Workshop-Based Work Systems Design

P. Nyhuis, F. Zoleko

***Abstract*— This paper discusses the prerequisites and pros and cons of applying a participatory approach to work systems design. The point of departure is the idea that conventional approaches are unable to equally accommodate the goals of economic efficiency and work humanisation Therefore the impact of the human factor is illustrated in the run up. The paper introduces a new concept for a 'Workshop-Based Design of Work Systems' that is founded on a participatory approach. This approach aims at combining advantages of expert- and worker-based approaches and promoting synergy between workers of different hierarchical levels. The implementation of the concept at a car manufacturer is illustrated in a case study.**

***Index Terms*— Ergonomics, Participatory approach, Production system, Work Systems design.**

I. Introduction

Germany's manufacturing companies are currently facing heavy competition from so-called 'low-wage countries' due to globalisation [1]. High labour costs, bureaucratic obstacles and an increasing number of older employees due to demographic change are disadvantages which must be counteracted with a high level of flexibility in production facilities, excellent product quality and work systems designs that are suitable for older people. As a result, manufacturing companies are under great pressure to adapt to this challenge by rationalising and by creating ergonomic work systems designs. An approach for designing work systems has been developped at the institute of productions systems and logistics. This new methodological approach is discussed in the following towards how to resolve the conflict between the goals of economic efficiency and work humanisation in work systems design. Examples from a case study done at the foundry of a German car manufacturer will illustrate the new approach.

II. The Human Factor in Work Systems

In industrial production, human labour is done in so-called socio-technical systems. A socio-technical system is one in which humans, machines and organisation cooperate to manufacture products.

Humans are in the majority of cases the most efficient element of the work system [2, 3]. The five main characteristics of humans are: independence, flexibility, creativity, skills and expertise.

Because humans are able to think independently, they are capable of taking initiative and setting other inactive elements within the work system into motion. The flexibility of humans is an advantage when there are jobs to be done with different content. Human labour is usually needed when technology-oriented planning has reached its limits or has failed. During a cycle of problem solving, workers' creativity can be optimally cultivated provided there are favourable conditions. Thanks to their professional performance skills and expertise, humans are able to perform their tasks effectively while functioning as 'dynamic knowledge data banks'. Their knowledge and experience helps them to find the best way possible to perform a task. In an open, communicative corporate culture, this knowledge and expertise can be profitably utilised for work systems design and/or productivity and quality improvement.

III. Analysis of Conventional Approaches to Work Systems Design

There are many approaches to designing work systems and processes in operational practice. What is decisive for successful planning, however, is choosing the right methodological approach. The objective of applying a certain method is to systematically and methodically support planning activities and gain objective planning information [4].

Conventional methods can be categorised into 4 main types that will be described in more detail below (see Figure 1).

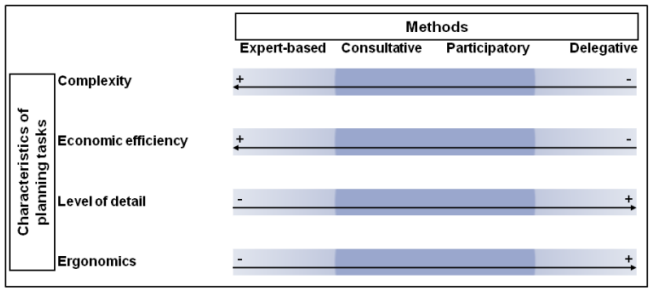

Figure 1. Analysis of conventional approaches to work systems design

Both expert-based and consultative methods are commonly used by management. In general the more planning tasks are complex and economically relevant, the more these methods are used (see Figure 1). Typical expert-based methods that are used in operational practice are simulations [5]. These design measures focus mainly on the best possible implementation of technology. They regard the human production factor as a 'black box' because of human quantitative availability and human skills are therefore not taken properly into account. In consultative methods, at best workers may be asked to suggest their own ideas for solutions. Experts, however, reserve the

Manuscript received September 4, 2008.

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right to pick and choose from workers' suggestions and requests.

The advantages of these methods are that designs can be developed quickly and projects can be managed relatively easily. The main disadvantage is that experts tend to rely heavily on figures and limits when designing work systems. Several research and consultative studies have determined, however, that workers were not always able to perform required work tasks without physical pain even when the legal limits and limits determined by natural sciences were observed. This can be explained by the fact that the physiological tests used in most simulation programmes are done a bottleneck-like manner and can only incorporate a single stress factor on a single affected bodily system or organ. Another disadvantage of this method is the potential resistance of workers who are also not very willing to make changes and cooperate with implementation.

Many examples of participatory work systems design can be founded in operational practice [6, 7]. The delegative approach offers more participation by entirely allocating planning tasks to workers. Participatory as well as delegative methods are commonly used, when the planning tasks need a high level of details or for ergonomicals issues (see Figure 1).

The greatest advantages of integrating workers into the designing and organising process can be divided into two categories: economical and human advantages. From an economic point of view, worker participation relieves indirect production areas and specialist departments from planning tasks and allows workers to react more quickly to disruptions. The otherwise unused potential of workers is activated and can be utilised effectively. This gives the organisation more flexibility. From the human point of view, this process promotes the development of skills and expertise in the long term. The designing process lends a variety to the tasks that must be done, allowing workers to develop their personal and professional skills. These advantages are mostly a benefit to the planning process itself. Participation ensures that the input values remain dynamic, meaning workers monitor the relevance and content of incoming information for the planning process and can make adjustments accordingly. In regards to 'lean planning', the workers affected are also integrated into the planning process and are best able to identify the types of wasteful spending and to suggest suitable solutions [8]. A case of 'over-planning', for example can be identified by workers by the amount of unnecessary detail and be eliminated early on. Finally, when involved in the process, workers are more willing to accept the planning results, which increase the likelihood of smooth implementation. The disadvantages are that this method requires greater effort for reaching an agreement and more time for planning.

Although the advantages of integrating workers into planning are well-known, there is a lack of design guidelines and experience with the actual procedure and the potential stumbling blocks that may be encountered along the way. These and other problems with this method are discussed below.

IV. WORKSHOP-BASED WORK SYSTEMS DESIGN

The 'workshop-based work systems design' is a methodologically participatory approach to work systems design. The primary goal of the approach is to effectively combine the knowledge and skills of experts and workers as well as to utilise the synergy between workers from different hierarchical levels and planning units. The approach is based on using a workshop for generating designs. It is best suited for projects to reorganise production areas. How often and how long the workshop should meet is dependent upon several different factors, such as the degree of planning task complexity. Generally, workshops can last from a minimum of half a day to a maximum of three days. Practical experiences with transfer projects offer additional proof of the necessity of engaging an external and independent process consultant for workshop moderation. This process consultant should have excellent skills that allow him or her to find a balance between expertise and independence while holding the workshop. As an expert, he or she must integrate his or her own expertise and experience into the planning process in an efficient manner, while at the same time, as a moderator, he or she must also observe, assess and shape group dynamics to create the best possible atmosphere for dialogue.

The workshop-based approach to work systems design that has been developed can be broken down into 8 steps or phases (see Figure 2). These steps are discussed as follows.

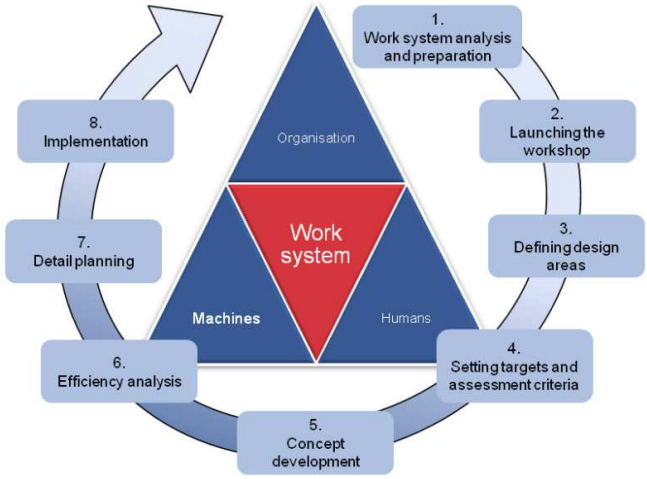

Figure 2: Workshop-Based Work Systems Desgin

A. *Work system analysis and preparation*

For this approach, a comprehensive work system analysis is necessary. The areas of potential optimisation in the work system are identified with the help of interviews or computer-assisted assessment tools. The collected data is evaluated and analysed, consolidating the information that is especially relevant for planning. The work area analysis also defines the basic conditions and determinants of the planning process. These can be divided into the categories of product, production, workers and organisation.

Organisational measures are a decisive step in the preparation phase. They include, for example, the moderator agreeing on a time for the workshop with a representative from the company and/or work area in question. The project team should include workers from every necessary planning unit so that different interests can be taken into account.

The project team should be limited to a maximum of 12

members for it to be most effective and efficient. For the duration of the workshop, the company's hierarchical structures and other external restrictions should be ignored. Organisational tasks, such as setting up a room and inviting representatives to join the workshop, should be left to the company or team representative.

B. Launching the workshop

Before kicking off the workshop, organisational matters must be addressed first. How long the workshop should last should be determined, for example. It is also important to go through the checklist of required data to ensure that, for example, planning input such as the production schedule is available. In order to bring all participants up-to-date, a presentation of the analysis results has proven to be a tried-and-true method. Participants are thus better able to focus on the chosen design areas.

C. Defining design areas

During this phase, the workshop identifies the areas of the current work system where improvement is needed and thus designates the design areas. Based on the results of analysis, a list is drawn up of the designated problem areas. What needs to be done in the work system is determined by categorising problem areas according to priority. Typical design areas are operational areas in the workplace and transport and materials flow. It is recommended that these designated areas be discussed within their own workshop sessions. Problem areas, however, should also be looked at from a holistic point of view. Their causes should not only be analysed in their local context, but in connection with other design areas so that the system can be improved as a whole. High throughput times, for example, are not only caused by long processing times, but also by long transport times. For this reason, not only should processing be improved by redesigning operational areas, but transport routes should also be reduced by reorganising the materials flow.

D. Setting targets and assessment criteria

During this phase, relevant targets and assessment criteria are established for the design process. Work humanisation and economic efficiency aspects of the developed approach are also brought to the fore. Projected goals should not only focus on what needs to be done but should also incorporate the work area's and the company's future targets, for example product quality improvement. Setting goals should follow the SMART rule, meaning goals should be Specific, Measurable, Achievable, Realistic and Time-bound. Quantifying targets especially makes it possible to assess solutions in terms of being able to achieve goals.

So that later design variations can be considered, assessment criteria should be determined. These criteria should be divided into two types: economic and human criteria. Economic criteria, such as efficiency and good part output, can be used to assess the organisational potentials of a work system. Human criteria, such as aspects of ergonomics and communication, can be used to evaluate the ergonomic work systems design. It is important to keep in mind, however, that it is not possible to establish universal criteria for all design areas. For this reason, new criteria should be determined for each particular design area. It is recommended that criteria be selected in agreement with all workshop members. This ensures that the final designs will be accepted by all planning units. Furthermore, experience with transfer projects has shown that a maximum of 12 criteria should be selected for each design area because this has proven a reasonable number for comparing pairs.

Determining goals and choosing assessment criteria are vital for setting the course for the workshop, and potential conflicts may arise during this phase. Different groups will try to assert their own interests. It is the moderator's job to identify and react to problems quickly by applying the appropriate skills of moderation. Using cards for brainstorming has proven to be a useful tool for this phase. This ensures that everyone's voice is heard and counteracts the dominance of certain workshop participants.

E. Concept development

To develop a design concept is to provide the basic conceptual framework for each design area. In this step, constructing a design should rely on the principle of establishing variants [9]. This means that participants should not latch onto the first best solution, but should try to maintain an overview of all potential solutions for a design area.

In order for a design to be successfully developed, two things are required: a constructive exchange between workshop participants, and the use of different tools of visualisation. When trying to come up with ideas, several techniques, such as cards, call out lists, Flashlight and mind mapping, can be used. These techniques encourage participants to interact with one another. The workshop moderator should also have enough experience and 'craftsmanship' to be able to choose the best tool.

The different solutions are discussed with the help of visual tools. In the workshop approach, the moderator can draw with felt pens on flipcharts or use the Office Visio programme. In practice, other visual tools, such as planning tables and cardboards, can be used [6, 7]. The moderator's job is to select the best possible methods of visualisation for planning tasks in advance of the workshop.

F. Efficiency analysis and reaching a decision

In order to decide which alternative is an adequate solution, it is useful to conduct an efficiency analysis of each alternative. The first step is to enter the defined assessment criteria in an Excel tool designed for this purpose. This tool allows the possible solutions to be judged according to the defined criteria. The design with the highest per cent score is favoured.

Although this tool is undeniably useful, it is never superior to the group's decision. Should the majority of participants be against the favoured solution, further alternatives may be discussed. This means that the planning steps C to F should be repeated before continuing to detail planning.

G. Detail planning

The goal of detail planning is to work out all the concepts within the favoured alternative and to make it a design

solution ready to be implemented. During this phase, constructional and technical restrictions are given special attention. In ergonomic work systems design, the interface between human and workplace is designed in detail. The design of operational areas should be based not only on industry standards (DIN EN ISO 6385), but also on the actual conditions of the work area in question.

H. Iplementation

The basis for implementing the design is the plan of action established in the workshop. Emerging tasks, necessary strategies of cooperation and intersections are also identified and dates are set. Detail tasks such as scheduling work shifts and training sessions should be allocated to production workers. This ensures that they identify themselves with the planning results and are willing to carry through with implementation. Specialty departments should function only as consultants. The work area leader, and/or team leader, should also support the workers while monitoring the progress of implementation and also serve as a mediator when necessary.

V. CASE STUDY

The following operational experiences with this approach are taken from a project carried out in cooperation with a German car manufacturer. The context for the project was to reorganise manufacturing processes in the company's foundry because the price of raw materials and competition had risen sharply. Another reason the project was done was workers demanded the optimisation of ergonomic work systems.

A work area analysis was done in cast core production, and several aspects where strain was put on workers and their health was endangered were identified. Cases where the physical strain of static and dynamic muscular work, short work cycles and harmful posture played a role were especially singled out. Analysis was also done on materials flow and flow of economic values and it was established that there were high levels of work-in-progress and long, overlapping walking and transport paths. In the workshop, the ergonomic design of work stations, the handling and transport processes, and maintenance processes were identified as design areas. Another design area was the work area layout. An individual workshop session was organised for each design area. The work area leader, team leader, works council representative, planner, representatives from surrounding work areas and group spokespeople from all three levels were on the project team. Improving productivity and quality were set as the highest project goals. Designing a work area in cast core production that would meet the challenges of demographic change was also set as a goal. The assessment criteria included, for example, reducing walking distances and the amount of multiple handling in order to make transport processes more ergonomic. To generate new ideas, the workshop relied mainly on cards and call out lists as tools.

After conducting an efficiency analysis, the favoured designs were handed over to the production groups for the detail planning. For this purpose, a comprehensive plan of action was drawn up. The planning unit / department offered its support to the production groups as consultants. The head of the work area, the team leader and the group spokesperson formed the monitoring committee.

VI. WEIGHING THE ARGUMENTS

When weighing the arguments and insights gained from previous transfer projects, the limits of the developed approach become clear. There are arguments both for and against the 'workshop-based work systems design' as illustrated in Figure 3.

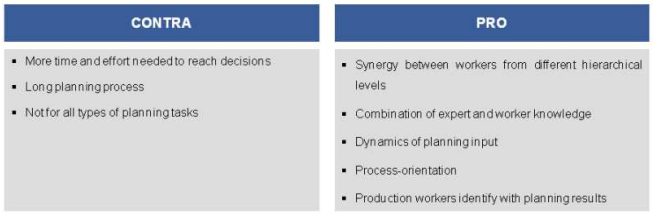

Figure 3. Weighing the arguments for and against the new approach

The advantage of utilising the synergy between workers from different hierarchical levels is listed next to the disadvantage of needing more time and effort to reach agreements during preparation and implementation of the project. Setting time frames is especially difficult in practice. The approach also demands that the moderator have in-depth knowledge about the work system that will be designed. This means conducting a thorough work area analysis before leading the workshop. The argument that the workshop combines the knowledge and skills of both experts and workers must be weighed against the argument of employing an experienced moderator. In order to lead the workshop, the moderator must have flexible skills. On the one hand, he or she must serve as a consultant with expertise knowledge about the work systems to be designed, while on the other hand, he or she must also be able to assert these ideas while also acting as a moderator. The moderator's expertise should also be reflected in the planning results. The dynamics of the planning input, which ensures the up-to-datedness and completeness of the information required for planning, is decisive for the quality of planning results. However, this argument begins to lose relevance the longer the planning process takes. The approach presented is characterised by its high level of process-orientation. This is what allows the approach to be holistic.

The limits of the approach become clear, however, when looking at the system as a whole because it cannot be applied to all planning tasks. It would not be possible, for example, to create a detailed design for complex and highly technical production systems with this approach because that would exceed its time limits and organisational capacity. This type of planning would additionally be inefficient in terms of time and organisation. The key advantage to this approach is that it lets workers identify strongly with the planning results. It increases their motivation and helps prevent friction when the design is implemented. The counterargument is that no proven results exist regarding the relation between worker motivation and a long-term increase in productivity.

VII. CONCLUSION

The hypothesis this paper set out to prove was that

achieving a balance between human and economic criteria in design can best be done by using participatory methods.

At the Institute of Production Systems and Logistics, the concept of 'workshop-based work systems design' as a participatory approach has been developed. The primary goal is to effectively combine the knowledge and skills of both experts and workers and utilise the synergy between workers from different hierarchical levels and planning units. This approach offers a solution to the conflicting goals of economic efficiency and work humanisation by allowing workers and managers to agree on the targets and assessment criteria for new designs together. It also shows how worker participation and lean planning can be combined to improve the quality of the planning process. In presenting this method a categorisation of conventional approaches to work systems design according to type has been done.

Finally, previous experiences with transfer projects were discussed in a case study in order to provide guidelines for design planning and to increase awareness.

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