Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 41 (2016) 490 – 495

www.elsevier.com/locate/procedia

48th CIRP Conference on MANUFACTURING SYSTEMS - CIRP CMS 2015

Introducing customized ICT for operators in manufacturing

Magnus Åkerman[a,*], Åsa Fast-Berglund[a], Malin Karlsson[a], Johan Stahre[a]

a:Chalmers University of Technology, Gothenburg, Sweden

* Corresponding author: Tel.: +46729-636518; *E-mail address:* magnus.akerman@chalmers.se

Abstract

Higher complexity and increased global competition emphasises the need of flexibility for organisations in manufacturing. To achieve this puts challenges on todays manufacturing systems and the human operators doing the tasks. The use of Information and Communication Technology (ICT) as cognitive automation and to increase information sharing among the operators has been discussed as important tools to meet those challenges. A highly customized mobile application was developed at a large Swedish manufacturing company. This application has been introduced on smartphone devices to the operators in a manufacturing process. This paper presents empirical findings from the first year of this test. The study provides an example where information and communication technology have enabled manufacturing operators to perform new work tasks through increased trust and knowledge.

Peer-review under responsibility of the scientific committee of 48th CIRP Conference on MANUFACTURING SYSTEMS - CIRP CMS 2015

Keywords: Manufacturing; Flexibility; ICT; Cognitive automation; Information sharing.

Introduction

The reality for many manufacturing companies today is to produce with ever increasing variety and decreasing lead times. This dynamic environment leads to more complex products and production systems with increasing demand for product flexibility [1]. Much is still to be discovered in the inter-relationship of flexibility and complexity [2] and it's underlying uncertainty [3] but one important factor of achieving product flexibility is to enable the human operators to perform the complex work tasks these systems brings [4, 5].

In order to enable operators in manufacturing to do complex tasks they need to be empowered with the tools needed, such as technologies for information sharing and decision support systems [6,7]. Utilizing information and communication technology (ICT) for this could be a way [8].

There are many opportunities to increase the level of empowerment of the operators. In a previous study it was established that the operators handle less than half of the tasks without help from other functions or managers [6]. However, there are many things to consider when introducing new technology. It is important that the strategy for the cognitive automation is clear so that everyone understands what needs to be changed in the system [9]. Furthermore the organization does also need to change accordingly, new decision support technology might even have negative impact on the work environment, also know as a dysfunctional sociotechnical system [10].

A mobile application has been developed at a large Swedish manufacturing company targeted for the shop floor operators at different departments. This paper presents empirical findings from the first year of a test conducted in which this mobile application was introduced. The purpose of this study is to provide an example of how information and communication technology can enable manufacturing operators to perform complex work tasks.

Peer-review under responsibility of the scientific committee of 48th CIRP Conference on MANUFACTURING SYSTEMS - CIRP CMS 2015
doi:10.1016/j.procir.2015.12.074

Views on ICT usage

Cognitive automation

Automation, that is a form of self-activation, can be applied to both physical and cognitive domain. Physical automation takes control of physical tasks and cognitive automation takes control of cognitive tasks. The amount of self-control can be classified and measured through levels of automation [11]. Some classification models separate the physical automation from the cognitive automation [12-14]. Cognitive automation is the level of decision support or cognitive aid a human operator has access to while doing cognitive work.

Information sharing

Cognitive automation can definitely be seen as a form of information sharing, especially when used as cognitive aid such as instructions for new work tasks. Information and communication technologies can also be used to aid more informal channels of information sharing. This happens through formal and informal meetings between people that could be more or less separated in time and space [15].

Case description

Overview

Several departments are included in the company's still on-going test but the study presented here is limited to one. The department is divided into five shifts with five to six operators in each shift and they work both day and night. It is a highly automated and large facility and the tasks include loading and unloading products, do quality checks, monitor machines etc.

This study is done as a part of a larger project with the aim to map what manufacturing operators need in terms of information and communication. That project has fed the company´s mobile application implementation project with information regarding these needs. Within the overall project previous studies have been done at the department in focus including interviews and a usability test considering the specific work task preventive maintenance [16]. The first version of the application was released and introduced to the operators in November 2013 and this study followed the test for one year. Each shift received smartphones that were dedicated to individual operators but they had to be shared between the shifts.

ICT

The ICT examined in this study consists of smartphones with a customized mobile application installed. The application was developed with the operators specific needs in mind with input from the research project described above.

The ICT can be divided into different functions, see Table 1, that is divided into how customized they are towards specific operator work tasks. Smartphone functions are the most commonly known functions that can be expected in any smartphone today. The application has been developed with several departments in consideration and some functions are generic to any operator and some are purposely designed towards a specific work task.

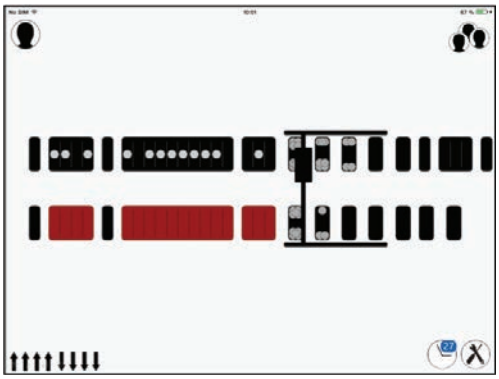

Fig. 1. Screenshot of production overview with alarm information.

Table 1. ICT functions analysed in this study.

Function	Type
Phone calls	Smartphone
Camera	Smartphone
Disturbance reporting	Generic
Chat	Generic
Work instructions	Generic
Production overview with alarm info	Specific
Preventive maintenance checklist	Specific

The production overview is designed like the real factory layout, a screenshot can be seen in Fig. 1.

Method

Both qualitative and quantitative data have been collected and analysed. The qualitative case data was collected using semi-structured interviews and surveys. Some of this information was gathered in June 2014 but most results are from November 2014. The quantitative data consists of log information from the databases that form the back-end structure of the information system and other already existing databases.

Results

This section presents important results from the interviews, surveys and databases.

Interviews with operators

Ten of the operators at the department were interviewed at the end of the study period. The results have been analysed by classifying their answers into the five categories: communication, information, preventive maintenance, usage, and work situation. Each of these categories were further

divided into three subcategories and each comment or respond where assessed whether it was positive, negative, neutral, or a suggestion for future change. The results regarding communication and information are presented below in Table 2 and Table 3.

Table 2. Interview responses regarding communication.

Communication	Comments or responses
How, meetings or using the tool	3 suggestions, 1 neutral
Smartphone functions	4 positive
Disturbance reporting	6 positive, 2 neutral

Table 3. Interview responses regarding information.

Information	Comments or responses
Work instructions and problem solving	5 suggestions, 4 positive
Content update and trust	1 suggestions, 5 positive, 1 negative
Information access, mobile information	2 suggestions, 4 positive, 3 neutral

Examples

Here follows a few examples to show typical responses or comments.

Interview nr 1
"What is missing today is that there are to few instructions in the application."

Interview nr 3
"It is difficult to post instructions because the error signs might look the same but the solutions might differ."

Interview nr 6
"Disturbance reporting is the best function."
"I have used a work instruction once and that helped me."

Interview nr 7
"Sometimes, when I have to call the technicians about an alarm, they ask me to describe it. With the smartphone I can take a photo and send them."

Interview nr 10
"I would like to be able to fill in measurements, or get help with priorities, or simply see what we are supposed to take 'incoming products' so that we don't forget anything."

Interviews with department manager

The department manager was positive towards working with the mobile application, especially after some time since some visible changes had been observed. Some general statements are presented in Table 4 grouped by the function discussed.

Table 4. Department manager interview.

Information	Comments or responses
Phone functions	*"I use the phone function directly to the operators phone, it is easier to get hold of the correct person that way."*
Instructions	*"There aren't many instructions yet but there seem to be a high demand for it, I'm waiting to see exactly what they want."*
Disturbance reporting	*"There aren't many instructions yet but there seem to be a high demand for it, I'm waiting to see exactly what they want."*
Preventive maintenance	*"More people do this task now, this provides a better 'feeling' for the process"* *"More smaller disturbances are reported now"* *"We have added some checks that technicians used to do. The operators have received more responsibilities since we can trust it will been done"*
Overview and alarm information	*"I use this all the time since I'm not always on sight"*
Other	*"In general we have become better at reporting things in almost all other, already existing, computer systems"*

General usage

Information from interviews and plain observation shows that not all operators did use the smartphone or the application. In Fig. 2 a graph displays unique logins of the application, the numbers are normalized but show that usage was rather similar during the test except during the summer vacation period.

A survey was issued at the end of the study period and from 21 respondents 20 claimed to have used the smartphone with the application to some extent.

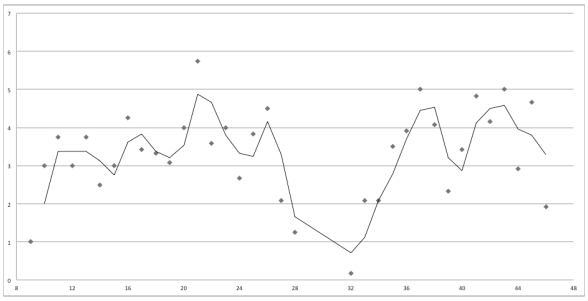

Fig. 2. Normalized values of unique weekly logins, the line shows moving average based on two previous values.

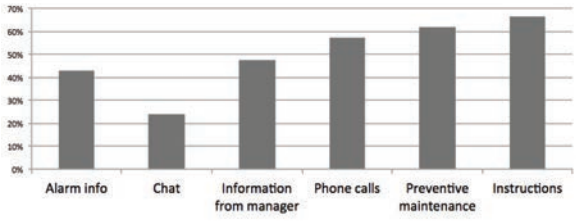

Fig. 3. Operators' own assessed usage of smartphone and mobile application according to the survey.

Function usage

It is not possible from the data to tell exactly to what extent the operators used each of the functions. However, a self-assessment of their usage was part of the survey. Fig. 3 shows the result to what purpose each operator used the smartphone. Unfortunately the questions in the survey does not map exactly to the functions, which is because the authors overall assessment have changed during this study. E.g. the function 'disturbance reporting' is represented in a mix of 'information from manager' and 'chat'.

Disturbance reporting

The function disturbance reporting can be used to post generic information about current events either connected to a specific machine or as a generic post. The operators preferred to use the generic type and the number of posts has actually decreased over the time period (Fig. 4). From the interviews it became clear that most reports in this tool came from a few dedicated operators.

Error reporting

This section regards the error reporting done in the computer system that existed before the mobile application test. It is the official channel between the department and the maintenance staff. For this manufacturing process error reporting is considered very important. If problems are found early they are easier to fix and, more importantly, they might not lead to breakdowns. Breakdowns must be avoided since product might be ruined and it also stops production for the entire production chain. During the test period the number of error reports in the database showed a quite dramatic increase as seen in Fig. 5. The numbers are normalized with the index one being the first value.

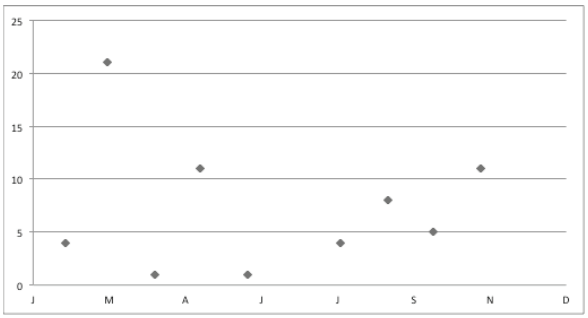

Fig. 4. Generic posts in the disturbance reporting function.

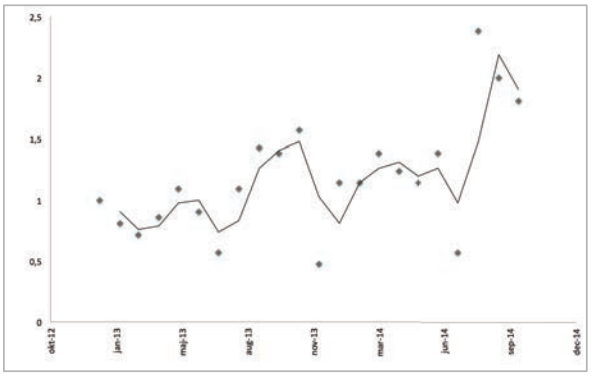

Fig. 5. The number of error reports in the database over the year (normalized values), the line shows a moving average of two previous values.

Discussion

Overview of the results

It is important to remember when assessing the results that the department that has been part of this test and target of this analysis has is under development. That being said the more general process changes are considerably slower than the observed changes. The fact that not everyone used the smartphone is also important to consider, even if it not necessary change the validity of the result. It is an interesting result of it's own that should be examined further in another study. Especially why some operators did like everything about the concept but still choose not to take part of it.

Cognitive automation

Most of the work in the manufacturing process is to monitor machines and respond to alarms. There are some tasks in the process where the mobile application could serve as cognitive automation that has not been included yet. Loading, unloading and measuring products are manual tasks that could be in need of some information or decision support and the operator in interview number ten even asked for functionality regarding measurements.

The specific checklist function designed for the task preventive maintenance was apparently a very successful example of cognitive automation. That was hardly a surprise considering previous tests [16] and the fact that after some

time it was no longer optional to use the application when doing this task. The cognitive work that the operator gets help with are what checks to do, how to do them and a validation function that a check has been done.

The instructions that are part of the checklist together with the fact that more operators are doing this task seem to have aligned the operators at a higher level of understanding of the process. The department manager states this in the interview but more importantly this is shown in the number of error reports found in the error report system. It could be considered a problem that the amount of error reported suddenly peaks but the number of real machine problems have not increased it is simply due to the fact that the operators now reports what they always should have done.

The validation of the checks, that is natural part of the mobile application since you have to mark them completed, is a direct control function. This control did actually exist before within the process because everyone knew that preventive maintenance was supposed to be done according to protocol and that included writing every deviation down and then report it immediately after the round. Making this checklist mobile reduced the number of steps from spotting the deviation and writing it down and it also forced the user to confirm each check. The interesting impact of this control, or validation, increased the trust between operators, technicians and managers as can be withdrawn from the interviews. As a result of that trust some preventive maintenance tasks previously done by technicians was moved to the operators normal routine. The reason for why this specific function was so effective and immediate should be connected to the extensive amount of preparation and the clear goal to what problem it was aimed to change [17].

The overview function with alarm information did serve the purpose of being more mobile than the HMI's found on the machines. The level of usage and the comments also shows that this function did not provide much of extra value to most operators. For some operators, the technicians and the department manager the mobility of the information was more valuable since they are not always in the facility.

There is also a more general function for work instructions that could have been utilized for various tasks. For this department that function was not extensively utilized during the test but it shows potential considering many operators asked for more instructions to choose from.

Information sharing

The disturbance reporting, that function like a form of newsfeed, have provides some good examples in this test. Several operators and the manager have exemplified how it has been useful for them. This function is likely a part of the explanation to how the general process knowledge has increased. Someone can raise issues that other might never have considered or dared to discuss. One problem that was brought up was the level of usage. That is naturally always an issue regarding information sharing, people must be willing to share their information and to use the tools available for it.

Regarding the normal smartphone functions the results are less decisive. One reason for that could be that these tools are so common nowadays outside the work situation that they are simply taken for granted. In that case their benefits are probably more important than what this study can claim from the data. The department manager states that having dedicated phones helps reaching specific operators faster. Among the operator there have mostly been more generic positive remarks about these functions. The exception is from interview seven with the example to use the camera when explaining a specific problem.

Other

As a generic problem that was raised form several operators was the question about the content and usage. A question can be asked if the specific tool is not designed according to it's users and purpose [9] or if the processes haven't been considered or changed according with the introduced technology [10]. A clue to the answer can be found in the interviews. No spontaneous or planned meetings or discussions between the operators or the department manager were initiated to talk about how this new tool should be used in more specific terms. This could be a sign that the expectations from every level in the organization need to adapt to their new possibilities to share and receive information.

Conclusions

A mobile application deployed on a smartphone was introduced to factory operators in a department managing a manufacturing process as a test of using customized ICT tools for operators. Empirical data from the first year of this test have been presented and analysed. The study shows that by utilizing this technology as cognitive automation and a tool for information sharing the operators have been empowered to do new work tasks through a higher general level of process understanding.

Acknowledgements

This research is part of a VINNOVA funded project, the Operator of the Future. The work has been carried out within the Production Area of Advance at Chalmers. This support is gratefully acknowledged.

References

[1] A. Jain, P. K. Jain, F. T. S. Chan, and S. Singh, "A review on manufacturing flexibility," *International Journal of Production Research*, vol. 51, pp. 5946-5970, 2013.

[2] G. Chryssolouris, K. Efthymiou, N. Papakostas, D. Mourtzis, and A. Pagoropoulos, "Flexibility and complexity: is it a trade-off?," *International Journal of Production Research*, vol. 51, pp. 6788-6802, 2013/11/18 2013.

[3] A. De Toni and S. Tonchia, "Manufacturing flexibility: A literature review," *International Journal of Production Research*, vol. 36, pp. 1587-1617, 1998/06/01 1998.

[4] H. A. ElMaraghy, "Flexible and reconfigurable manufacturing systems paradigms," *International journal of flexible manufacturing systems*, vol. 17, pp. 261-276, 2005.

[5] P. Oborski, "Social-technical aspects in modern manufacturing," *International Journal of Advanced Manufacturing Technology*, vol. 22, pp. 848-854, 2003.

[6] S. Mattsson, M. Karlsson, Å. Fast-Berglund, and I. Hansson, "Managing production complexity by empowering workers: six cases," in *47th CIRP Conference on Manufacturing Systems*, 2014.

[7] A. Wilkinson, "Empowerment: theory and practice," *Personnel Review*, vol. 27, pp. 40-56, 1998.

[8] M. Karlsson, S. Mattsson, A. Fast-Berglund, J. Stahre, Å. Fast-berglund, and J. Stahre, "Could the use of ICT tools be the way to increase competitiveness in Swedish industry?," in *The 6th International Swedish Production Symposium*, 2014, pp. 179-186.

[9] Å. Fast-Berglund, M. Åkerman, M. Karlsson, V. G. Hernández, and J. Stahre, "Cognitive Automation Strategies – Improving Use-efficiency of Carrier and Content of Information," presented at the Procedia CIRP, 2014.

[10] H. W. Hendrick and B. M. Kleiner, *Macroergonomics - An introduction to work system design*, 2001.

[11] Å. Fasth, "Quantifying Levels of Automation - to enable competitive assembly systems," Chalmers University of Technology, 2012.

[12] M. R. Endsley, "Level of automation : Integrating humans and automated systems," Lubbock, Texas, 1997.

[13] R. Parasuraman, T. B. Sheridan, and C. D. Wickens, "A model for types and levels of human interaction with automation," *IEEE transactions on systems, man, and cybernetics. Part A, Systems and humans : a publication of the IEEE Systems, Man, and Cybernetics Society*, vol. 30, pp. 286-97, 2000.

[14] J. Frohm, V. Lindström, J. Stahre, and M. Winroth, "Levels of Automation in Manufacturing," *Ergonomia - an International journal of ergonomics and human factors*, vol. 30, 2008.

[15] P. Gullander, Å. Fast-Berglund, U. Harlin, S. Mattsson, C. Groth, M. Åkerman, *et al.*, "Meetings – The innovative glue between the organisation system and information system," in *The 6th International Swedish Production Symposium*, 2014.

[16] M. Åkerman, M. Karlsson, and L.-o. Bligård, "Refining the needs: An exploratory study through usability testing," in *The 6th International Swedish Production Symposium*, 2014.

[17] Å. Fasth-Berglund, M. Åkerman, M. Karlsson, and V. G. Hernández, "Cognitive Automation Strategies - Improving use-efficiency of carrier and content of information," in *47th CIRP Conference on Manufacturing Systems*, 2014.