10. The E/S tool

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Abstract. PSIM aims at a continuous and integral improvement of assembly processes. The E/S tool was developed to ensure that up-to-date ergonomic and sociotechnical knowledge is considered in these improvement processes. Designed to be used by employees of assembly enterprises, the tool offers support by means of visualizations and by means of a flexible procedure that offers structured guidance in optimizing the assembly environment. In this chapter the structure, the participative application procedure and the developed software prototype of the E/S tool are presented.

10.1 Introduction

Within the PSIM project a concept and a software prototype have been developed to apply state of the art sociotechnical and ergonomic knowledge in manufacturing enterprises. This E/S tool (Ergonomics/Sociotechnics tool) supports a participative approach enabling employees to improve or redesign their daily work considering ergonomic and sociotechnical aspects.

The *ergonomic approach* aims both at lead time reduction and improvement of the human assembly tasks. *Participation* of company representatives is crucial in this approach, for reasons that have been discussed in previous papers on participative ergonomics [1]. Another feature of the approach is that two disciplines are brought together: assembly engineering and industrial ergonomics. Previous

projects demon-strate the surplus value of combining assembly engineering expertise with ergonomics expertise [2] [3].

The *sociotechnical approach* (SocioTechnical System Design or STSD) considers social and technical factors, therefore making interactions between these factors apparent and allowing a joint optimization that aims at avoiding technical biases in system design. Such biases not only neglect the potential of the human factor but - in the extreme - even destroy human potentials. Instead a system design is aimed at that explicitly considers the differences in strengths and weaknesses of both human and technical factors. The *participative* approach allows employees from different levels of the hierarchy and with different professional backgrounds (operators, supervisors, managers and engineers) to analyze their work and develop design solutions together. Consequently, the experience and knowledge of the involved staff is integrated in the problem solving process.

The E/S tool bases on the sociotechnical and ergonomic theory described in Chapters 8 and 9 respectively. In this chapter the relevant aspects of the E/S tool are described. First, the integration of ergonomical and sociotechnical theory is presented, then the procedure and structure of the E/S tool are explained, followed by the description of the prototype of the E/S tool and the conclusions section.

10.2 The E/S Tool: The Integration of Ergonomics and Sociotechnics

The E/S tool integrates the ergonomic and the sociotechnical approaches. The advantage of this integration is that reorganizations can be addressed in a comprehensive way. The reorganization of a manufacturing unit focusing on sociotechnical issues for instance would normally neglect possible ergonomic consequences, but as sociotechnical and ergonomic aspects can be analyzed and designed within the framework of one tool, possible interactions between sociotechnical and ergonomic aspects can be elicited and taken into account.

The E/S tool aims at supporting employees in the description, visualization and evaluation of current and future assembly processes focusing on ergonomic and sociotechnical aspects. To be able to focus on the ergonomic and sociotechnical aspects in a detailed way specific modules were developed that all support participative usage.

The E/S tool consists of four modules that focus on *ergonomic* aspects (the physical load module, the process flow module, the mental load module, the safety module) and of one module that focuses on *sociotechnical* aspects. Furthermore, there is a *shared task analysis* module that can be used in combination with the ergonomic and the sociotechnical modules. The modules of the E/S tool are graphically outlined in Figure 10.1.

The ergonomic and the sociotechnical modules 'share' the *task analysis* module as all these modules require a detailed description and definition of the unit of analysis (that part of an enterprise that needs to be analyzed and possibly redesigned) as a starting point. The shared task analysis module allows to choose which aspects are considered relevant depending on which module will be used in the next step (e.g. the mental load module) and allows to detect possible relations between different sociotechnical and/or ergonomic aspects at an early stage.

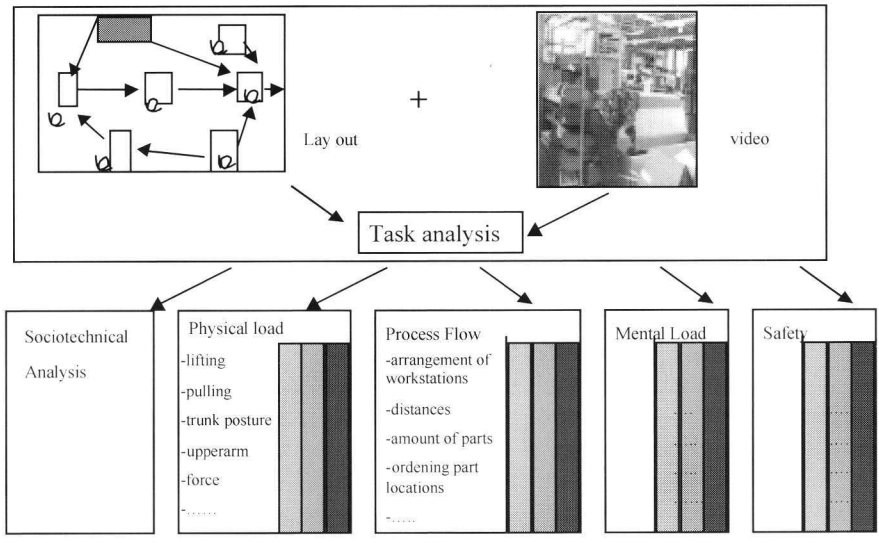

Figure 10.1 Outline of the E/S Tool Consisting of the Shared Task Analysis Modules, Four Ergonomic Modules and One Sociotechnical Module

The *physical workload module* evaluates the physical load in every assembly station according to guidelines (red/yellow/green). Green means "safe", yellow means "some risks, so measures must be taken" and red means "a lot of risks, so measures must be taken immediately". Tool users can evaluate aspects like lifting loads, pushing and pulling, static working posture, repetitive movements and hand forces. In this evaluation module we incorporated the most recently developed knowledge and standards on physical workload.

The *process flow module* evaluates process flows between different workstations and on every workstation according to guidelines (red/yellow/green). It considers aspects like arrangements of workstations, distances between workstations, amount of parts and order of part locations.

In the *mental workload module* users can evaluate the mental load based on a cubic model in which three dimensions play an important role: characteristics of activities (knowledge or routine based), time occupied and amount of task set switches.

With the *safety module* tool users can evaluate aspects concerning safety, and environmental factors using a checklist (red/yellow/green).

The *sociotechnical module* allows multidisciplinary project teams to analyze and design tasks of individuals and groups as well as work processes and work organization on basis of the sociotechnical approach. To support this process the module contains a flexible problem solving procedure consisting of different steps. For every step specific support is offered, e.g. visualizations, sociotechnical background information, criteria for analyzing and evaluating the work and the derived solutions as well as solution concepts and questions for adapting solutions to the needs of the unit of analysis. Starting points of the module use can be problems related to production processes and work organization, the evaluation of already existing ideas for redesign or the general goal to optimize production processes and

work organization. During the STSD module use the project team is supported by a facilitator that coordinates the project team and can offer additional information.

The concept of the STSD module foresees that not all steps of this procedure need to be executed together in a group but that certain steps can be performed indivi-dually. This feature however has not been developed in the software prototype yet (see below).

It is essential to analyze work processes and work organization in detail, but the developed solution needs to consider the unit of analysis as a whole. Therefore the sociotechnical module supports a procedure that takes both an analytical and a holistic perspective into account by integrating the two sociotechnical approaches described in Chapter 8. The implementation of the two approaches is presented in the description of the sociotechnical module procedure in the next section.

10.3 The Procedure of the E/S tool

In the previous section the different modules of the E/S tool were presented. The shared task analysis module, the four ergonomic modules and the STSD module have different application procedures. With certain limitations (no connections to other tools or databases) it is possible to use the E/S tool as a stand alone tool. Integrated in the PSIM environment however, the PSIM procedure guides users to the E/S tool.

The PSIM procedure guides tool users to one or several tools depending on the issues that want to be addressed. Depending on the addressed issue(s) and the selected tool(s) the relevant organizational units of the enterprise that need to be considered for the analysis and redesign are defined (the unit of analysis) as well as the employees that need to participate in the optimization process. This group may comprise operators, manufacturing engineers, production managers, product de-signers, ergonomists etc. The steps of the PSIM procedure are scrutinized in more detail in Chapter 8.

As previously mentioned the E/S tool is designed for participative use. During the application of the tool it is required however that the user group is supported by a facilitator that can offer additional background information on the ergonomic and the sociotechnical approach respectively and that has experience in guiding project teams. The different steps of the E/S tool procedure are described below.

10.3.1 The Collection of Sociotechnical and Ergonomic Inputs for the Task Analysis Module

In this step the tool users perform several activities. Depending on which of the modules will be applied in the next step (modules for ergonomic or sociotechnical analysis and design) the focus on the different aspects of the task varies.

A graphical representation of the assembly lay out in the user group is made. This lay out focuses on three levels: (1) general lay out, (2) workstations and transport-ation lines and (3) the tasks performed on the workstations.

A video-recording of each assembly process step can be made. Ergonomic data can be elicited, if required for detailed evaluation. On basis of this input the user

group makes an ergonomic assessment of the current situation. Then the user group enters the results of the assessments into the E/S tool and they will be stored into the E/S tool database.

To analyze organizational aspects the tool users have to answer several questions regarding the current situation of the organization. The tool presents visualized schemes of the unit of analysis in which the user group is asked to mark communication and process paths. Employee related questions focus on the number of staff, the level of education, the tasks the employees have to perform, the number of employees directly involved in the production process and the number of employees not directly involved in the production process. Questions related to the organization focus on the overall organization (hierarchy levels, teams etc), communication paths, interfaces with other organizational units and the wage system, e.g. are individuals or teams rewarded. Questions related to the tasks focus on the task(s) of the unit of analysis, input and output relations referring to information and material flow as well as the tasks of the individuals. Finally the tool user(s) have to list problems they face in their work. The input gained by these questions is stored in the E/S database and will be used later in the design phase, which is part of the STSD module.

10.3.2 The Sociotechnical Module - See Chapter 8

The procedure of the sociotechnical module consists of two phases. The analysis phase, based on the KOMPASS method [7], and the design and evaluation phase, based on the Integral Organizational Renewal (IOR) approach [4] [5] [6].

Sociotechnical Analysis of the Current Situation

The aim of this phase is a detailed sociotechnical analysis of the current situation of the unit of analysis.

First the objectives that need to be achieved are defined. This step is supported by four categories provided by the STSD module to assure that relevant aspects of production units are not neglected: Business management, organization, employees and technology. The collected objectives are then clustered according to similarity, for each cluster a name is defined that expresses best the essence of the cluster and finally the objective clusters are prioritized. The clusters are then used for a first assessment of the unit of analysis.

After providing the project team with the essentials of the sociotechnical approach, the criteria for the sociotechnical analysis are introduced and applied for analyzing the current situation of the unit of analysis. As a final step the criteria are related to the objectives thereby developing a network that will enable the project group in the next phase to evaluate developed solutions systematically. The STSD module automatically summarizes the analysis made in this phase in a report.

Sociotechnical Design and Evaluation

In this phase the user group is provided with conceptual solutions as support for generating and designing concretized solutions for reaching the objectives. This step focuses on the holistic perspective by offering conceptual solutions in terms of organizational structures with certain characteristics. The module stimulates the tool users to learn from these alternatives and to apply what is useful for their situation.

To concretize the concepts to the needs of the own situation a list of questions is offered. Moreover the tool provides the tool users with the information they gathered in the task analysis module to support the development of an adequate design.

Then the tool users evaluate their solution by means of the network containing the criteria and the objectives developed in the previous phase. For every criterion the project team has to assess the expected change of the solution, the network then visualizes the effects on the objectives. Based on this evaluation it is decided whether the solution needs further improvement. The result of this phase is a concretized and systematically evaluated solution for redesigning the unit of analysis.

10.3.3 The Four Ergonomic Modules - See Chapter 9

The ergonomic modules can be used on two levels. Firstly, for the ergonomic evaluation of the unit of analysis all the checkpoints of the modules are considered one after another, thereby the project team discusses all ergonomic aspects participatively. Secondly, if during redesign solutions are found, that might increase the load for workers only on a certain ergonomic aspect, the respective items in the modules can be checked. This focused approach, however, requires skillful tool users that have a good ergonomic background.

The input from the task analysis module is necessary especially for the physical and mental load modules. They rely on detailed information of task characteristics like forces, body postures and time periods. Without this data the use of the ergonomic modules gives unreliable results.

The procedure to use the ergonomic modules is the following:

- Evaluation of the current ergonomic situation using the four ergonomic modules. The tool automatically summarizes these evaluations in a report,
- Generation of possible alternatives (improvements). This is done by the participative project team and is supported by the modules when comparing alternative designs with each other,
- Evaluation of the selected alternative to be implemented.

10.4 The Software Prototype of the E/S Tool

After developing and testing a paper and pencil version of the E/S tool, a software prototype was programmed. The prototype allows to work participatively on ergonomic and sociotechnical aspects as described above and can be used as a stand alone tool. The prototype consists of the task analysis module (for both the sociotechnical and the ergonomic modules), the sociotechnical module and four integrated ergonomic modules. Following the task analysis module and the sociotechnical module prototypes will be described.

10.4.1 The Task Analysis Module

If the PSIM procedure guides the user group to the E/S tool (see above) the task analysis module is presented. A possible starting point of the task analysis module is a lay out of the assembly containing workstations and lines of transportation (see Figure 10.2). By clicking on a workstation or a transportation line descriptions of the tasks performed at that workstation or transportation line can be entered and recalled at any later point. It is then required to fill in data of the current situation in the tool as previously described. As a next step the user group can choose to work with the sociotechnical module or the ergonomic modules.

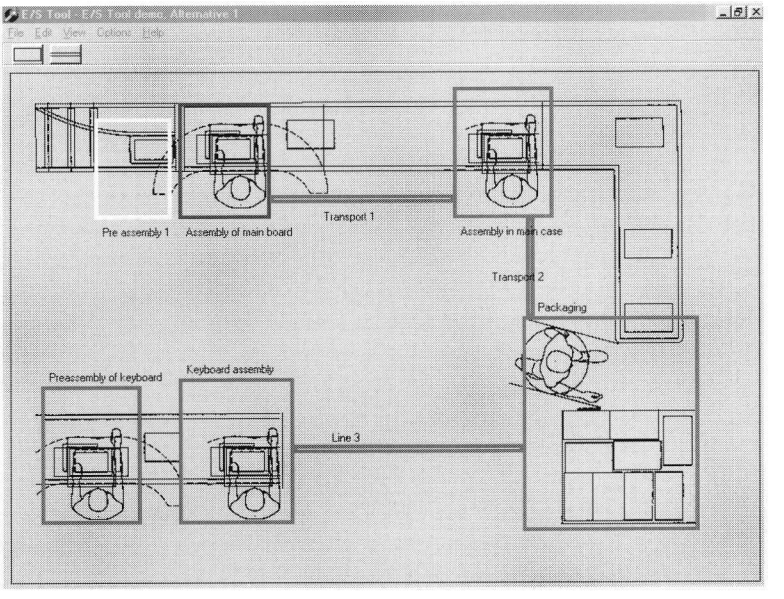

Figure 10.2 Visualization of the Lay Out Containing Workstations and Transportation Lines as Presented by theTask Analysis Module

10.4.2 The Sociotechnical Module

Within the sociotechnical module prototype the procedure consisting of the two phases and the features (e.g. visualizations, criteria-objectives network, theoretical background information) were implemented. As a starting point the prototype presents and overview of the procedure that can be viewed at any later point again. It is not required to perform the steps in the listed sequence, steps can be repeated or previous steps can be reconsidered. For every step described, the prototype offers specific support and the result of each step is stored in a database:

Sociotechnical analysis of the current situation:

- Step 1: Defining concrete objectives,
- Step 2: Describing the relevant system with the objectives,

- Step 3: Explanation of the theoretical background,
- Step 4: Explanation and application of the tool criteria,
- Step 5: Relating the objectives to the criteria.

Sociotechnical design and evaluation:

- Step 6: Generating solutions,
- Step 7: Concretizing solutions,
- Step 8: Evaluating solutions.

Based on the requirements of the industry partners of the PSIM consortium, a selection of the criteria of the KOMPASS method (Chapter 8) was made and integrated in the prototype for step 4. The selection included the following criteria:

Criteria on the level of the work system:

- Independence of the work system,
- Task completeness of the work systems,
- Autonomy of the work system,
- Polyvalence of the work system.

Criteria on the level of the individual task:

- Completeness of the individual task,
- Task variety,
- Amount of decision making and planning,
- Flexibility.

Also based upon the requirements of the industrial partners the conceptual design solution offered in step 7 of the procedure was limited in the prototype to Self-Managed Work Teams.

Chapters 11 and 12 contain descriptions and evaluations of the application of the prototype of the sociotechnical module.

10.4.3 The Ergonomic Modules

The outline of the software prototype of ergonomic modules is shown in Figures 10.3 and 10.4. Most required input is numerical data or selecting one of the options given by the software. Options can be very distinct and need measurements in workplaces (or direct data from company's database). Some evaluation items are, however, qualitative, and the result of analysis bases on the input of the participative group.

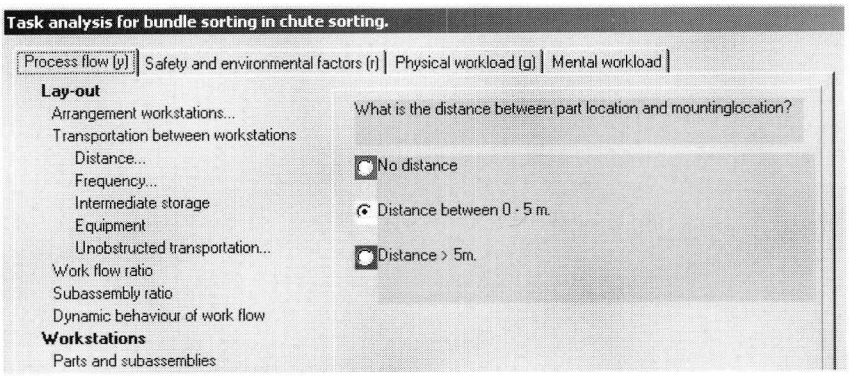

Figure 10.3 Evaluation of Transportation Characteristic in the Process Flow Module

To help the evaluation video clips can be linked to the tool. This helps in the analysis of ergonomic features, but it has also a drawback, because it might concentrate the discussions to the points outstanding in the video.

The results of analysis can be seen in the layout picture in the traffic light format (Figure 10.2). Squares which mark the workstations change their color according to the evaluation: if one aspect of a workstation in the ergonomic modules in red, the square will be red, too.

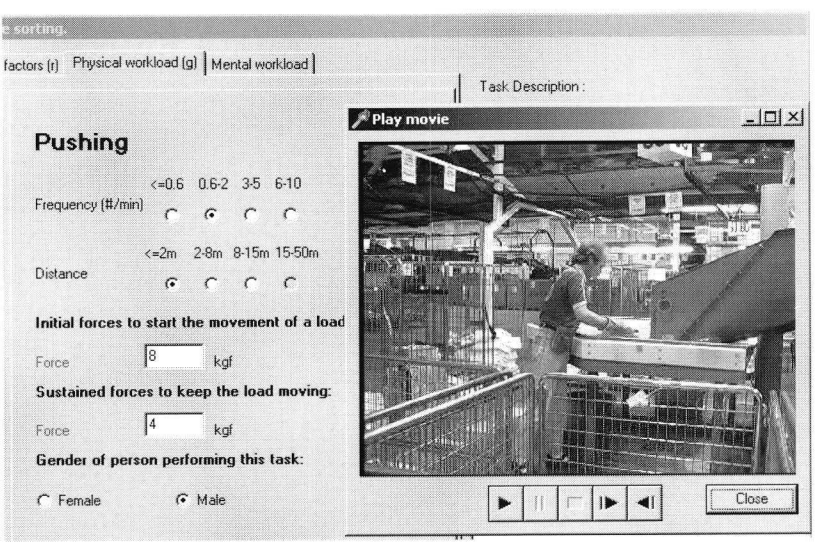

Figure 10.4 Evaluation of Required Pushing Forces in the Physical Workload Module. Video Clips Showing Actual Work Tasks Can Be Very Helpful in Participative Group Discussions.

10.5 Conclusions

The E/S tool is unique regarding the integrated approach of sociotechnical and ergonomic knowledge that employees can apply in a participative way supported by a software environment. Besides this the participative use of the tool is essential enabling groups of employees from different hierarchical levels and functions to work on improvement of the current work situation.

The software prototype test was considered as successful by both tool users and tool developers (see Chapter 8 and 9). The test of the tool demonstrated the value of involving work staff in companies and working in these groups on organizational and ergonomic problem solving, supported by an ICT tool. This enables the users to find solutions which are accepted by all stakeholders. Although designed to operate without intensive support of experts, a process facilitator proofs to be of considerable importance in the tool use. Nevertheless the E/S tool can be used by workgroups as well as experts (both sociotechnical and ergonomic).

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