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6.1.136

Linking the Technical and Social Dimensions of Shop Floor Work in the Materials Flow System to the Companies' Overarching Superstructures

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Abstract:

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

This type of analysis and co-operation procedures may be looked upon as offering an integrated research approach. In total, all activities discussed in this article have proved to crystallise what might be referred to as a 'transcending research approach' with practitioners and researchers co-operating from a cross- and multi-disciplinary point of view, aiming to link technical and social dimensions in the materials flow system to the companies' overarching superstructures.

At least two methodological key innovations were important to achieve synergy in the co-operation between practitioners and researchers linking technical and social dimensions of working life.

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 possible 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 earlier research and development work by one of the authors, by means of study visits at work sites, as well as discussions with various employees and union representatives.

In this article the authors report how this type of analysis and co-operation procedures has been used, i.e. how the relationship in-between statistical analyses of the questionnaire data and the constructed tables has been dealt with. Four 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 technical and social dimensions.

In this article we will mainly exemplify and discuss the second methodological key innovation, but we will also touch upon the first one.

Key words: Assembly system design, Customer-oriented work time, Multi-disciplinarily, Socio-technology, Work organisation.

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. [1]

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.

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). This research design has, apart from scientific matters lead the authors to ponder upon relationships between practitioners [2] and researchers.

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 the results from this co-operation with union representatives from two large automotive enterprises regarding evaluation of flexible work time scheduling, i.e. 'customer-oriented work time'. Secondly, a specific type of analysis is discussed and illustrated by data from the co-operation.

The table in figure 1 defines and exemplifies combinations of research work. The discussions and research results brought forward in this article will specifically deal with field six in the table, i.e. the co-operation between practitioners and researchers with a cross- and multi-disciplinary research approach.

	'Restricted research approach':	'Transcending research approach':
Researchers:	(1) Traditional single-science research.	(2) Cross- and multi-disciplinary research.
Practitioners:	(3) Practitioners working in a specific field, e.g. conducting restricted surveys.	(4) Practitioners in different fields of co-operation, e.g. union representatives in co-operation with engineers dealing with complex problems, such as product development activities.
Practitioners and researchers:	(5) Researchers from a particular scientific discipline in co-operation with practitioners.	(6) 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 1. Table defining and exemplifying possible spectra of combinations of co-operation and research approaches.

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. working life. Thus the goals of the practitioners and the researchers are not always in agreement.

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[1] 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).

[2] In the text the authors use the term practitioners when referring to individuals employed outside of the university and lacking formal scientific (academic) education or training.

An especially intriguing situation appears when a 'transcending research approach' is established, which itself comprises both researchers from different disciplines and practitioners in the data collection and the 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.

*

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 analyses 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 method of socio-technical analysis is deficient regarding analysis of technology; for example, guidelines are lacking regarding how the technical sub-system should be changed (Lindér 1990).

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

In the experience of one of the authors, the design of complex production systems, especially unorthodox production systems[3], in many respects do not constitute a truly rational process (see e.g. Engström, Jonson and Medbo 1998). In fact, a process of reinvention along with neglect of earlier experiences and established knowledge is frustratingly common, at least within the Swedish automotive industry. This brings out the need for new or maybe even more untraditional methods for production system evaluation than those touched upon below.

2 BACKGROUND AND SOME METHODOLOGICAL CHARACTERISTICS OF THE QUESTIONNAIRE STUDIES REPORTED

Questionnaires are commonly used for evaluating various aspects of working life 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 work and work conditions 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, mainly methodological, reasons. 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.

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[3] When using the term unorthodox production systems the authors refer to less traditional production system designs comprising e.g. parallel product flow, intermediate buffers, autonomous work groups and collective working, etc.

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, denoted company A, company B, and a supplier park belonging to company A. However, this article will 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.

The questionnaires have been complemented and further analysed by the use of tables comprised of data from each department investigated (se figure 3), and in some cases also complemented by schematised layouts which could be either detailed or more aggregated (see figures 7, 8 and 10). In this article the authors will exemplify how these tables 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 union at those companies the authors received an opportunity to conduct a series of surveys at companies A and B.

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

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 union representatives when conducting their own survey studies in the future was a joint ambition. Thirdly, the 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.

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. It has e.g. proved difficult for the union to organise the necessary meetings with all the involved operators present. This fact is explained by outsourcing, removal of intermediate buffer volumes on the assembly line, modular product architecture, etc. Another reason is the fact that the companies have been more reluctant to establish long-term relationships with external researchers, and this has especially been the case within newly established large international conglomerates not yet fully integrated.

The co-operation with the 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.

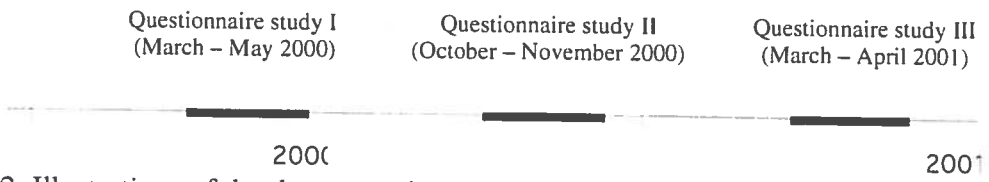

Figure 2. Illustrations of the three questionnaire studies conducted.

Questionnaire study I was conducted in March through May 2000. This study comprised a stratified selection of 200 operators at companies A and B. It included questions concerning

work and production, the 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 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 employees. [4]

Questionnaire II was conducted in October – November 2001 at company B and included every blue-collar employee with 'customer-oriented work time'. Questionnaire III was carried through 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.

	Work site:	Response rate:	Number of distributed questionnaire forms:	Comments:
Questionnaire study I (March – May 2000):	Companies A and B	>90%	200	- Included questions concerning work and production, the 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):	Company B	>70%	1 600	- Aimed at evaluating 'customer-oriented work time' and at the authors' ongoing research regarding design and evaluations of production systems.
Questionnaire study III (March – April 2001):	Company A	>70%	1 800	- Aimed at evaluating 'customer-oriented work time' and at the authors' ongoing research regarding design and evaluation of production systems.

* 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 3. Table describing the three questionnaire surveys conducted.

It should be noted that questionnaire I was a study strictly for scientific purposes aimed at grasping aspects of work time scheduling (Jonsson 2002), which provided the authors with both experiences and routines for the following two surveys whereas questionnaires II and III partly were aimed at clarifying to the Volvo Metal Workers' Union the blue-collar employees' opinions on the new work time scheduling. And they also included questions directly related to the authors' ongoing research. The table in figure 4 below provides information about the three questionnaires.[5]

As hinted above the three different questionnaires in many respects used similar questions. The questions concerning background variables are similar in all three surveys. The table below gives an overview of the three surveys by means of categorising the questions.

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[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 company B weekly working time has been extended since 1999. At company B this is e.g. 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 union representatives (Fördelaren 2001). 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 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.

[5] This prototyping consisted of a panel of 15 blue-collar employees who first filled out the suggested questionnaire forms. The questionnaire forms were then discussed and developed in-between the union representatives and the researchers and afterwards each question was debated for 1,5 – 2,0 hours. This prototyping lead to a final and detailed revision of the questionnaire forms.

	QUESTIONNAIRE STUDY I:	QUESTIONNAIRE STUDY II:	QUESTIONNAIRE STUDY III:
A BACKGROUND VARIABLES	8	9	9
B PRODUCTION ENGINEERING ASPECTS	8	1	3
C WORK TIME			
C1 Actual work time	9	4	3
C2 Perception of work time	12	6	7
C3 Information on work time (quality)	-	3	3
C4 Information on work time (source)	-	1	2
D PERCEPTION OF WORK			
D1 General view on work	3	2	1
D2 Work environment	2	-	-
D3 Work security	-	-	-
D4 Work education	6	-	-
D5 Work stress	4	-	1
E WORK/LEISURE TIME			
E1 Relation work and leisure time	6	-	-
E2 Perception of leisure time	2	1	-
F SALARIES/EXPENSES	6	-	-
G FUTURE PLANS	2	-	1
H PERCEPTION OF THE COMPANY	1	1	1
TOTAL NUMBER OF QUESTIONS	69	33	31

Figure 4. Categories of questions and number of questionnaire variables comprised in questionnaires I, II and III.

2.2 Co-operation procedures

Obviously, some sort of procedure to structure the planned co-operation in-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 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. For example:

> (1) 'Preparation for data collection' (B1 in figure 5) comprised e.g. defining the exact number of blue-collar employees at each department. This was somewhat intriguing since the companies' overarching superstructures were not congruent with union organisation, 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 5) utilising 95 diagrams, which were discussed with the union representatives who also used these statistics for reporting the findings to e.g. their members.

Albeit, the frames defined by practitioners (i.e. the evaluation of 'customer-oriented work time' at companies A and B) sometimes contrasted with the researchers' specific goals and this instigated a need for (1) discussing, almost negotiating, the exact content and formulation of each question in the questionnaire forms. Furthermore, the researchers first of all had (2) the ambition to cross-refer the findings in-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 in-between the questionnaire studies were to be considered.

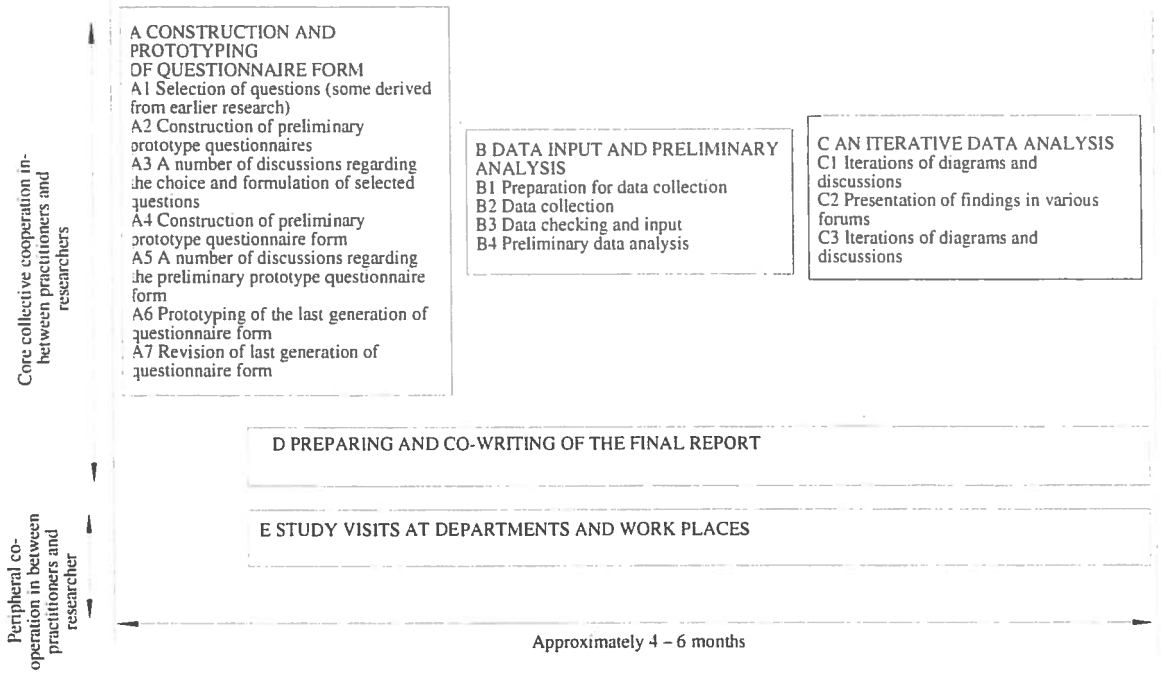


Figure 5. A schematisation of various co-operation procedures during the execution of the three questionnaire surveys.

Originally, the authors had the ambition to report each survey as a separate publication. Later on, the idea of writing one single report surfaced. Such a combined report could then be split into two reports, one for company A and one for company B. This was a rational choice to make since many of the written passages were almost identical. One advantage was also the possibility to include comparisons between the two companies. Originally it was not the intention of the union to make comparisons between the two companies but these kinds of questions turned up as work proceeded and the findings were successively evaluated.

The reporting of the findings was conducted in different contexts that generated feedback from different categories of practitioners. For example, the results from the questionnaire surveys were presented at union meetings in which the researchers participated. The discussions among the 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 in-between researches and practitioners might seem quite simple it may be based on intriguing procedures and insights.

3 THE CONSTRUCTION OF TABLES AND SCHEMATISED LAYOUTS

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 6, it was e.g. possible to relate the questionnaire variables to the companies' overarching superstructures as well as to the plant design. Note that these tables enclose all the departments in the company regardless of whether

or not they were included in the surveys. Thus it was possible to overview the total function of both companies, which in fact is helpful when e.g. constructing different analytical categories to be compared, i.e. clusters of departments with similar functions, similar production systems, similar type of work, etc.

	9 SUP-PLANT 1 COMPANY A					
DEPARTMENT NUMBER:	DEPART-MENT CODIFI-CATION:	NUMBER OF EMPLOYEES:	WORK TIME:	ACTIVITY:	LOCAL UNION COMMITTEE NUMBER:	CONTACT PERSON:
86 241*	Floor – Sub-plant	18	A	Welding of XXX	No 11	Edmund Dahlström
86 242*	Floor – Sub-plant	17	B	Welding of XXX	No 11	Edmund Dahlström
86 221*	AB1 – Sub-plant	18	A	Welding of ZZZ	No 11	Edmund Dahlström
86 261*	AB1 – Sub-plant	19	B	Welding of ZZZ	No 11	Edmund Dahlström
86 231*	AB1 – Sub-plant	15	Night	Welding of ZZZ	No 11	Edmund Dahlström
86 232*	AB2 – Sub-plant	17	A	Welding of ZZZ	No 11	Edmund Dahlström
86 262	AB2 – Sub-plant	16	B	Welding of YYY	No 11	Edmund Dahlström
86 262	AB2 – Sub-plant	14	Night	Welding of YYY	No 11	Edmund Dahlström
86 421*	KSL – Sub-plant	20	A	Welding line	No 11	Edmund Dahlström
86 422*	KSL – Sub-plant	21	B	Welding line	No 11	Edmund Dahlström
86 461*	KSL – Sub-plant	17	Night	Welding line	No 11	Edmund Dahlström
86 431*	ÅÅÅ V – Sub-plant	17	A	Welding of ÅÅÅ	No 11	Edmund Dahlström
86 433*	ÅÅÅ V – Sub-plant	17	B	Welding of ÅÅÅ	No 11	Edmund Dahlström
86 432*	ÅÅÅ H – Sub-plant	17	A	Welding of ÅÅÅ	No 11	Edmund Dahlström

* The department numbers filled in by the blue-collar employees when answering the questionnaire forms.

Figure 6. Example of a section of a table used for relating the companies' overarching superstructures in the form of the various department numbers and department codification to the number of blue-collar employees, work time, activity (in this case naming the components fitted), the local union committee number and the union representatives contact person. 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 a number of sections of the serial product flow. The local committees are in fact mainly organised according to the sub-plants.[6] This means that the smallest local committee in company A, for example, comprises 134 blue-collar employees and six departments while the largest local committee includes 445 blue-collar employees and 23 departments, both with 'customer-oriented work time'.

The analyse procedures 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 appropriate analytical categories to be used for various statistical analyses of the questionnaire data.

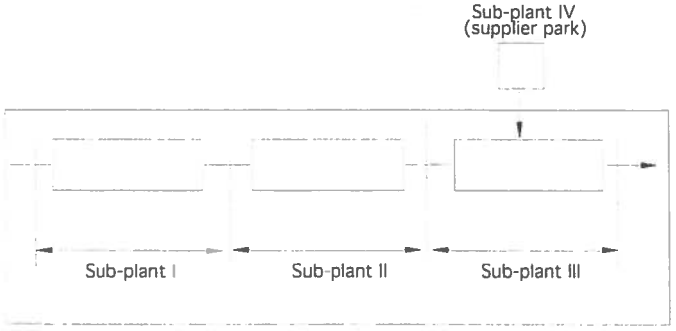
The reasons for constructing different analytical categories are based on a strive for generalisation, i.e. what started as a relatively delimited study initiated by the researchers to

[6] When using the term sub-plant the authors refer to physical sub-plants, i.e. specific separate geographically situated plants.

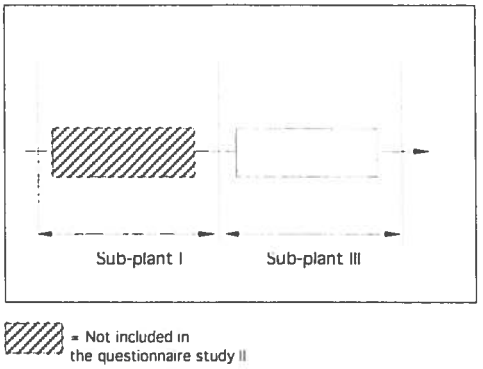
illuminate specific aspects of work time scheduling by means of questionnaire I (Jonsson 2002) later on proved to hide an opportunity for collecting extensive data.

*

In order to explain some of the reasons for the analyse procedure described above, taking companies A and B in consideration, it must be understood that company A is manufacturing a product which requires a sub-plant for painting while company B does not need such a sub-plant (see figure 7).



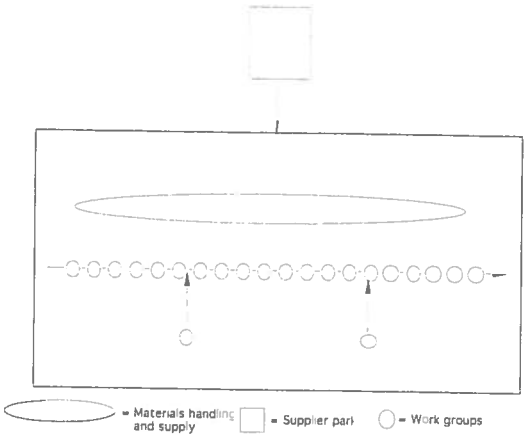
Company A.



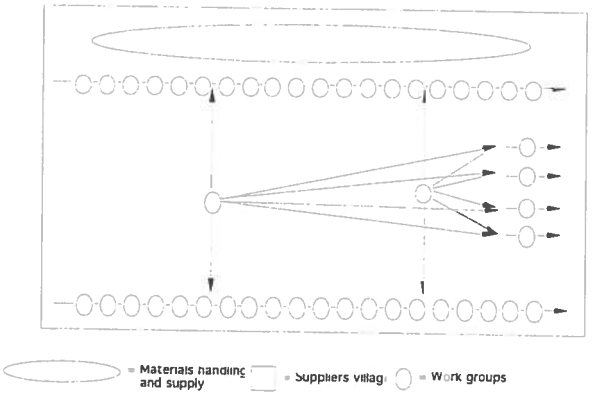
Company B.

Figure 7. The materials flow systems in companies A and B are compared on sub-plant level, i.e. by means of aggregated schematised layouts which illuminate that sub-plant II e.g. is not included in company B. The functions of sub-plant II in company A are in fact decentralised in sub-plant III in company B. Note that questionnaire study II does not include sub-plant I at company A since this specific plant does not use 'customer-oriented work time' (marked with diagonal lines in the figure). Sources of data: earlier knowledge, interviews and study visits.

On the other hand, focusing solely on sub-plants III of both companies, which at both companies comprise most of the manual assembly work, the materials flow systems within these sub-plants are somewhat differently designed. Company A has one main line supplied by an internal materials feeding and supply department and by internal sub-assembly workshops and a supplier park, which in turn could be organised both as serial product flow or parallel product flow assembly systems. In a serial product flow assembly system the products are assembled in a serial product flow (i.e. an assembly line), while in a parallel product flow assembly system, the products are assembled in parallel by individuals or work groups. Company B, on the other hand, contains a mix of parallel and serial product flow assembly systems feed by materials from an internal materials feeding and supply department (such as company A), but does not utilise a supplier park such as company A (see figure 8).



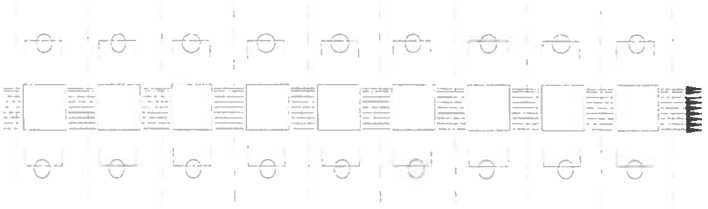
Sub-plant III at company A which comprises most of the manual assembly work.



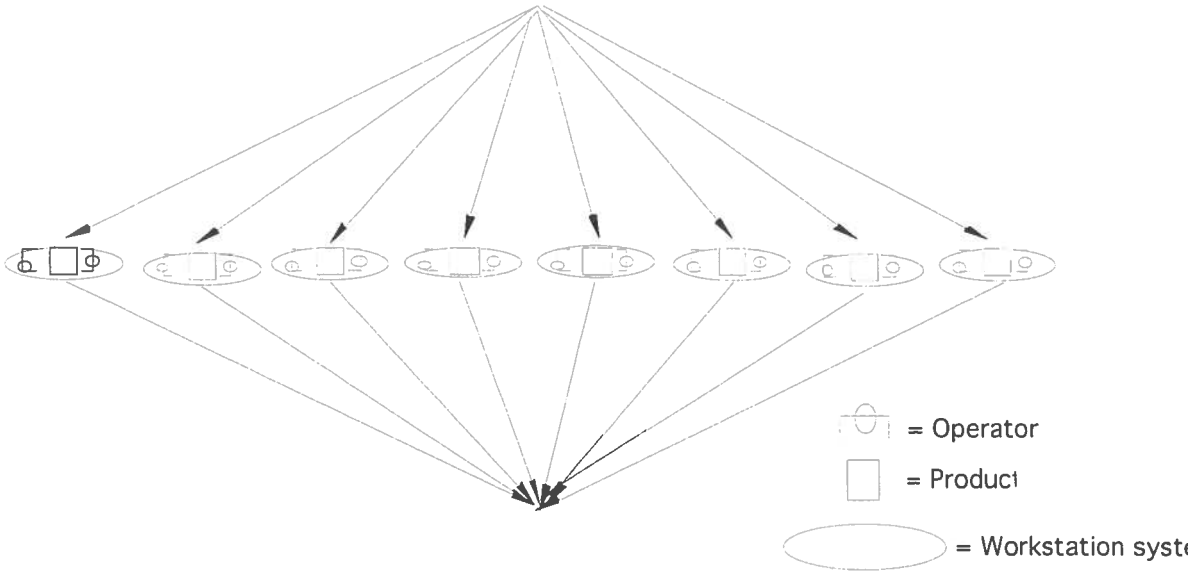
Sub-plant III at company B which comprises most of the manual assembly work.

Figure 8. The materials flow systems in sub-plant III at companies A and B compared by schematised layouts. At company A the products are completed by means of one serial product flow assembly system while company B utilises two serial product flows as well as a number of parallel work groups to complete the products. On the other hand, a department at company A comprised of a number of parallel workstations completes one extensive sub-assembly, i.e. parallel product flow assembly systems are used for this specific sub-assembly. Sources of data: earlier knowledge, interviews, and study visits.

To explain this still further figure 9 offers a simplified schematisation of serial and parallel product flow assembly systems. The products being assembled in a serial product flow system pass all workstations along the product flow. Cycle time is short. Two principally different versions of the serial product flow exist. One type has a machine-paced assembly work, i.e. the products are moved at a continuous pace. At the non machine-paced versions the products are moved intermittently, i.e. the operators push or command the products to be moved. In the latter case the products usually hook to a floor-mounted conveyor or else they are moved by means of automated guided vehicles (AGVs). On the other hand, in a parallel product flow assembly system the products will in extreme cases only pass one workstation and the assembly work is less repetitive due to increased work cycle time. The workstation design varies between assembly systems. In particular, workstations may accommodate a varying number of products and operators (in the cases shown above: one product and two operators). Furthermore, if operators co-operate collectively on one or more products then we have a case of special type of working denoted 'collective working' in a defined sub-system of workstations and operators, i.e. workstation systems. There, in contrast to individual working, the individual operators perform defined assembly work within their own work cycle.



Serial product flow assembly system.



Parallel product flow assembly system.

Figure 9. Schematised layouts of serial and parallel product flow assembly systems in a serial product flow system. In the figure the workstation systems comprised of two operators and one product are encircled by ellipsoids. Within these parallel ellipsoids 'collective working' is carried out, which stands in contrast to the individual working along the serial product flow on the traditional assembly line as shown at the top of the figure. In the latter case the ellipsoids are omitted and instead the symbols for operators are intersected by dotted lines to emphasise the individual working, i.e. one operator completes his or her specific work on their side of the product.

*

According to the table in figure 6 it is also obvious that the organisation of the union is not congruent with the overarching superstructure of company B, i.e. the local union committee numbers (the sixth column in the table) are not mirroring the companies' overarching superstructures in the form of department numbers (the first column in the table). Note also in figure 6 the difficulty to understand the companies' overarching superstructures with the aid of department numbers alone, i.e. the department numbers do not form a coherent hierarchy of figures.

The differences in materials flow systems, the companies' overarching superstructures, and the idiosyncrasies of the department numbers are facts that need to be considered and this became obvious for the authors when comparing the original tables, achieved with the help of union representatives and used for monitoring the administration of the questionnaire studies with the actual department numbers notated in the questionnaire forms. In fact, quite a large amount of department numbers were mismatched and also a number of other peculiarities turned up which will need to be clarified. The situation was quite similar at both companies A and B, mainly because of recent changes in the department functions and department numbers due to an ongoing reformation of the assembly systems (company A was introducing a new model and company B had just closed down some departments due to the recession) but also due to old information which was at hand.

Note that the administration of the questionnaire studies, such as distributing and collecting the questionnaire forms meant distributing only the exact number of questionnaire forms required. They were enclosed in envelopes marked with the name and number of the local union committee and containing envelopes in which the forms were to be returned. Such a procedure was necessary in order to assure a high data quality as well as a smooth administration, i.e. extra questionnaire forms e.g. had to be ordered and any remaining unused forms had to be returned. This careful monitoring of the distribution and collection of questionnaire forms also served as a method for understanding some of the organisational peculiarities at both companies. However, some of these somewhat frustrating details have not been reported on in this article.

*

In the case of questionnaires I, II and III the authors personally visited all the departments included in the surveys. During these study visits at the work sites, which lasted about half a day, union representatives guided the authors and arranged direct dialogues with various personnel, such as operators, manufacturing engineers, and other specialists concerning specific questions asked by the researchers. The study visits at the work sites were aimed at understanding the manufacturing process in greater detail (hence the use of schematised layouts containing buffer size and location, materials flow structures, equipment, etc.). For this reason the study visits sometimes also included the construction of schematised layouts (see figure 10).

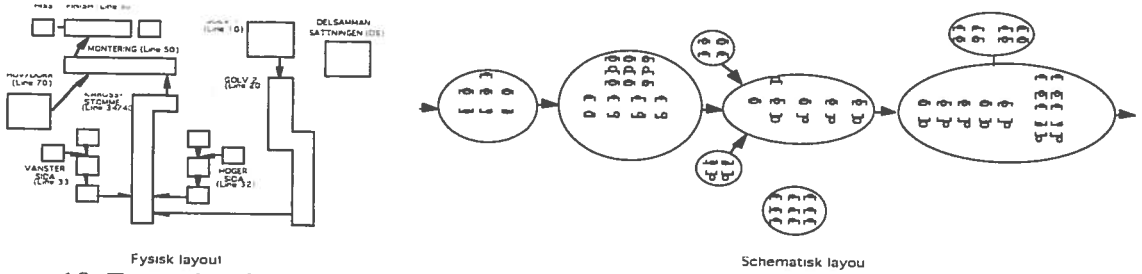


Figure 10. Example of a detailed schematised layout used in a questionnaire survey conducted at a body shop in an automotive plant. Since the physical layout (to the left in the figure), as well as a verbal description of workstations and work groups (not shown) were also included in the questionnaire, it was possible to e.g. formulate questions on workstation level. With this approach the authors were able to relate the statistical analysis of the questionnaire data to e.g. specific workstations or specific work groups.

*

To conclude, the construction of tables comprised of data from each department investigated served 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 in-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 were aimed at understanding the manufacturing process in closer detail the visits also served as an opportunity to establish personal relationships with the employees. This facilitated the possibility afterwards to check up on some of these peculiarities.

All these measures carried through in co-operation with the union have allowed the authors to relate the statistical analysis of the questionnaire data to specific characteristics at a single department or clusters of departments. In short, the total plant design was grasped by combining department numbers where in turn each department's function was understood due to earlier research work complemented by strategic study visits at work sites.

4 RELATIONSHIP IN-BETWEEN STATISTICAL ANALYSIS OF THE QUESTIONNAIRE DATA AND THE CONSTRUCTED TABLES

As mentioned above, the use of department numbers in the questionnaire forms made it possible to aggregate specific analytical categories at the plants and this signifies an important analytical potential.

It means that single departments form clusters due to e.g. similar types of work such as non-machine, semi-machine and machine-paced work, or work accomplished in similar production systems (e.g. work performed in serial product flow assembly systems, by work groups in parallel product flow production systems or at individual sub-assembly stations), i.e. different analytical categories.

Below the authors have reported four examples illuminating how this type of analysis and co-operation procedures has been used, i.e. how the relationship in-between the statistical analyses of the questionnaire data and the constructed tables has been dealt with by examples 1 – 4. Examples 1 and 3 deal with analytical categories used for facilitating the comparisons in-between companies. And examples 2 and 4 treat specific analytical categories for facilitating the comparisons in-between different functions within a specific company.

Interesting differences in the answering frequency between blue-collar employees at various parts of the plants are shown below. The differences at hand may of course depend on other factors besides the assembly system design. Factors such as sex and age structure, time of employment, etc., should be studied by means of a multivariate analysis of the questionnaire data that has to be developed and reported elsewhere. In this context (examples 1 – 4) it is mainly our aim to give some examples of the reasoning brought forward in this article.

This type of analysis and co-operation procedures has been facilitated by the extensive data collected in relation to questionnaires studies II and III (i.e. including 1 193 respectively 1 438 persons as is evident in figure 3). These two questionnaire studies were 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.

Example 1: Comparisons in-between companies A and B comprising departments involved in direct production regarding time of employment

As a starting-point it may be interesting to overview the two companies. As is evident in figures 4 and 5 companies A and B have quite different overarching superstructures and materials flow systems. In order for it to be possible to make relevant comparisons it is sometimes necessary to define equivalent analytical categories as has been done in example 1. There the authors have defined the departments dealing with direct production and thereby omitted departments with different categories of indirect work within the two companies. Employees involved in direct production means operators engaged in manufacturing by operating or surveying manufacturing equipment or performing assembly tasks. Thus blue-collar employees dealing with materials handling and supply, maintenance operators, etc., have been omitted.

This means e.g. that the work in sub-plants III at companies A and B (see figure 6) has been divided into the category 'direct production' comprised of the departments included in (1) serial product flow assembly systems, (2) parallel product flow assembly systems, and (3) auxiliary direct work. The category 'indirect work' consists of departments dealing with (4) materials handling and supply and (5) auxiliary indirect work. Finally, there is the category of non-relevant departments. According to similar principle the work in sub-plant 1 and II, as well as supplier park (only relevant for company A), has been categorised in order to construct examples 1 – 4.

Figure 11 compares the blue-collar employees involved in direct production and it shows that both companies follow quite similar patterns.

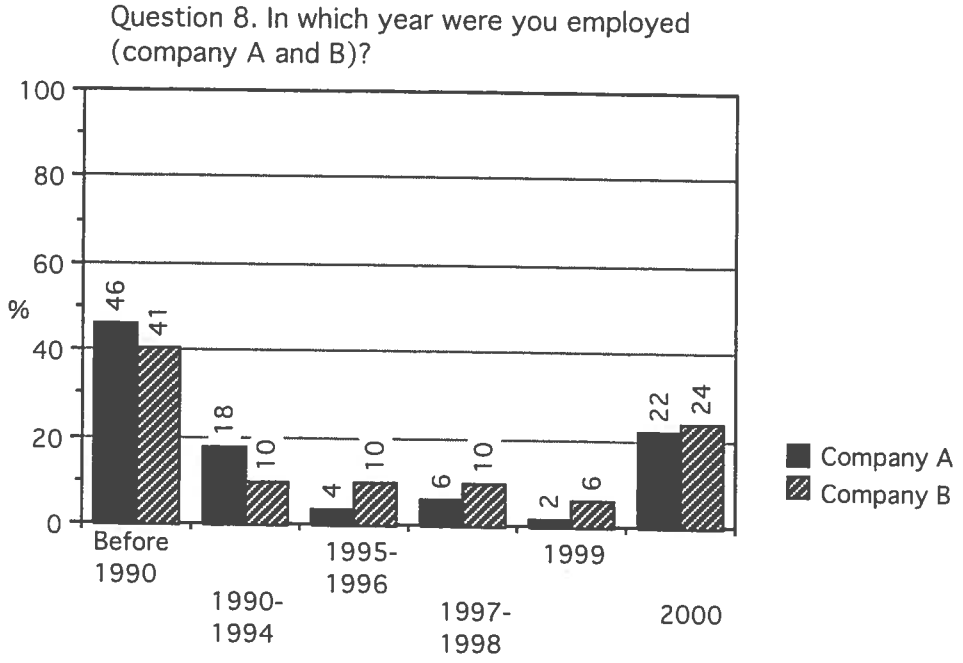


Figure 11. Diagram illuminating the percentage of blue-collar employees at companies A and B involved in direct production regarding the question of time of employment. Sources of data: questionnaire studies II and III.

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.

The authors have used these types of diagrams in order to discuss with the 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 in-between introduction of new products and recruitment has functioned over the years at both companies A and B, thus avoiding generalisations by drawing inconclusive conclusions from the data which hide a far more complex situation. 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 inflict upon all departments.

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To conclude, this example illustrates the need for complementary insights far 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.

Example 2. Comparisons in-between company comprising departments involved in direct production regarding belonging to different sub-plants and possibilities to fulfil the stipulated productions goals

As was described in figure 11, company A consists of four sub-plants with different characteristics and types of work. Figure 12 compares the four sub-plants at company A, in this case answering the question 'Do you and your co-workers manage to fulfil the production goals formulated by your company?' asked in questionnaire III.

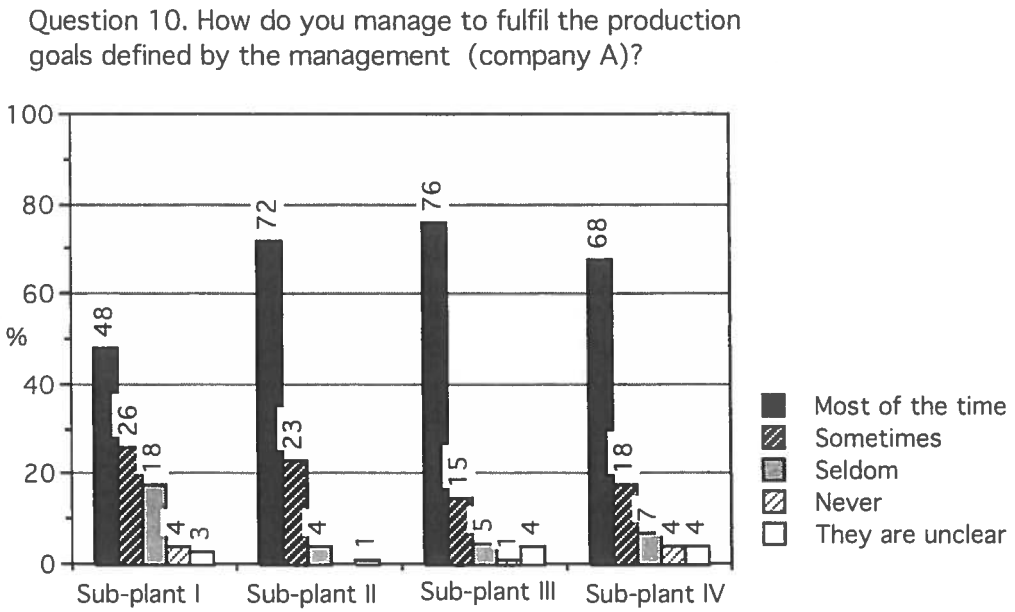

Figure 12. Diagram illuminating the percentage of blue-collar employees at company A involved in direct production regarding belonging to sub-plants and the question of possibilities to fulfil production goals. Source of data: questionnaire study II.

Figure 12 shows that the operators in sub-plant I to a lesser degree than the others managed to fulfil the production goals defined by the management. Also note that in total it was approximately 1/3 of the blue-collar employees who were not always able to fulfil the production quantum. This particular finding makes it interesting to understand exactly what the various stipulated production goals are. What are the job descriptions for each category of personnel? Exactly how extensive are any technical disturbances, reliability, etc.?

Even though the researchers possessed knowledge of the production systems it was helpful to discuss e.g. the causes of these differences with the union representatives (and also with the employees) in a systematic way and during an extended period of time. In this case the extensive automation was most likely the cause of the perceived difficulties in fulfilling the stipulated production goals. This was especially the case in sub-plant I, which comprised quite a number of newly installed automated equipment, while in sub-plants II – IV the work mainly included various types of manual assembly work. See figure 13 for understanding some of the characteristics of the four sub-plants.

	SUB-PLANT I:	SUB-PLANT II	SUB-PLANT III:	SUB-PLANT IV:*
Characteristics of work:	- Highly qualified work (maintenance, programming of equipment, etc.).	- Machine-paced and short cycle time work. - Quite qualified work.	- Machine-paced and short cycle time work.	- Highly qualified work (maintenance, programming of equipment, etc.). - Machine-paced and short cycle time work.
Type of production system used:	- Two transfer lines with mixed automated and manual workstations and sections.	- One transfer line with mixed automated and manual workstations and sections.	- One serial product flow assembly system.	- Three transfer lines. - Metal cutting of components (e.g. sub-frame).
Comments:	- A new transfer line is under introduction. - Some sections totally automated.	- Some sections totally automated. - This plant was built in 1992.	- Quite a high personnel turnover.	- Established in 1986.

* A supplier park.

Figure 13. Example of comparisons between sub-plants I – IV within company A regarding characteristics of work and type of production system, including some comments. Sources of data: interviews and study visits.

A further statistical analysis of the authors' data will illuminate some questions brought forward above since one of the questions included in questionnaire III concerned the reasons why blue-

collar employees did not fulfil their production goals. This question had the response alternatives (a) the productions goals formulated are unrealistic; (b) there are not enough people employed; (c) I and my co-workers do no have the competence required; (d) technical disturbances (such as lack of materials, troublesome equipment) or (e) some other reason.

To the question why the production goals could not be fulfilled the two most frequent answers were technical disturbances (60%) and personnel shortage (43%). The amount of disturbances was somewhat puzzling to the union representatives since the company during the 1990s had tried to attend to these problems as a general adaptation to a more pronounced competition situation in the automotive industry. Earlier, the need for efficient production had not been that vital since the market was quite advantageous for the company's products. The personnel shortages, on the other hand, seemed like a plausible explanation and the union representatives did not perceive the response rate of 43% as unreasonable. These communications with the practitioners may not seem particularly unique, but various intensive co-operation procedures however proved to bring forward aspects that might otherwise have remained unnoticed if e.g. the questionnaire surveys – as is sometimes the case – would have been solely aimed at confirming predestined hypotheses or theories.

*

To conclude, as is evident in figure 12 it was possible to relate the answering frequency in questionnaire study III to the various departments, in this case the sub-plants at company A.

One of the important features is to start with a basic unit, i.e. department, and thereafter form various analytical categories according to the requirements at hand.

Figure 12 also illuminates the fact that sub-plant I had the main difficulties in reaching the production goals. This type of analysis and co-operation procedures makes it possible to carry on the analysis by dividing the sub-plants in order to define differences in-between e.g. departments and to make complementary data collections to clear up some of the reasons for the noted conditions.

Example 3: Comparisons in-between companies A and B comprising departments involved in direct production regarding satisfaction with their work for serial versus parallel assembly systems

Questions regarding work satisfaction have been included in the two questionnaire studies. Figure 14 compares the departments using serial product flow respectively parallel product flow assembly systems at companies A and B regarding whether or not blue-collar employees are satisfied with their work.

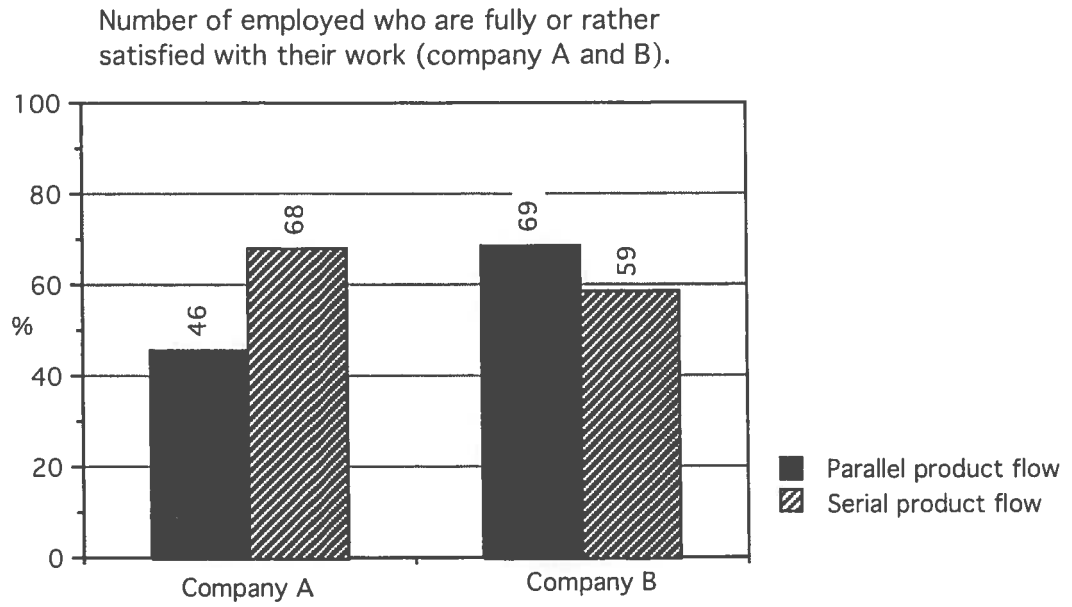

Figure 14. Diagram illuminating percentage of blue-collar employees at companies A and B involved in direct production regarding the questions of satisfaction for blue-collar employees working at serial and parallel product flow assembly systems respectively. Sources of data: questionnaire studies II and III.

As is evident in figure 14 there are quite extensive differences in-between companies A and B 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 the parallel product flow assembly systems. And this was also the case at company B even though the noted differences were not especially large.

However, it must be noted that the expected increased work satisfaction presumes correctly designed parallel product flow assembly systems. And according to the authors' knowledge and insights the assembly systems in companies A and B were not correctly designed in all respects.

The assembly work at the parallel product flow assembly system in company A was in fact not 'true' group work, i.e. no collective work was at hand. It was a parallel product flow assembly 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 earlier.[7] This situation was partly explained by management practices and ideologies as well as by assembly system design.

[7] An 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 assembly system requires less working hours compared to a serial product flow assembly 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 assembly systems. The explanation for this phenomenon is as follows: Traditionally, when determining cycle times production engineers use mean operation time based on time-and-motion studies. And accordingly they concentrate on dividing the assembly work evenly between the workstations, neglecting the effects of individual variation, i.e. the fact that operators show inherent variation in pace and efficiency in their performance of repetitive work. Such variations occur both as inter-operator variation and as intra-operator variation, i.e. variation between operators on the same assembly line as well as variation between successive work cycles for a particular operator. Furthermore, the amount of work to be performed at each workstation varies between work cycles and workstations due to product variation. There will also be process variation due to tools and mechanised equipment etc. If the amount of time in which the product is available at a work station equals the mean time needed to complete the work tasks assigned to that work station – meaning that inter-operator and intra-operator variation as well as other sources of variation in required assembly time are neglected – then idle operator time will occur in some cases, while unfinished work will result in other cases. If the

Another reason for the extreme situation was the fact that in company B, on the other hand, did the parallel product flow assembly system for several reasons and in most respects represent more of a 'true' group work, i.e. collective work was at hand. 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 was at hand, something which however was not all too common. In fact, company B´s product was far more complex and included relatively less product design engineering hours than did the product of company A. Somewhat roughly stated it might be considered more or less as a prototype.

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

*

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 analysis at hand. In this example it was not possible to carry the analysis further since the parallel product flow assembly system studied was not composed of different departments. Due to the detailed knowledge concerning the function of different departments it is quite easy to conduct various complementary studies. In this case the union representatives later on helped to arrange for the authors to conduct video recordings of the assembly work and to make interviews in two different departments at the two companies in order to evaluate different assembly system designs. In the future it will be possible to link these data to the findings in the questionnaire surveys.

Example 4: Comparisons in-between company A's departments involved in direct production regarding future work for serial versus parallel assembly systems

Finally, an example which will illustrate how this type of analysis and co-operation procedure might be used for international comparisons in the future. At company A the questionnaire form contained a question regarding future work within 1 – 3 years. This question was unfortunately omitted at company B due to time restrictions, i.e. the questionnaire form was prototyped to be possible to fill in within 10 – 15 minutes during pause at working time.

As an example the authors have compared below blue-collar employees at the serial and parallel product flow assembly systems respectively.

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production pace is increased, idle time will decrease but unfinished work will increase; if the production pace is decreased, unfinished work will decrease but idle time will increase. In practice, the allocation of work tasks to work stations is often based on the product variant requiring the greatest amount of work, i.e. the most time consuming product variant will pace the flow.

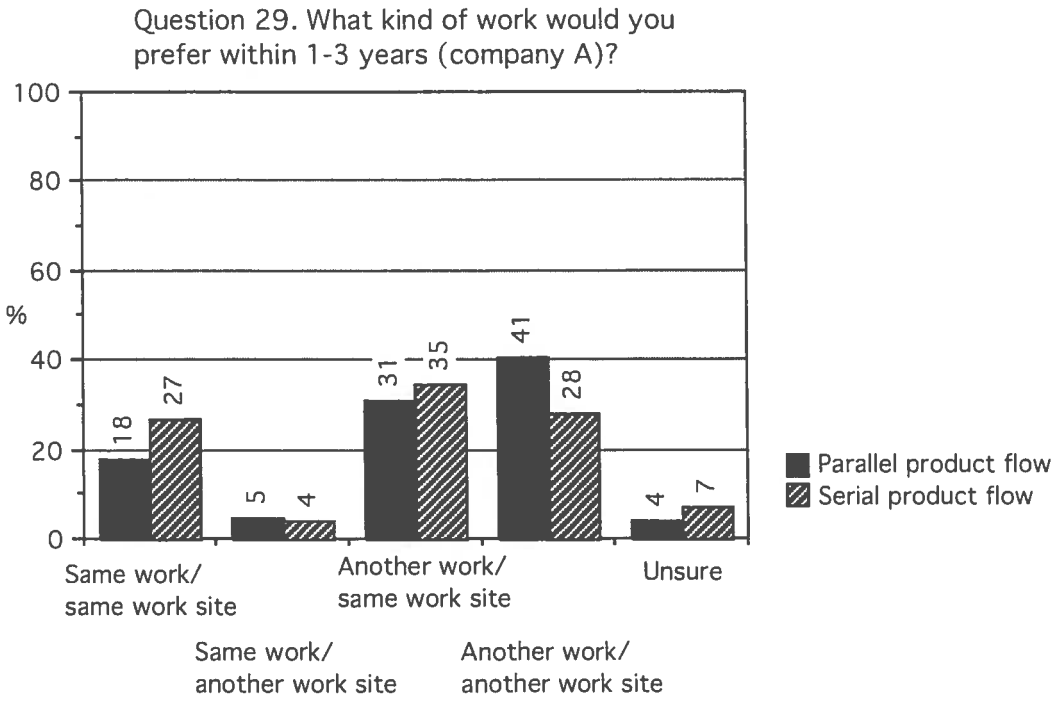

Figure 15. Diagram illuminating the percentage of blue-collar employees at companies A and B involved in direct production regarding the questions of future work preferences for blue-collar employees working at serial and parallel product flow assembly systems respectively. Source of data: questionnaire study III.

In figure 15 differences are evident in-between operators in serial and parallel product flow assembly systems at company A regarding this specific question. More of the blue-collar employees working at the serial product flow were considering remaining at the same work site than was the case at the parallel product flow. On the other hand, more of the operators at the parallel product flow assembly systems considered another kind of work at another work site.

These findings may have depended on at least two facts. Firstly, the fact that the assembly system was not correctly designed in all respects as was discussed above in connection with example 3. According to earlier research the authors might have expected an increased work satisfaction at the parallel product flow assembly systems, but in this case the data in figure 14 show quite the opposite situation. Secondly, during the period of the questionnaire study the parallel product flow assembly system at company A was being closed down and revised into a serial product flow assembly system. During our interviews it became obvious that some of the personnel at the parallel product flow assembly system had been satisfied with their job but now were reluctant to consider working at a serial product flow ('reverting to an assembly line') and thus were more eager to search for another work at another work site. Generally speaking they may in fact have been more competent or at least viewed themselves in such a light.

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To conclude, this type of question has been used by other researchers to evaluate work conditions in various plants (e.g. JAW 1992). Thus it is most likely that this type of analysis and co-operation procedures would be helpful in future international studies. Moreover, this type of analysis and co-operation procedures is also appropriate for various types of other industries since appropriate analytical categories such as non-machine, semi-machine and machine-paced work as was briefly mentioned at the beginning of section 3 above also may be defined within other branches.

As was hinted above one of the authors has for a long period of time conducted research and development work regarding serial versus parallel product flow assembly systems mostly regarding e.g. materials handling and supply, layout planning, etc. By means of this type of

analysis and co-operation procedures it will be possible to organise joint cross- and multi-disciplinary evaluation of production systems and work conditions, i.e. not only technical dimensions but also to a larger extent evaluations from e.g. psychosocial and ergonomic points of view.

5 DISCUSSIONS

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 union representatives 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 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 the future. 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 working life based on 'true shop floor data'. One interesting procedure to be mentioned in this context is the use of the 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 union representatives in fact already have an impressive computerised network of communication at hand for fast communication concerning union matters. And from an international perspective this is a communication network which in fact is quite unique.

Some pitfalls to be underlined are e.g. different lines of thought in-between practitioners and researchers and the variation in conceptualisation as well as verbalisations 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. Accordingly, 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. 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. [8]

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

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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.

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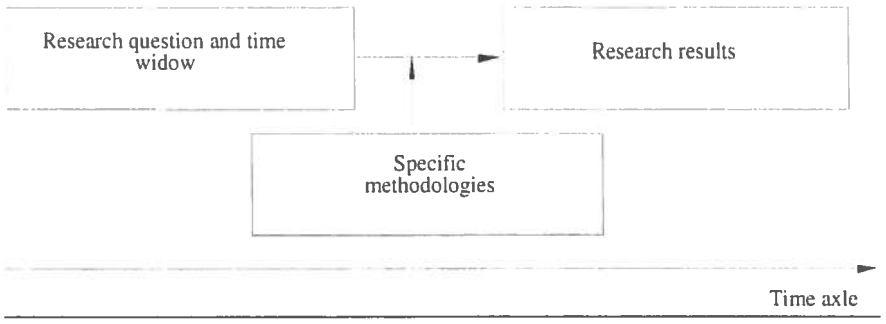
[8] The risk of mixing up the roles in-between union representatives and researcher is e.g. underlined several times in a handbook dealing with co-operations with researchers. See LOFO 4 (1983).

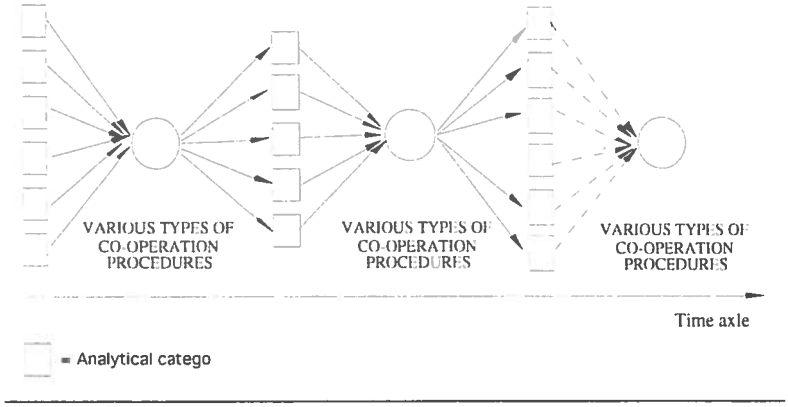
Albeit the findings and experiences reported above are not always possible to generalise and apply to other contexts but the authors nevertheless regard them to be of general interest in a methodological discussion.

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 in-between various co-operation procedures, analytical categories and sometimes also research questions (see figure 16).

Thus, rather than organising the research according to a straight-line process solely aimed at treating a delimited number of research questions to match specific issues and methodologies 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 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.



A straight-line research process.



An iterative research process.

Figure 16. The type of analysis and co-operation procedures discussed in this article implies the existence of an iterative research process comprising various shifting in-between co-operation procedures, analytical categories and sometimes also research questions.

Thus is may be possible in the future to further prospect by the synergetic effects caused by contrasting or quite different points of departure. By giving prominence to cross- and multi-disciplinary research such a phenomenon 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.

Discussing eventual synergetic effects it is possible to regard the spin-off effects of the joint venture co-operations. The construction of tables comprised of data from each department investigated is an example of a 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 these tables became increasingly advanced and it was discovered that they could be used in contexts other than those originally intended.

Our aim in the future is to develop a more generalised method 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 assembly systems.

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