

# Reduction of ergonomics design flaws through virtual methods

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*A work method for product and production system development that includes virtual methods for ergonomics analysis is presented and argued. The proposed work method is described and illustrated with an example, which the authors believe shows how a virtual work method can contribute to a better workplace design, and thereby, if utilised, would have prevented some of the design flaws that existed in the actual final product design in the example. This paper will also present the outcome, gain, and setbacks that are connected to the use of virtual work analysis methods within a design process.*

*Ergonomics Simulation, Virtual Methods, Ergonomics Analysis.*

## 1 Introduction

Within industry today the access to physical mock-ups, such as product prototype and manufacturing equipment test rigs, is becoming more limited due to time and economic reasons. This, together with the fact that there is a constant need to reduce the development cycle without sacrificing the performance and quality of the products and production systems, calls for a change in the development process where virtual reality and simulation are important contributors, and sometimes even the only option, for performing analyses of the products or systems being developed (Cohen et al. 1996). A development process that includes simulation can support the design of an ergonomic workplace through early assessment of ergonomic conditions. This calls for an established work method for ergonomics simulation.

The product realisation process in modern industry is typically very complex, with a lot of issues to consider before finding the best balance between the full range of value adding characteristics, and the process is normally constrained by tough time and cost restrictions. As a result, marketing, product and manufacturing development activities must be performed efficiently and the money put where it is most beneficial.

In the product realisation process work, two things cause large costs. One is the product realisation process itself, strongly influenced by the Time-To-Market span. Another major expenditure is the cost of building physical mock-ups. In addition, the quality of the outcome of the realisation process, i.e. the product, naturally has a major effect on a project's economic return. Common approaches to increase efficiency of the product realisation process are to carry out activities more or less parallel, to work in cross-functional teams, and to employ methods that support Right-First-Time outcomes

(Rauglas 1998). The costs and effort required for design alterations are moderate at early development stages compared to design changes later in the process, which are typically expensive, time consuming and complicated to handle (Ullman 2003).

As a result, simulation is intensively used in industry to uphold profitability and competitiveness by reducing development time and cost and by promoting product quality. This means that expensive, inflexible and time-consuming physical mock-ups are only built towards the end of the development process. Thus, the ability to evaluate a design from an ergonomics point-of-view in a virtual environment has become vital to reduce the risks of time consuming and expensive iterations, or products that do not meet the full ergonomics specification (Porter et al. 1994; Landau 2000; Chaffin 2001).

## 2 Objectives

The objective of this paper is to present and advise a work method that can reduce the risk of design flaws from an ergonomics point-of-view. The work method is essentially based on a pro-active approach towards ergonomics, where ergonomics simulation is utilised in an early stage of the design process. The work method has been proven very successful, at the company linked to this research, in at least three industrialisation projects where it has been used as a tool for evaluating work place designs. A common result from these projects is that the work method assisted in the identification and illustration of ergonomics problems in the production design, which could have led to reduced system performance of the production plant (poor ergonomics, quality and profitability), should the design had been approved. General processes – work methods – for human model analysis have been proposed by both Green (2000) and Hanson (2004).

In order to illustrate the work method, and also to show that the method is applicable in other areas, the following section presents a basic case study where the work method is employed in the ergonomics evaluation of a desk.

## 3 Work method and case study example

This ergonomics evaluation example includes a work place that can be used in a public environment, e.g. as a newsstand (Figure 1).

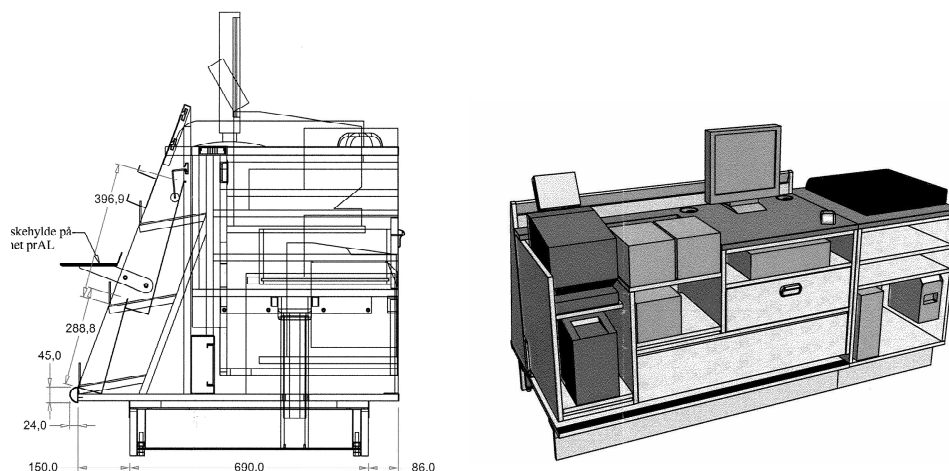


Figure 1: The work place design (Pictures courtesy of Ole Broberg, Institut for Produktion og Ledelse, Danmarks Tekniske Universitet).

The aim with the case study example is to find out if it is possible to discover ergonomic problems already at the design stage, instead of finding them when evaluating the physical product. It is important to stress that there are parameters in this evaluation example that are not considered. An example of such a parameter is frequency, i.e. how often does a person use the equipment in the work environment. This is of great importance in a real analysis, but is excluded here.

The evaluation was conducted according to the proposed work method (Figure 2) which is divided into three different phases where part of phase two and phase three are of most interest in this case study. The different phases are:

1. *Preparation of the virtual work environment.* Includes “Problem Formulation” to “Program Devices”
2. *Analysis,* divided into 2a) Run simulation, and 2b) Run analysis. Includes “Run Simulation” to “BUMS Analysis”
3. *Evaluation of results.* Includes “Evaluation” and “Documentation”

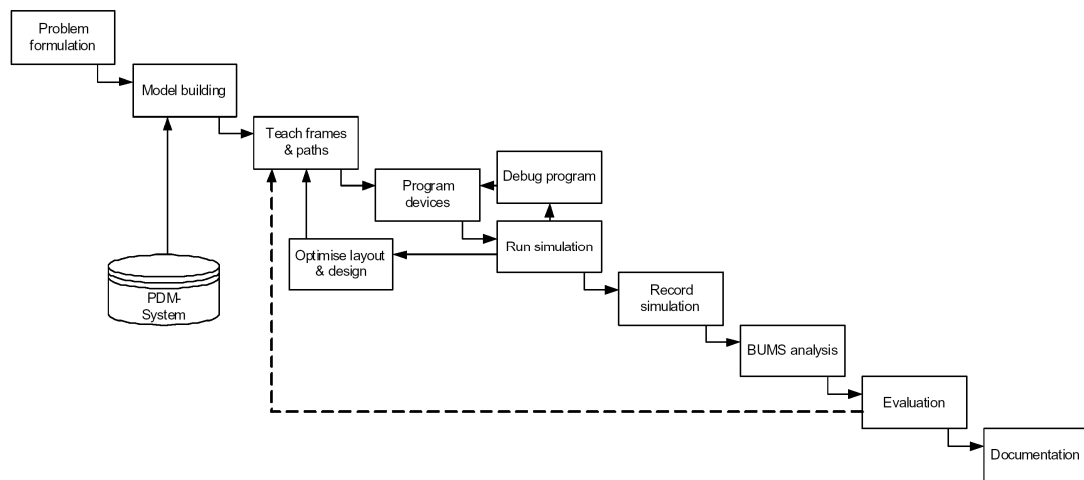


Figure 2: Work process for ergonomics evaluation in a virtual environment.

### *Phase 1 - Preparation of the virtual work environment*

The overall objective for this phase is basically to build the virtual environment, to define users and to define the tasks to be performed. This phase is typically controlled by a number of steering documents and regulations, e.g. related to ergonomics, layout and logistics. A conceptual workplace design model is created based on these regulations together with:

- *Product:* Desk, Newsstand, Computer etc.
- *Process:* The process controls how a task should be performed but also how it might be performed. For instance, available lifting aids may not always be used in practice.
- *Resources:* Computer manikins.

### *Phase 2 - Analysis*

The analysis method used is basically the same as for the analysis of physical objects. A Microsoft Excel sheet is connected to the simulation software, which makes it possible to export analysis results from the virtual environment in real-time to the sheet. A

simulation engineer conducts a number of analyses with different manikins, different product designs and so on. The main objective for this phase is to generate analysis results in an efficient manner so that as much time as possible can be spent on the actual evaluation work in later stages.

### *Phase 3 - Evaluation of results*

The evaluation of the analysis results is done in a workshop with participants representing different competences and interests, e.g. ergonomics experts (EE), simulation engineers (SE) and representative workplace users. This workshop contains:

- Validation of model: Evaluation conducted by production preparation personnel and EE.
- Simulation walkthrough: Run simulation, Change postures etc.
- BUMS (a Swedish abbreviation for Saab's Ergonomics Strain Assessment Guidelines) analysis: From the problem definition the SE has prepared a list of different areas that should be of special interest in advance. A BUMS analysis is conducted, the result is discussed and snapshots are produced showing the analysis object.
- Discussions and decisions: The objective is to generate a suggestion/solution on how to use a possibility or how to solve a problem in the best possible way.

## **4 Case study results**

The results from the evaluation example gave that if the proposed work method had been used in the design phase, at least some of the problems with the work environment would have been found early on, and it would have been easy to modify the design to reduce or remove these problems. The results from the evaluation, from BUMS together with the visualisation, can easily be interpreted and give a clear view of the problems connected to the design (Figure 3).

Three main problems were identified and verified.

1. Neck: The bending of the neck.
2. Wrists: The wrist angle is exceeded according to the limits stated within BUMS. The wrist flexion/extension is more than 45 degrees.
3. Feet: The design of the stand makes it difficult to positioning the feet in a way that makes it possible to use the stand as a support while working with the computer.

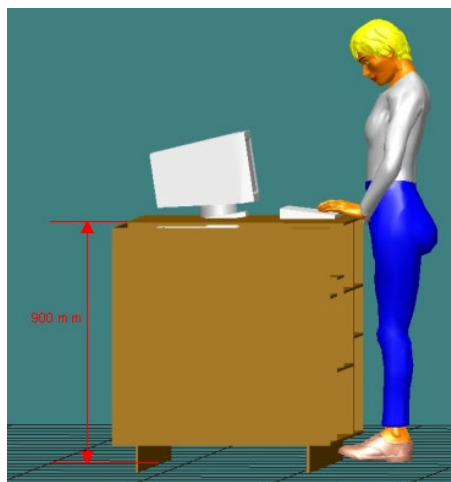


Figure 3: Visualisation of workstation.

The evaluation results led to modifications of the newsstand. These design modifications included two different heights: 800 and 1000 millimetres (original design, 900 millimetres). The evaluation of two new designs showed that the stand with a height of 1000 millimetres was the better of the two, for the studied tasks and population.

The results from the evaluation showed that there were problems connected to the original design and that it was possible to find and to support a redesign based on the outcome of the virtual evaluation. If an evaluation method had been used in the design phase of this stand, the input from this could have contributed to a much better design, and thereby to a better workplace. The impact of a bad design might make the difference between a good profit and an un-sellable product, in addition to the obvious disadvantages from an ergonomics point-of-view. Had the product been meant for mass production, the economical risk of not using a virtual method for product evaluation would be substantial.

## **5 Discussion**

A virtual evaluation can be a very time consuming process. The first phases described in section 3, "Preparation of the virtual work environment", is the main reason for this. There is more than one factor that influences the time it takes to create/prepare a virtual environment. Experience has shown that the DHM (Digital Human Modelling) tools are overly time demanding and the gathering of information for use in simulation tasks takes too much time with the effect that too few simulations are made. In some cases requests for simulation to support the time limited synchronous engineering loop go unsatisfied as decisions are made before simulations can be completed (Wegner et al. 2007). DHM tool activities are, of considerable extent, associated with communication, including different kinds of contacts and meetings, where there appears to be potential to increase efficiency with respect to communication. Integration of the tool into the organization, e.g. understanding the tool's desired input, possible output and analysis limitations, is essential for successful usage (Blomé et al 2006). DHM tools have improved significantly over the past 10 years, what has not improved is interoperability and consistency across tools. DHM tools must be integrated into the process tools, without this integration a fast and flawless transition of (3D) simulation data from one software to another, as well as easy CAD data importation, will be impossible to accomplish. There is a set of basic human function features that a DHM tool must include: anthropometry, biomechanical kinematic model, realistically posture/ motion manipulation, and several other features are required to properly and realistically simulate human activities. These include simple but realistic movement, body balance control, load exertion capacity, environment interactions, object grasping and carrying, field of view and advanced movement manipulation. (Lockett et al 2005; Wegner et al 2007).

## **6 Conclusions**

With the advancements in research and development of human modeling tools, the technology impact and potential is growing on a yearly basis. Increased industry and government investments in human modeling research and development are driven by

corporate vision to increase application and scope in virtual manufacturing resulting in decreased physical hardware builds, improved ergonomics and reduced costs. This is evident based on industry investment in virtual manufacturing tools and utilization by many companies of multiple DHM tool packages to address their increasing scope of applications.

## **7 Acknowledgements**

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