department investigated exemplifies the emergence of a synergetic spin-off effect. This procedure first of all fulfilled the practitioners' and researchers' need for monitoring the distribution and collection of the questionnaire forms. Later on, however, it also proved to comprise an analytical potential. As the authors continued to work with the tables of the departments the use of

disciplinary research has long been advocated (see e.g. Klein 1996 for a résumé of aspects on inter-disciplinary research). In this article the authors have brought forward some constructive examples and procedures on broadening these co-operations to include practitioners in the research process.

Our aim in the future is to develop a more generalised which can be used in different problem areas and with different constellations of researchers and practitioners. As was mentioned at the end of section 1 there exists according to the authors a need for more untraditional methods for production system evaluation, especially regarding unorthodox production systems such as parallel product flow production systems.

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these tables became increasingly advanced and it was discovered that they could be used in contexts other than those originally intended.

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FIGURES:

Figure 1 below:

	'Restricted research approach':	'Transcending research approach':
Researchers:	(1) Traditional single-science research.	(2) Cross- and multi-disciplinary research.
Practitioners and researchers:	(3) Researchers from a particular scientific discipline in co-operation with practitioners.	(4) Researchers from different scientific disciplines in co-operation with practitioners.*

* Note that practitioners by no means are in lack of complex intellectual or theoretical frames of reference compared to scientists. In their daily work they deal with intriguing problems requiring complex decision-making processes. This is most often the case independently of whether they are blue- or white-collar employees. However, industrial systems do not prioritise verbal and written formalisation combined with clarification of connections with already established frames of reference, while such formalisations and connections are a matter of course to scientists.

Figure 2 below:

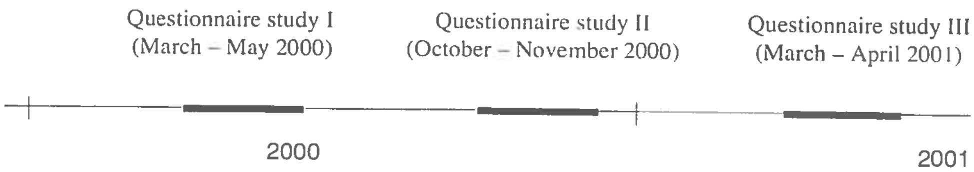


Figure 3 below:

	Work site:	Response rate:	Number of distributed questionnaire forms:	Number of departments included:	Comments:
Questionnaire study I (March – May 2000):	The Volvo Car and Truck Companies	>90%	200	80	- Included questions concerning work and production, the blue-collar employees' working hours and their views on working hours, relationships between working and leisure time, salaries and views on salaries, etc.
Questionnaire study II (October – November 2000):	The Volvo Truck Company	>70%	1 600	56	- Aimed at evaluating 'customer-oriented work time' and at the authors' ongoing research regarding design and evaluations of production systems and shop floor work.
Questionnaire study III (March – April 2001):	The Volvo Car Company	>70%	1 800	95	- Aimed at evaluating 'customer-oriented work time' and at the authors' ongoing research regarding design and evaluation of production systems and shop floor work.

* The response rate is difficult to ascertain since the number of blue-collar employees at a specific department is often unclear. The data received from the personnel department differ from the data given by the local union representatives. This might be explained by the fact that some of the blue-collar employees sometimes are lent to other departments, that the data are mirroring different time perspectives, etc.

Figure 4 below:

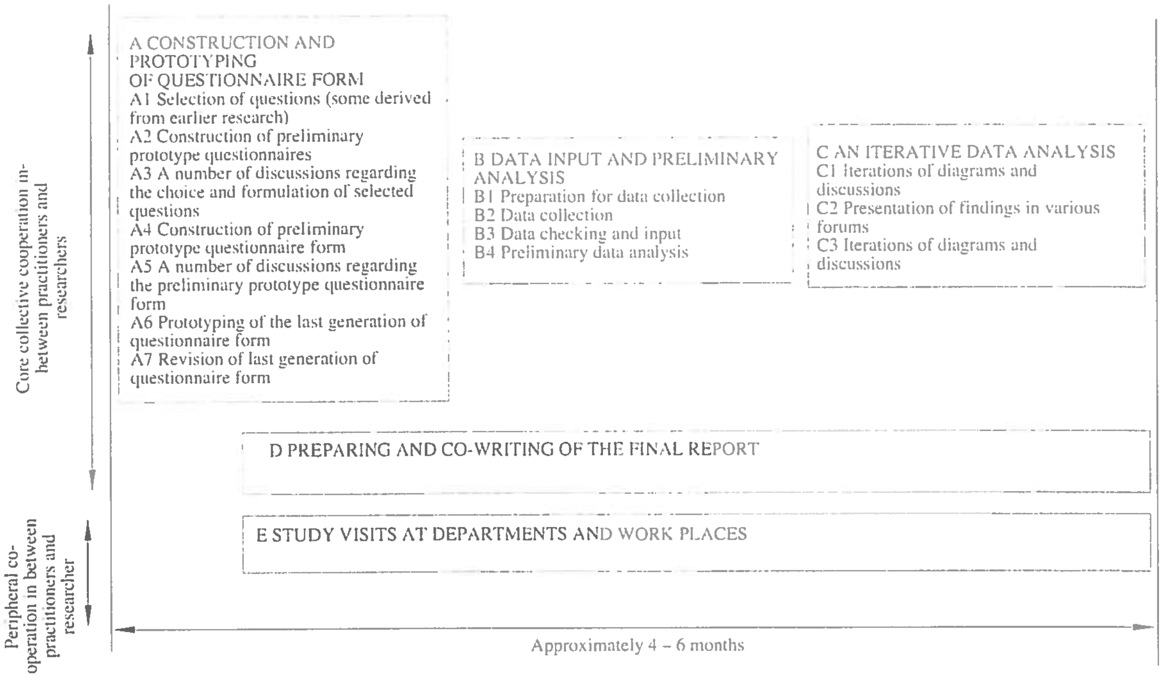


Figure 5 below:

DEPARTMENT NUMBER:	DEPARTMENT NAME AND COMPANY DENOTATION:	FUNCTION:	COMMENTS:
29 830	Assembly dock 'LE 25'*	Assembly of complete truck chassis	The most complex trucks
29 840	Assembly dock 'LE 26'*	Assembly of complete truck chassis	The most complex trucks
29 850	Assembly dock 'LE 27'*	Assembly of complete truck chassis	The most complex trucks
29 860	Assembly dock 'LE 30'*	Assembly of complete truck chassis	The most complex trucks
29 870	Assembly dock 'LE 31'*	Assembly of complete truck chassis	The most complex trucks
29 245	Chassis dock A and B*	Suspension, axles before delivering to the assembly docks or to the two main product flows	Simple and moderately complex trucks chassis
29 246	Chassis dock C and D*	Suspension, axles before delivering to the assembly docks or to the two main product flows	Simple and moderately complex truck chassis
29 247	Chassis dock E and F*	Suspension, axles before delivering to the assembly docks or to the two main product flows	The most complex truck chassis
29 248	Chassis dock A, B, C and C, evening work shift*	Suspension, axles before delivering to the assembly docks or to the two main product flows	The most complex truck chassis
29 261	Product flow 1 production section I**	Pneumatic leads, tubes, piping and electrical harnesses	The most simple truck chassis
29 271	Product flow 1 production section I, evening work shift**	Pneumatic leads, tubes, piping and electrical harnesses	The most simple truck chassis
29 264	Product flow 2 production section I**	Pneumatic leads, tubes, piping and electrical harnesses	Moderately complex truck chassis
29 262	Product flow 1 production section II**	Engine and components between 'engine marriage' and fitting of the cab.	The most simple truck chassis
29 272	Product flow 1 production section II and 3, evening work shift**	Engine and components between 'engine marriage' and fitting of the cab.	The most simple truck chassis
29 265	Product flow 2 production section II**	Engine and components between 'engine marriage' and fitting of the cab.	Moderately complex truck chassis
29 263	Product flow 1 production section III**	Cab, wheels and components after the 'cab marriage'	The most simple truck chassis
29 266	Product flow 2 production section III**	Cab, wheels and components after the 'cab marriage'	Moderately complex truck chassis
29 273	Product flow 1 and 2 production section IV***	Complementary painting and testing on a rolling road.	Both the most simple and moderately complex truck chassis
29 267	Product flow 1 and 2 production section IV***	Complementary painting and testing on a rolling road.	Both the most simple and moderately complex truck chassis
29 268	Product flow I and II production section V****	Checking for delivery to customer	Both the most simple and moderately complex truck chassis

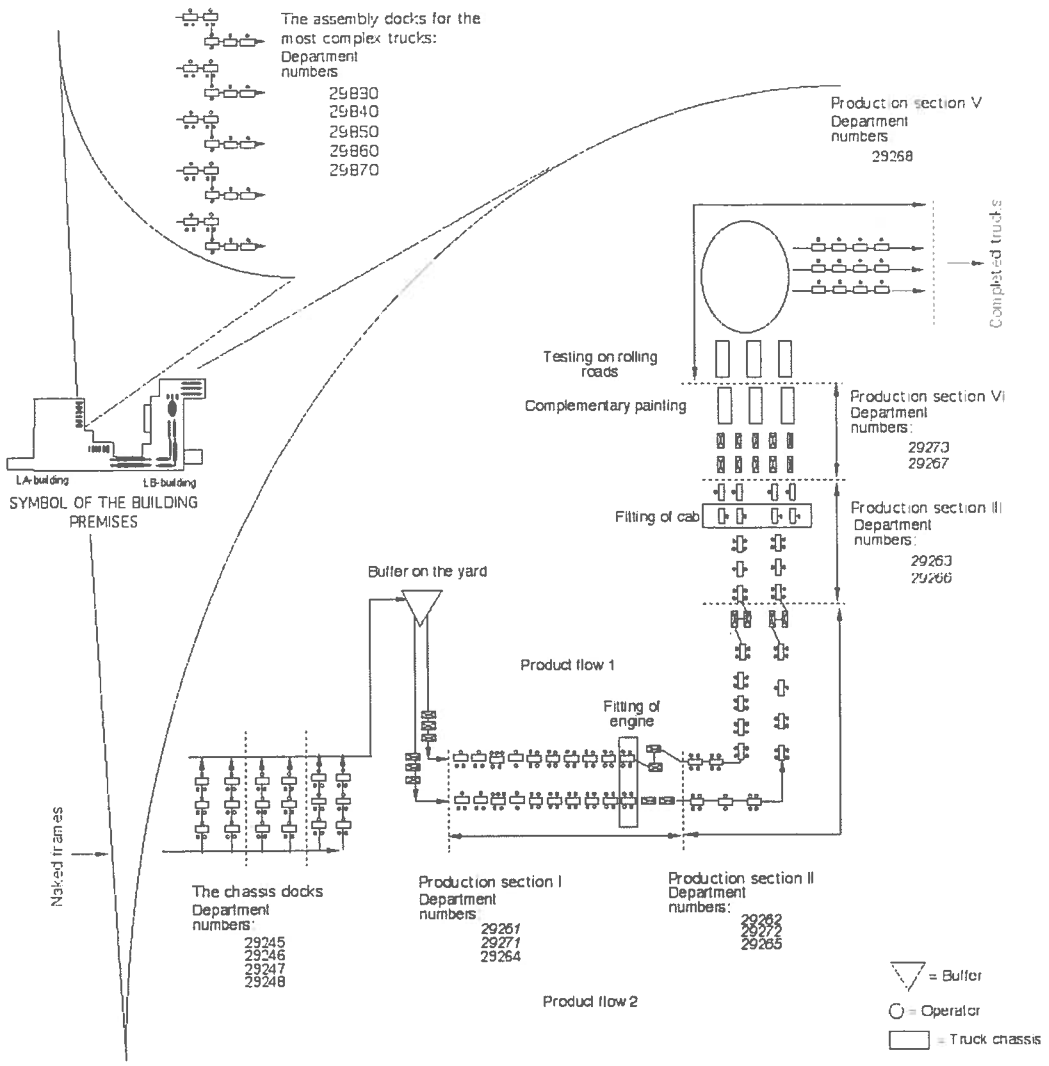
*) Parallel product flow production system (i.e. docks).

**) Serial product flow production system (i.e. assembly line).

***) Also denoted 'slussen' by Volvo personal.

****) Also denoted 'green ok' or the 'final section' by the Volvo personal.

Figure 6 below:



Schematised layouts of the chassis- and assembly docks and the two main product flows at the Volvo Truck Company. i.e. departments where most of the manual work is carried out on the truck chassis.

Figure 7 below:

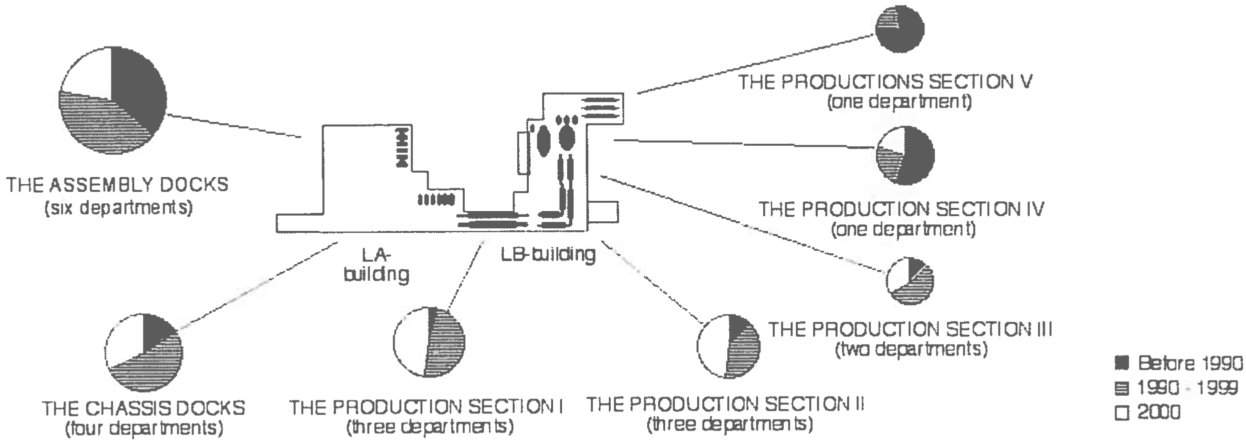
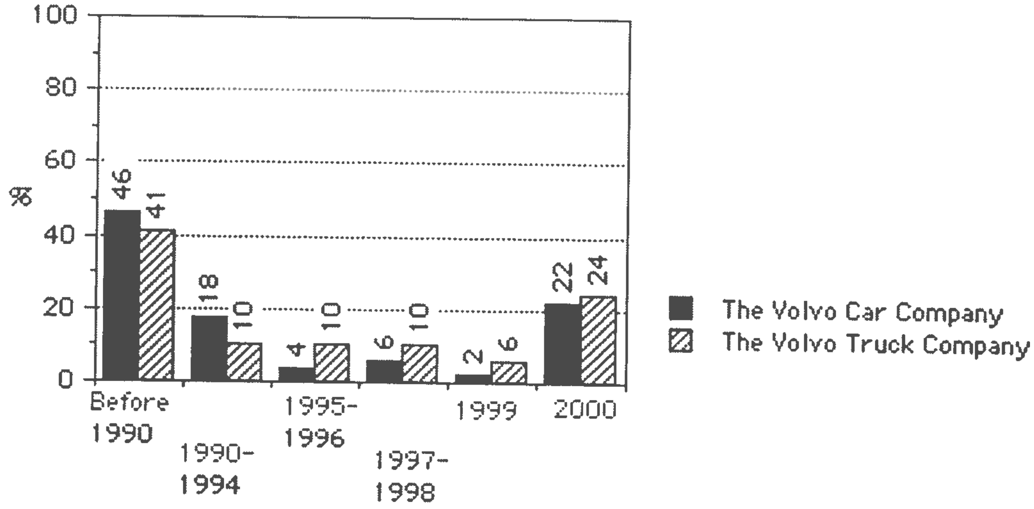
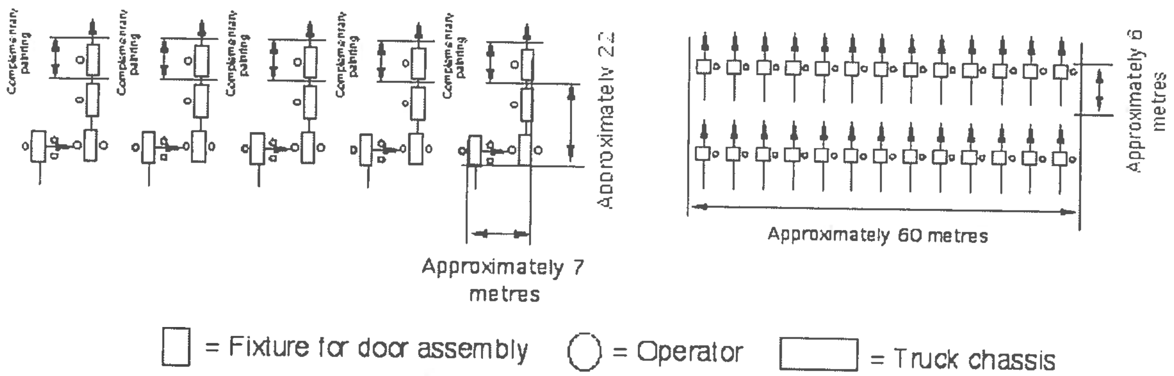


Figure 8 below:



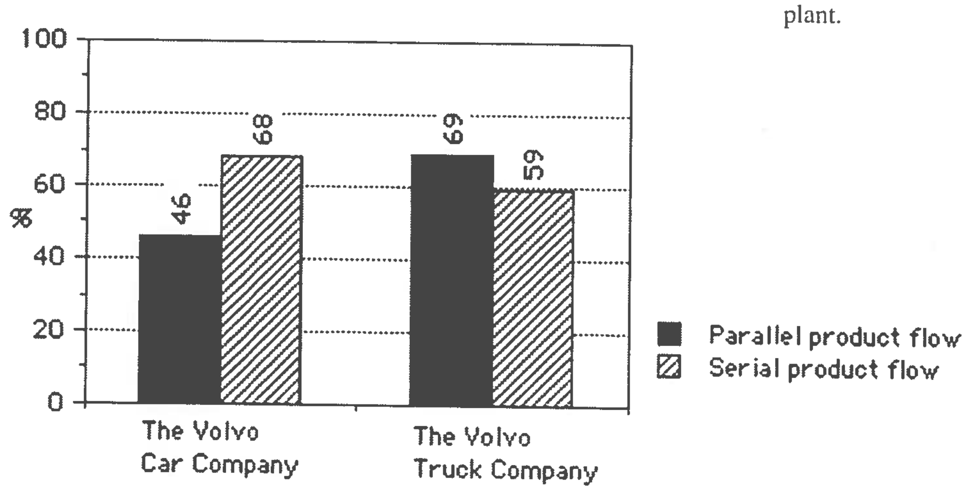
The Volvo Car Company: N=691; the Volvo Truck Company: N = 1 067.

Figure 9 below:



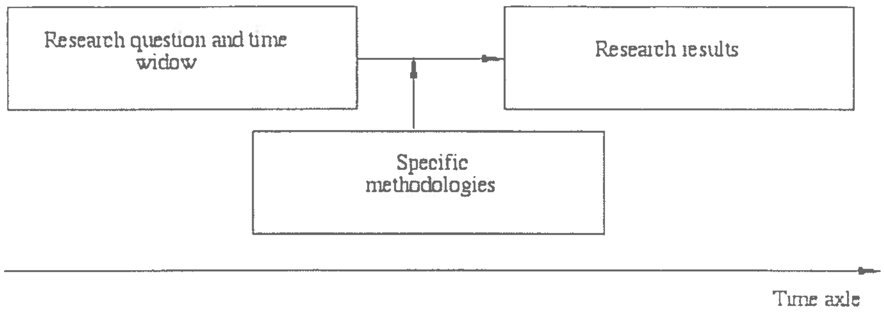
Schematised layout of the Volvo Truck Company's assembly docks at the Volvo Tuve plant.

Schematised layout of Volvo Car Company's sub-assembly department for doors at the Volvo Torslanda plant.

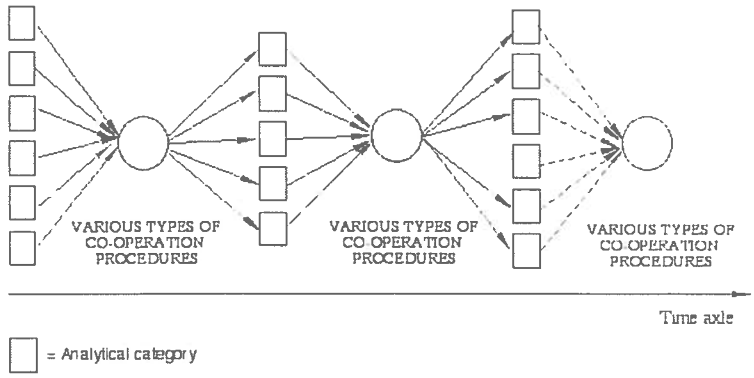


N = 465 446

Figure 10 below:



A straight-line research process.



An iterative research process.

LEGENDS:

Figure 1. Table defining and exemplifying possible spectra of combinations of co-operation and research approaches.

Figure 2. Illustrations of the three questionnaire studies conducted.

Figure 3. Table describing the three questionnaire studies conducted.

Figure 4. A schematisation of various co-operation procedures between practitioners and researchers during the execution of the three questionnaire studies conducted with help from the Metal Workers' Union Volvo.

Figure 5. One constructed table organised in accordance with the physical locations in the plant for twenty of the departments dealt with during the analysis and co-operation procedures at the Volvo Truck Company. These twenty departments represents approximately 36% of all departments investigated and approximately 46% of the blue-collar employees at the Volvo Truck Company in 2000. Sources of data: questionnaire study II.

Figure 6. Schematised layouts of some departments at the Volvo Truck Company in 2002. The detailed schematised layouts shown above are the parallel product flow chassis and assembly docks (these two types of docks comprise four and five departments, respectively) and the two main product flows with serial product flows (formed by eleven departments along the two assembly lines). The assembly docks and the two main product flows are completing the truck chassis. The chassis docks, on the other hand, are situated just before the two main product flows and fit the suspension and axles, and delivers truck chassis to a buffer where they are re-sequenced to fit the planned production sequence of the two main product flows and the assembly docks. Sources of data: questionnaire study II and study visits and interviews.

Figure 7. An overview of the manning of the various manufacturing processes at the main Volvo Tuve plant in 2000, i.e. special constructed figures comprising various questionnaire data combined with one type of schematised layout. This is the same twenty departments as shown in figures 5 and 6. The circle diagrams surround a simplified line drawing of the present premises, and the circle size corresponds to the actual number of blue-collar employees working at the manufacturing process in question. The segments of these circle diagrams represent the number of years of service of each category of blue-collar employees. N = 550. Sources of data: questionnaire study II.

Figure 8. Diagram showing the percentage of blue-collar employees at the two companies involved in 'direct production' regarding the question of time of employment. This type of diagrams were interpreted by means of interviews, constructed tables and various forms of schematised layouts as exemplified in figures 6 and 7. Sources of data: questionnaire studies II and III.

Figure 9. At the top of the figure schematised layouts of the assembly docks at the Volvo Truck Company and the sub-assembly department for doors at the Volvo Car Company. At the bottom of the figure a diagram showing the percentage of blue-collar employees at the two companies involved in 'direct production' regarding the questions of work satisfaction for

blue-collar employees working at serial and parallel product flow production systems respectively. Sources of data: questionnaire studies II and III.

Figure 10. The type of analysis and co-operation procedures discussed in this article implies the existence of an iterative research process comprising various shifts between e.g. analytical categories and sometimes also research questions. It is especially fruitful if the co-operation procedures included in the points of convergence (marked by circles in the figure above) deals with hands-on activities.