Dynamic Description with Computer Supported Pictures

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Summary
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Dynamic description with computer supported pictures

A methodology was developed and tested in six case studies at four medium-sized manufacturing companies within the machine engineering industry. Existing and planned work environments and production processes were described with the aid of computer-generated pictures. The pictures were used within the framework of an action research methodology, in which managers and those employees affected, together with trade unions and company health care representatives, cooperated to establish the preconditions for improved planning from the point of view of both productivity and work environment.

The picture methodology using animated pictures, developed to create and present two- and three-dimensional views of a computer model with manipulable objects, was tested both in a workshop with 20 participants from manufacturing companies and corporate health care and in an experimental study with 30 psychology students as experimental subjects. At a Community College with an artistic bent, the way in which different groups within the college described its organisation with the aid of pictures and symbols was studied.

MDA — an interdisciplinary research programme

There are a variety of ways in which computer technology can be used in working life and in which it can be combined with development, in both an organisational and personal skill sense. These combinations have important effects on working conditions, and consequently, on both the health and well-being of individuals, and on their productivity and efficiency.

The Swedish research programme entitled "People–Computers–Work" (known as the MDA Project, after its Swedish acronym), was set up to promote the development of computer technology adapted to human needs, capabilities and requirements. In practical terms, this entailed initiating and supporting multi-disciplinary research by technological and social scientific experts. The programme was a joint undertaking on the part of the Swedish Work Environment Fund and the Swedish National Board for Industrial and Technical Development, and ran from 1987 to 1992.

Three interrelated fields of research were prioritized:

- People–computer interaction.
- Computerization and work organisation.
- Computerization and change, learning, and development.

The research projects were carried out by 18 multi-disciplinary groups, comprising approximately 125 researchers working in association with people from all walks of life. The results are documented in almost 400 publications and have subsequently been applied in workplaces.

Background

During the 1970s and 1980s, work environment legislation gave the trade union organisations increased insight into companies by means of union representation on Boards and through bodies com-

mon for employers' and employees' organisations. The legislation also paved the way for increased employee influence in designing their work environment and production process lay-out and in changing the work organisation. Computer technology developed rapidly during the latter half of the 1980s and the advent of PCs made it available to large groups of employees. Simulation programs made it possible to analyze the consequences of various manufacturing methods and manning principles with relative ease. Powerful modelling programs facilitated both lay-out work and the realistic representation of premises and work environments with accurate perspective. Dynamic aspects such as production and transport processes could be illustrated using moving pictures in animation programs.

It was against this background that the "Dynamic description with computer supported pictures" project (also known by its Swedish acronym of DBDB) was conducted during the period from 01-01-1988 to 31-12-1991. The purpose of the project was to develop a methodology in which employees, together with managers and specialists in such areas as corporate health care, could participate in and influence the process of change. By making the most of the knowledge possessed by various professional groups collectively, the project intended to establish the preconditions for improved planning from the point of view of both productivity and work environments. The tradition of study circles in Swedish education and the action research theory in behavioural scientific research, constituted the basis for the cooperation methodology developed by the project. A method of consolidating changes in a company with the help of computer generated pictures of existing and planned work environments and production processes was developed from architects' traditional way of working, using perspective pictures to clarify their ideas. The pictures were also utilized to facilitate communication and mutual understanding between areas of professional competence and to span such limitations as might arise from the use of technical language and professional jargon.

Implementation

The project has been implemented in two phases:

- developmental phase
  - case studies
  - symbolic organisational description
- test phase
  - workshop
  - experimental study

Case studies

The DBDB methodology was developed in six case studies conducted at four medium-sized manufacturing companies in southern Sweden. The methodology development concentrated on the following aspects of the process of change:

- mapping methodology
- picture methodology (picture creation, picture presentation, simulation)
- cooperation methodology

The case studies commenced with a mapping of relevant company and work environment conditions through observation (photography and video filming), interviews, surveys, physical measurements questionnaires and psychological measurements. A model of the workshop or workplace including production and transportation equipment plus people, all shown as three-dimensional objects, was created in the computer on the basis of the mapping (see figs. 1 and 8). By using the computer to create graphic pictures of the model with the objects in various positions, short sequences of animated film were generated, all able, for example, to show a particular work activity. The models could also be reproduced as two-dimensional lay-outs (see fig. 7). The objects in the model could be moved around to analyze different ways of designing the premises and production environment. The realism of the pictures was reinforced by using light and shade and by reproducing machine noise and other sounds.

The development of the picture methodology led to two fundamental presentation approaches: "audience perspective" and "actor's perspective". The former, which is illustrated in figs. 1 and 8, means that the viewer looks at the work environment from the outside and sees how the machines work, how people work and move around, and how trucks and overhead cranes transport materials and products.

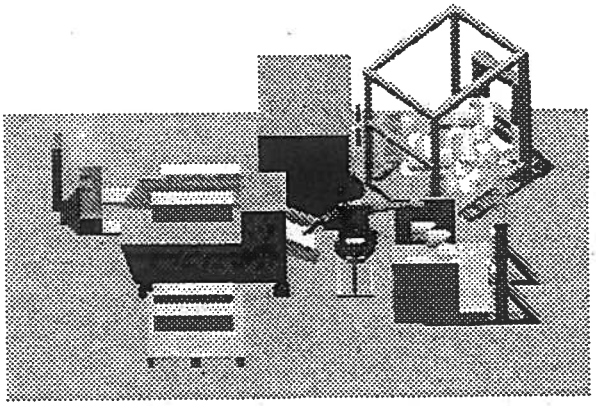

Fig. 1: Three-dimensional computer model of a workplace in one of the case study companies.

The "actor's perspective", as illustrated in fig. 2, means that the viewer is standing on the workshop floor, that he "moves around" in the computer model's work environment and looks at premises and areas and their coloration.

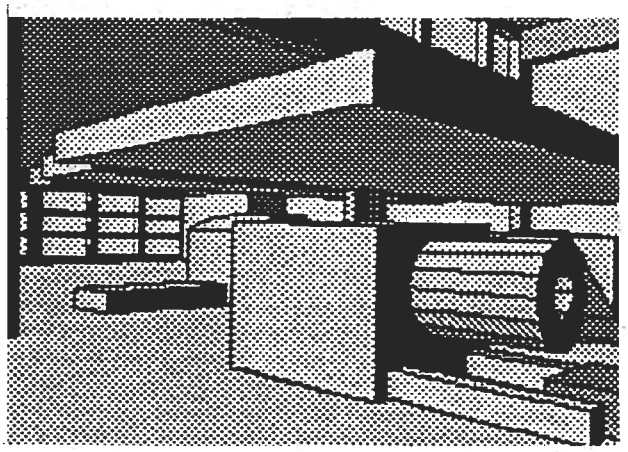

Fig. 2: "Actor's perspective" of a planned machine shop in one of the case study companies.

The simulation methodology was used to study the effect of changes to machine capacity and manning levels, bottlenecks, manufacturing buffers and other dynamic aspects of the production process. Statistical parameters for different activities and the mutual time relationships could also be studied.

The case studies were carried out in project groups comprising between 5 and 15 people, from the following categories:

- Managing Director or corresponding level of managerial responsibility
- Production Manager or Production Technology Manager
- Foreman or other work supervisor
- affected workshop employees
- union representatives
- corporate health care representatives
- DBDB researchers

The project groups, constituted as study circles, worked on defined change process problems, in which context the participants' experience and professional competence were used for the compilation, analysis and interpretation of data. The groups initially studied animated pictures in order to discover how the research group perceived the work environment and the production process. The pictures focused the participants' attention on conditions which they had previously overlooked. After various changes and planning proposals had been discussed, the research group concretized them with new animations.

The DBDB methodology was used at one of the case study companies to design the production lay-out in a newly renovated machine shop. The picture methodology underwent further development and was used in the same company to plan new construction work and the interior fittings in an engineering workshop. Work organisational aspects were also taken into consideration. In another of the case study companies, the DBDB methodology was focused on work organisational changes when the company changed over from traditional component manufacture to flow group production. The cooperation methodology was taken further in a third company as a result of the Factory Manager and the workers conducting in-depth analyses of work routines and production technology. In all three of these companies, the companies' own personnel were involved in creating their own pictures and building compugraphic models of work and production environments. In the fourth company, the DBDB methodology led to the company implementing full-scale trials of alternative methods of designing a new production environment. Corporate health care representatives in the project groups contributed to the developmental work by measuring the physical work environment and by producing checklists and conducting risk analyses.

The case studies showed that the picture methodology stimulated the participants to problematize and analyze different aspects of the work environment and production process. The companies' efficiency requirements did not, however, usually allow them to try out more than one alternative design of work environment or production process lay-out. The cooperation methodology contributed towards the companies being able to use previously unused experience and knowledge pertaining to the way in which the production process was carried out or could be changed. The simulation model proved to be time consuming with regard to building simulation models, and demands a good deal of knowledge with regard to interpreting the results of the simulation. It thus requires additional development. The methods of work analysis tested in the case studies (VERA and WEBA), were difficult to adapt for computer use and difficult to use for initiating work organisational changes within the framework of action research.

Symbolic organisational description

An exploratory study was conducted at a Community College with an artistic bent in order to investi-

gate the way in which different groups within an organisation perceive and describe that organisation. Eighteen voluntary participants – six men and twelve women, representing school management, administration, teachers, students, caretakers, cleaners and catering staff – were asked to illustrate how they perceived the school's organisation using a sheet of A4 paper and coloured crayons. After approximately 10 minutes of free drawing, they were asked to visualize or symbolize power, influence, knowledge and support/service.

The drawings were scored from a number of dimensions, derived in part from Piaget's theory of cognitive development. The level of inter-rater reliability of two independent judges was high.

Drawings and "think aloud" protocols showed that it was difficult for the experimental subjects to describe their organisation using pictures. Fewer than one third of the experimental subjects – all school managers, teachers or students – illustrated the school organisation in pictures. Reificatory symbols such as houses, wheels etc. were more common than organic symbols such as people, animals or plants. None of the administrative or service personnel used pictures alone; instead they described the organisation using both pictures and text or text alone, such as an organisation chart or job descriptions. People with key positions, such as school managers, teachers and administrative personnel, largely based their drawings on centrally positioned elements, whilst students and service personnel with more peripheral roles presented the organisation from subjectively limited perspectives. The majority of the experimental subjects used colour, size or personification to stress different organisational aspects.

Cluster analysis of the drawings indicated that the experimental subjects differed greatly in their modes of self-expression. One third of them – the majority of whom were teachers – were united by their description of the school in a holistically orientated but somewhat formal manner, with centrally positioned units drawn in soft shapes, different colours and sizes, which indicated various directional associations. An almost equally large group – all of whom were women – illustrated the organisation in an intellectualized and conventional manner. They used straight lines and hard shapes and their drawings lacked any dynamic or emotional content. A smaller group of three individuals illustrated the school organisation in an artistically expressive but individual, naive manner which was difficult to interpret. Without the experimental subjects' "think aloud" protocols, these drawings would have been very difficult to understand. The remaining four experimental subjects broke down into two groups which were united more by their lack of expressiveness than by any common mode of expression. One of these groups described the school organisation exclusively in terms of job positions without using pictures, whilst the other group focused on details of the experimental subjects' immediate surroundings.

The result of the cluster analysis indicates that it is still difficult, even in an artistic environment, to discover a common mode of expression for illustrating abstract things such as a school's organisation. Drawings and "think aloud" protocols showed that the concept of power was often associated with straight lines, hard shapes, organisational charts, superior/inferior relationships, size variation and the colour, black. The concept of knowledge, on the other hand, was associated with round shapes, soft shapes and the colour, green. Influence and support/service were concepts which the experimental subjects found difficult to illustrate using pictures and symbols.

Workshop

A workshop was held during the autumn of 1990 in order to complement and clarify the results and experiences of the case studies. The aim of the workshop was to study the following factors under controlled conditions:

- the planning potential of the DBDB methodology
- cooperation in planning groups
- the content and character of the planning discussion
- pictures as a planning aid

Three manufacturing companies and a group from Föreningen Teknisk Företags-hälsovård, FTF (the Association for Industrial Hygiene and Occupational Safety), took part in the workshop. The composition of the corporate groups complied with the cooperation model developed in the case studies. Two of the three corporate groups included a representative of corporate health care. Invited researchers, without any links with the project, participated as observers in the workshop groups.

The participants planned an alternative production process for bicycle handlebars on two occasions with an interval between them of 10 days. Before the workshop, the participants received documentary information in the form of paper pictures illustrating: company exteriors, machine shops, workplaces, manufactured products, production data and work organisation. At the first meeting, which lasted for half a day, a current situation

description of the manufacturing was done with the aid of animated pictures. The complex planning problems were then analyzed using computer support to the extent required by the groups, and each group developed its own first draft proposal for a change in the manufacturing process. In between the two meetings, the research group produced animated presentations of the groups' proposals. At the second meeting, which lasted for an entire day, the groups put the finishing touches to their proposals and presented them to each other as computer display animations.

The corporate groups' planning proposals for new production process lay-outs and work organisation were similar to a very great extent, as were the contents of the planning discussions and the use of pictures. The FTF group differed markedly in these respects from the corporate groups. This is exemplified in figs. 3 and 4, in which one of the corporate groups has been selected to represent all three corporate groups.

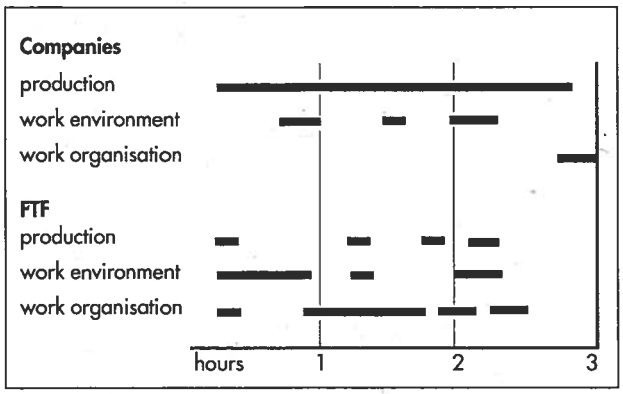

Fig. 3: Orientation of the planning discussions in corporate groups and the FTF group, 1st day.

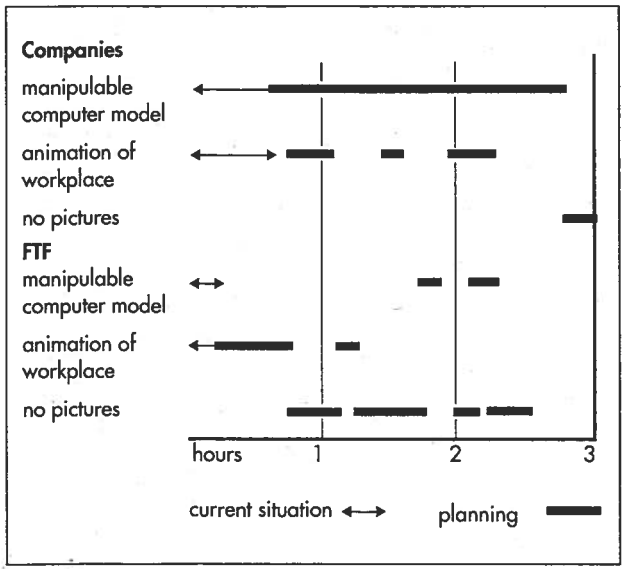

Fig. 4: Use of pictures in corporate groups and in the FTF group, 1st day.

Using well known, tried and tested technology, and in a manner in accordance with accepted work organisational principles, the corporate groups had taken the development of the production system further down the road towards flow group manufacturing. Traditional machines were placed to one side and operated, as in the case of transport within the flow group, partially manually. Modern technology had been employed to a certain extent for robot control and the interconnection of machines. Production flow, automation principles and, to a certain extent, physical work environments, had all been well thought through.

The FTF group's production system was based on overall work organisational analyses. An almost fully automated manufacturing process would reduce physically heavy and stressful work activities as well as reducing those which were monotonous, uniform and repetitive. The manufacturing process, which was monitored by a couple of people, was based on new, untried technology. A manipulable computer model, reproduced from a three-dimensional viewpoint, was used by preference for descriptions of current situations and for evaluating planning proposals, whilst two-dimensional plan projections of the model were better suited to planning production process lay-outs and production flow. Animated pictures of workplaces were used when the work environment was discussed, primarily with regard to working positions and monotonous or restricted movements. When work organisational issues were discussed, pictures were used to a limited extent. Some workshop participants felt that the DBDB pictures, to a certain extent, focused the planning discussions on technical aspects and removed the human element of the worker from the discussion.

The connections between technocentric and anthropocentric planning (with technology and man, respectively, at the centre), planning discussions and the use of pictures are shown in the table below.

Planning	Concrete discussion	Abstract discussion
Techno-centric	Manipulable computer model	
Anthropo-centric	Animation of workplaces	No use of pictures

Although the workshop participants felt, in many respects, that the paper pictures gave a good picture of both the machine shop and the workplaces therein, they overwhelmingly preferred animated presentations (see fig. 5). The animations were, however, regarded as less well suited for illustrat-

ing the physical work environment (noise, lighting, ventilation), social contacts and "on the job" learning.

Experimental study

The way in which two- and three- dimensional views of a machine shop and workplace are perceived when they are shown as stills and as animated pictures on computer displays was investigated in a laboratory experiment. The picture motif was taken from one of the case study companies. Thirty psychology students, with no experience of workshop work and who were not used to reading drafts or interpreting lay-outs, were asked to look at eight pictures. The first picture shown was always the machine shop, whilst other pictures were shown in a random order. Each picture was assessed in twelve different respects.

Fig. 6 illustrates how the experimental subjects evaluated the usability of the pictures with regard to planning the manufacture of a product. As is apparent from the graph, pictures of the machine shop were preferable to pictures of a workplace, 3-dimensional pictures were preferable to 2-dimensional ones, and animated pictures were preferable to stills.

Irrespective of the way in which the pictures were evaluated, three-dimensional animated pictures offered the optimum combination of view and presentation method for both machine shops and workplaces.

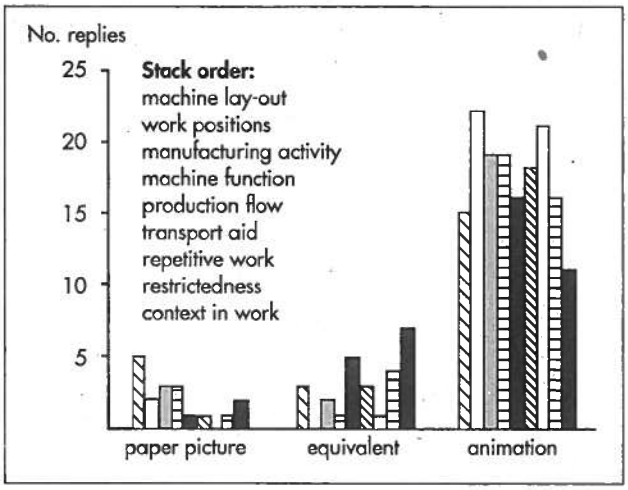

Fig. 5: Preference for paper picture or animation of various aspects of a workplace.

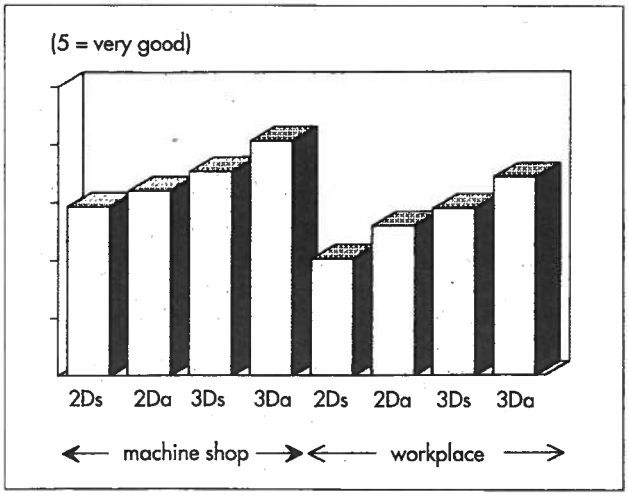

Fig. 6: Evaluation of 2- and 3-dimensional views of machine shops and workplaces, shown as stills (s) and animated pictures (a), with reference to the pictures' usability for planning manufacturing.

Summary

- The picture methodology of the DBDB project acted as a common language between different professional categories. It stimulated the emergence of problems and analysis of issues relating to work environment, production and work organisation. A certain risk does, however, exist that planning discussions using computer pictures of the type so far developed by the DBDB project may focus on technical aspects at the expense of the people in the work environment. Work organisational aspects were discussed in connection with production planning during a workshop, preferably without the use of computer pictures, a fact which does not, however, exclude the possibility that pictures previously shown during the workshop affected the work organisational discussion. Three- dimensional animated pictures were the optimum combination of view and presentation method.

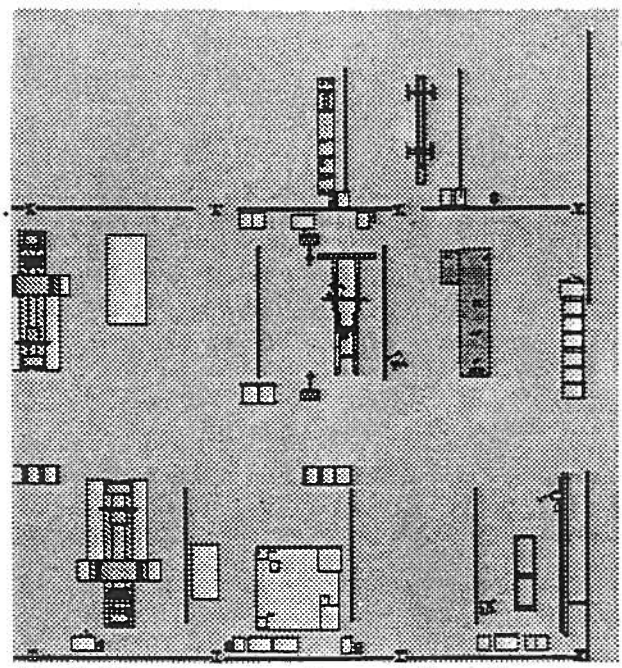

Fig. 7: Two-dimensional lay-out of machine shops at one of the case study companies, based on the same computer model as fig. 8.

- The cooperation method mobilized knowledge and experience which the case study companies had only been able to activate by other means to a very limited extent. Corporate groups and safety engineers within FTF utilized computer pictures and discussed production changes in different ways and with different results during a workshop on the DBDB methodology.
- The work analytical methods (VERA and WEBA), which were tested during the developmental phase were successful as research instruments but were difficult to use as action research tools within the framework of the DBDB methodology.
- It is difficult for people working in an artistically orientated sphere to describe an organisation using pictures or symbols. The individual differences in this context are great, which renders the use of pictorial languages which have not been standardized or which are based on cultural conventions, more difficult.

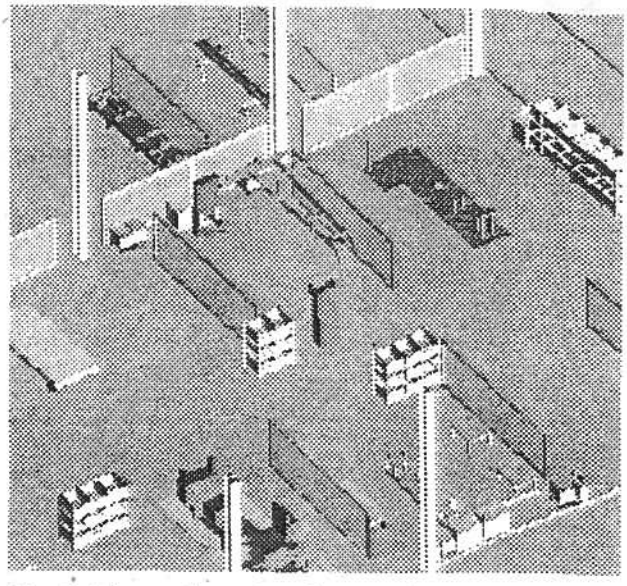

Fig. 8: Three-dimensional view of machine shops at one of the case study companies, based on the same computer model as fig. 7.

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