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Visual management of OEE at the semi-automatic assembly lines

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ABSTRACT: *The modern industrial environment has to face and handle a plethora of information. Production systems, especially semi-automatic assembly lines are becoming more and more complicated, thus the corresponding visual performance management is getting more complex. Nowadays, a visual control system is more than just a collection of metrics. Manufacturing companies often apply manual and digital performance boards to follow up Overall Equipment Effectiveness (OEE) values in production. The role of a production performance indicator is to show the current state of assembly lines in production as well as to monitor and control operational efficiency. This paper gives an overview of OEE-visualization at semi-automatic assembly lines. Firstly, a literature review demonstrates scientific relevance. Secondly, perceptibility of manual and digital performance boards is compared and the correlation between the length of the assembly line and the number of operators is described. Based on the findings of the survey, this article gives an answer to the question which type of performance boards are supported by assembly operators.*
KEYWORDS: *OEE; visual management; assembly line; performance board*

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I. INTRODUCTION

Information and decisions

In the modern world, we are surrounded by different kinds of information and data are ubiquitous. Traditionally, manufacturing entrepreneurs have focused on using data for analysis, monitoring and control, e.g. production analysis, assembly process monitoring and quality control [1]. Nowadays, information availability does not constitute a problem, it is the conveyance of information which seems to be ineffective [2]. Information overload is considered as receiving too much information which could have a negative impact on individuals and organizations at companies [3]. In recent years, it has been clear that decision-making process based on information has become faster and faster as well as more and more complex. It is essential to reach a series of appropriate decisions in factories in time. Performance management systems support decision-making - not only monitoring and measuring [4]. A well-designed measurement system provides the link between strategy and daily operations [5].

Performance measurement system and indicators

One of the main goals of manufacturing companies is to enhance their performance [6]. The performance measurement system (PMS) has become a key issue in industry. It helps to increase productivity, set goals and track progress. Performance management includes performance methods, measures, processes and systems [5] [7]. While the indicator system focuses on the past, performance measurement is mainly future-and process-oriented [4]. Obviously, complexity negatively impacts the process of improving performance management systems [3]. Entrepreneurs need to measure their processes so that they can define their level of performance and can improve it [8]. In the field of production, it is inevitable to measure efficiency continuously. Indicators (I's), Performance Indicators (PI's) and Key Performance Indicators (KPI's) actually drive performance assessment of production systems. Throughput and Overall Equipment Effectiveness (OEE) are widely used performance indicators in evaluating internal efficiency of a production system [9] [10] [11]. Other typical metrics are delivery time, due date performance, Cost of Poor Quality (COPQ), turnover rate, inventory, etc. [12]. Due to unpredictable downtimes caused by machine failures, missing raw materials or short-term customer changes, manufacturing companies often have difficulty in fulfilling different logistical targets [13]. There are several factors affecting assembly lines productivity which are related to manufacturing environment, human factor and sudden activities [14].

Visual management

For human brain, daily visual perception is fast and efficient [15]. About 60% to 80 % of information gained from the outside world is perceived through vision. According to Galsworth [16], visual management is a "self-ordering, self-explaining, self-regulating, and self-improving work environment where what is supposed to happen happens on time, every time, because of visual devices". The purpose of visual management (VM) is to

enhance transparency with a wide-scale utilization of colours which increases information value [17]. Successful companies generally use Lean Manufacturing methods and tools. One of the most often applied Lean tools is visual management because it is simple and easy to understand. Data visualization is becoming increasingly valuable [18]. There are two main methods to follow up the OEE performance of assembly lines by performing visualization. The first method is the usage of manual boards and meeting system, the second one is the digital information system. Both of them make communication flow more efficient in different situations [3]. A visual management system can be implemented within a smart production system environment focusing on the enhancement of assembly lines efficiency and cost reduction [19]. Effective visual support includes graphical representations, pictures, posters, schematics, words, numbers, symbols, cartographies, transparencies and colour coding which can be improved by audio signals [2] [5]. Widespread forms of visualization are charts, diagrams, graphs and virtual reality [20].

II. LITERATURE REVIEW

Andon board as a line stop indicator and visual control were developed by Toyota Production System and published by Ohno [21]. Visual management is a management system that tries to improve performance of an organization by means of visual motivation [22]. A lot of research is being conducted to create more effective and efficient ways of sharing data, information and knowledge in the manufacturing domain (e.g. Industry 4.0, IoT, cloud based manufacturing) [3]. There are two ways to capture data: the first type is manually data collection with human intervention, the second one is an automatic method without human intervention [23]. Manufacturing companies collect shop floor data in digital format using the Manufacturing Execution System (MES) [24]. MES can provide a sufficient database for work planning and production control [25]. Companies are often investing in MES where OEE measurement is a central part and important reason for the investment [10].

Smart factory cyber physical systems continuously collect data from the shop floor [26]. Smart manufacturing includes manufacturing assets with sensors, computing platforms, communication technology, data intensive modelling, control, simulation and predictive engineering [1]. Companies increasingly use wireless technologies to capture data at all stages of the product's life. More and more devices, production tools, manufacturing equipments are equipped with barcodes and vision systems. Therefore, they can be connected to each other and share information about OEE components (availability, performance, quality) within a network [27] [28] [29]. Online dashboards display important manufacturing KPI's collectively to improve transparency and productivity at the area of assembly lines [22].In the assembly industry, the following widespread OEE visual measurement methods are applied:

- manual visual management tools (Fig. 1.)
    - manually filled performance boards (cell boards, production boards, performance tracking table, etc.)
    - manually filled white boards with schedules and fulfilments, project layout, priority classification [11] [22]
    - manually filled systems (e.g. Manual Web Entry Tool – MWET)

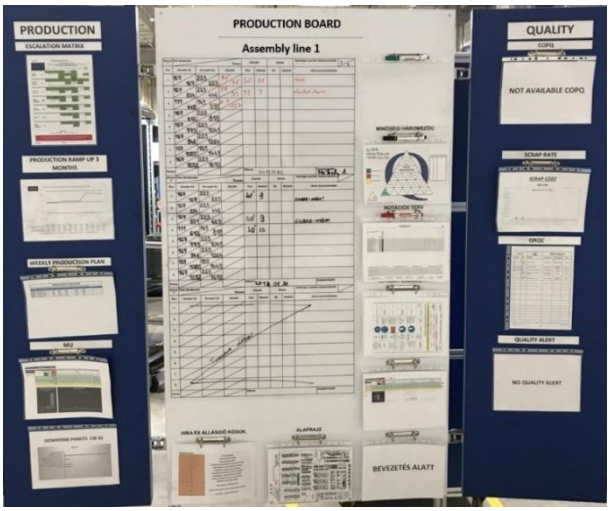

Fig. 1 Manual performance board of an assembly line

- digital visual management tools (Fig. 2.)
  - visual control in form of electronic boards, Andon signals
  - informative boards [30]
  - Manufacturing Execution System (MES) based on visualization representation
  - Obeya room and IObeya (digital visual management platform for lean) [3]
  - cloud based visual management tools (e.g. STC-LAM) [22]
  - web-based IoT Platforms (e.g. IoT-Ticket Platform)

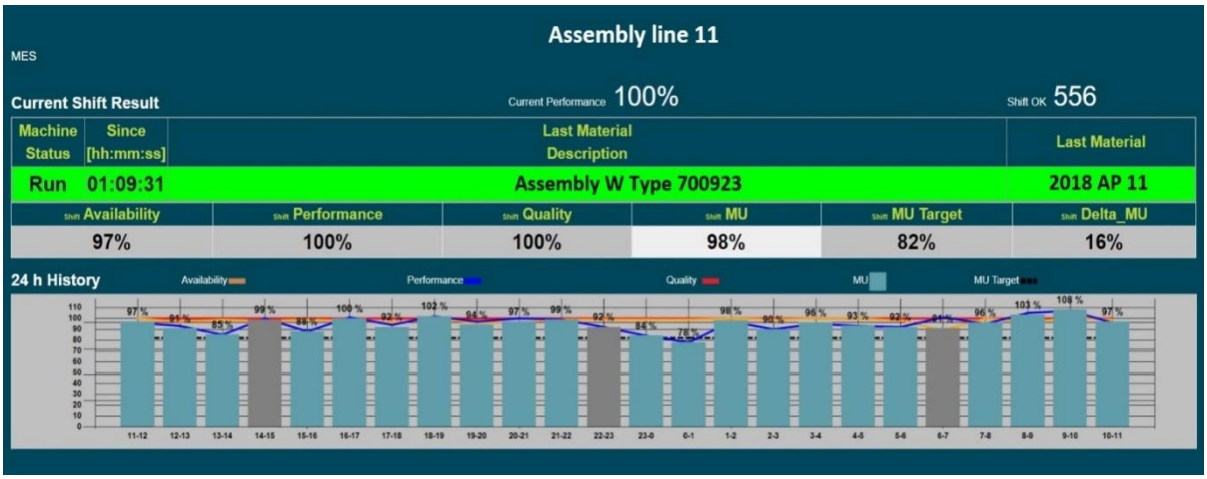

Fig. 2 MES based Andon board of an assembly line

According to Hedman et al. [10], OEE measures are highly dependent on data collection and availability of data, but do not guarantee that data are accurate. Sly et al. [31] presented a web-based Andon environment for assembly lines. The Factboard system can be accessed via mobile tablets and phones. Dashboards which are essential parts of the system can send an alert to the management before a line is stopped. Steenkamp et al. [22] works with Haldan MES visual management tool which collects OEE data in the factory in order to display information on different factory levels. Based on Antosz et al. research work [32], 10 % of the inspected small and medium-sized enterprises (SME's) use visual management tools every day, 10% use the OEE indicator and only 4 % use Andon boards. Glass et al. [2] points out that visual management tools are mainly used in assembly industry [33]. Parry et al. presented a visual control board used to communicate ERP-output to shop floor operators in order to facilitate process flow.

Kurdve et al. [11] describe Daily Visual Management (DVM) meetings on two levels (operator and plant) with standardized visual management (VM) boards. Purpose of DVM is to provide increased efficiency and improved information flow horizontally and vertically within an organization. Information may be manually written on whiteboards or digitalized (smart) and usually include some key performance indicators (KPI's). Based on research work, operators and leaders mentioned that they did not need a lot of KPI's, but they needed comprehensive information on machine status and problems that may affect quality or productivity such as OEE- value.

Batangouna[5] compared an old data measurement system where assembly operators collected data before they had sent them to the management to a handwritten cell measurement board which was regularly updated by employees who worked at the shop floor. Performance and efficiency are measured and visualized in order to monitor different process statuses in real time-mode. Real-time performance indicators for visibility and traceability allow decision makers to reach quick shop-floor decisions and help to improve factory information and production flow [29]. For digital Andon board, many suppliers provide solutions to visualize OEE, complex data and process in real time [17].

III. OEE VISUALIZATION AT THE SEMI-AUTOMATIC ASSEMBLY LINES

Environment of OEE visualization

Semi-automatic lines consist of the following components: people, machines, and the interaction between people and machines. Visual information systems are connected to machines, workers and products. It is important for each employee at the production plant to have the same goal perception. It is essential that people working at the assembly lines know why performance is important, why to measure it, what are the expectations and what an OEE-indicator means. The human factor (operators) is the most important and critical factor which influences assembly lines productivity. Team leaders, supervisors, managers have a main responsibility to help their team to work efficiently. Assembly operators have access to relevant and important

information in real time-mode or in the required time-period. Based on these information, operators can influence the loss of time and the OEE-value can be increased. Enterprises may fail to implement a system that facilitates daily performance measurement as they neglect the assembly operators' responsibilities in the decision-making process.

Perceptibility of performance boards

Operation of performance-management boards can be done in the most efficient way if immediate measures, actions and interventions are taken or performed due to the OEE-outputs during the assembly or supporting processes. The team leader can take the necessary steps and measures involving operators and machine setters, if availability, performance or quality problems arise. It is important to know that structure and shape of the performance board as well as the types of the depicted data can be different in each factory, but standardisation within the factory is inevitable to enhance productivity. It is vital to have enough information, but too much information at the same time may cause disturbance and delay. As for perceptibility of performance boards (Fig. 3. and Fig. 4.), the performance of digital boards can be followed up so that the employees do not have to leave their workplaces and they visualize the OEE-value in real time-mode on one central display or more ones.

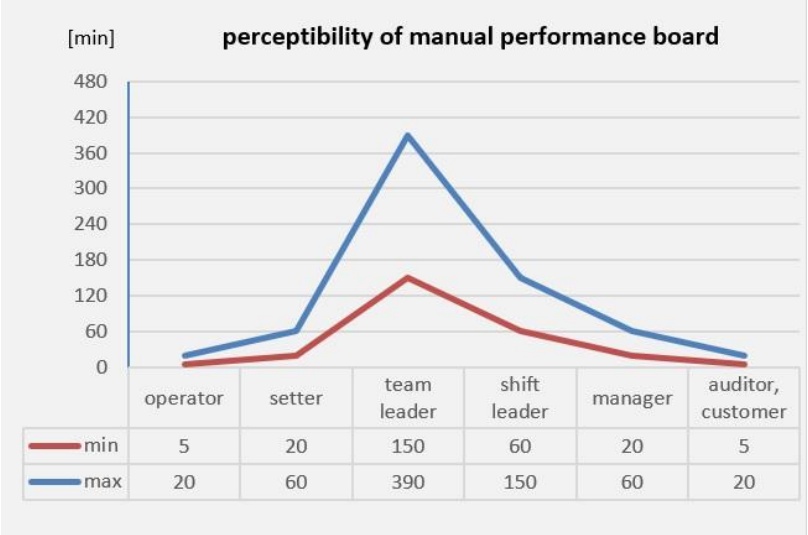

Fig. 3 Perceptibility of manual performance board during eight working hours

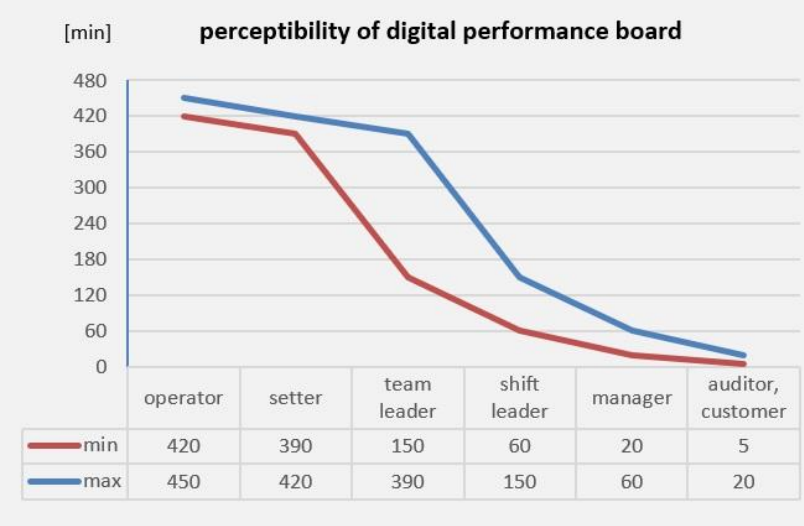

Fig. 4 Perceptibility of digital performance board during eight working hours

Fig. 3. and Fig. 4. show the main participants of the production system (operator, setter, team leader, shift leader, manager and customer) and the possible time period during a normal shift (8 working hours) where they could get in touch with the performance management boards. The ideal state would be if each participant could monitor the OEE-value during the whole shift, but it is not possible for different reasons such as break time, spatial location, picks up maintenance materials, etc.. The greatest disadvantage of manual boards is that employees have to leave their workplaces when filling and inspecting the manual boards, although production status should be visible and accessible for all employees and the boards should stand in the middle of assembly lines. Well-placed digital boards show the current operating condition of the assembly lines in the production with millisecond refresh rates.

Manual and digital performance boards

Nowadays, assembly operators and machine setters manage a huge amount of information when they perform their daily tasks. In many companies, the question is raised if manual or digital performance board should be used in case of assembly lines. Depending on the number of staff working at the assembly line and the length of the assembly line(which means the distance between the operators and the performance boards), the following cases are possible according to Fig. 5.:

- in case of short assembly lines (>8 m) with small staff (approximately 6 employees,), it is advisable to use a manual performance board because this board is easily accessible and monitorable for everyone and information flow is slight
- in case of longer assembly lines with large staff (over 6 employees), it is advisable to use digital performance boards, even two or three pieces of them, so the current OEE-value can be seen from the workplaces without having to leave them
- short assembly lines with large staff (over 6 employees) are not typical in the industrial practice and no performance board is used to indicate the OEE-value like in individual production

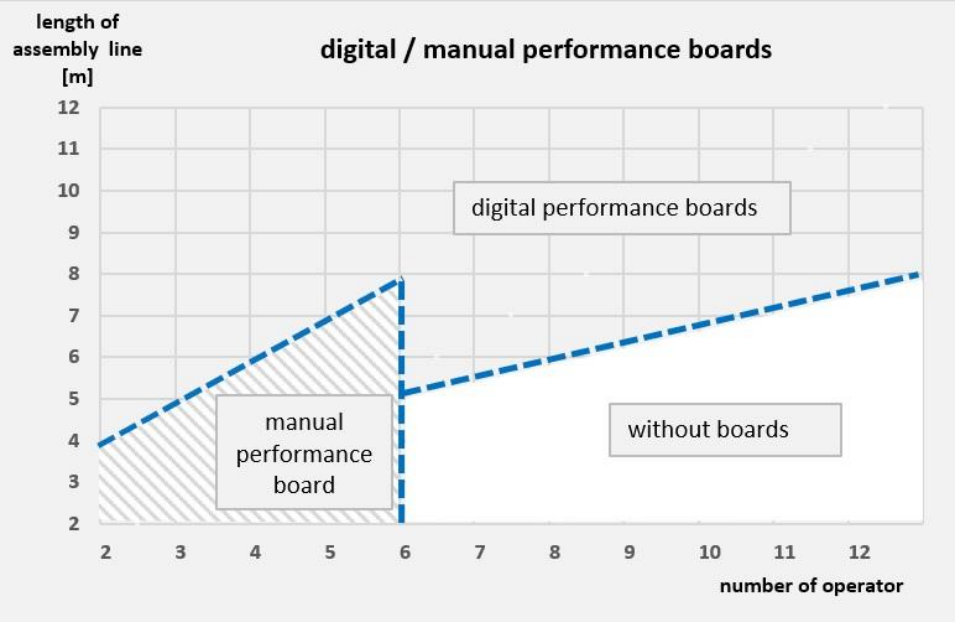

Fig. 5 Graph for using manual and digital performance board

When defining the number of performance boards, it is the best, but a costly solution to have a digital display at each workplace, therefore each employee can follow up the OEE-value from close vicinity in real time-mode and can influence it positively (in the right direction). In case of manual and digital monitoring, it is important that all participants of the assembly process understand the essence and importance of the OEE-figure and the impacts caused by of the change of certain components.

Survey about the supported boards

The survey focused on which performance monitoring method is supported and accepted by the employees working on semi-automatic assembly lines. According to a survey conducted in an automotive company in Hungary, the digital performance board is better-supported than the manual one. Four out of five assembly operators choose the digital type. Fig. 6. shows the result of survey.

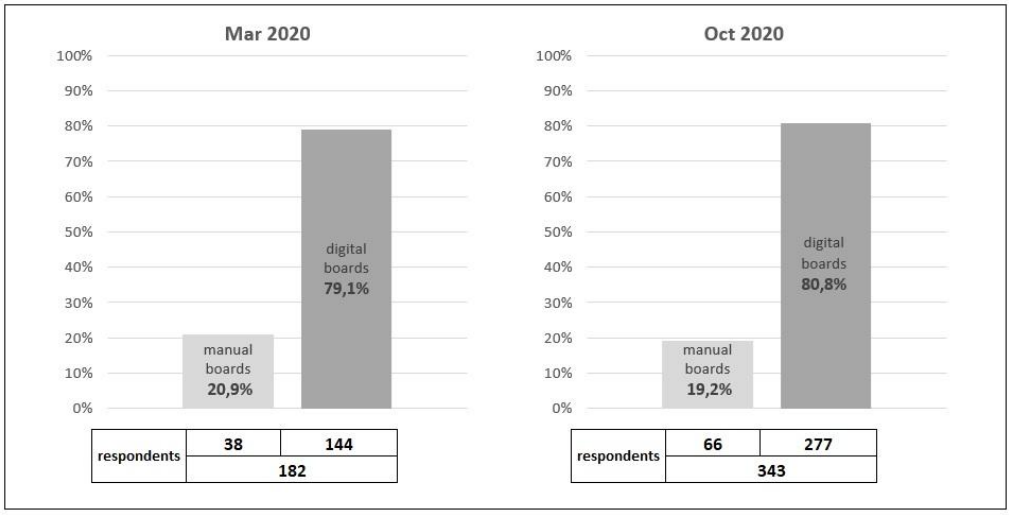

Fig. 6 Result of survey

The survey has shown that operators under 35 opt for the digital performance board. The older someone is, the more likely it is that he or she chooses the manual performance board.

IV. CONCLUSION

As far as semi-automatic assembly lines are concerned, two methods of visual performance management are applied in the industrial practice in connection with the measurement of the OEE-value. The first one is the usage of a manual performance board where data are usually recorded by the operators. The second method is the usage of a digital performance board where the MES-system calculates the OEE-value resulting from the multiplication of performance, availability and quality-figure. Digital monitoring is more precise, it can be done in real time-mode, it is more efficient and can be followed up by the users more easily. This can be confirmed by a survey which has shown that 80% of the employees prefer this version. It may be a possible research direction in the future that particular guidelines will be defined in addition to the visual management of the OEE-value. Accordingly, the time of the interference in processes can become even shorter. Another possible option could be the display in 3D which enables that visuality is constantly improved.

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