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THE INTERNET OF THINGS SOLUTIONS IN THE PROCESS OF ELIMINATING WASTE ACCORDING TO LEAN MANAGEMENT ASSUMPTIONS

ROZWIĄZANIA *INTERNET OF THINGS* W PROCESIE ELIMINACJI MARNOTRAWSTWA WEDŁUG ZAŁOŻEŃ *LEAN MANAGEMENT*

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Summary: The Internet of Things solutions in addition to their most popular consumer use in the form of smartphones, smart watches and many smart home solutions have the potential to be used in a production environment for more effective work. Due to the number of processes taking place in such enterprises and the multitude of tools used, the possibilities of implementing such solutions are unlimited. Taking the example of the types of waste that occur in enterprises as detailed in the process of the development of the Lean Management concept, the authors of the article point to the possible use of the Internet of Things tools while eliminating waste, which reduces costs and creates a competitive advantage of the company. The considerations presented in the article were presented on the basis of conducted literature research and using such research methods as case analysis, direct participation of the authors in the selected cases and co-participating in observations.

Keywords: Internet of Things, waste, Lean Management.

Streszczenie: Rozwiązania *Internet of Things*, oprócz swojego najpopularniejszego, konsumenckiego wykorzystania w postaci np. smartfonów, inteligentnych zegarków oraz wielu rozwiązań z zakresu inteligentnego domu, mogą być wykorzystywane w środowisku produkcyjnym do efektywniejszego wykonywania pracy. Ze względu na liczbę zachodzących w takich przedsiębiorstwach procesów i stosowanych narzędzi możliwości tego typu rozwiązań są nieograniczone. Biorąc za przykład wyszczególnione w procesie rozwoju koncepcji *Lean Management* rodzaje marnotrawstwa w przedsiębiorstwach, autorzy artykułu

wskazują na możliwe zastosowanie narzędzi Internetu Rzeczy do ich eliminacji, co wpływa na redukcję kosztów i tworzenie przewagi konkurencyjnej przedsiębiorstwa. Zaprezentowane w artykule rozważania przedstawione zostały na podstawie przeprowadzonych badań literaturowych oraz przy wykorzystaniu takich metod badawczych, jak analiza przypadków, bezpośredni udział autora w identyfikowanych przypadkach, a także obserwacji współuczestniczących.

Słowa kluczowe: *Internet of Things*, marnotrawstwo, *Lean Management.*

1. Introduction

The concept of enterprise management called Lean Management, despite its simple assumptions of providing customers with products in accordance with their requirements at the lowest possible price while maintaining respect for the staff working in the enterprise, is very strongly associated with the development of methods and technologies production. Thanks to the concept of Lean Management enterprises apply the Kaizen philosophy, which assumes the continuous improvement of all processes occurring in enterprises, which is the starting point for the development of not only the knowledge and experience of the staff or methods of production in line with the prevailing trends, but also assumes an unconventional approach to solving problems in everyday work in a production environment.

On the other hand, the Internet of Things solutions assume that machines and devices connected to a shared network transfer information to each other through sensors, sensors or technology RFID. On this basis, they generate reports, automate activities and learn using artificial intelligence technology. They also limit human participation in data generation, which makes it more difficult to make mistakes.

The fusion of the form of the Internet of Things and the content contained in the Lean Management concept can be an excellent starting point for building an organization that will eliminate the still-encountered human error in production and be distinguished by a high degree of process automation and be able to lay the foundations for the use of artificial intelligence.

The purpose of this article is to indicate the possibility of combining the concepts of the Internet of Things and Lean Management in production process management processes. As a result of the hybridization of these concepts, it is possible to achieve synergy effects that will contribute to the reduction of waste and, consequently, the costs of operating the enterprise.

As the article has a conceptual and designing character, it was prepared as a result of conducted literature research, simultaneously using the knowledge and experience of the authors resulting from their direct participation in production processes and modelling of the production process management system in the discussed case study examples.

2. Concept of the Internet of Things

The Internet of Things is a concept first used by Kevin Ashton in 1999 during a presentation for Procter & Gamble, in which he described the possibilities of using RFID technology in supply chain management of this company. In his article from 2009 in which he mentions the above, and describes the main problem with information processing in information systems - most of them are generated by people. It is a costly process and has a high risk of error. Ashton puts forward a theory that if machines and computers were able to communicate with each other, send information they obtain from sensors and sensors, and save measurement results, this could significantly reduce costs [Ashton 2009].

The Internet of Things does not have one correct definition. Cisco IBSG in its report on the Internet of Things, theorises that one can talk about this phenomenon only from the moment when the number of devices connected to the Internet exceeds the population, which happened at the turn of 2008 and 2009 [Evans 2011]. The Internet of Things is really a vast infrastructure of all devices connected to the Internet, which due to their hybrid digital and material nature are an excellent set of tools for measuring and describing phenomena occurring in the real world. As a result, they are able to provide services that have never seen been before, regardless of whether they are related to household appliances, medicine, heavy industry or transport and forwarding. The IoT technologies are applicable in all areas.

In everyday practice, the Internet of Things is understood as a set of connected devices sharing a common server (e.g. a cloud computing solution). These devices can be: smartphones, tablets, smart wristbands, CNC machine tools, means of transport, elements of an automated production line or devices measuring physical properties. All these devices within the connection can exchange information that they obtain based on the sensors they are equipped with (e.g. temperature, motion or atmospheric pressure) or using RFID technology and based on them make decisions and actions, often automatically, without human intervention [Kwiatkowska 2014]. Moreover, by collecting all data and automatically interpreting them and presenting in the form of reports – charts, tables or graphs – they provide excellent support for decision-making processes at both the strategic and operational level.

The Internet of Things solutions can apply to any area of the enterprise, both administrative and production processes, the synergy of human creativity and efficiency of machines in data collection and processing gives infinite possibilities for their use e.g. for process optimization, their automation at the moment when it turns out that human intervention is not need or even their complete elimination, when after analysis they prove unnecessary. A production hall is great for using the Internet of Things. It consists of a multitude of processes taking place in this area as well as the need for the ongoing monitoring of measures indicating the degree of their implementation. Moreover, it is not only the continuity of monitoring that

is important, but also the accuracy of measurements that enable the creation of multidimensional analyses that contribute to the continuous improvement of the implemented processes. This creates conditions for setting higher and higher business requirements, as well as creating and maintaining the competitive advantage of the enterprise.

3. Types of waste according to Lean Management assumptions

Lean Management is a concept of enterprise management which is based on providing customers with products/services in the easiest way while maintaining respect for the staff working in the company [Bednarz 2019]. It covers all the main processes taking place in the company: from product development to delivery to the customer as well as auxiliary processes such as maintenance and internal logistics.

Lean Management is also a wide set of tools and practices that, due to their universal nature, can be used in many manufacturing and service enterprises, as well as in administration sphere.

The most popular model of presenting the concept of Lean Management is the so-called Lean House, see Figure 1. Most importantly, there is no single, correct interpretation of a Lean House. They differ depending on the specifics of the enterprises for which they are dedicated and the approach to the Lean Management method itself.

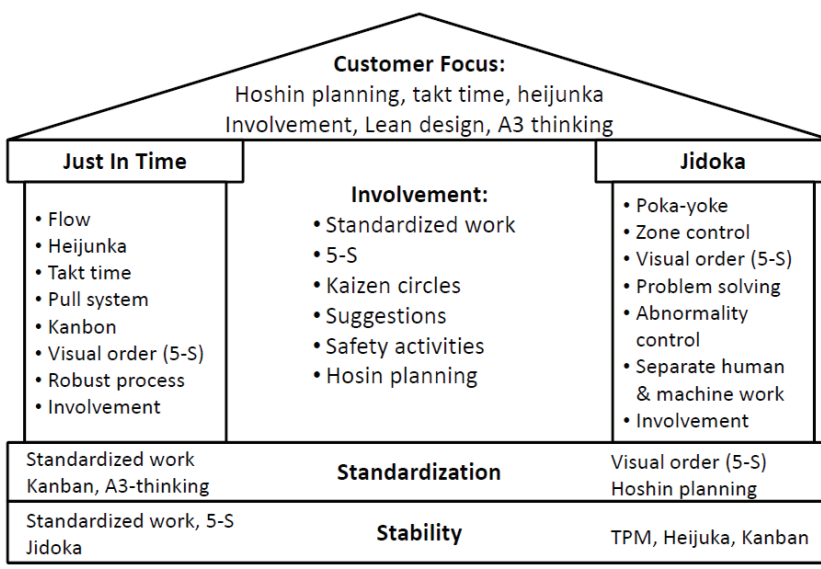

Fig. 1. Example of the presentation of the concept of Lean Management as a Lean House

Source: [*Overview of Lean Tools…*].

However, at the root of the concept of Lean Management is always stability, understood primarily as the ability to control the variable processes that occur in the enterprise. By this the authors mean the ability to describe and modify processes and the ability to provide the appropriate resources necessary for their occurrence [Lean Masters 2019] Another important foundation of the "House of Lean" is the Kaizen philosophy, which consists in the continuous, endless improvement of all areas of the company's activity. According to Kaizen, the process never reaches its final form. One is unable to achieve optimal solutions through human creativity and constantly evolving technology. The last basis of Lean Management most frequently indicated in the literature is the standardization of work, which is understood as determining the exact time necessary to complete the work, all the steps that need to be taken, and providing the necessary standardized set of tools [Lean Enterprise Institute 2019].

Another element, the concept of "House of Lean", is a set of tools that are used in Lean Management, for example:

- 5S – standardization of jobs.
- Just in Time – ensuring the right amount of materials at the right time and in the right place, which will ensure continuous flow.
- Kanban – a method of production control based on the identification of materials and assigning them the appropriate actions to be performed at a given moment.
- Value Stream Mapping – a graphic description of the entire process, identification of times and paths of information flow, materials and the impact of the environment (e.g. suppliers) on the process. It allows to look at the whole process and check for imperfections in it.
- 5WHY (5 times why) – a method that supports problem solving, which involves finding the source of the problem by answering the question "Why?".

One of the assumptions of Lean Management is the continuous identification and elimination of waste (Japanese word 'muda'). Waste is defined as those activities that bring no added value to the customer. The added value is all the elements of the product for which the customer is able to pay.

Taiichi Ono in his book "Toyota Production System: Beyond Large-Scale Production" [Ono 2011] indicates seven types of waste, which were later expanded by another one – the unused potential of employees. In total, there are eight types of waste, which are described below.

Overproduction – making too many products in relation to the demand for this product. The authors understand demand as internal for semi-finished products and external for ready products that reach the customer. In excessive production, one mainly wastes production capacity that could be used to manufacture other products at a given moment. Warehouse space and time to handle these stocks are also wasted.

Inventory means a greater than needed at a given time quantity of materials in warehouses – this applies not only to finished products but also to semi-finished products. This waste is associated with the use of larger than needed storage space, and also 'freezes' cash in the materials. In some cases, extended shelf life may also

affect the final product quality. Excessive inventories can also camouflage certain problems related to the company's operation, such as quality errors or logistics failure.

Defects that occur in products can be caused by many aspects such as the wrong choice of technology, tools, carelessness of the employee in the performance of his work, and poor machine maintenance. A quality error identified at the enterprise level may result in a waste of production capacity or material necessary to make subsequent pieces. At the time of delivery of a defective product to the customer, the effects, in addition to the time spent solving the complaint, can be much more harmful at the level of the entire enterprise – loss of customer trust in the brand, a decrease in the ranking of suppliers (in the case of cooperation between companies) which may cause a decrease in the number of orders or ending cooperation with the enterprise.

Waiting is the time wasted on the flow of material in the process – it can be caused by poorly organized internal logistics, problems related to product quality, maintenance or poorly estimated time necessary to perform the previous technological operation. Waiting is also a common waste in administrative processes: waiting for a decision, signature, standing in queues.

Excess processing – all unnecessary operations that do not add value to the customer, e.g. ensuring too high quality, using too advanced technologies or materials to make the final product. In administrative and management processes, these may also be redundant permits, signatures, consents or unnecessary convened meetings.

Transportation means unnecessary logistics operations performed on materials, semi-finished products and products, or wrong layout of the production hall. This creates unnecessary costs.

Motion – all physical activities performed by the employee that are not needed. They are usually associated with poor employee training or a poorly designed workplace.

Non-Utilized Talent is the last type of waste added after some time of Lean Management functioning. It consists in the enterprise not using the ideas, creativity and the whole time of its employees; very often it also manifests itself in outsourcing tasks below their competence.

As one can see in the examples above, the types of waste defined by the Lean Management concept affect all areas of the company's business and intertwine. Frequently waste of one type is the cause of waste of another type, which indicates the need to identify them and try to eliminate them.

4. The use of the Internet of Things in the process of eliminating waste

Given the possibilities of identifying waste that gives practical application to Lean Management and the use of the Internet of Things, the synergy of both methods gives a wide field of application in the process of eliminating waste.

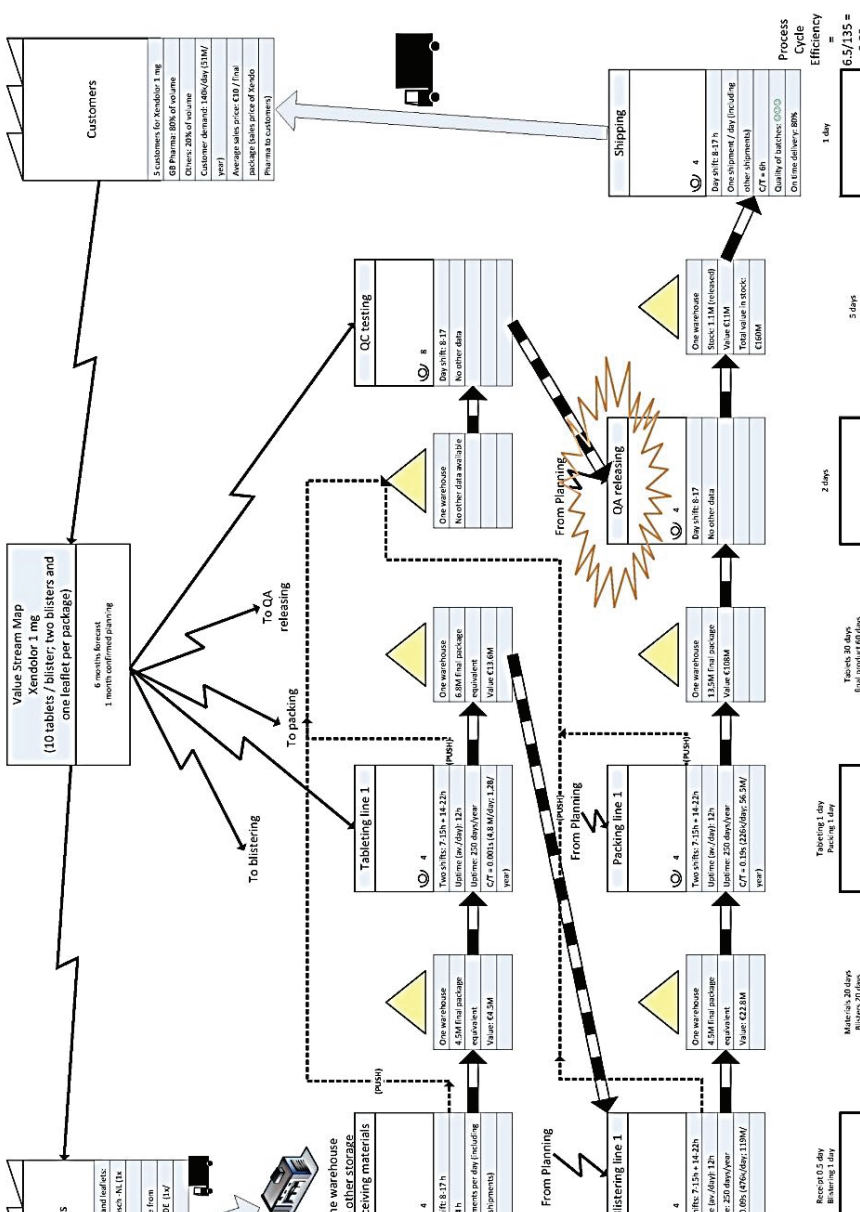

Fig. 2. Value Stream Mapping Example

Source: [*Xendo #lean…*].

An effective starting point for optimizing processes to reduce waste according to Lean Management is using the Value Stream Mapping method. This is a presentation in the form of a flow diagram of materials and information through the process, including all operations to which the objects of the process are subject. In process maps, one can indicate the time necessary for their execution, resources used, delivery time of these resources (including external suppliers), an indication of the required execution technologies and other process parameters that are of interest to us. This notation (Figure 2) may evoke BPMN or UML records used in the business analysis of solutions in the IT industry.

The next step is to analyze all the above-mentioned components of the process, select those that result in not adding product value and eliminate them. In this process, one also strives to simplify the entire stream of values as much as possible so that it does not leave the possibility of subjective interpretation of the process, which in itself can lead to waste. For example, due to the lack of definition of internal transport methods or the lack of tools or steps to perform a given operation, incorrect implementation solutions may be used. The result of using the Value Stream Mapping method is to create a process improvement action plan. In this plan, solutions related to the Internet of Things can be used.

4.1. Overproduction and excess inventory

Demand for materials and semi-finished products in the production process of goods in the vast majority of enterprises is dictated by external and internal customers. In this case we are dealing with a suction system (pull). This system involves releasing for production and supplying exactly the amount of products that the customer ordered. In the case of such a system, there is a risk that production surplus and improper management of materials will result in an increase in the cost of making finished products and producing such a quantity of products that cannot be sold later due to high market saturation. The result will be an excessive amount of material costs and the work that has been done.

Maintaining a continuous flow of materials is one way to counteract the waste of overproduction and excessive storage. One achieves a continuous flow by effectively planning the production schedule, determining the appropriate batch sizes for release and execution, determining storage fields and "work in progress" warehouses and their capacity.

In the case of a company making hundreds of thousands or even millions of identical items a year (e.g. screws of the same type), ensuring a continuous flow is a key issue. In the case of such quantities it is often difficult to count how many have been made, which leads to overproduction or the maintenance of high inventory levels. However, due to the fact that it is assumed that every element produced by the

company has the same mass, it becomes the value by which the number of pieces produced is easiest to identify. In this case, a system of electronic scales in the storage areas and in warehouses connected to a common network can help to ensure a continuous flow of materials. This type of solution is the use of the idea of the Internet of Things thanks to which in each storage field – whether during production or already in the warehouse of finished products – it is possible to determine (by dividing the total weight by the weight of one item) how many pieces of a given semi-finished or finished products are stored in a given place. Combining this with software that visualizes the layout of the production hall in a graphic form, one person from one place will have access to information on the number of pieces available in all warehouses and on all storage areas without the need to enter this data manually by employees, and thus the factor human which can lead to error is eliminated. This knowledge seems to be key in reporting on production performance (including work in progress) and to creating appropriate work schedules. Moreover, the use of this technology could strongly support further improvements in this area. Knowledge of the number of items at each stand could be a starting point for the introduction of automated internal logistics through the use of robots that would be responsible for maintaining the inventory at individual storage fields and warehouses at the appropriate level.

4.2. Quality errors and defects

Quality control in the production environment is one of the most important processes ensuring the organization's competitiveness by minimizing waste – it confirms the proper selection of technologies, tools, materials as well as the efficiency of machines and employee skills. By detecting quality incompatibilities, it is possible to take corrective actions that can be the beginning of major changes introduced in technologies and production management to eliminate errors and waste. Quality controllers in many areas are often highly qualified persons, with diverse training and appropriate certificates, and licence to use specialized measuring devices. Quality control, however, due to the main contractor being a human, cannot completely eliminate human error, and thus the admission of incompatible elements.

Thus, in particular in the area of quality control, the Internet of Things solution can be used. In some industries such as defence or aviation, complete quality control of all products is often required, along with checking the compliance of all dimensions of a given detail or subassembly, e.g. in the case of welded assemblies subject to mechanical processing. In this case it is possible to use 3D scanners that provide measurements within the required tolerances and work with minimal human involvement. If such scanners are connected to the network, one can control

measurements at many stations at the same time, receive automatic measurement reports and approve the releasing of products for further production, and in the case of automation at an even higher level, the machines themselves will be able to decide on passing materials further. Moreover, in the event of any inconsistency, in this case one can automate the stoppage of the entire production line, which is consistent with the Jidoka concept of Lean Management. This is the concept according to which, if any incompatibility of the product with the expected state is detected, the entire production line should be stopped immediately. This protects against the production of other incompatible elements but, above all, allows the whole team of people working on the process to focus on the problem to determine the causes and correct errors, which will eliminate the error and production can be started again.

4.3. Unnecessary movement

Mankind, despite its creativity, sense of commitment to the process, adequate motivation and training, is most often the cause of error and waste at every stage of the production process. One of these is unnecessary traffic, which mainly refers to manual workers, e.g. machine operators, operators of various types of transport, or maintenance department employees who deal with the maintenance of machinery and equipment. Most of the activities performed by these people have their optimal ways to being performed, including the number of steps and specific movements that are necessary. In the case of work in production, the places where the employee must reach to do his/her work are also important, such as warehouses, tool stands, storage areas or the workplace itself, which can be relatively large due to the dimensions of the machines being used.

In order to identify the places where the employee must go to perform their duties, production engineers use "spaghetti diagrams" (Figure 3).

These are marked on the layout of the place of work, which illustrate the route to the anticipated places that the employee will visit as part of the activities. Often, however, especially in the case of complex works such as machine retooling or maintenance, unpredictable steps can occur that must be carried out as part of the processes.

Creating a "spaghetti diagram", which is a record of the real route taken by an employee, is not a simple task. Usually it requires delegating another person who will draw the mentioned diagram during the observation. This is a waste of time of the observer who could then do other tasks, moreover, human observation does not guarantee the correctness of certain results. In this case, it is possible to apply the Internet of Things solutions such as GPS locators that workers would carry. When

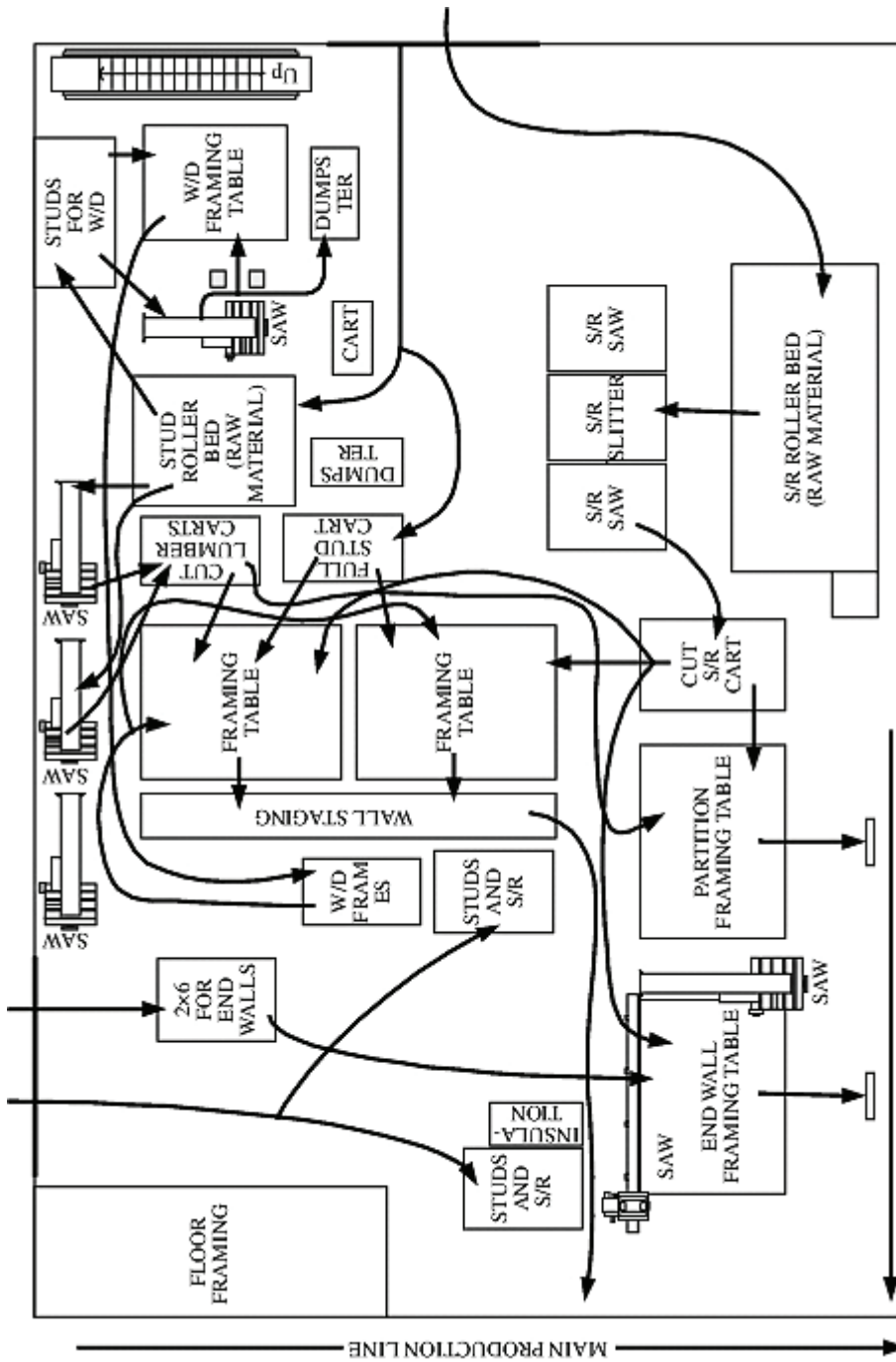

Fig. 3. Example of a "Spaghetti Diagram"

Source: [Nahmens, Mullens 2008].

connecting locators to the network and using appropriate software, it is possible to draw a "spaghetti diagram" on the layout of the production hall without the need to involve additional people in this process.

5. Conclusion

The article presents examples of the use of the Internet of Things solutions in the process of eliminating waste according to the assumptions of the Lean Management concept. Considering the fact that both the Internet of Things and Lean Management solutions can affect every sphere of activity of a production company (as well as a services or government administration), the possibilities of using these methods are limitless.

The combination of the concepts and tools related to Lean Management with the Internet of Things creates opportunities to optimize processes and thus reduce costs, in particular through the automation of processes carried out so far by people. In this case, one can save human labor time and eliminate the human factor, which is the most common cause of error and waste.

Thanks to the presented solutions, it is possible to plan production work, ensure the continuous flow of materials, manage warehouses and the supply chain, and optimize the process of quality control. Using data generated and presented by the Internet of Things devices that have sensors to measure and describe phenomena occurring in the production environment, one can obtain reports that will support decision-making processes implemented at the strategic and operational level.

The use of the Internet of Things solutions can also contribute to the development of the enterprise in using Big Data technologies and artificial intelligence.

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