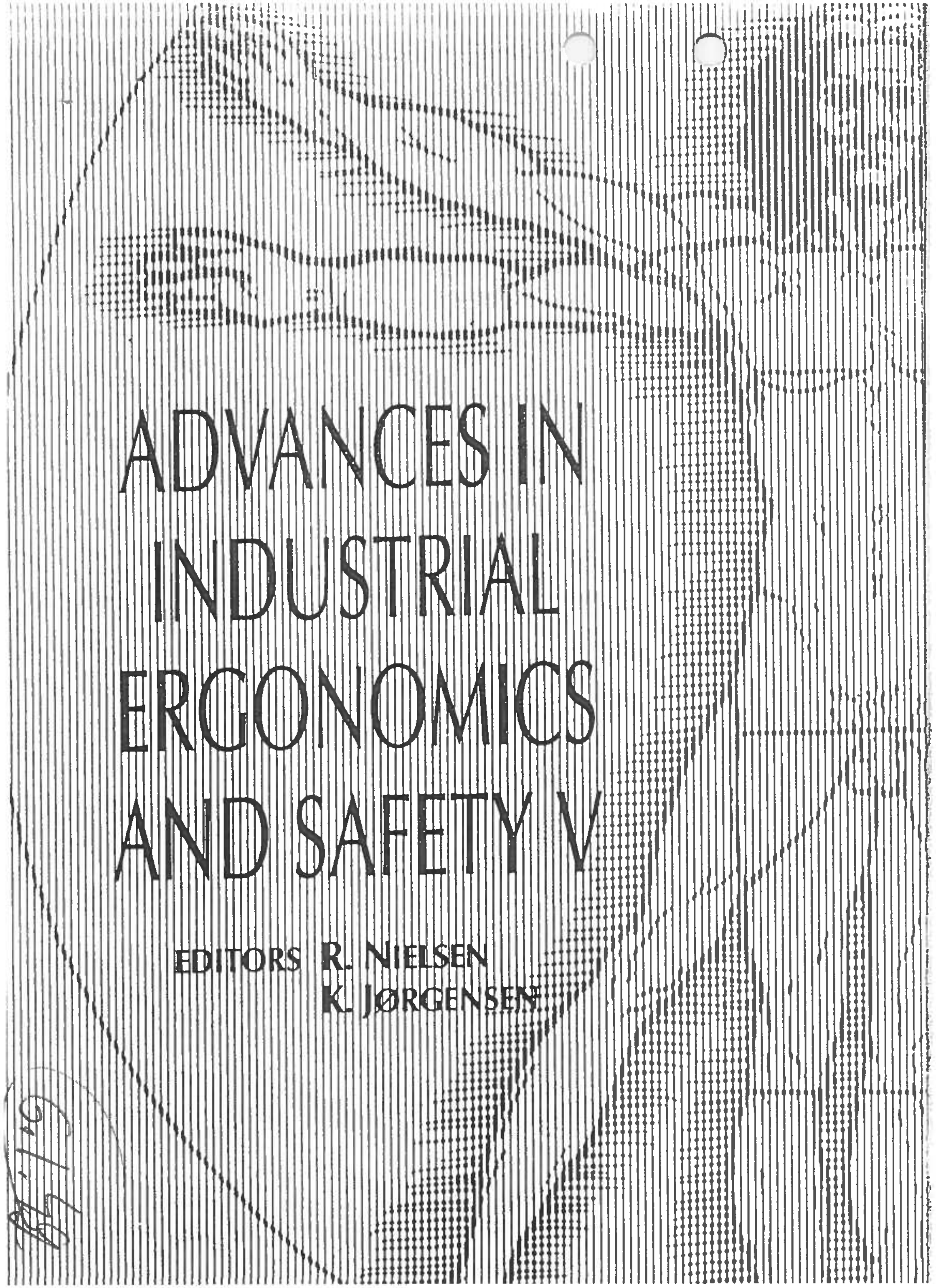

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METHOD ASPECTS ON MULTI-LEVEL INTERACTIVE WORK PROCESS MAPPING

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This paper is based on action research on non-traditional automobile production in the Volvo Corporation. We report on the theoretical frame of reference put into practice, containing different classifications of picking and materials handling work concerning material feeding to parallellized final assembly.

The method of work process mapping and structuring outlined comprises a mix of empirical data from observation on the shop floor and video recordings analysed by means of a prototype of an interactive computer and video system.

As a result, we report on time distributions for different activities that occur in a picking system.

TRADITIONAL TIME AND MOTION STUDIES AND EFFORTS TO HUMANISE THE SHOP FLOOR WORK

The original motion and time studies assumed the use of data collection by "stopwatch-techniques". A refinement of these studies was the development of formalised motion and time techniques (e.g. MTM), which are still practised. The MTM reformed the work for the industrial engineer, and it became possible to predict the work performance by combining the mean times for elementary work tasks.

Nowadays, when new products are introduced at an accelerating rate and the number of product variants increases, this "MTM-puzzle" tends to get out of hand. Note that these time and motion studies are time consuming, which is why the industrial engineer's work is not always up to date. However, the official pace is often more a question of company and union negotiations than reality.

The practical effect is that the real knowledge about the work process is mainly found on the shop floor. This makes it difficult to predict the total production system performance and flexibility, because the shop floor knowledge about the work process is not fully formalised. This fact has often proved to be a restriction on further development of the production system.

Even if the very detailed, up-to-date MTM-work process information is available, the production system performance cannot be predicted based on formalised work process data. Since these data emanate from a standardised individual, (not from the interrelationship between man and machine) waiting times will occur in practical work.

Human work is characterised by variation in work pace, antrophometical differences, work methods, etc., and the ideal standardised human is nonexistent. This fact makes it difficult to analyse and elucidate the internal structure of the work. As a consequence, efficiency-potentials cannot be identified based on the shop floor reality. This hampers identification of methods for rationalisation, since rationalisation assumes a generalised theory about the production system performance and its interrelation with the detailed shop floor activity.

If the work is performed in group's, the intra-group work patterns, i.e. the group's internal division of labour, ought to be included in the analysis. This implies a much more complex work than traditional time and motion studies assume.

All this makes it vital to develop some kind of instrument or method that makes it possible to restructure the work and still have the original data of the work studied intact. This supposes a multidimensional data collection and method of analysis, where the advantage lies in the use of modern computer and video techniques.

We call this instrument or method "work process mapping", referring to a generalised method only roughly outlined in this paper.

These results gained from such an analysis are expected to be helpful in locating, explaining and eventually identifying the present restrictions on, for example, manual materials handling work, with the aim to allow further development of today's production systems in the future.

Work process mapping is primarily a method (technique) for collecting and structuring data for production processes, in addition to making the structured data usable for different kinds of analyses of the production system. We have made efficiency analyses such as loss analysis, i.e. zero based analysing (Engström et al., 1993, Engström et al., 1991) but many other analyses can also be performed based on the structured data. Examples are ergonomic analyses, simulations of different production system layouts and time budgets. Examples of ergonomic studies are calculation of the time (and frequency) of for example all the "bending positions" and comparison of the results with different kinds of picking systems in addition to classifying more or less suitable picking systems from the picker's point of view. These sequences of bending could then be classified into different types of bending motions.

OUR METHOD USED FOR DATA COLLECTION AND THE SCOPE OF ANALYSIS

Our work to classify the interaction between man and machine into different activities involves, among other things, an analysis performed through video recordings by means of a prototype of the PAVIC (Productivity Analysis with Video and Computer) system. PAVIC was originally developed for motion and time studies of construction work (Bengtsson and Björnsson, 1983 and 1986)

In addition, we have used both databases based on the vehicle's original product structure and databases that support the actual production process, but restructured by us to fit the research questions.

The video/computer equipment consists of a computer with an extra video card that makes it possible to show the video picture on the screen but also a video tape-recorder that can be monitored by the computer. This equipment makes it possible to synchronise the video and the computer by a timing code on one of the videotape audio canals, which is done by the video tape-recorder. When this time coding is finished, the computer can monitor the video tape-recorder with an accuracy of 1/25 second.

The hardware consists of:

- Video camera (Panasonic NV-MS4E)
- Computer
- Video card (Screen machine)
- Video tape-recorder (Panasonic AG-7350)
- Time generator (Panasonic IA-232 TC)

When the film has the time code, the film speed can be monitored from the computer. This type of monitoring is vital, because it makes it possible to control the speed of the video recording being analysed. The aim is to minimise the required time of analysis, by excluding (speeding up) invalid or long video sequences by slowing down the shorter or valid ones.

Old video tape recorders could not be monitored from the computer, which made the analyses more difficult to perform and often less exact, because the speed of the video tape recorder must be constant.

During the analysis, video sequences are labelled according to the activities performed, which makes it possible to accumulate different sequences of one specific activity into one connected sequence. One example could be to accumulate all bending activities and then show them as one sequence.

Note that this sequence labelling might not always be correct or performed properly from the start. In practice, the analysis phase ought to start with a rough labelling and analyses and if necessary a reanalysis, of complete sub-activities into sub-activities of lower levels. With this procedure, the work could be effective in terms of the time needed for the analysis, and for a rough labelling or a categorisation when the sought activities are uncertain. For example, for 15 minutes of work, a first rough labelling takes about 30 minutes to analyse, while a more detailed analysis takes about 60 minutes, depending on how frequently the activities are changing. In our case we assumed about 150 activity changes for a detailed analysis and 60 for a less detailed one. This might seem to be a great difference, but note that one more activity at the picking place increases the frequency by about 40.

After the video recording has been analysed, the registered data is often transferred to a calculation program. This program simplifies overview of the result in relation to the total time and frequency of specific activities.

From the beginning, the PAVIC (video/computer equipment) system was not intended for analyses of production processes, such as manual assembly and materials handling work, why some modifications had to be done. The most important modification was to make it possible to record more than four activities during a sequence and more than ten registrations during a sequence for each activity. Another modification was to enable the comments and data files that are connected to a specific activity to be transferred to a calculation program.

We have applied and developed the work process mapping method within materials handling and order picking activities. To put it briefly, the data collection and analyses have, among other things, included:

- Explorative interviews on the shop floor, when the pickers expressed their personal view on their work.

- A survey of the implications for the work of generic product characteristics, and the relations between components, work positions and work movements (Engström and Medbo, 1991)

- Testing of the method of analysis on a hypothetical case in order to test and modify the video/computer equipment to suit our purposes (the hypothetical activities were first categorised into different activities, then tested using the equipment and short video recordings from the case studied).

- Analysing by using a video/computer equipment on video recordings from four picking tours in a picking system.

- Visualisation of the components with the use of an axonometric visualisation system to make it possible to simultaneously survey the co[illegible]ete produ[illegible] and identify the individual components. This is an aid in pre-production, describing jobs, redesigning layouts etc. (Engström et al., 1992).

- Making drawings of the actual layouts where the analysed process takes place.

- Collecting and transforming data (about the process) from the company's databases in order to make the data available to the Pavic and other PC-applications and hereby make the data easier to use and exploit.

During the analysis, some practical problems emerged:

- The persons being filmed were not unaffected by the fact that they were being filmed.

- The group work pattern in relation to the invidual operator performance.

- The choice of moment to shoot the sequence.

GENERALLY APPLICABLE WORK-STRUCTURE HIERARCHY

In order to perceive a complex interaction between man and machine, the observations ought to be organised into modules of activities according to some criteria that for some reasons appear to fulfil the aims of the analysis.

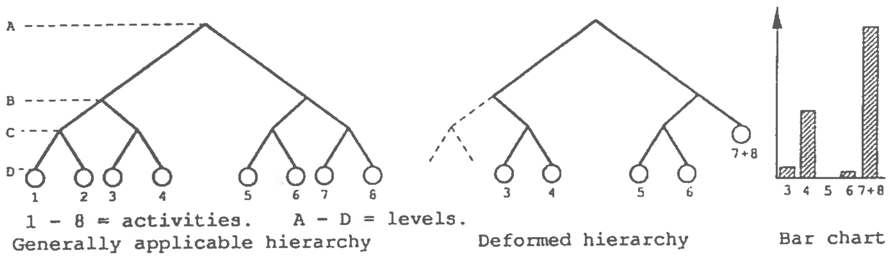

Figure 1. Relation between a generally applicable work-structure hierarchy and bar chart for activities registered for a specific case study.

Reforming the generally applicable work-structure hierarchy to suit a specific case study, as we for example have done with the picking and materials handling work studied, implies deforming the original general hierarchy by excluding and integrating different parts of the hierarchy, as illustrated in figure 1.

The same discussion is relevant in the case of performing an analysis based on a work-structure hierarchy already developed. This means that if one for example wants to use an existing work-structure hierarchy, it will have to answer questions for which it was not originally designed.

In this case one has to reform the hierarchy, but by using the codification techniques shown in figure 1, it will always be possible to retransform the reformed hierarchy back to the original one.

If the aim is to generalise data from a multitude of case studies, some of which are not already known, it will be even more vital to integrate several different specific hierarchies in order to facilitate data collection during the video analysis. At the same time it is, in some cases, just as vital to collect data from a more detailed level than the specific case implies, to ensure that the future total data bank will be able to perform intercase comparisons.

GENERALLY APPLICABLE WORK-STRUCTURE HIERARCHY APPLIED FOR SPECIFIC AIMS OF ANALYSIS

We have tried our method of analysis on materials handling and picking work. We have chosen to organise the observations into modules of activities according to how much manual work is required for the basic activities related to the picking operations as such.

The net picking time required is based on the utopian situation that the picker moves without time delay between picking positions during the picking tour. The work time required for net picking by the picker is defined as "necessary work". Necessary work is defined as reaching for the component (or components) to be picked, grabbing it and transferring it to a position in front of the body or to a position from where it is to be placed in the picking package, whichever is closest (Bryznér et al., 1993).

To quantify or understand this work as it is performed in practical reality, one of course has to include at least three more categories of activities. The first activities are the ones necessary for the absolute minimum of work required in practice by the picker, denoted "Direct supporting activities". The second category of activities is related to the work required because of disturbances that occur during the picker's work, denoted "Disturbances". The third category includes activities related to materials handling and picking work that could be performed by the picker itself but not necessarily so. These are denoted "Related activities". These three categories, denoted "Basic activities" are further divided into sub-activities, as can be seen in figure 2.

Necessary work, Z_p		
Direct supporting activities	Picking location activities	Placing of items in picking package
		Materials preparation for picking
		Transfer of information at picking location
		Operator movement without picking package
	Picking cycle activities	Operator movement with picking package
		Transfer of information
Disturbances	Waiting time	
	Unexpected events	Helping others, be informed
		Other disturbances
	Miscellaneous unforeseen activities	
Related activities	Picking preparation and finishing	Sorting materials
	Handling of package	Storing package
		Picking package
	Administrative work	Adm. work in connection to the picking tour
		Miscellaneous administrative work
	Quality assurance	Control
		Adjustment
	Materials preparation for customer	
	Miscellaneous	

Figure 2. Classification scheme (Bryznér et al., 1993).

In figure 2, the levels of analysis are shown for a specific picking system, to which we have applied the work process mapping method. The activities we chose to include in the analysis have been shaded in the figure. The two activities at the bottom of the scheme (Materials preparation for customer and Miscellaneous) were not included in the analysis.

Note that the classified activities on each level in the structure are not structured in relation to each other.

Short description of the analysed picking system

A picking tour comprises the picking of a batch of four picking orders. Moreover, there are great similarities between orders. The mean picking order consists of 48 part numbers, 32 which of are common to the orders in the batch. Replenishment of the picking location is ordered by the picker by means of a hand-held scanner (wand). The picking information is given to the picker in the form of a paper picking list. The components are structured by location so that components that are ordered together are also stored close to each other.

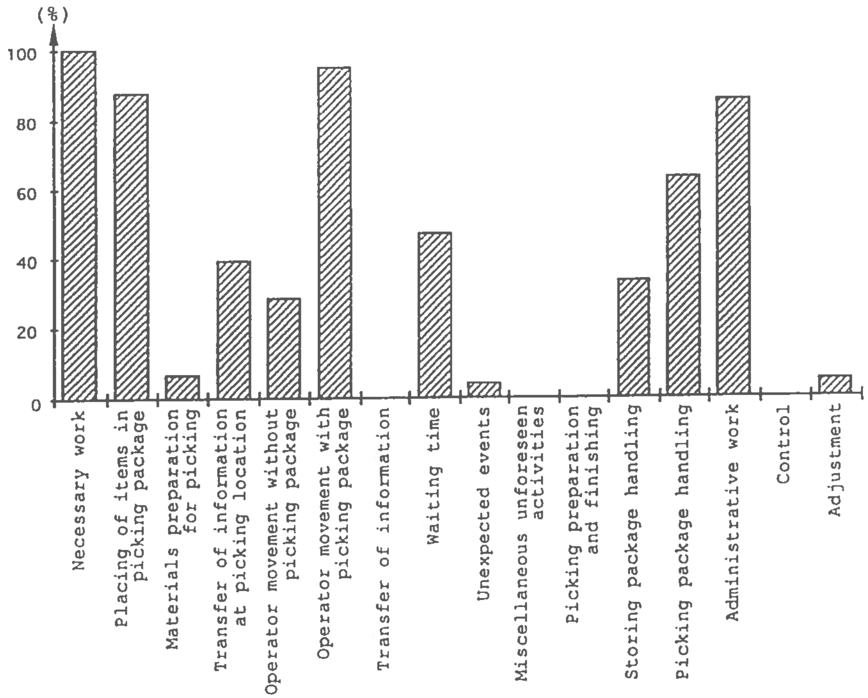

Figure 3. Calculation of the shaded activities in the classification scheme of the described picking system. The different activities are measured in percentage of the necessary work often used in zero-system calculation (Brynzér et al., 1993)

Figure 3 shows data drawn from a sample of four picking tours, and the activity times have been measured using video recordings of the work. In

the system calculated in figure 3, the movement including the picking package corresponds to 95 % of the necessary work, which indicates a potential for improvements.

As could be seen in figures 5, the picking system could be described by giving an overview that leads to further questions. These questions might be answered using a more detailed analysis. This way of describing a picking system, at the same time retaining the ability to view particular activities, makes it possible to know where the greatest efficiency improvements could be made.

Additional analyses of the kind presented here will give reference values for specific activities, which will serve as guidelines when evaluating different kinds of picking systems.

A work process mapping method can be used for evaluation of new (smaller) ideas (changes). For example, how would a different storing area affect specific activities, or would changing the picking batch affect the time need for placement and movement?

FINAL COMMENTS

This work process mapping could in the future be used as a way to design new materials handling systems by using a data bank, which includes different forms of picking and assembly found in specific case studies. A data bank could replace traditional instruments for time studies, because such a data bank would make it possible to come closer to the reality (i.e. shop floor) and to reach a broader foundation for different kinds of analyses and simulations of the process. Work process mapping is an aid in deciding the resources needed and the time consumption.

The industrial engineer must estimate the performance in relation to the time needed. The performance of the study depends on the characteristics of the product and on how long the work, put into the analysis, will be up to date. Moreover, process mapping could always be a method for checking the calculated (analysed) times or it could precede an efficiency analysis. The reason for this is that it will be possible to formalise a number of different activities collected from a broad selection of case studies, by combining these activities into a new, restructured work, a work which will be able to predict performance as well as provide illustration by simulation.

If this formalisation aims to be general, one ought to develop work-structure hierarchies based on explicit criteria for organisation in order to give the interrelation between activities on each level an implicit meaning. A precondition is that the criterion for structuring and categorising activities in an hierarchy are ascertained.

This work process mapping method will, fully developed, generate general knowledge, of for example, materials handling work in a complex interaction between man and machine. However, this could only be achieved if it is possible for the analyser to shift between different types of general classifications and specific data generated from problem areas identified in specific case studies.

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were considered to imply a risk of injury because of prolonged working postures of forward flexion of the back, and a high frequency of lifts implying a risk of injury. Loads at the knees, neck and shoulders were also considered to imply a risk of injury to the health because of the degree, the duration and the frequency of the working postures and movements. Chasing of chickens at both methods is very injurious to the health and the work should be strictly time limited and the work station should be redesigned.

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