doi:10.5937/jaes14-11664 Paper number: 14(2016)4, 398, 433 - 442

PROACTIVE APPROACH TO SMART MAINTENANCE AND LOGISTICS AS A AUXILIARY AND SERVICE PROCESSES IN A COMPANY

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The article describes a proactive approach to smart maintenance and smart logistics. It presents the areas through which all companies must pass. For its successful implementation it is necessary to introduce appropriate management practices also into the area of maintenance. Irrespective of the level of maintenance work in a particular organization, gradual development of maintenance management is needed. The goal is excellent quality of equipment maintenance. The logistics of tomorrow will be supported, to a high extent, by logistics assistance systems. The logistics world is changing – key terms such as Smart Logistics, digitization of the supply chain or Industry 4.0 are widely discussed and already mega trends.

Key words: Smart maintenance; Proactive maintenance; Technical Diagnostics; Digitalization; Industry 4.0; Logistics 4.0; Handling solutions

INTRODUCTION

Strategy and the overall concept of maintenance affect the performance of machinery and equipment. This is closely related to the productivity of manufacturing processes, investment returns of capital invested and the total profit of the company. The system of maintenance must be developed on the basis of customer requirements in terms of quality, operational capability of both machinery and processes, operational reliability of machinery, which affect value added and costs. Maintenance activities are currently seen as key success factors for manufacturing companies. It is the result of changing management concepts of manufacturing companies that put high and new requirements on management. To be prepared for future requirements based new concepts means to be interested in the current situation, analyze it and create new visions and a new model of proactive maintenance systems.

IMPLEMENTATION OF PROACTIVE APPROACH OF MAINTENANCE IN A COMPANY

The problem, which appeared after the arrival of Industry 4.0, is the solution of maintenance transformation into Smart maintenance in the context of a proactive approach. Basically, it is a transition to a new maintenance concept. The problem has so far been dealt with neither in literature nor in enterprises. In the following parts of the article we are going to outline some recommendations for the transformation of maintenance activities. [01]

EVALUATION OF PROCESSES

Two groups of methods are generally used for evaluation of maintenance efficiency: [16]

1) Process methods – evaluating maintenance efficiency of individual devices (assessment of appropriateness of repairs, introduction

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of technical diagnostics, etc.)

2) Complex methods - evaluating the overall maintenance efficiency on the basis of basic parameters of the maintenance performance. This category consists of two methods.

The first method is the MEE (Maintenance Efficiency Evaluation) method. It is used to evaluate the overall efficiency of maintenance both as a whole and its individual activities or organizational departments. The method assesses precisely defined maintenance parameters and compares them with optimal (recommended) values.

The second method is the MOPE (Maintenance Possibilities Outsourcing Evaluation) method. This method enables to evaluate the appropriateness of organizational provisions of individual activities and maintenance areas. The evaluation of individual criteria is done through recommendation of an organizational provision (centralization, integration, earmarking).The evaluation should focus on the assessment of maintenance processes with an objective to improve them and not to rationalize the maintenance staff.

PROACTIVE MAINTENANCE

Modern maintenance strategy prefers a proactive approach that should be the basis of the oil care program. Proactive maintenance is a continuous activity which consists in monitoring and management of the root causes of failures. Proactive maintenance enables to establish such an environment which would extend life-time of oils and machines. Failure prevention is focused on avoiding disorder occurrence or on evading other serious consequences. In other words, prevention is a proper care of equipment in the form of lubrication, calibration, functional tests, settings and so on. [14] [13]

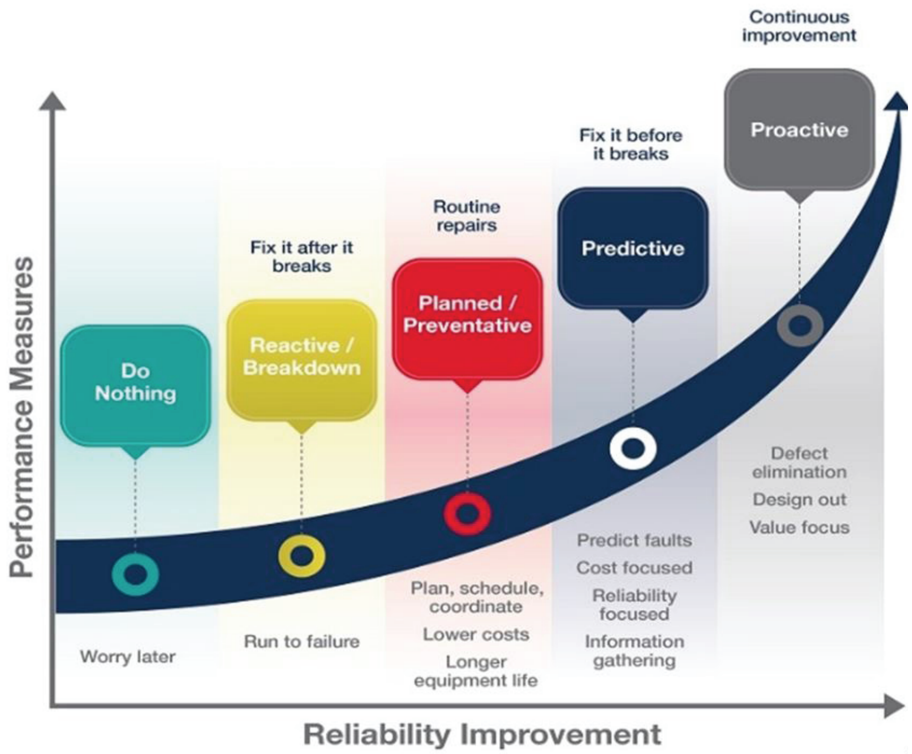

Figure 1: Development of reliability improvement [14] [13]

Before the proactive maintenance begins three basis steps are required: [14]

1) To identify limit values,
2) To identify methods of oil care to remove pollutants and contaminants,
3) To set up a monitoring program for oil and machine.

In order to successfully complete the oil care program, a lot of tiny tasks are to be thoroughly performed. The choice of maintenance strategy is substantial. While proactive maintenance focuses on monitoring the root causes of failures, predictive maintenance monitors, for the time being, only symptoms of disorders. Figure 1 presents the development of maintenance reliability. Following ten points are to be respected to avoid the failure of the analysis program: [14]

1. proper selection of sampling sites,
2. proper sampling procedure,

3. clean and appropriate samples,
4. analysis performed ASAP after sampling,
5. correct choice of criteria for evaluation parameters,
6. correct setting of boundary limits,
7. proper selection of procedures and testing methods,
8. adequate interval of sampling,
9. training, qualified personnel,
10. applicaion and interpretation of results.

An insufficient quality of data also becomes a problem. The analysis of micro-world of oils enables to gather a lot of information from a small amount of oil – information about oil, about invisible molecules of additives, and oxidation products. At first glance, to take a small amount of oil from a relatively large volume may seem to be quite simple. But this is decisive to achieve a good result. What is the significance of a sampling operation? The probability of default is dangerous especially if the repair takes several days or weeks. When to start with maintenance operations? What is the correct inspection interval? The following theory can give answers to the questions. [16] [15]

Every equipment wears down with usage over time; its condition deteriorates and performance decreases. After certain time it stops to be active and is prone to failure. The origin and development of a failure is shown in Figure 2. According to the new concept of maintenance, the equipment should achieve maximally P1 or P2. A few years later, after the process has been debugged, the points should disappear and the equipment should no longer enter the critical zone, i. e. a potential failure zone. [14]

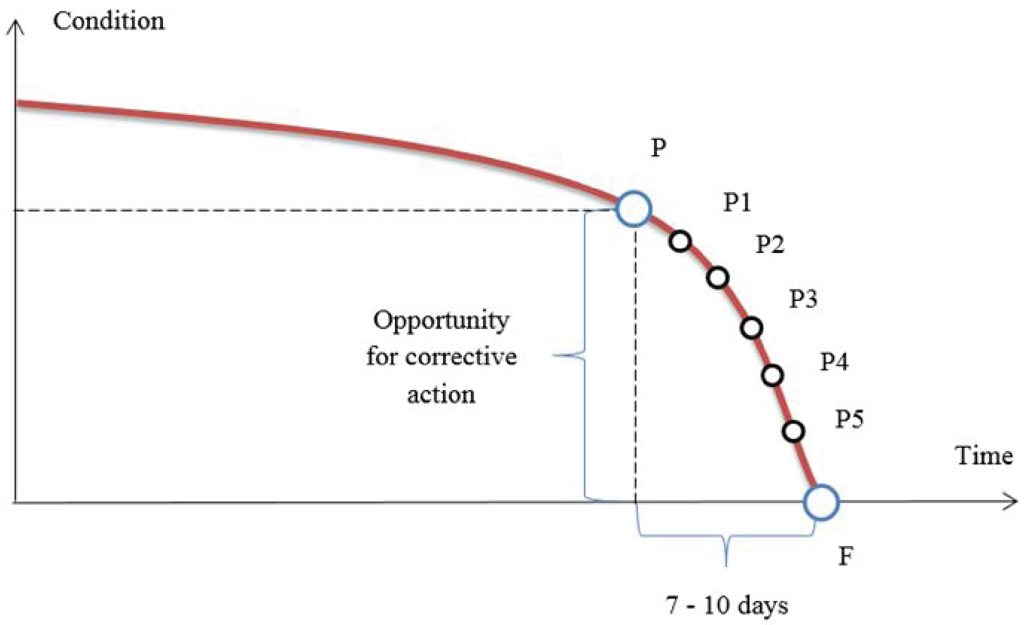

Figure 2: P-F curve of operating parameter
(P – potentiall failure; P1 – shown by vibrations; P2 – shown in oil; P3 – shown in the infrared spectrum; P4 – could be detected by an operator; P5 – shown by noise, heat, smoke …; F – failure)

The shutdown of a machine represents high production costs and losses. As there are many machines operating in industry, the probability of failures is high. A general rule says that the higher the probability of failure, the shorter the inspection interval. [09] Another rule says that the more stringent the criteria, the more frequent inspections. The situation depends on the quality of working environment. Following examples can serve as explanation: a requirement for extremely pure oil in a dusty environment or requirement for low temperature oil to be used in a heat load operation. Such conditions may require more frequent sampling. [02]

Several tests are to be carried out when checking the condition and quality of oils. But not all of the tests require the same inspection frequency. For example, ferrite components are measured only when the number of strange particles has a tendency of either to reach or exceed the limit value. Analytical ferrography is a technique of microscopic testing which determines a shape, composition, and concentration of wear ferromagnetic particles. If the analysis reveals a high number of Fe particles, it points to the increased friction. Such a situation requires emission spectroscopy or other tests as well as additional diagnostic methods. [13]

Implementation of the oil analysis program itself has no impact on taking better care of machines, unless the overall maintenance philosophy has been revised. Effective new oil care programs are accompanied by certain “revolutionary” changes that require a change in the thinking of management. It is connected with staff retraining, continuing education, introduction of new technology and other strategic changes.

TECHNICAL DIAGNOSTICS

The basic premise for the proper implementation of proactive maintenance and making decisions is a technical diagnostics. It is an efficient tool of reliability and is of great importance for the operation and maintenance of equipment. One of the most frequently used methods of technical diagnostics for rotating equipment is vibrodiagnostics. The main component in these devices is a bearing which provides a rotary motion and captures a dynamic load. High demands are currently put on modern machine tools; this affects not only their design and technological parameters, but also reliability and its diagnosability. [15] The most demanding is the operation of machine tools in unattended continuous operation. Figure 3 shows an OFF-line diagnostics device. Workers must go out with him around the factory and make diagnostics of machines. The data is not real-time.

Figure 3: OFF-line diagnostic device (Adash company)

On the contrary, Figure 4 shows the sensors and devices that are used for real-time parameters monitoring. The data is transmitted in real time with the software, where are further processed.

With such use of machinery great emphasis is put on its time and correct self-check which ensures that the diagnostic system detects a dangerous trend of any of the monitored parameters or directly failure. Each of today’s CNC machine tool has a standard operating diagnostics. [16]

Figure 4: ON-line diagnostic device (sensors from IFM company)

The common observed values are primarily critical temperature of the motor winding, temperature coolants, filters and fluid permeability and critical range achievement of the pressure in the fluid systems.

Signals from measuring component are usually evaluated by PLCs (Programmable Logic Controller) and critical messages are displayed via the interface of machine. Critical conditions induce programmed task in the PLC to avert a crash or prevent damage. The amount of such monitored quantities depend on the complexity of the machine, it is the order of units, maximum tens of measured signal. Higher requirements for machine diagnostics lead to draft extensive diagnostic tools. [12]

The aim of technical diagnostics is:

1) To increase the service life and operational reliability of machinery and equipment,
2) To reduce unplanned downtime due to fault conditions at the machines and devices,
3) To reduce the cost to perform the repairs and maintenance.

Formula for savings from the diagnostic by introduction of diagnostics in the automotive industry is following:

(m1- specific fuel consumption before application of diagnostic maintenance; m2 – specific fuel consumption following the introduction of diagnostic maintenance;

$$U = \frac{(m1 - m2) \cdot P_e \cdot k_v \cdot W_r}{\rho \cdot 1000} \cdot C_p - N_{di} \quad (1)$$

Pe – effective power of engine; kv – coefficient of utilization of engine power; Wr – annual machine utilization; ρ – specific weight of oil; Cp – the price of oil; Ndi – diagnostic costs)

COMPLEX OF MAINTENANCE

We live surrounded by SMART world. Everywhere we have SMART things, like: phones, cars, code, applications, and so on. Our data can be stored somewhere in the cloud and shared with friends around the world. We can also connect remotely to the Internet via the phone, tablet or computer and we can remotely control things in the home. In this same development stage is also industry. Now it will be Internet of Things. Some companies refer to as The Internet in the Things, where conventional things are becoming sophisticated. Maintenance must adapt to this new trend too. [10]

For some companies is Industry 4.0 a revolution, for another evolution but for some it can mean the collapse (Figure 5). It is for this reason that the market represents a large number of companies that are at various stages of development. Also, not all companies have implemented comprehensive maintenance package, which should be the basis or whether a springboard for the implementation of Smart maintenance.

Some people and companies think that if they implement Smart Maintenance, they already have everything resolved. But the opposite is true. If the companies have not undergone development and they have not implemented previous approach they will only grope and Industry 4.0 will really mean to crash. Lower are shown three basic concepts that are the basis for the implementation of Smart maintenance. The roles of each concepts:

1) TPM – Total productive maintenance, this concept will make order in the company and in the data,

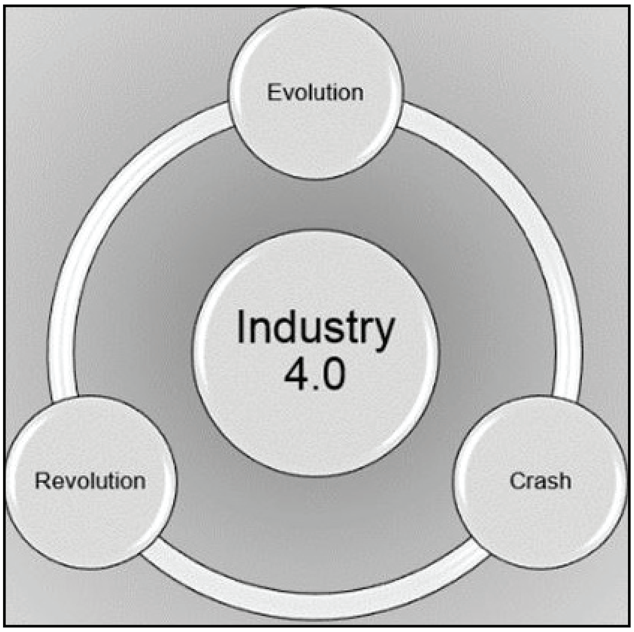

Figure 5: What means Industry 4.0 for companies

2) RCM - Risk centered maintenance, this concept focuses on the reliability of machinery and devices,

3) RBM - Risk based maintenance, this concept focuses on the risks of machinery and devices,

4) VDM - Value driven maintenance, this concept focuses on the maintenance costs.

These four concepts cannot exist without each other as they complement each other. Of course, they must be supplied by intelligent sensors, by the Internet and so on, so that they together will create Maintenance 4.0.

In the Smart companies all the processes have to be changed. People will be assisted by machines, devices or internet.

Figure 6: Picking materials in Smart companies

Workers will have to control tablets, touch screens or smartphones to be able to perform activities such as picking material or methodology SMED (Single Minute Exchange of Die), (Figure 6, Figure 7).

Figure 7: Diagnostics and SMED (Single Minute Exchange of Die) SMART line in the future

DIGITALIZATION

Companies in years 2009 - 2010 experienced unfavorable conditions: the financial crisis has exposed their structural weaknesses that had to be remedied if they wanted to survive. Many companies have achieved this, they change their policy. But many companies also did not succeed. The world has already digitalized in a so called “simple areas”. Today is the turn of industrial companies and their processes. Customers will in future expect easy and seamless cooperation. [11]

And why should be industry companies occupied by the digitalization? Here is a small example: every minute is in Apple’s App Store downloaded 48,000 applications. Every hour is to internet connected 5 million devices. Every day it is created so much data, as shown in the cradle of our civilization until year 2003. The products that customers want to buy on the internet they look at least 10 times and Malinowski contact possible suppliers. And when they do, it is often discouraging, if they cannot confess at the sellers home page or find the right product or person.

Digitalization opens the door to great opportunities. The digital future will combine the products with the software solution, which is already happening. Advantages can be already seen in maintenance. If companies have in their software right information and can trust them, then handyman can already be prepared in advance to failure, planned maintenance or patrol. This reduces implementation times and improves the work efficiency of maintenance workers and thus less production will be shut down. [07]

The advantage for the companies would also be complex software, where workers can found all necessary things and data. Here is an example: Handyman is working in his own system, but he must visit other system in order to find the necessary parts and solutions. It would be easier for him if to be connected to a single system. The same also goes with documentation, manuals and installation instructions. If the failure of an unexpected problem occurs, the servicemen would only scans the barcode or QR code and get the information directly to their phone, as opposed to reading user manuals. It would also be appropriate to be able to take a photo of the recent installation of new spare parts and post this photo as part of the technical documentation. [23]

The condition for the proper and efficient digitalization of the company is the proper data management of companies, preparation of the transformation for companies and for their production and for the maintenance department, devices categorization and their proper unique characteristics. Therefore we have to pay attention to this in the following years. Digitalization in maintenance will mean a new approach, a new strategy. And without the new design of the production systems, maintenance, logistics and simulation it will not be possible. These are areas, which we also deal with at the Department of Industrial Engineering at the University of Zilina. [23]

PROACTIVE APPROACH OF LOGISTICS IN A COMPANY

The distribution logistics is currently undergoing a paradigm shift. First and foremost, the change is driven by the market itself: Food and non-food consumers have completely new possibilities to cover their needs with E-Commerce and online trade. The good old supply chain has long developed to a consumer-controlled demand chain. Moreover, technical developments such as Big Data, Predictive Analytics, or Smart Logistics (4.0) create the conditions to practically realize concrete solutions for partially new business models. [16]

Tomorrow’s supply chains will be intertwined supply networks predicated on responding to supply and demand changes as they happen, not after the fact. Transaction and shipment exceptions are common, so businesses must be able to account for these variables by enabling a proactive supply chain. When problems occur, the earlier and faster information is communicated to partners, the better they can work toward finding an efficient and economical resolution. [3] Every transaction involves at least two parties - buyer and seller. But many others have a stake in its success, including raw materials suppliers, contract manufacturers, 3PLs, carriers, and freight forwarders, among others. Changes can come from either direction and from any partner: a spike in sales demand can trigger an inventory shortage; a fire in a supplier's warehouse can shut down a production line; over-production and slack sales can create overstocks. [6]When supply and demand fall out of sync, companies and their supply chain partners have to make quick, informed decisions to resolve the problem. In a proactive supply chain, the end user is in a position to immediately address supply and demand shifts before they become critical. [20]

NEW TECHNOLOGY DIRECTIONS

Industrial automation can and will generate explosive growth with technology related to new inflection points: nanotechnology and nanoscale assembly systems; MEMS and nanotech sensors (tiny, low-power, low-cost sensors) which can measure everything and anything; and the pervasive Internet, machine to machine (M2M) networking. [8] Real-time systems will give way to complex adaptive systems and multi-processing. The future belongs to nanotech, wireless everything, and complex adaptive systems. Major new software applications will be in wireless sensors and distributed peer-to-peer networks – tiny operating systems in wireless sensor nodes, and the software that allows nodes to communicate with each other as a larger complex adaptive system. That is the wave of the future. [17]

LOGISTICS 4.0 AND NEW HANDLING SOLUTIONS

The requirements to logisticians in all domains and all over the world increase every day. "If companies fail to provide their products at the right time, in the right quantity and at the right price in these times of growing online business, they can no longer satisfy their customers' Complex requirements. The industry is facing increasing pressure for optimization. Many companies have not yet recognized that Industry 4.0, the Internet of Things and Big Data are more than just marketing buzzwords. Intelligent solutions are the basis for the logistics of the future. [18]

Some new handling solutions [24] for intelligent factories: [21] [19] [05]

Laser guided Vehicles (LGV) and Automated Guided Vehicles (AGVs)

An automated guided vehicle (AGV) is a robot or driverless forklift truck designed, built and configured to increase efficiency and reduce costs by helping to automate the movement of goods in a manufacturing facility or warehouse. There are a number of different sizes and types of automatic guided vehicles depending on the application and use. The automated guided vehicle can either be programmed to follow markers or wires in the floor of a warehouse or manufacturing plant or they can work through the use of vision or lasers. They are used to perform a repetitive sequence of operations however their role can be changed at any time to perform any type of towing or carrying tasks. This is particularly useful when the role changes or the re-configuration of a manufacturing plant or warehouse takes place.

Figure 8: The Intralogistics concept of the future of CEIT in real operation [22] [04]

Automated Storage & Retrieval Systems (ASRS)

An Automated Storage and Retrieval System (AS/RS) refers to a variety of computer-controlled methods for automatically depositing and retrieving loads to and from defined storage locations within manufacturing, warehousing and distribution environments. They are compact machines that utilize the unused high level space of a plant or warehouse for the storage of products.

Figure 9: Automated Storage & Retrieval Systems (ASRS)

Items can be placed in specific locations either on pallets, trays or hanging from bars and can be accessed very easily. They are used to automatically to retrieve and put away products and can operate within a very narrow high space.

Sortation Conveyor Systems & Sortation Technology

A conveyor is a mechanized piece of handling equipment that moves materials from one location to another. There are many types of conveyor depending on the application and environment. Within a warehousing environment a Pallet Conveyor or a Mezzanine Floor Conveyor can be used to transport goods from one location to another. Within a postal environment a Belt Conveyor or Roller Conveyor can be used to move parcels and letters. Specialist Garment conveyors are used within the apparel industry and other types of conveyor include Gravity Roller Conveyors, Lineshaft Roller Conveyors, Modular Plastic Chain Conveyor and Stainless Steel Conveyor. A conveyor system can be used in overhead applications or mounted on the floor. They can be fixed to a specific location or can be mounted on wheels.

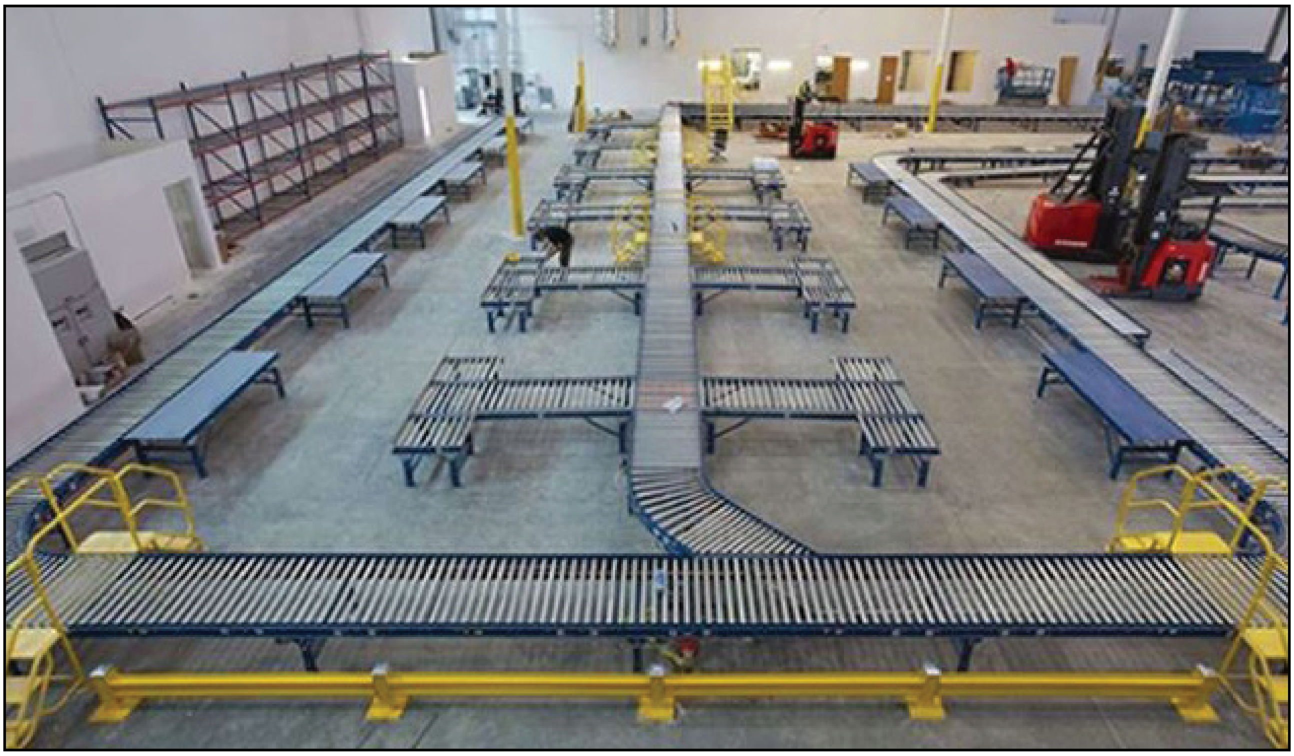

Figure 10: Sortation Technology

Voice-Directed Warehousing, VDW, Voice Picking, Voice in the warehouse.

Voice-directed warehousing (VDW) utilizes Voice direction and speech recognition software in warehouses and distribution centers (DCs). Other terms related to the deployment of Voice technology in the warehouse include Voice-directed picking and Voice-directed distribution. Voice-enabled workers wear a headset connected to a small wearable computer. The computer provides instructions to the worker in terms of what where to go and what to store or pick within the warehouse or DC. Workers are then required to confirm each task has been completed by saying pre-determined stock phrases and codes found at different warehouse locations or goods. The often cited benefits of 'Voice' include its being hands-free, 'eyes-free' and a faster and more accurate methodology than using paper 'pick lists' etc.

Figure 11: Voice in the warehouse

CONCLUSION

In the article is shown the view of the upcoming changes that need to be made in the area of processes in companies. Some changes in auxiliary and service processes (maintenance and logistics) have already begun. In "Industry 4.0", the movement of goods is no longer centrally coordinated; instead, production is in a sense self-organized – in some cases even beyond the boundaries of individual factories. This not only calls for complex logistics concepts that can respond flexibly to short-term production changes, but also requires fully networked trucks that automatically adapt their route planning. Another benefit is even fewer empty runs – that lowers fuel consumption and improves haulage firms' economic efficiency. From the viewpoint of production it is the intelligent maintenance which is basically a new concept, the transformation from classic maintenance to digital maintenance has to go through each step of process design.

ACKNOWLEDGEMENT

This paper is part of research supported by project KEGA 043 ŽU-4/2014.

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Paper sent to revision: 31.08.2016.

Paper ready for publication: 14.11.2016.