Prognostic Work Analysis Using a Simulation Approach

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Abstract

Procedures for work analysis usually reflect exclusively the actual state of a real work system at a given point in time. If one wants to examine e.g. future work situations with respect to their scope of action and work requirements, appropriate objective prognosis methods are then necessary. The high complexity of the prospective work analysis demands computer-supported aids, e.g. in the form of simulation procedures, which allow the work analyst or planner not only to explore the static, but also the dynamic correlations within the work system.

In the following article an overview of simulation applications in the industrial environment will first be provided. Subsequently, attention will be drawn to the necessity of prospective work analysis. The simulation procedure discussed here serves the prospective work analysis and is aimed at forecasting the repercussions of planned work systems to the employee in this work system. A focus of this article is the exemplary implementation of the computer-supported simulation for prognostic analyses of assembly work.

1 Introduction into Simulative Planning

1.1 Field of Application

In order to ensure the long-lasting competitiveness modern production enterprises strive to attain a higher degree of cost efficiency and customer-orientation. Furthermore in the wake of the globalization of markets, it becomes necessary to create ever more elaborate and exact plans of the production systems.

When analytical procedures fail due to the complexity of the work system, simulation can be used as a planning tool. Normally, simulation tools, which are specialized for the application areas of production and logistics, are used for this purpose. Since these material flow oriented procedures were at the beginning of their development, merely able to represent the technical components of a production system the holistic consideration of sub-systems, including the personnel, has gained in importance in the past few years.

The planning of future personnel assignment and the construction of the work system is carried out afterwards as a derived planning stage which is often merely comprised of rough determinations of the necessary workplaces. A detailed, prospective analysis of the operational and qualifications-oriented demands and the future physiological and psychological requirements is however mostly not executed (Zülch, Heel, Lunze, Hohendorf & Schweizer, 1998, p. 93). Thus. the usual planning procedure is too limited in its ability to prospectively determine good ergonomically personnel structures and human-oriented work systems in industrial production.

1.2 Approach to Simulation

The system behaviour of modern production systems cannot be illustrated exactly in an analytical manner due to complex interferences, stochastic influences and increasing demands for flexibility. For this reason simulation technology can be used as a tool in the planning of these systems. The relevant guideline of the German Association of Engineers (VDI 3633, sheet 1, 2000, p. 2) defines simulation as the "reproduction of a system with its dynamic processes in an experimentations model, for the purpose of gaining insights that are transferable to the reality". In accordance with the planned simulation objectives, a model of the real/planned system, limited to the essentials, is created. With this model the user can execute experiment series in order to either understand the real/planned system behaviour, to develop various strategies for system operation or to obtain decision support for his work. The principle approaches to the execution of a simulation study are shown in Figure 1.

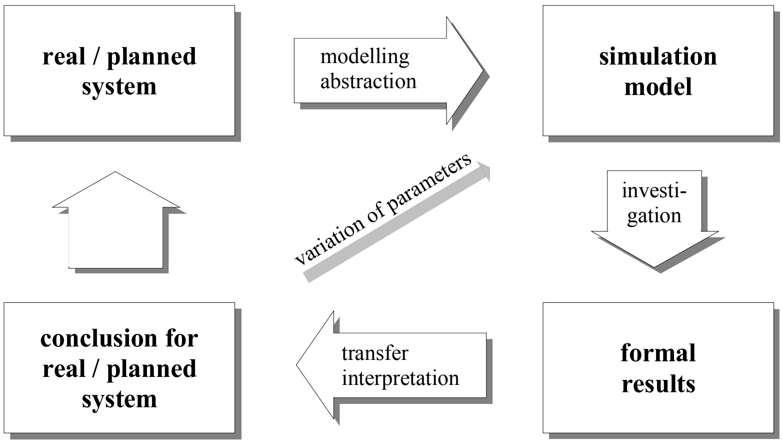

Figure 1: Procedure of a simulation study (following ASIM, 1997, p. 3)

The first experiments with the simulation model serve its validation. The simulation data obtained are compared with the data of the real system, whereby it must be ensured that the abstracted model represents the reality of the respective system with suitable exactness. If the necessary exactness is reached, empiric examinations of the system behaviour follow by systematically varying one or more system or process parameters. The results of a simulation run are composed of a large amount of data, which must then be compressed and interpreted, while keeping the surrounding conditions and simplifications from the model creation phase in mind. Prerequisites for the interpretation are e.g. results presented in the form of a graphs or animations. Finally, the solution approaches gained for the optimization of the system can be reviewed again in a simulation run and, in the case of positive results, transferred to the real/planned system.

2 Significance of Prospective Work Analysis

The analysis of work activities is focussed on work demands and work system attributes. The procedures which are used for this purpose usually have the disadvantage that they merely reflect the actual state of a real work system at a certain point in time. If one wants to examine e.g. future work situations with respect to their work demands and scope of actions, appropriate prognosis methods are then required. The high complexity of prospective work analysis demands computer-supported aids, e.g. in the form of simulation procedures, which allow the analyst or planner to explore not only the static, rather also the dynamic correlations within the work system and thereby to support the planner in his search for a solution.

When dealing with such planning tools for the configuration of future work systems one can differentiate between static prognosis procedures, procedure for post-run-analysis and simulation procedures with integrated work analysis. While static prognosis procedures do not consider the dynamic coherences of a work system, thus not allowing for an exact reality approximating illustration of the work situation, post-run-analyses are well suited for the assessment of simulated work processes. Post-run-analysis procedures have already been developed for several application fields, such as e.g. for static and dynamic muscle work or noise load (see list of post-run-analysis procedures in Schindele, 1996).

In contrast, event simulation procedures allow for control strategies to react (e.g. work interruptions) to resulting work situations (e.g. to much stress for a worker) already during the simulation. The stress progression is hereby designated by the occurrence of events and reactions during the simulation. Such simulation procedures present the possibility to represent various statically operative factors influencing the worker e.g. climate, noise or lighting. Furthermore, so-called dynamic influencing factors (work load, practise, time stress, monotony), which change over time or rather the course of the simulation and which are thus influenced by the specifications of the work demands, work organization and workplaces, are taken into account for the estimate of human reliability. There are only isolated approaches to simulation-integrated procedures in the area of work analysis, although they are of great importance as a prognosis and planning tool for work systems, as has been sufficiently shown in other application areas (e.g. productions logistics).

3 Illustration and Assessment of Future Assembly Work Activities

An simulation-integrated procedure for prospective stress analysis e.g. in the assembly area should allow for the temporal progression of stress to be determined over an arbitrarily long period of time (e.g. one shift, one week or one month) for each worker, dependent upon the activities executed (in simulation). Not only the objective, measurable stress factors should hereby be taken into account, rather also those stress factors, which are only indirectly ascertainable, for example due to work organization and work content. With respect to the development of the simulation procedure discussed here, this means that a suitable procedure or module for the determination of combined stress factors must be made available.

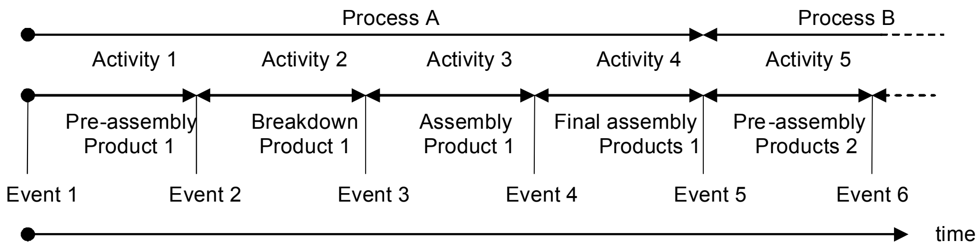

Figure 2: Representation of event-controlled activities in the assembly area (following Backes 1997, p. 119, modified)

The starting point of the simulation could be, for example certain, actual stress situations, which are determined with available or yet to be conceived work analysis procedures. The subsequent

simulative stress prognosis then considers, for example work organizational or technical changes to the work system as planning scenarios and the resulting stress situations can be investigated in a computer model. Not only the stress situation of an individual worker or workplace can be forecasted with such a procedure, rather also an entire work area or work group. In this manner overloading of individuals can be determined and offset with appropriate measures (e.g. with change of personnel assignments). The procedure could support the planner with hints as to which elements in the work system have been changed, and in what way, in order to avoid critical stress situations.
A correlation between a simulated event and the executed activity can occur as illustrated in Figure 2. In an event-oriented system structure the system state remains constant between two events. For this reason it is know immediately after an event which events will occur next. These can be administered in a list, which assumes the timing. The activities 1-4 represented here, each terminated by two events, make up Process A, which is followed by Process B etc.
Each activity can then be assigned to a defined combination of stress factors. The resulting worker stress can be ascertained and transferred into an appropriated assessment scheme. A stress prognosis for an individual worker and a defined event timeframe can then be derived from this scheme (e.g. superposition, using a separate module). A subsequent assessment of the total stress of a worker can only be carried out in this manner to a limited degree since, for example the individual stress of a worker resulting from the stress factors and from personal and situational factors is not yet taken into account here.

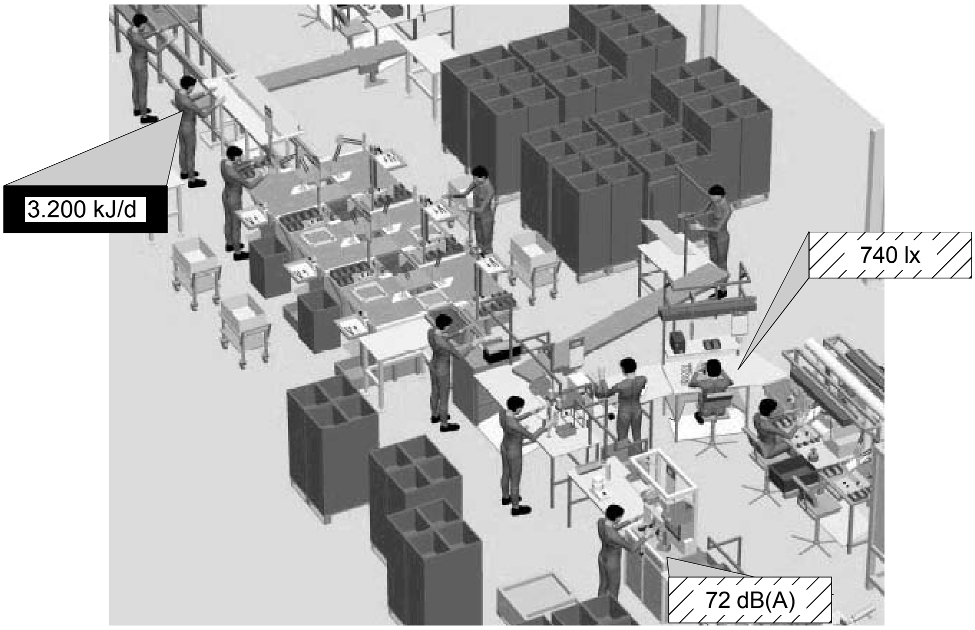

Figure 3: Stress levels in a 3D-layout-representation
(here ERGOMAS; following Zülch, 2000, p. 195)

The complete set of data required for a prospective simulation procedure is assuredly very complex, very difficult to acquire and must be continuously actualized after changes to the work and activity processes. The data material provided for this purpose can not only be used to describe the working conditions of the work processes, rather can also be prepared as an aid for the configuration of work systems or be made available as an information system. Generally, it seems feasible

that currently available logistic and plant management systems can be provided with this data material.
The visualization of this data requires a user-interface corresponding to communications ergonomic demands. One possible procedure is illustrated in Figure 3. As an example, the resulting stress for the workers from individual events, activities or even individual workplaces in connection with activities in an assembly area can be deposited in a 3D-layout of the area to be considered using a menu technique and, in an almost arbitrary manner, filled with further, relevant data. It must however be considered that, for example in case of the rearrangement of a machine in the shop floor, all measurement points need to be measured and entered anew. Experiences with computer-supported plant management systems show that the data administration associated with this type of data management entails large personnel expenditures. These expenditures are however justified when compared with the possible advantages from the examination of the simulation results.

4 Future Works

The solution elements of a simulation procedure presented in Figures 2 and 3 are only examples. Although this list is not exhaustive, a discrete event simulation procedure for worker stress assessment should support all of the following fields of functions:

- Simulation of work psychological stress factors,
- Simulation of organizations psychological stress factors,
- Planning-equitable visualization of the simulation results, and
- Representation of combined stress types.

The complexity of the models necessary for simulation-integrated prognostics increases dramatically with increasing number of stress types to be taken into account. Due to the complexity of the mentioned task areas some aspects of the following sub-modules should be developed in future:

- Consideration of pauses and operation time, simulation of the stress situation resulting from informational work content;
- Organizations psychological assessment with respect to the sequential completeness of work content;
- Assessment of time stress from tasks to be executed simultaneously.

5 References

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