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A tool to assist and evalute workstation design

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It can be argued that it is common that industrial workstations are "built" rather than purposefully designed with user and task requirements in mind. Afterwards, built-in problems typically need to be corrected, causing undesired costs and efforts. With the objective to assist workstation designers in avoiding most problems already in the design phase, a design support tool is being developed. The paper argues the need for such a tool and presents the fundamental tool functionality. Expected advantages are more efficient and ergonomic workstations and a more efficient design process with built-in learning and documentation.

Keywords: Production, Ergonomics, Lean, Workstation, Design

Introduction

A workstation that is to be sold to a customer, e.g. the interior of a truck, has gone through a rigorous development process where ergonomics and attractiveness for the driver (the user) are major issues considered in the design process. However, when workstations in the plant where the product is built are developed, this is not the case. Studies performed within the research project reported here, show that these workstations are often just "built" rather than purposefully designed with user and task requirements in mind. Thus, it can be argued that it is common in today's industrial workstation design processes to adopt a machine centred approach, i.e. with focus on the technology or the workstation in isolation, rather than adopting a more systems oriented user centred approach. A downside of the current approach is that it is common that major problems with the workstations are found after they are built, e.g. when audits are carried out and workstations are evaluated in terms of ergonomics and lean production principles. This often leads to costly and unnecessary rework, which is a waste in itself according to lean production principles.

In the Swedish research project Lean & Green Production Navigator, where the work presented here is a part, initial observational studies at the collaborating industrial research partners were carried out. The studies, focusing on the design of current workstations and current processes for how workstations are being designed, gave that there were a large amount shortcoming of current workstation designs related to ergonomics and lean

principles, as highlighted by one of the collaborating companies' audit tool for assessing production systems. Also, the studies gave that several of the items considered during audits could have been addressed already at design stages.

Objectives

The objective is to develop a support tool (from hereon called *Workstation Design Navigator* or just *Navigator*) that assists workstation designers to work proactively with ergonomics and lean principles. The proactive approach aims at reducing total losses in production by supporting design of workplaces that meet ergonomics requirements and lean production principles already from the start. In general terms, losses are reduced by solving problems before they occur; thereby reducing the need for corrective measures.

The basic idea for the Navigator is that, if a workstation could be designed using a similar method as when designing a consumer product, where workers are regarded as users of the product, requirements regarding issues like inclusive design, ergonomics and lean production can be proactively addressed through guidelines and best practices from previous projects. Advantages would be a more efficient and ergonomic workstation, and a more efficient design process with built-in learning and documentation. The Navigator should help the designer ask the right questions, gather useful information, define requirements, assist in decision-making and support evaluation of goal fulfilment.

There are three major purposes the Navigator should fulfil:

1. Assist in creating workstations that offer better ergonomics and a more efficient production. The tool can be used both for developing new workstations or upgrading existing workstations.
2. Educate users: Novice designers will learn the process and learn from examples.
3. "Institutionalise knowledge": Any workstation designed or evaluated using the Navigator could be automatically documented so that successful designs can be reused for other workstations.

Methods

The underlying idea is to apply a product development paradigm to the process of designing workstations. Key elements in a generic product development process are: Identifying customer needs, setting requirements, generating and evaluating many alternative solutions (Ulrich & Eppinger, 2012). When designing a complex workstation, it is assumed that an efficient way would be to use "building blocks", i.e. successful examples from earlier solution principles, rather than creating and evaluating lots of alternative solutions for each function. Still, the design process in the Navigator is closely linked to a generic product development process. As seen in Table 1, the design process used in the Navigator has close similarities to both the LAMDA model (Ward, 2007) and the Design for Six Sigma model (DFSS) (Ginn et al., 2003).

Table 1: The Workstation Design Navigator process in comparison with LAMDA and DFSS.

LAMDA As described in Ward (2007).	**DFSS** Key items from Ginn et al. (2003).	**Design process in the Navigator**
Look: as in go and see for yourself.	**Define:** e.g. clarify expectations, identify risks.	**Step 1:** Understand the purpose of the workstation. Look for existing solutions.
Ask: get to the root cause.	**Measure:** e.g. understand the voice of the customer, prioritize requirements.	**Step 2:** Identify and talk to users to find their needs. Use the xPS Assessment method (further explained below) to set additional requirements.
Model: using engineering analysis, simulation or prototypes.	**Analyse:** e.g. identify key functions, generate and evaluate concepts.	**Step 3:** Create workstation designs. A database provides valuable examples from existing workstations.
Discuss: peer reviewers, mentors, and developers of interfacing subsystems.	**Design:** e.g. develop and test.	**Step 4:** Perform preliminary evaluation using xPS and discuss with users and experts.
Act: test your under-standing experimentally.	**Verify:** e.g. conduct and evaluate the pilot tests.	**Step 5:** Build the workstation or a prototype to test it.

A vital part of the Navigator is the use of xPS Assessment. This assessment method is a working material from AB Volvo, inspired by the Toyota Production System and the SwePS evaluation method (Harlin et al., 2008). The xPS Assessment is a combination of lean principles and the Volvo group's overall manufacturing strategies concerning human factors, material supply (internal logistics) and personnel strategies. It is used to analyse work procedures and workstations to see that they follow for example ergonomics guidelines and lean production principles. Each assessment item is given a maturity level score, from L0 (poor) to L5 (excellent), with clear criteria for each level. Some assessment items focus on work procedures in up and running production, and these were considered not applicable for proactive use in the design process. However, the fulfilment of many items can be enabled by a successful workstation design, such as: Health & Safety Risks, Noise level, How to handle and reduce waste and packaging, Station layout flexibility, Facade design, Tool/equipment handleability, Movement, Handling of heavy parts or tools, Assembly ergonomics, Space utilisation, Changeover time and Ratio of Value-adding work.

Results

The Navigator is still under development and has not yet been tested on representative users. The functionality as intended is presented below.

Step 1

At the start-up of a project, the Navigator assists in defining a framework for the project by providing a form for a "Mission statement" document. This

helps defining the purpose of the workstation as well as the expected outcomes of the project. The team is asked to identify existing solutions for inspiration. Stakeholders and their needs and expectations are to be listed in the mission statement, and assistance for that task is given by the Navigator in Step 2.

Step 2

In the process of identifying all kinds of users and their needs, the Navigator displays a matrix dividing users into four categories: *primary users*, *secondary users*, *side users* and *co-users*, as suggested by Janhager (2005) and on the other axis, the phases of the life cycle of the workstation are presented (Figure 1).

User type:	Role	Needs during Ramp-up	Needs during Normal use	Needs during Maintanence & Repair	Needs during WStn end-of-life
Primary user	Operator		Sven has problems gripping small items in bulk. Would like automatic feed.	Be able to access material to be able to continue working during inspections	
Name, who to talk to:	Sven, Fia	Eva (Ergonomist)	Eva (Ergonomist)	Björn (inspector)	
Secondary user	Maintenance			Easy access to compressor	Easy disassembly, prefer manual or no tools
Name, who to talk to:					
Side user	Next station	Does not interfere with workflow at next station			
Name, who to talk to:					
Co-user	Material supply				
Name, who to talk to:					

User needs at different times
Fill in each user's potential needs for each relevant stage/type of use for the workstation.
Eg. Primary users needs during normal operation

Figure 1: The navigator helps to identify many users and their needs at different times.

This is assumed to help the designer seeing the user in a broader context and identifying more stakeholders and needs. Also, experts that may assist in addressing the needs or issues can be listed, e.g. presented in the form of a simple to-do-list; "*Talk to* <person> *about needs concerning* <identified need> *during* <phase>."
The Navigator also provides functionality to identify the required "hardware" such as articles, tools and other equipment needed to perform the tasks at the workstation, as seen in Figure 2. After the articles to be assembled or processed are listed by the workstation designer, the appropriate task is selected from a list of value-adding and semi-value-adding operations (tasks that are not value-adding should not be built into a work-station). For each operation, a set of suitable tools are presented. For each tool, component or box, information about weight and size is planned to be included to instantly alert the designer if heavy lifting might occur and how much physical space is needed for the workstation.

Art.no	Component	Packaging	Operation	Tool	Media	Accessory 1
1	Nail X	Cardboard box	Insert	(Manually)	(Manual)	
2	Screw M8	Plastic box 700	Screwing	Pneumatic driver	Pneumatic	Spring balancer
3	Turbo	Pallet	Insert	(Manually)	(Manual)	
4	Nail		Hammering	Nailgun	eumatic	Spring balancer
5	Snap-on	Cardboard box	Insert		lanual)	
6	Metal plate	Plastic box 1100	Cutting		eumatic	
7	Bolt	Plastic box 900	Hammering		lanual)	

Hammer
Sledge
Nailgun

Figure 2: The Navigator helps identify components, value-adding operations, suitable tools and equipment.

The applicable xPS Assessment items are used proactively to create the list of requirements for the workstation (Figure 3). The reason for each assessment item is clearly defined, giving the designer a good understanding of the item and a sense of purpose for fulfilling the item by the workstation design. In cases where an existing workstation is to be improved, the assessment of current levels serves as a benchmark. Designers can discuss the desired level for each assessment item with management. The highest level might not always be the most suitable level to aim to obtain, since it may require not only investments but also organisational capability. In some cases it may even be unsuitable.
The selected levels are then compiled in a list of requirements, as seen in Figure 4.

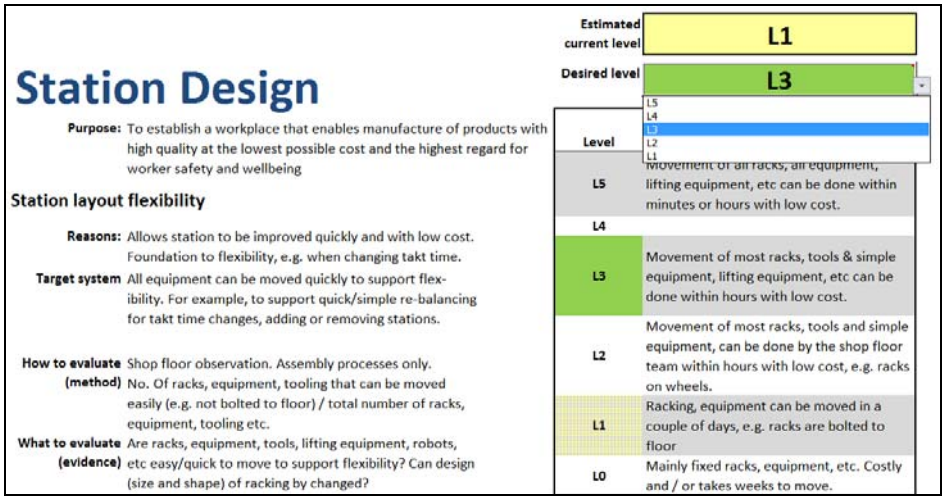
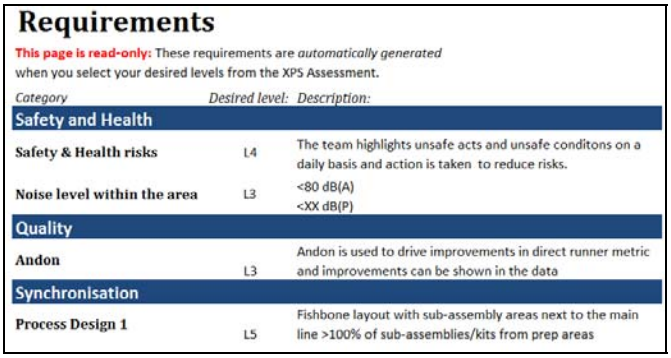


Figure 3: The xPS Assessment implemented in the Navigator lets the designer set a desired level for the new workstation.



Requirements

This page is read-only: These requirements are *automatically generated* when you select your desired levels from the XPS Assessment.

Category	*Desired level:*	*Description:*
Safety and Health		
Safety & Health risks	L4	The team highlights unsafe acts and unsafe conditons on a daily basis and action is taken to reduce risks.
Noise level within the area	L3	<80 dB(A) <XX dB(P)
Quality		
Andon	L3	Andon is used to drive improvements in direct runner metric and improvements can be shown in the data
Synchronisation		
Process Design 1	L5	Fishbone layout with sub-assembly areas next to the main line >100% of sub-assemblies/kits from prep areas

Figure 4: A list of requirements generated from the xPS Assessment.

Step 3

At present, the development of the Navigator has not yet reached this stage. The plan is that the Navigator should provide example solutions from a database of existing, successful workstation designs. The actual design phase would probably be the most difficult part to try to automate so the objective is rather on giving valuable assistance to workstation designers when utilising their creativity, competence and experience. However, with the use of examples and generated lists, images of all articles, boxes & tools are generated, meaning that even a novice designer can experiment with the workstation layout.

Step 4

For the evaluation of the workstation design, the xPS Assessment is used once again, as criteria in a concept selection table (Ulrich & Eppinger, 2012), where suggested design alternatives are compared to each other and evaluated against each other. If the solutions are chosen from the database of successful designs, all solutions for separate functions should meet the criteria, but all combinations might not work well together, hence the need to evaluate the full workstation. As seen in Figure 5, alternative solutions are evaluated based on how well they meet the criteria on a scale 1 (poorly) to 3 (excellent). The solution with the highest score for each criterion is visually marked to give a good overview, so that the best partial solutions can be combined in the final design.

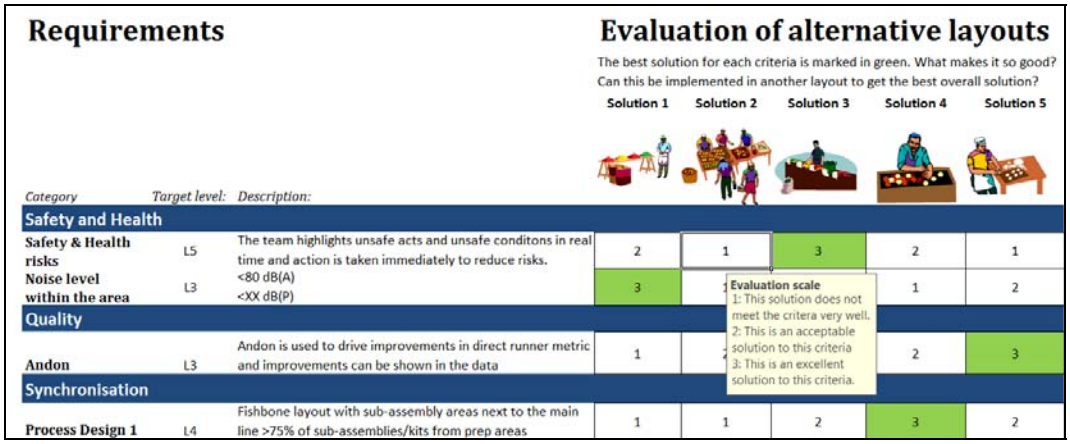


Figure 5: Evaluation of alternative solutions against criteria defined by xPS Assessment and user needs.

Step 5

At the final stage, a prototype or the actual workstation is built and tested. Activities related to the Navigator in this stage would be to add documentation such as pictures and comments on the results of pilot tests, so the workstation can be added as a successful reference when building future workstations.

Discussion

There is still much development and testing to be done before the Navigator can be released and put into practice. The activities described in the steps in the process are likely not going to be as strictly separated as described in this paper. To make the tool as efficient and rational as possible, some tasks will be performed concurrently. In creative phases in product development it is generally recommended to suspend judgement (Ulrich & Eppinger, 2012). This to avoid evaluating ideas while generating them since that may hamper creativity. However, when using existing "building blocks" and successful examples, it can be argued that the evaluation is actually performed at the same time as the examples are selected. Of course, solutions to all possible problems are not likely to exist in the database, in which case a more traditional process can be utilised.

At present, the Navigator is developed in spreadsheet software, since it arguably would be easy to implement at most companies; such software is widely used and programming and customisation is fairly easy. The database should help identify good previous examples of workstation designs; e.g. by letting the Navigator user make queries such as "I'm looking for a workstation that has excellent waste sorting" or "I need solutions for a workstation that uses heavy tools but with low strain on the user."

To take full advantage of this kind of database functionality and keeping it updated as new workstations are designed, a web-based database driven solution might be preferred. This however requires more expert knowledge and resources such as a web server to implement. Finally, there is always

the trade-off between ease-of-use and powerful functions. The Navigator has to encourage use, not deter users.

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