Proceedings of TMCE 2012, May 7–11, 2012, Karlsruhe, Germany, Edited by I. Horváth, A. Albers, M. Behrendt and Z. Rusák

APPROACH AND TOOLS TO DESIGN AN EFFICIENT AND FLEXIBLE PRODUCTION FLOW AND HUMAN CENTRED WORKSTATIONS IN SMES

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ABSTRACT

Nowadays customers of manufacturing companies demand a larger variety of products to be delivered at shorter time intervals than before, which may certainly not be at the cost of a lower quality or a higher price. To survive in the coming years there is a need for manufacturing companies to improve production systems on efficiency without compromising flexibility quality, and workload on employees. Lean manufacturing and a participatory ergonomics approach were integrated and interactive tools were developed especially for use in SME. These approach and tools were applied to 37 SMEs. Increase of productivity of about 15-40 % and order lead time of 20-25 % were measured without any increase in physical load parameters.

KEYWORDS

Production flow, workstations, mixed reality, lean manufacturing, human factors

1. INTRODUCTION

Due to the recent financial and economic crises the manufacturing companies are under a lot of pressure. Generally, customers demand a larger variety of products to be delivered at shorter time intervals than before, which may certainly not be at the cost of a lower quality or a higher price. This all force manufacturers of (complex) products to improve the flow of production orders together with a more efficient employment. The pressure on the organization is likely to increase the mental and physical stresses on the individual workers. At the same time, it is increasingly important to keep the workforce healthy and well, as there will be fewer people in the workforce due to the ageing population (de Beer and van Wissen 1999 [1]).

In addition to the need for more efficiency, there is a need for flexibility. One aspect of flexibility concerns the growing level of customization and a shorter product lifecycle resulting in smaller batch sizes and more variety in products. In order to produce small batch sizes of varying products, production systems must be both flexible and efficient. There is no machine as flexible as a human being, which is the reason that manual handling will continue to exist (Rosecrance, et al., 2005 [5]). Another aspect of flexibility deals with fluctuations in volume demand throughout the year. Many companies are exposed to relatively short periods of times (about one or two months), where the volume demands are significantly higher compared to the rest of the year. In some companies these periods are predictable, in other these are not. To improve flexibility there is –again- an increasing awareness of the role of the human workers. The adaptability of human workers makes them the most flexible part of the production system.

To survive in the coming years there is a need manufacturing companies to improve production systems on efficiency without compromising flexibility quality, and workload on employees.

2. IMPORTANCE OF WORK AND STATE OF THE ART

Many companies have embraced the lean manufacturing philosophy in the pursuit of reducing wasteful activities and improving productivity and profits (Genaidy and Karwowski, [2]; Rosecrance, et al., [5]). Automation, along with methods like lean manufacturing, can reduce manufacturing costs. However, automation is most suitable for moderate or large batch sizes. The currently growing level of customization and shorter product lifecycle results in smaller batch sizes. In order to produce these small batch sizes production systems must be both flexible and efficient.

When a participatory ergonomics and a lean manufacturing approach are integrated, it may be possible to improve productivity and prevent injuries and illnesses to a greater extent possible than if either one is performed in isolation [5, 8].

The question becomes how one implements such a participatory approach to define and mitigate ergonomic and manufacturing problems, especially in the small to medium enterprise (SMEs).

In this paper a combined participatory ergonomics and a lean manufacturing approach is described and applied to 37 SMEs . In these cases the effects in terms of both productivity, flexibility, and physical loads on the workers were studied.

3. APPROACH AND METHODS USED

The approach, from start to implementation and evaluation, includes seven steps. Below a short overview is given.

Step 1. initialization of a multidisciplinary working group

Step 2. Process visualization and evaluation

The second step involves the analysis of the production process by setting up a “Productie Afloop Schema” (PAS) [6]. The PAS is a process scheme, which is drawn on paper during working group sessions.

Step 3. Inventory of bottle necks and waste

In the third step, the working group makes an inventory of the bottlenecks with regard to the material flow and ergonomics. Tools used in this step are video observations, interviews and checklists.

Step 4. Design of the production concept

In the fourth step, alternative production concepts including transportation systems are assessed and compared.

Step 5 Workstation design

In the fifth step the selected production concept is designed in details: the involvement of people is filled in and the tasks workstation and per worker are defined. Workstations are designed on paper. The design of the workstation can be evaluated with the help of the mobile mixed reality tool Ergomix.

Step 6 Implementation

The production line and workstations are actually built and implemented in the sixth step.

Step 7 Evaluation

Finally, the effects and benefits of the implemented new production process flow are evaluated. The results of this evaluation can be used to fill in a cost benefit tool described by Looze [4], in order to get an overview of the costs and benefits.

4. THE SPECIFIC DETAILS OF THE RESEARCH AND DEVELOPMENT WORK

The seven steps are explained in more detail:

Step 1. initialization of a multidisciplinary working group

The first step comprises the initialization of a multidisciplinary working group within the company. This small working group involves a mix of participants, including assembly operators, middle management, process engineers, planning and logistics, production management, management. The working group is supervised by two external specialists: one assembly engineer and one ergonomics engineer. The specialists guide the company through the process and give their expert input.

Step 2. Process visualization and evaluation

The second step involves the analysis of the production process by setting up a “Productie Afloop Schema” (PAS) [6]. The PAS is an process scheme, which is drawn on paper during working group sessions. It visualizes the sequence of the various process steps, which are required to produce a certain product.

Process steps that can occur in parallel are visualized in parallel with the main process flow. The scheme also indicates where in the process these steps should finish. Both the actual process time and the lead time for each process step are measured. These two figures give input to calculate waiting time and value added time.

On the basis of the PAS, the current layout with its various work places is drawn. Questions to be solved: what happens where and how is the transport in between work places? Finally, the organization of the work among people is illustrated, e.g. do people make the whole product or only a part. The above forms the starting point for further analysis of failures and improvements in product design, process design, factory-lay out, and workstation design.

Step 3. Inventory of bottle necks and waste

In the third step, the working group makes an inventory of the bottlenecks with regard to the material flow and ergonomics. To give input to the working group sessions, direct observations of the production work are made. Interviews and discussion with workers also take place, in which we address items like the factory lay-out, the delivery of components, the availability of tools and equipment, the time needed to walk and search for tools and components as well as the physical and mental loads in assembly or transport. These interviews are structured by using checklists (Checklist Lean Manufacturing; Lay out; Ergonomics) In addition, the assembly work and manual transport of materials can be recorded by video. The video frames are also shown to the whole working group. On the basis of the observations, interviews and the video records, the bottle necks and possible solutions are discussed in the group.

Step 4. Design of the production concept

In the fourth step, alternative production concepts including transportation systems are assessed and compared. Based on total work content and expected production volume and product variability, the required number of workstations are determined. Next, various concepts are discussed in the working group. These concepts are evaluated on the basis of various criteria which concern the flow of materials, the logistics, the balancing of activities, the work/job content per individual, the time to learn (for new employees), and the flexibility to cope with volume and product variances, required space and investments. Examples of different production concepts are parallel docks, serial line, flexible flow etc. On the basis of these evaluations, one of the production concept is selected for implementation.

Step 5 Workstation design

In the fifth step the selected assembly concept is designed in details: the involvement of people is filled in and the tasks workstation and per worker are defined. Workstations are designed on paper. The design of the workstation is evaluated with the help of the mobile tool of Ergomix [3]. In the Ergomix, a real assembly-line worker is placed in a virtual workstation, represented as a drawing. These assembly workers are the actors in their own “virtual” workstation and are asked to perform their usual assembly activities. Using the ergomix the location of components and tools, the requirement of space, and the working and picking heights are defined and evaluated. After designing on paper a test workstation can be actually built in cooperation with the production workers (figure 1). In the test workstation currently existing tools and equipment are used as much as possible. The workstations interactively designed, evaluated and adapted. All acknowledgments for technical and financial support should be included in this section, which follows the text but precedes the references.

Figure 1 A test workstation is build in cooperation with an operator

Step 6 Implementation

The assembly or production line and workstations are actually built and implemented in the seventh step.

Step 7 Evaluation

Finally, the effects and benefits of the implemented new production process flow are evaluated. Increase of productivity, order lead time and ergonomic parameters related to physical and mental load are the major parameters which are measured in this step. The productivity is measured in terms of the number of products per person per day. Furthermore, the order lead-time is calculated, i.e. the duration of stay of product in the line. The required floor surface is measured including the work area, transport space and the material storage space. With respect to the physical load on the workers, the time of occurrence of awkward body postures can be determined, the occurrence of high risk lifting situations and the perceived physical load and fatigue. In addition, standardized questionnaire with regard to physical load, the mental load, the worker's satisfaction, the health risks and the experienced fatigue can be used. These results of this evaluation can be used to fill in a cost benefit tool described in Looze et al 2010 [4], in order to get an overview of the costs and benefits

5. THE RESULTS

The described approach and tools were applied in 37 industrial companies, mainly SMEs. One example is an innovation project that was performed at a company that produces emergency lights. This company experienced a steep increase in the market demand. Due to lack of space, plans were already made for a new production facility, but the management decided to have the production systems first critically analyzed. The described participatory and integrative approach of the 7 steps was used.

An increase of 44% in productivity and a reduction of the order lead-time of 46% was obtained. The time that workers spent to added value activities significantly increased from 74% to 92%, without any increase in postural and experienced loads. The NIOSH equations for lifting boxes in the old and new situation showed an improved and safe way of lifting in the new situation. In the traditional situation the lifting situation was unacceptable due to the low placement of the pallets on the floor and the reaching before placing. In the new situation the boxes were placed on a pallet at adjustable height on a lifting table and reaching was less far. The workers experienced significantly less overall fatigue at the end of the day in the new situation.

The results obtained in the present study are well in line with our experiences in the applications of the same approach in the other 36 companies (e.g. producers of mowing machines, car roof systems, food equipment, office furniture, and magnetic stop valves), where estimated gains in productivity of about 15-20 % and order lead time of 20-25 % without any increase in physical load parameters were not uncommon [7]. In figure 2 the different effects measured in the 36 cases are shown.

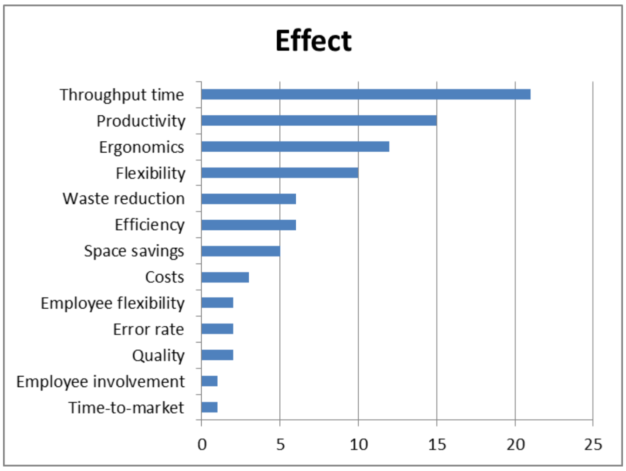

Figure 2 effects in amount of cases, where the combined approach was applied

6. CONCLUSION AND FUTURE WORK

More than 30 cases demonstrated the surplus value of a integrative approach combining production engineering expertise and tools with ergonomics expertise and tools. The approach of really bringing together these different disciplines and the involvement of employees in various meetings was evaluated to be successful by the companies themselves. Increase of productivity of about 15-40 % and order lead time of 20-25 % were measured without any increase in physical load parameters.

The tools PAS (production process scheme), the checklists and Ergomix demonstrated their strength in involving production staff and in increasing interaction between different disciplines. This enabled to find solutions which were accepted by all parties involved. Especially for SME's the tools paper tools proofed to be quick and easy to use.

However, research is needed to investigate the feasibility of digital tools in stead of paper tools. In a new, recently started EU project IMOSHION (EU Call FP7-SME-2008-2) a new digital tool for process evaluation will be developed in which both performance and OSH factors will be integrated.

In addition we experience a need in SME industrial companies for simple flow simulation that can be performed rather quickly to evaluate different production concept both on performance and human issues. In a new recently started research project a new augmented reality tool is developed to interactively visualize and simulate a new flow line in a group session. This tool will give industrial companies a more realistic 'prediction' of a new production system.

REFERENCES

[1] Beer, de J. and van Wissen, L., (1999), Europe: One Continent, Different Worlds. Population Scenarios for the 21st Century, Kluwer Academic Publishers, Dordrecht.

[2] Genaidy, A. and Karwowski, W. (2007), "A roadmap for a methodology to assess, improve and sustain intra- and inter-enterprise system performance with respect to technology-product life cycle in small and medium manufacturers" , Human Factors and Ergonomics in Manufacturing, 18(1), pp. 70-84

[3] Hallbeck, M.S.; Bosch, T.; Van Rhijn, J.W; Krause F.; De Looze, M.P. ; Vink, P. (2010) "A tool for early workstation design for small and medium enterprises evaluated in five cases", Human Factors and Ergonomics in Manufacturing and Service Industries 20, pp. 300-315

[4] Looze, M.P. de,Vink, P., Koningsveld, E.A. P., Kuijt-Evers, L., & Van Rhijn, J. W. (2010), "Cost-effectiveness of ergonomic interventions in production", Human Factors and Ergonomics in Manufacturing&Service Industries, 20(4), pp. 316–323.

[5] Rosecrance, J., Douphrate, D. and Cross, S. (2005), "Integration of Participatory Ergonomics and Lean Manufacturing: A Model and Case Study. Human Factors in Organizational Design and Management", VIII, Edited by P. Carayon, M. Robertson, B. Kleiner and P.L.T. Hoonakker. IEA Press, Santa Monica, California, USA, pp. 437 - 442.

[6] Tuinzaad G.H., Rhijn J.W. van, Deursen J. van and Koningsveld E.A.P. , (2000), Efficient flow and human centred assembly: the success of an interactive approach. TNO Industrial Technology/TNO Work and Employment, Eindhoven/Hoofddorp.

[7] Tuinzaad G.H., van Rhijn J.W., Bosch, T., De Looze M.P. (2008), Increasing productivity and flexibility in industry, Industrial Technology/TNO Work and Employment.

[8] Vink, P, van Rhijn, G. and Krassi, B. (2008) "Collaborative design using mixed reality: suggestions from INTUITION partners" In: Karwowski W, Salvendy G, Eds. Conference Proceedings, 2nd International Conference on Applied Human Factors and Ergonomics, AHFE 2008, 14-17 July 2008, Las Vegas, USA. Louisville: AHFE International, CD Rom.