Possibilities of Applying Augmented Reality Elements in the Concept of Lean Management

Stella Hrehova[1](✉), Jakub Kaščak[2], Rebeka Tauberová[1], and Matúš Martiček[1,2]

[1] Faculty of Manufacturing Technologies with a Seat in Prešov, Department of Industrial Engineering and Informatics, Technical University of Košice, Bayerova 1, 080 01 Prešov, Slovak Republic
{stella.hrehova,rebeka.tauberova,matus.marticek}@tuke.sk

[2] Faculty of Manufacturing Technologies with a Seat in Prešov, Department of Computer Aided Manufacturing Technologies, Technical University of Košice, Štúrova 31, 080 01 Prešov, Slovak Republic
jakub.kascak@tuke.sk

Abstract. Increasing efficiency and reducing costs in production is currently a very desirable trend. In many areas, we can see the trend of introducing or improving lean techniques and tools, the task of which is to get as close as possible to achieving the ideal state in terms of customer satisfaction and the elimination of any losses. The fundamental benefit of introducing the lean production methodology into the corporate philosophy is the constant effort to achieve perfection and the periodic application of improvement. In this context, lean management is based on the condition that there is no level of perfection with which the company should be satisfied and which cannot be further developed. The introduction of the Industry 4.0 philosophy and the development of information technologies brought new possibilities for lean management. It offers new tools and options that can increase the efficiency of management and the achievement of set goals. In the presented contribution, we will focus on the possibilities of using augmented reality tools for selected areas of lean management. Augmented reality is a key technology enabling the implementation of the Industry 4.0 concept. This technology makes it possible to bridge the gap between the physical world and the increasingly important digital environment. We can see its application in many areas.

Keywords: Lean management · Augmented reality · Marker

1 Introduction

Lean management is a business management approach based on the Japanese example developed at Toyota [1]. The roots of Lean can be found in the relatively early stages of modern management. Already in 1910, Henry Ford promoted the ground-breaking theories of Frederick Taylor, Frank Gilbreth, or the founder of the Gantt chart, Henry

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Gantt. The common feature of these approaches was the effort to maximize the production process in the shortest possible time. James Womack, the author of the term lean production, or Taiichi Ohno can be cited as other exponents of the Lean philosophy. We can find several definitions of the term "Lean management" in the literature, e.g. [2, 3], in which the authors characterize the role of lean management as streamlining processes, reducing unnecessary activities, production times and minimizing the consumption of raw materials and energy, in [4] the authors characterize lean management as a system that includes the most efficient methods and techniques of production organizations with wide and successful applicability. The gradual introduction of the lean management principles into practice is carried out by applying small changes, which, however, have a large impact on the entire business system. In this context, the most descriptive definition of lean management [5] is the one that states that lean management is an approach to managing an organization that supports the concept of continuous improvement, a long-term approach to work that systematically tries to achieve small, gradual changes in processes in order to improve efficiency and quality.

The key principles of lean Management relate primarily to two elements [6]:

- value - is understood both in relation to the organization and the client. All activities carried out in enterprises should focus on creating value,
- efforts to eliminate waste - eliminating any activity or part of the process that does not create value.

The concept of lean management consists in continuous cyclical improvement of business management with the aim of reducing all possible operating costs, eliminating waste and increasing business performance [1]. The following figure (Fig. 1) shows the lean management history and development [7].

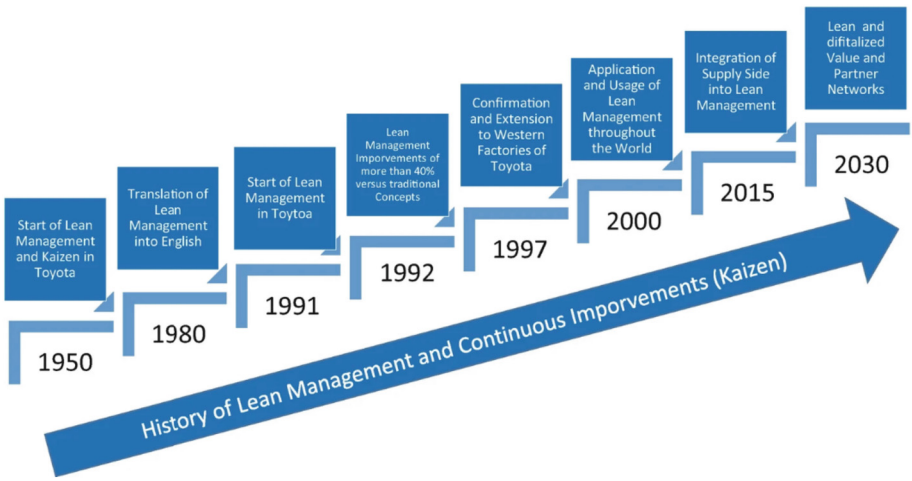

Fig. 1. History and development of lean management

Currently, managers have the opportunity to use digital information available in various IT (information technology) sources to make the right decisions and implement actions [1]. The concept of Industry 4.0. it has been implemented in various areas only in the last decade, but it has brought with it many tools and methods whose task is higher efficiency and digitization. However, the philosophy of "Lean" management was applied in some industries much earlier. These philosophies are currently influencing and intermingling, as shown in the following figure (Fig. 2) [8].

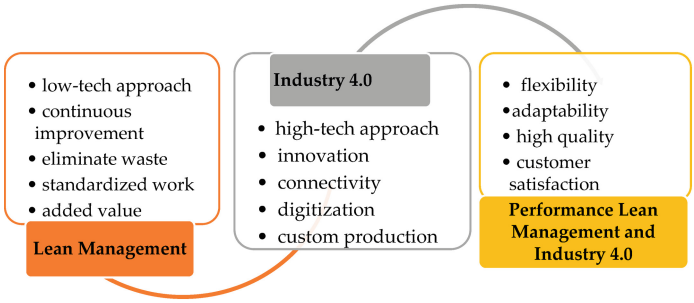

Fig. 2. Lean management and Industry 4.0 in mutual conjunction

However, the possibility of effective use of Lean tools rests on the shoulders of top and middle management, who need to have the necessary information and data at their disposal. This area could be covered by virtual reality technology, when it is possible to see and understand individual processes and workplaces in a short time and in real form. In the presented article, we will show the possibilities of using virtual reality technology in selected lean methods and procedures.

2 Methods and Tools

2.1 Lean Management

Lean management methodology represents [9] a philosophical approach promoted by top management through long-term strategic plans. This procedure is focused on the process as the bearer of the manufactured product quality or the service provided. Key functions in the enterprise related to the achievement of goals in this area include the following prerequisites:

– correctly designed process - the products will then achieve the required quality,
– the process is balanced and smooth - the costs resulting from maintaining stocks will be eliminated,
– production of what the customer requires and when he needs it,
– focus on quality in every single operation - costs resulting from repairs and complaints will be reduced.

Other features include:

- Intentional search for individuals through whom it is possible to implement the company's intentions in the area of quality improvement or cost reduction and supporting their personal development.
- Long-term support of self-educational processes and the prosperity of the company without exception:

  – control of processes and thorough understanding of address situations,
  – consideration of all eventualities and precise discussion before choosing a suitable solution and its implementation,
  – constant efforts for organizational self-reflection.

After the values of one improvement cycle are designed, applied and verified, it is necessary to reassess other, new needs and demands of customers. It is also necessary to pay attention to further improvement, whether it is changes in the area of increasing the capacity of processes or removing everything that is undesirable and unnecessarily burdening processes.

The basic principles of Lean management are [9]:

- Determination of value. The key point is that value can only be defined by the end customer and is truly meaningful when expressed as a concrete product that meets all of the customer's needs and wants;
- Identification of activities involved in value creation. A value stream represents a set of all specific activities required by an organization,

  – product development management – all problem-solving tasks from concept through detailed design and engineering to production launch,
  – information management - all information management tasks from product conception to product delivery
  – operational management - the entire physical transformation takes place from raw materials to the finished product in the hands of customers.

- Flow. Setting processes in motion. Ongoing processes cancel the idea of dividing the company into separate departments. All activities related to the completion of a product or service should be organized in a single, uninterrupted flow
- Pull. Processes are conditioned by the need to deliver a specific product or service. The product is produced only when there is real demand from the customer, and not to work on stock. This concept is called thrust and ensures that none of the eight areas of waste are created, or at least minimized
- Striving for perfection. The ability to strive for excellence from the customer's perspective is fundamental to the continuous improvement process. It represents an endless effort to reduce time, costs, errors and malfunctions in the production of products or the provision of services.

The following table presents a description of selected lean management tools for which augmented reality application options will be proposed (Table 1)

Table 1. Selected Lean management tools.

Tool	Description
Shop floor (SF)	Shop floor management (SFM) describes the supportive interaction among managers and employees. The emphasis is placed on the value creation process and the exchange of information is accelerated. Early meetings and problem analysis are held at the event location, i.e. in the workshop [10]
Value Stream mapping (VSM)	Value Stream Mapping is a lean tool that helps users see and understand the material and information flow as products move through the value stream. The value stream includes the value-added and non-value-added activities required to deliver a product from raw materials to delivery to the customer [11]
SMED	SMED Setup is a set of activities that prepare a system to produce a product, with setup time being the preparation period between the end of the last product produced and the first product produced in the next process [12]
5S	The 5S methodology is a lean philosophy that gives order and meaning to work dynamics and solves situations of disorganization in the workplace [13]

2.2 Augmented Reality

Augmented reality (AR) is among the leading technological applications in various fields. It is also part of the Industry 4.0 philosophy and has been among its fastest growing areas in recent times. AR is computer-generated virtual information that overlaps with a real scene. Virtual information is displayed in a realistic manner so that it appears to be part of the real environment. AR does not use a complete replacement of the real world with a virtual one, but complements or changes the perception of the real world. Thus, AR supplements the real world with elements of the virtual world. AR technology allows a person moving in a real environment to perceive objects made in the digital world [5, 14]. A typical AR application consists of three layers, as shown in Fig. 3 [15]. The bottom layer represents the real and material world. In the middle layer, digital information that is relevant and useful is added to the real world. The combination of these two layers creates a third extended world in which users have access to digital content. AR applications provide interaction between users and the augmented world in real time

This virtual content is displayed by devices such as tablets, smartphones or smart glasses. The user has the possibility to interact with both the real world and the virtual world and manipulate virtual content [16].

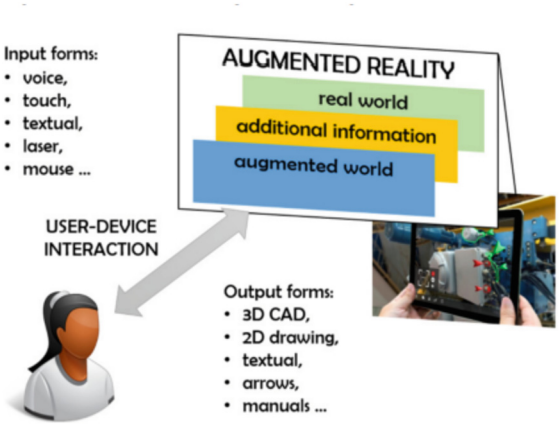

Fig. 3. AR application layers

AR application dividing is shown the following figure Fig. 4 [17].

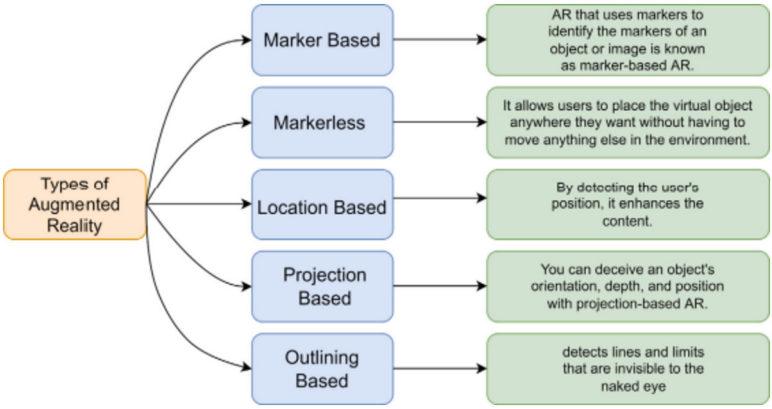

Fig. 4. AR applications dividing

Marker-based and marker-free methods are most often used in the creation of AR applications. AR marker-based methods rely on affixing a marker to a known location or object of interest to define the origin of the virtual world. However, this method has some limitations. Markings must be high contrast and non-reflective, occlusion may occur and the user must stay close to them. In addition, tags must be attached to all moving objects or the scene must remain static [18].

The success of introducing these principles and procedures is influenced by the quality of information about individual processes and workplaces. Individual management members can only have partial and incomplete or old data. This then leads to ineffective and partial solutions, which has a negative impact on achieving the set goals. An application that will use virtual reality can bring more detailed and complete information.

By using markers, problematic workplaces can be processed in detail and presented in a realistic form.

Based on the analysis of selected works [19], it is shown that systems based on markers are the most frequently accepted solutions in the creation of AR applications. In the following section, we focused on the application of this approach.

3 Possibilities of Applying Augmented Reality for Selected Methods of Lean Management

In the following section, selected lean management tools and the possible implementation of augmented reality applications using markers will be briefly described.

3.1 Shop Floor

One of the basic tasks of this approach is to obtain real data directly from the place where the process takes place. In many literary sources, the opinion is presented that entering the gemba and directly observing the process allows the best value flow analysis [6]. Such an approach brings measurable benefits. Working at the place where the process is performed allows managers to change their perspective and see the process exactly where it occurs. In small establishments, it is possible to obtain the necessary data by personally walking around the given establishment and writing down what is real. However, if teams of experts are involved in solving problems or optimizing processes, this is insufficient. For this reason, other methods with the use of modern information technologies began to be used [20, 21]:

- Simplified virtual Gemba walks – use hand-held cameras in a remote location to record or broadcast your walk live for other members.
- Extended walks Gemba – when wearable technologies such as Augmented Reality (AR) smart glasses are used. This method enables real-time IIoT-enabled "see and listen" (eg real-time performance data).
- Advanced Virtual Gemba Walks – when lean managers use digital technologies to "remotely interact" with intelligent, social machines and IIoT-enabled operators through digital twins, in a virtual environment (VR).
- Automated Guided Gemba Walks – when Gemba Walks are "automated and guided" by trend predictions based on data provided by IIoT (Industrial Internet of Things), social machines and operators in digital lean factories.

As part of augmented reality, it is possible to use the option of playing videos based on a marker. The workplace (or workplaces) will be photographed with a camera, or a virtual tour of the workplace will be created. The virtual tour can also contain a technical description of individual machines and devices that are adapted to the desired goals (Fig. 5). Command buttons can also be added within the application, which are used to override between possible individual scenes. The appearance of the marker can be a simple figure.

The created markers and the application saved in the tablet, or the mobile phone is portable, so it is always available.

Fig. 5. Virtual tour of the workplace with a technical description of the equipment

3.2 Value Stream Mapping

Optimizing the value stream of the process so that it brings the desired effect is a difficult task that requires the cooperation of several experts. The most important element of this method is the creation of a current state map, which should take into account the real state. In this activity, it is necessary to apply the already described shop floor method.

From the point of view of using the Unity and Vuforia environments options, we can propose two ways of displaying this map of the current state.

1. By using a marker - the corresponding marker is replaced by the corresponding map when it is used (Fig. 6)

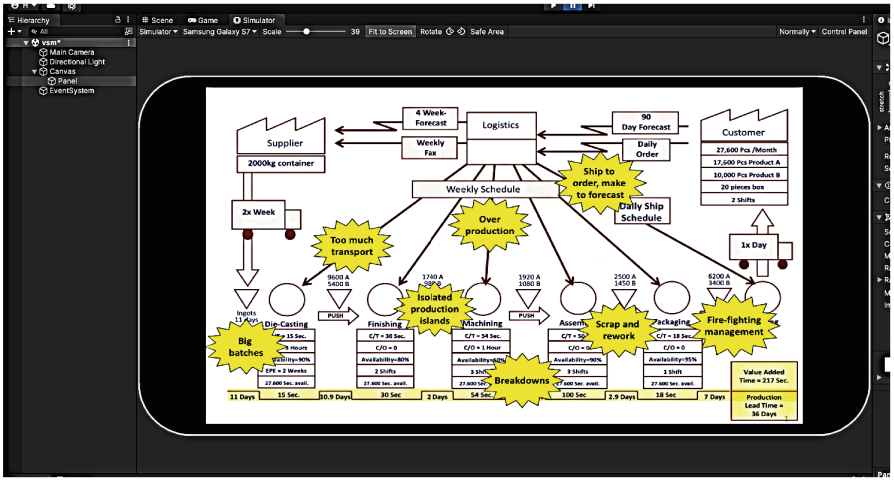

Fig. 6. Current state map with Kaizen

2. Using the scene itself, when the desired map is displayed based on pressing the appropriate button. In this case, however, it is tied to only one map for a specific operation. In the end, it can also be an advantage if a comprehensive application of augmented reality is created, which is managed, for example, by command buttons

Such a map can also show opportunities for improvement (Kaizen). The specific procedures to be chosen are usually determined by a team of experts. The necessary information can be obtained (supplemented) by displaying the map using the appropriate markers.

3.3 Single Minute Exchange to Dies

Switching to another type of product and subsequent machines setting up are necessary, but they do not add value. Therefore, the aim must be to reduce the time needed to perform these activities. SMED focuses on the identification of internal and external activities of the transition, the separation of internal and external activities, the transformation of internal activities into external activities and the streamlining of activities [22]. During analysis, the internal setup time is converted to an external setup time to reduce this time [4]. The main principle of the method recommends performing the maximum possible number of switching steps during the so-called external phase, which is the period of time when the machine or device is in operation. At the same time, the remaining internal operations are simplified and standardized in order to eliminate any unnecessary operations, downtime or waste of other resources [23]. Significant time losses can occur here, which are caused either by inexperience or poor preparation. The field of augmented reality tools application can be:

1. Reducing the time needed to find the appropriate tool, toolset, etc. To make it effective, it is advisable to use the 5S lean method, which will ensure the standardization of the individual tool location.

The basic 5S method is divided into five steps, which are: Seiri (Sort), Seiton (Set in Order), Seiso (Shine), Seiketsu (Standardize) and Shitsuke (Sustain) [24]. The workplace standardized in this way is then the basis for the application of augmented reality, when, based on the marker, the desired location is shown to individual workers [25] (Fig. 7). This will ensure the reduction of losses arising from the search for the correct location of individual tools.

The following image interprets an organized workplace in the Unity environment in simulator mode.

2. Training of necessary activities:
   a. One of the possibilities is to record a video, when an experienced operator performs all the necessary activities for an individual machine. Subsequently, based on the marker, the given video can be started, which will allow you to train and check the performed steps. This possibility illustrates next figure [26] (Fig. 8).
   b. Static option, when the sequence of individual steps is displayed based on the marker. In this case, the application may contain separate command buttons that will enable the transition to the next operation only after confirming the execution of the previous operation

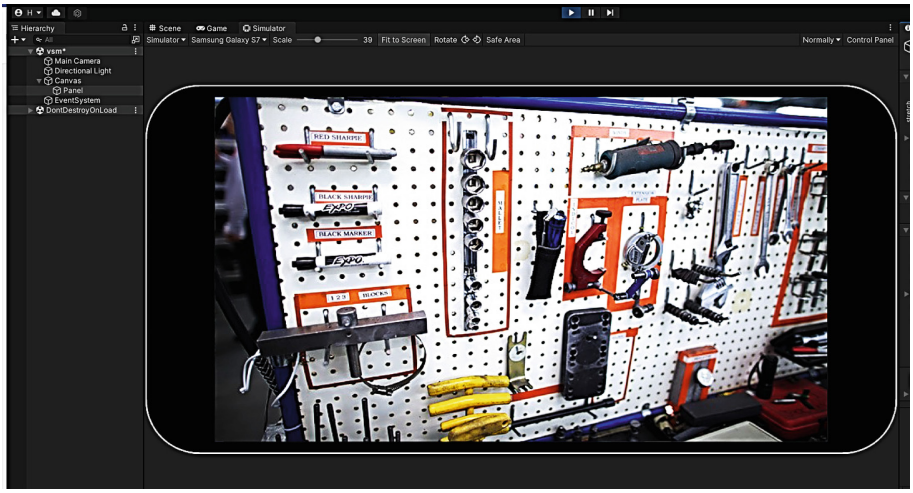

Fig. 7. The workplace after applying the 5S method in simulator environment.

Fig. 8. The possible approach to using AR for training.

The assumption is that the application will be intended for medium or top management. In this case, it should serve as a source of information, especially in cases of using the Shop floor and Value mapping stream methods. In the case of 5S methods and educational activities, it is determined by a specific user. However, the common denominator is the use of markers. A generalized application development procedure will be built based on the following steps:

- selection of the end user,
- creation of markers
- interface design
- selection of end device and application testing

Last but not least, it is possible to create an application that will contain both options, and by creating a user interface, the user will decide what to use.

4 Conclusion

Several years of implementation of Industry 4.0 principles and methods and the use of advanced information technology tools in the field of lean management can bring significant efficiency and flexibility of management in various areas. The connection of these approaches gives lean management the possibility of using many tools to improve and streamline processes in all parts of the material flow. Even if the use of a specific tool is conditioned by the company specificity and capabilities, there is always a tool that can be applied. Augmented reality is one such tool. It represents a tool that will allow better visualization and connection of the real world with the digital one. For managers, it can be a highly effective tool in decision-making and evaluation activities. It is possible to create different scenarios in a digital environment, simulations based on real data and thus flexibly manage individual processes.

In the submitted paper, some cases of the augmented reality use for selected methods applied in lean management are presented. These examples are based on the use of markers, which are used to the greatest extent in terms of augmented reality. The examples were designed to show the ease of their creation in individual environments.

In the future, the authors would like to focus on the possibilities of applying more advanced VR tools in the field of Lean, mainly for the needs of top management decision-making activities. By using this technology, individual members can achieve better results in managing and planning their activities.

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