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Maintenance Management Systems in the Czech Enterprises of Chemical and Food Industries

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Abstract

Purpose of the article: The aim of this article is to use the results of the qualitative research to describe the current form of maintenance systems used in enterprises of chemical and food industries, and then to discuss and generalize the results.
Methodology/methods: The primary qualitative research was conducted in five companies, which can be regarded as typical representatives of the industries. The main objective of the primary research in individual companies was to determine how they perform the strategic and tactical operational planning of maintenance, implementation of these plans and their control. Individual interviews with respondents were used as the research method. The results of the research were processed using the content analysis method. Subsequently, comparison of the findings from individual businesses and subsequent synthesis thereof was performed, which allowed making generalizations.
Scientific aim: The scientific aim of the article is to develop knowledge in the field of maintenance management by specifying the form of the maintenance systems utilized in Czech enterprises of the chemical and food industries and identifying the main opportunities for their improvement.
Findings: Czech enterprises of the chemical and food industries utilize maintenance management systems. These systems are aimed at prevention, emphasizing the planning of maintenance activities in fixed periodic intervals. Also, they often utilize diagnostic maintenance. However, the maintenance systems currently used cannot be considered fully operational, with regard to the relatively large volume of after-failure repairs.
Conclusions: Production equipment maintenance systems are irreplaceable in chemical and food industry enterprises, but there is great potential for improvement. Improvement should be focused on the area of strategic as well as tactical and operational planning of production equipment maintenance. In terms of strategy, the biggest opportunity for a dramatic improvement is the implementation of modern maintenance methods. In the context of the existing systems, improvement can be achieved especially in setting strategic objectives, the system of indicators to measure the performance of maintenance and in implementing an information system. In the tactical and operational level, it would be useful to develop a maintenance planning system linked with suppliers and customers and utilize mathematical methods and models to optimize plans for this business activity.

Keywords: maintenance, maintenance systems, production equipment, chemical industry, food industry

JEL Classification: M11, M21

Introduction

Maintenance of production equipment in industrial enterprises plays an increasingly important role. It is quite obvious that it can eliminate a number of risks associated with the business and ensure effective use of financial resources necessary to ensure the working order of the machinery and equipment of the businesses. According to Jirgl (2008), a large part of the maintenance costs arises due to poor maintenance management.

Properly performed maintenance can contribute to gaining a competitive advantage. The maintenance process enhances customer satisfaction (Chan, Prakash, 2012), that is often directly dependent on the reliability, flexibility and speed of suppliers (Branska *et al.*, 2016).

Increasing satisfaction through better products or services is accepted as an essential step leading to customers' repurchase intentions and/or reducing switching intensions (Park, Jang 2014). This is essential for increasing the profit of the manufacturer (Chan, Prakash, 2012).

At the same time, as a supporting manufacturing process, maintenance can significantly affect the efficient use of production equipment, thereby helping to increase manufacturing productivity and economic performance of the entire organization (Legát *et al.,* 2013). Additionally, effective maintenance influences the success of the company's quality management systems and material flow control systems at the in-house and out-house levels. Therefore, maintenance of production equipment is accentuated especially in those businesses that:

- cannot afford to disappoint its customers mainly due to the technical quality of their products and/or due to delivery times,
- have limited production capacities,
- own outdated production equipment that requires high investments and
- pose a significant threat to the environment and/or its own staff as a result of accidents with production equipment.

For chemical and food industry enterprises, maintenance of production equipment is very important. In enterprises of chemical industry (especially those at the beginning and in the middle of supply chains), maintenance contributes significantly to the ability to consistently deliver the production material to their customers for further processing within the agreed deadlines, or to more or less synchronize material flow with suppliers and downstream manufacturers. Maintenance allows manufacturers of chemical products for final consumption (*e.g.* detergents, washing powders and personal care products) as well as food industry enterprises to meet retail and wholesale requirements for supplies. However, the question remains as to how advanced the maintenance systems are in companies of these industries. The aim of this article is therefore to use the results of the qualitative research to describe the current form of maintenance systems used in enterprises of chemical and food industries, and then to discuss and generalize the results.

1. Theoretical background

Maintenance is a business function that serves and supports the primary process in an organisation (Chan, Prakash, 2012). According to ČSN EN 13306 (2010), maintenance can be defined as "a combination of technical, administrative and managerial measures during the life cycle of the object, focusing on its maintenance in the state or its return to the state in which it can perform the desired function". To ensure the maintenance of its own production equipment, companies build maintenance systems. According to Rakyta (2002), the maintenance system should perform mainly the following tasks:

- identify the major types of repair works according to the nature of the equipment used and the operating conditions,
- identify the required period of repair works,
- identify the necessary amount of work based on the standards of maintenance labor
- effectiveness, the volume of material costs and minimizing downtime of production equipment,
- use modern methods of organizing repairs,
- establish an appropriate stimulation system based on the outcome of maintenance,
- ensure proper organization of material provision of maintenance,
- ensure proper quality of the maintenance work performed and
- create a system for planning supporting maintenance activities, with the possibility of their integration into related business activities.

The enterprise must establish such a system of the production facility maintenance that makes it possible to carry out maintenance in an optimal way, from the point of view of both ensuring smoothness of the material flow and its effectiveness (Bransk a, Baronova, 2012). This is basically a vision for maintenance, which is specified in the strategic objectives of maintenance. These objectives must be designed so as to contribute to the fulfilment of the higher-ranking objectives.

To allow monitoring the fulfilment of the objectives, it is necessary to define specific objectively measurable indicators and their target values (*e.g.* the determination of time to repair the production equipment, the expected total maintenance costs for the period, the volume of stocks of spare parts, etc.). Using selected objectives for the whole maintenance, we can then deduce even subordinate sub-goals for individual production centers and their maintenance, or even specific staff (Sláma, 2012).

Maintenance strategy addresses the conceptual issues associated with maintenance of production equipment, especially with (Al-Turki, 2011):

- maintenance system,
- outsourcing and organization of maintenance within own enterprise,
- ensuring human resources for maintenance of production equipment,
- planning of material resources and spare parts and
- planning of technical resources.

Within the maintenance system, the enterprise decides on the application of different methods and approaches to maintenance. The question is to what extent and how repairs will be applied after failure, preventive repairs and, within them, systems such as TPM (total productive maintenance), RCM (reliability-centred maintenance) and 5 S. Typically, companies tend to be inclined rather to the methods focused on prevention, because corrective maintenance is more expensive than the time used for preventive maintenance. Further, the unplanned stops often become longer due to longer waiting times, time for trouble shooting, lack of spare parts, etc. (Salonen, Bengtsson, 2011).

Next the enterprise addresses whether and to what extent it will make use of outsourcing in the implementation of maintenance activities, which activities to perform on its own, and sets the form of cooperation with the supplier of the maintenance activities. At the same time, organizational integration of maintenance within the enterprise is dealt with, relationships are adjusted between business processes (including the relationship between the production and maintenance), also addressed is the actual organizational structure of the maintenance (Branska, Baronova, 2012).

Ensuring human resources for maintenance of production equipment, planning of material resources and spare parts and planning of technical resources means to create support system for maintenance realization. Within the support system, systems are set for training maintenance workers and the principles of teamwork are applied. When addressing planning of technical resources, the enterprise especially decides on the implementation of information systems. The information system enables collecting and storing data, data filtering, data aggregation, statistical techniques for data analysis, analytical and computational tools for modeling (Klepek, Lenort, Straka 2011), analysis, optimization and optimal decision making, data distribution and data visualization (Murthy, Atrens, Eccleston, 2002; Karim, Candell, Söderholm, 2009). The system must provide the right information at the right time, of the right quality, to the right actor (Karim, Candell, Söderholm 2009).

Corporate maintenance systems should reflect the level of cooperation with partners in the supply chains. If the enterprise deepens cooperation with suppliers and customers, it will probably affect the method to manage the production equipment maintenance. The maintenance management should be carried out with regard to the maintenance management in other enterprises of the chain. In the closest forms of cooperation, it can be applied coherent maintenance management throughout the supply chain. In this case, the same principles must be applied as for the maintenance management in the enterprise that implements the production in several production stages (Branska, 2011).

The maintenance system of individual production equipment must respect the specificities of the production process and used production equipment (Branska *et al.*, 2016). At the same time, the system must be based on respect for aspects of environmental management and health and safety management. It is important to ensure that all maintenance activities are carried out with respect for the environment and also so as not to endanger the health and lives of the maintenance and production staff.

Finally, it should also be noted that the maintenance of production equipment in the company must not be planned and implemented regardless of costs. We need to constantly monitor the efficiency of maintenance and actions performed within it. The emphasis on economy can mean increased efficiency not only within one company, but even in the entire chain.

Based on the outcomes of strategic planning, tactical plans are made, which specify and elaborate strategic plans, specify substantive tasks and budgets. Tactical and operational planning of maintenance is very difficult. This is primarily because the number of repairs is large, their scope is different and they are implemented with minor or major regularities.

The tactical planning is followed by operational planning, which is used to secure the routine course of activities, solving problems, failures and shortcomings. The maintenance plan determines the set of operations, time intervals, and resources (staff,

supplies, and spare parts) necessary to conduct maintenance operations (Duffuaa, 2000; López-Santana *et al.*, 2016). The decision-maker determines how many maintenance periods to allocate and when to start each of them in order to minimize the makespan, *i.e.*, the completion time of the last job to be processed (Rustogi, Strusevich, 2012).

Specialized literature only marginally deals with maintenance systems in enterprises of the chemical and food industries (*e.g.* Tsarouhhas (2007), describes implementation of total productive maintenance in a pizza production line, Mwanza, Mbohwa (2015) implementation of TPM in a chemical industry enterprise, Heins, Röling (1995) a model usable in maintenance planning). Other publications may be found in the field of, for example, shipbulding industry (Carter, 1999), health care (Chompu-inwai, Tipgunta, Sunawan, 2008), steeel industry (Gajdzik, 2009), electronics industry (Chan *et al.*, 2005; Chen, 2013) or paper mill (Maletic *et al.*, 2015). However, these articles often come from a single company, rather taking the form of case studies. Rather than forms of maintenance systems, they deal with examples of the implementation of new methods in maintenance, especially TPM (*e.g.* Carter, 1999; Chan *et al.*, 2005; Tsarouhas, 2007; Chompu-inwai, Tipgunta, Sunawan, 2008; Gajdzik, 2009; Mwanza, Mbohwa, 2015). Forms of maintenance systems, particularly the modelling thereof, have been dealt with by, for example, Tan *et al.* (2011), Chan, Prakash (2012) or Zhang *et al.* (2013). Tan *et al.* (2011) proposed the analytical hierarchy process technique that combines many features which are important for the maintenance policy: safety, cost, value added and feasibility. Chan, Prakash (2012) focused on the selection of appropriate maintenance policy in a manufacturing plant using mathematical modelling. Zhang *et al.* (2013) through numerical examples demonstrate that environmental conditions and opportunistic maintenance pose significant impacts on how to determine an optimal maintenance policy, and that how cost parameters affect the optimal average costs and maintenance policies.

Maintenance systems in the Czech chemical and food businesses and their quality are not addressed in the literature at all. Therefore, the article contributes to the development of knowledge in this area.

2. Methodology

The research was conducted in five companies that were selected as typical representatives of the enterprises of the respective industries. Information on the enterprises included in the research is presented in Table 1.

The main objective of the primary research carried out in individual companies was to determine how they perform strategic and tactical-operational planning of maintenance, what input data enter these processes and how the plans are implemented and controlled.

In preparation for the survey, suitable production equipment was selected in each company in order to examine the maintenance system of the company. Then, eligible respondents were selected who are in each company responsible for maintenance management or any of its phases.

The research method used was in-depth individual interviews with respondents. The basic tool for conducting interviews was a questioning scenario based on literature search. Several successive interviews were conducted in each company. Individual sessions did not exceed 2 hours. As an additional source of information, the authors used in-house documentation of individual enterprises.

The research results were processed using the content analysis method to identify common and different features of maintenance systems in individual companies. On the basis thereof, a comparison of the systems examined was performed. Since the research was conducted in companies that can be considered typical representatives of the enterprises of the industry, some generalizations for selected industries were made.

3. Research results

Based on the results of the literature search, we can specify the content of maintenance management and, within it, also individual components of the strategic and tactical operational planning of production equipment maintenance. In an effort to know the current method of maintenance management carried out in the chemical and food industries, the authors investigated whether the individual components of maintenance management are implemented and how. The research results are shown in Tables 2, 3 and 4.

Qualitative primary research has shown that all the companies surveyed have established a production equipment maintenance system. Enterprises A, B, C and E have set a vision in maintenance area. Enterprises A and E have set this vision in essentially the same way, aiming "to guarantee the working order of the production equipment while exerting optimum maintenance costs in accordance with the time requirements of production and business activities".

Table 1. Characteristics of enterprises and production equipment included in the research.

Characteristics	Enterprise				
	A	B	C	D	E
Industry	Chemical industry	Chemical industry	Chemical industry – rubber industry	Food industry	Food industry
Size of the enterprise	Large (about 2000 employees)	Large (about 600 employees)	Large (about 1 700 employees)	Medium-sized (about 75 employees)	Medium-sized (about 100 employees)
Manufactured products	Chemical products for further processing in industrial plants	Chemicals for specific industrial and military use	Rubber and rubber materials	Dried coffee substitute drinks and colonial products	Dairy products
Characteristics of the process	Chemical-technological production process	Mechanical-technological production process	Chemical-technological production process	Biochemical and biological production process	Supporting process
Major operations of the process examined	Nitration	Cutting and sifting	Parkerizing	Roasting and extraction	Filling, packaging and labelling of products
Age of production equipment	1–10 years	30–40 years	20–30 years	50–60 years	10–20 years
Positions of the key respondents in the enterprise	Senior maintenance mechanics, maintenance and production technicians	Maintenance mechanic	Maintenance department director and maintenance division manager	Operations and technical director and head of maintenance	Technical manager

Source: Own research.

Table 2. Characteristics of strategic maintenance management in enterprises.

Characteristics	Enterprise				
	A	B	C	D	E
Vision in the field of maintenance	YES	YES	YES	NO	YES
Strategic objectives in the field of maintenance	NO	NO	NO	NO	NO
Maintenance outsourcing	YES	YES	YES	YES	YES
Centralized organization of maintenance	YES	YES	YES	YES	YES
Decentralized organization of maintenance	YES	YES	YES	NO	NO
Planned preventive maintenance (periodic)	YES	YES	NO	YES	YES
Planned preventive maintenance (after inspection)	NO	NO	YES	NO	NO
Diagnostic maintenance	YES	YES	YES	NO	YES
Using new methods in maintenance	NO	NO	NO	NO	NO
Information system for maintenance	YES	NO	NO	NO	YES
System for evaluating the performance of maintenance	YES	NO	YES	NO	NO

Source: Own research.

Enterprise B seeks to achieve the same, but at minimum cost. Enterprise C does not take maintenance costs into account in its vision. However, neither of the companies has set strategic goals in the area of maintenance, not even Enterprise B, which draws up a long (five-year) maintenance plan.

All enterprises use maintenance outsourcing, but to a lesser extent than they perform maintenance by

themselves. Enterprise D is the only company that employs outsourcing more. The external company has placed maintenance workers in the company who carry out not only preventive maintenance, but also after-failure maintenance (Hradecká, 2015).

All the enterprises have incorporated maintenance into the company's organizational structure and resolved internal maintenance organization. In Enterprises A, B, C it is combined maintenance (combining decentralized and decentralized maintenance). In Enterprises D and E it is centralized maintenance. The way they organize their own maintenance is obviously related to the size of enterprises; combined maintenance has been identified in large enterprises.

All the companies surveyed have a prevention-oriented maintenance system; apart from Enterprise C they apply the system of planned periodical repairs. Enterprises A, B and E combine it with a diagnostic maintenance, implemented, however, using especially human senses. Enterprise E is the only one to use diagnostic tools to monitor various characteristics such as noise, leaks, overheating, vibration or poor quality products. Enterprise C uses an "after inspection" preventive maintenance system and does not use diagnostic maintenance. All the enterprises surveyed also conduct after-failure repairs. Still, it is not a targeted strategy, yet malfunctions that indicate a preventative maintenance system failure. The scope of after-failure maintenance, however, varies in individual companies and is also affected by the aging of production equipment and the volume of funds invested in maintenance; for example, Enterprise D performs after-failure repairs almost every other day (Hradecká, 2015).

None of the companies surveyed use modern methods to improve maintenance such as RCM and TPM. However, we can identify the use of some ideas underpinning the TPM method. This is particularly the delegation of maintenance activities to maintenance workers and operation of production equipment and use of knowledge of production equipment that production workers have. Enterprise B's operators are responsible for cleaning and lubricating the machine, those in Enterprise D are responsible for cleaning and setting up the machine (Hradecká, 2015) and those in Enterprise E for lubricating the machine. The operators' expertise related to the correct operation of the machine is used in all enterprises to conduct inspections of production equipment by production workers. However, beyond the initial training and regular testing of the knowledge of production duties there is no targeted deepening of the maintenance knowledge and skills of production workers in any of the enterprises.

Only in two Enterprises (A and E), maintenance management is supported by specialized software. Enterprise B uses the SAP system, but only to record information about the production equipment and spare parts used in the repair and about maintenance costs. Enterprise C uses only the MS Excel system to record requests for repairs. Enterprise D does not use any information system; it only works with paper documentation (Hradecká, 2015).

Enterprise A is the only one to have set up a system of indicators that allows evaluating the effectiveness of production equipment maintenance (Solilová, 2015). Enterprises B and C only use a limited number of indicators – Enterprise B monitors the costs associated with maintenance, the number of maintenance workers and overtime hours worked by the maintenance staff; Enterprise C monitors the same indicators, but they use only one indicator for the actual assessment of maintenance, namely downtime, defined as the number of devices that are inactive because of an accident.

Table 3. Characteristics of tactical and operational management in enterprises.

Characteristics	**Enterprise**				
	A	**B**	**C**	**D**	**E**
Using information inputs into the planning process	YES	YES	Unidentified	YES	YES
Using mathematical methods and models	NO	NO	NO	NO	NO
Continuity in equipment maintenance planning and enterprise-wide maintenance plans	YES	YES	YES	NO	NO
Linking maintenance planning with the production plan	YES	YES	YES	YES	YES
Linking maintenance planning with maintenance planning of suppliers and customers	NO	YES	NO	NO	NO
Planning purchases of spare parts	YES	YES	YES	YES	YES
Warehouse for spare parts and overhead material for maintenance	YES	NO	YES	NO	YES

Source: Own research.

Table 4. Parts of tactical and operational maintenance plan in enterprises.

Enterprise	Parts of tactical and operational maintenance plan
A	Schedule of specific events, repair plan, schedule of revision, lubrication schedule, plan for inspecting the condition and functionality of equipment, maintenance budget
B	Annual repair plan following the five-year repair plan, schedule of shutdowns, annual plan of revisions, lubrication schedule, plan for inspecting the condition and functionality of equipment, maintenance budget
C	Annual plan, lubrication schedule, plan for inspecting the condition and functionality of equipment, maintenance budget
D	Annual plan (self-maintenance, outsourcing), lubrication schedule, maintenance budget
E	Annual plan, operational maintenance plan, lubrication schedule, maintenance budget

Source: Own research.

All enterprises carry out tactical and operational planning in maintenance. Enterprise B has based it on the strategic maintenance plan (conceived for a 5-year period); the most complex maintenance schedules in the other enterprises are tactical plans (usually for one year). Tactical plans are further elaborated (for months in Enterprise B, for weeks in Enterprises D and E or for divisions in Enterprise C). Repairs are scheduled in all the enterprises.

All the enterprises use a wide range of information inputs into the process of tactical and operational planning of maintenance. Enterprises A, B and E use mainly national (or international regulations), internal guidelines, corporate manuals and instructions, years of experience of mechanics and other technical maintenance staff, manuals and manufacturers' recommendations and information gained from the maintenance control process. Enterprise D mainly uses records from audits in retail chains, records of inspections of the working environment, records of energy, food and environmental inspections and also experience of the company technical staff (Hradecká, 2015). However, none of the companies surveyed uses mathematical methods and models in planning maintenance of production equipment.

It was found in Enterprises A, B and C that maintenance plans are first conceived for the whole company and then used as a base for strategic plans (Enterprise B) and tactical-operational plans (Enterprises A, B and C) for maintenance of individual machines. Enterprises D and E directly draw up tactical-operational maintenance plans for individual machines, and it can be assumed that this is so due to the company size. Maintenance planning systems in smaller enterprises are generally simpler. Primary research has demonstrated that the maintenance plans in all companies are created in close relation to production and sales plans. Especially scheduling of shutdowns is aligned with the needs of the production process. There is only one enterprise (Enterprise B) that synchronizes maintenance plans with its supplier's maintenance plans, specifically temporary shutdowns are synchronized. However, none of the enterprises surveyed synchronizes its maintenance plans with customers. However, it is true that Enterprises D and E do not even have this option, because customers are not processing companies but dealers of food products (*i.e.* wholesales and retails).

Primary research has shown that the output of tactical-operational maintenance planning in all businesses is a set of plans. Not only repair plans are created (which are developed into plans for own and external maintenance in Enterprise D), but also downtime plans, audit inspections, lubrication plans, plan for inspecting the condition and functionality of production equipment. In addition, Enterprise A creates plans for specific events (Solilová, 2015). It is a precisely defined plan of repairs, which also includes general and medium-sized ones. All the enterprises supplement these plans with maintenance budgets. In connection to tactical and operational planning of maintenance, all enterprises also plan purchasing of spare parts. Enterprises A, C and E also have a warehouse for spare parts. The other Enterprises (B, D) order parts as needed. Order processing is a matter of weeks (Enterprise C states 6–8 weeks). As a certain defense against a lack of material required for maintenance (in enterprises not building up stocks) and a defense against excessive amount of stocks (in enterprises with warehouses), there is an effort to unify spare parts in a way.

4. Discussions

Based on the results of the qualitative research, it can be stated that Czech enterprises of the chemical and food industries utilize systems for maintenance management. If we evaluate these systems in

relation to the theoretical approaches, we can state that they are aimed at prevention, and enterprises also strive for efficiency in the implementation of maintenance activities. The maintenance systems utilized are based on traditional approaches, *i.e.* they emphasize the planning of maintenance activities in fixed periods. While diagnostic approaches to maintenance are also certainly coming into practice, technical measurements to determine the present and the marginal rate of wear are used relatively little. However, an entirely conventional method is sensory assessment of the state of the production equipment, which is performed very often by operators of the equipment.

The maintenance systems currently used cannot be considered fully operational, given the relatively large amounts of after-failure repairs which may be perceived as a failure of the system. While corporate maintenance systems are being improved, it seems to be done in a relatively slow pace. In addition, enterprises of the chemical and food industries quite inadequately apply modern methods used in the maintenance of production equipment, such as RCM or TPM, described in literature for a relatively long time. However, it is true that selected principles of the TPM method are used in business practice – in particular, dividing the simplest maintenance activities between the maintenance workers and operators of the production equipment.

The research results and confrontation thereof with theoretical approaches show that the production equipment maintenance systems in these industries have much space for improvement. Improvement should be focused on the area of strategic as well as tactical and operational planning in maintenance of production equipment. If we compare the theoretically recommended content of maintenance planning in the strategic area, the greatest opportunities lie in setting strategic goals and implementing a method to monitor achievement thereof (especially setting benchmarks to monitor the performance efficiency of maintenance).

In accordance with the recommendations of scientific literature, it appears that a suitable tool for improving all phases of the maintenance management could also be introduction of an information system (either as part of a company-wide information system or specialized information systems for maintenance). Of course, step improvement of business maintenance systems could be ensured through implementation of modern maintenance methods. In the tactical and operational level, it would be useful to develop a maintenance planning system, especially in interlacing the maintenance plans with suppliers and customers. Optimization of maintenance plans could also be increased in consequence of the application of mathematical methods and models often cited in theory.

5. Conclusion

The production equipment maintenance systems are irreplaceable in enterprises of the chemical and food industries, but as is clear from the research mentioned there is a big potential for their improvement. The follow-up research should be focused on examining barriers to implementation of modern maintenance methods and their greater use. Follow-up research could also focus on maintenance systems in companies of other industries in order to identify opportunities for improving maintenance in chemical and food industries.

References

Al-Turki, U. (2011). A framework for strategic planning in maintenance. *Journal of Quality in Maintenance Engineering,* 17(2), pp. 150–162. DOI: 10.1108/13552511111134583.

Branska, L., Baronova, Z. (2012). Changes in the company maintenance system to increase effectiveness of the material flow. In: *International Carpathian Logistics Congress (CLC 2012)*, 7–9 November 2012, Jesenik, Czech Republic.

Branska, L. (2011). Maintenance Management in Quick Response Systems. *Economics & Management*, 16, pp. 676–682.

Branska, L., Pecinova, Z., Patak, M. (2016). Maintenance as a Tool for Increasing the Efficiency of Chemical-Technological Process. In 9th *International Scientific Conference "Business and Management 2016",* 12–13 May 2016, Vilnius, Lithuania.

Carter, R. (1999). Under way with TPM at NASSCO. *Industrial Maintenance & Plant Operation*, 60(6), pp. 26–29.

Chan, F. T. S., Lau, H. C. W., Ip, R.W. L., Chan, H. K., Kong, S. (2005).

Implementation of total productive maintenance: A case study. *International Journal of Production Economics*, 95(1), pp. 71–94.

Chan, F. T. S., Prakash, A. (2012). Maintenance

policy selection in manufacturing firms using the fuzzy MCDM approach. *International Journal of Production Research*, 50(23), pp. 7044–7056. DOI: 10.1080/00207543.2011.653451.

Chen, Ch-Ch. (2013). A developed autonomous preventive maintenance programme using RCA and FMEA. *International Journal of Production Research*, 51(18), pp. 5404–5412.

Chompu-inwai, R., Tipgunta, S., Sunawan, A. (2008). Implementation of Total Productive Maintenance in Healthcare: A Pilot Study. In: *5th International conference on service systems and service management*, 30. 6.–2. 7. 2008, Melbourne, Australia.

ČSN EN 13306 Údržba – Terminologie údržby. Praha: Úřad pro normalizaci, metrologii a státní zkušebnictví, 2011.

Duffuaa, S. O. (2000). Mathematical models in maintenance planning and scheduling. In: M. Ben-Daya, S. O. Duffuaa, A. Raouf (Eds.), *Maintenance, Modeling and Optimization*. New York: Springer, pp. 39–53.

Gajdzik B. (2009). Introduction of total productive maintenance in steel works plants. *Metalurgija*, 48(2), pp. 137–140.

Hradecka, A. (2015). Improvement of production equipment maintenance in the food company. Master's thesis, 72 p., Czech Republic.

Heins, W., Röling, M. W. M. (1995). Application of multiattribute theory in a safety monitor for the planning of maintenance jobs. *European Journal of Operational Research,* 86(2), pp. 270–280.

Jirgl, B. (2008). *Benefits of systems for maintenance planning and control.* [in Czech]. Retrieved from: http://www.systemonline.cz/clanky/prinosy-systemu-pro-planovani-a-rizeni-udrzby.htm.

Karim, R., Candell, O., Söderholm, P. (2009). E-maintenance and information logistics: aspects of content format. *Journal of Quality in Maintenance Engineering*, 15(3), pp. 308–324. DOI: 10.1108/13552510910983242.

Klepek, R., Lenort, R., Straka, M. (2011). Modeling and simulation of permeability of heat treatment of forged pieces. In: *20th Anniversary International Conference on Metallurgy and Materials (METAL 2011)*, 18–20 May 2011, Brno, Czech Republic.

Legát, V., Grenčík, J., Rakyta, M. a kol. (2013). *Management a inženýrství* údržby. 1st ed. Praha: Professional Publishing, 570 pp.

López-Santana, E., Akhavan-Tabatabaei, R., Dieulle, L., Labadie, N., Medaglia, A. L. (2016). On the combined maintenance and routing optimization problem. *Reliability Engineering & System Safety,* 145(1), pp. 199–214. DOI: 10.1016/j.ress.2015.09.016.

Maletic, D., Lovrencic, V., Maletic, M., Al-Najjar, B., Gomiscek, B. (2015). Maintenance Solutions for Cost-Effective Production: A Case Study in a Paper Mill.
In: P. W. Tse, J. Mathew, K. Wong, R.
Lam, C. N. Ko (Eds.), *Engineering asset management – systems, professional practices and certification*. New York: Springer, pp. 375–385.

Mwanza, B. G., Mbohwa, C. (2015). Design of a Total Productive Maintenance Model for Effective Implementation: Case Study of a Chemical Manufacturing Company. *Procedia Manufacturing*, 4, pp. 461–470. DOI: 10.1016/j.promfg.2015.11.063.

Murthy, D. N. P., Atrens, A., Eccleston, J. A. (2002). Strategic maintenance management. *Journal of Quality in Maintenance Engineering*, 8(4), pp. 287–305. DOI: 10.1108/13552510210448504.

Park, J-Y., Jang, S. (2014). Why do customers switch? More satiated or less satisfied. *International Journal of Hospitality Management*, 37, pp.159–170. DOI: 10.1016/j.ijhm.2013.11.007.

Rakyta, M. (2002). Údržba ako zdroj produktivity. 1st ed. Žilina: Slovenské centrum produktivity, 198 pp.

Rustogi, K., Strusevich, V. A. (2012). Single machine scheduling with general positional deterioration and rate-modifying maintenance. *Omega,* 40(6), pp. 791–804. DOI: 10.1016/j.omega.2011.12.007.

Salonen, A., Bengtsson, M. (2011). The potential in strategic maintenance development. *Journal of Quality in Maintenance Engineering,* 17(4), pp. 337–350. DOI: 10.1108/13552511111180168.

Sláma, L. (2012). *Strategie* údržby *ve výrobních společnostech* s *využitím informačního systému*. Retrieved from: http://www.systemonline.cz/clanky/strategie-udrzby-ve-vyrobnich-spolecnostech.htm.

Solilova, T. (2015). Maintenance planning in a chemical industry: Master's thesis, 57 p., Czech Republic.

Tan, Z., Li, J., Wu, Z., Zheng, J., He, W. (2011). An evaluation of maintenance strategy using risk based inspection. *Safety Science*, 49(6), pp. 852–860.

Tsarouhas, P. (2007). Implementation of total productive maintenance in food industry: a case study. *Journal of Quality in Maintenance Engineering,* 13(1), pp. 5–18. DOI: 10.1108/13552510710735087.

Zhang, Z., Wu, S., Li, B., Lee, S. (2013). Optimal maintenance policy for multicomponent systems under Markovian environment changes. *Expert Systems with Applications*, 40(18), pp. 7391–7399.

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