Digital Transition of the Maintenance Process: Case of Rail Transport Company

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Digital transformation of business activities has outgrown from competitive advantage to necessity in recent years. Evolution of information and communication technologies (ICT) has created the world where electronic business (E-Business), document management systems (DMS) and enterprise resource planning (ERP) solutions have become standard, even for micro, small and medium enterprises (MSME) in developing countries. Modern businesses focus on implementing data analysis, business intelligence (BI) and even artificial intelligence (AI) concepts in their everyday activities, thus the digitalization of business activities is simply considered as default. Nevertheless, public companies in developing countries fall behind and struggle in this transformation process, as usual. Due to various reasons, they are still in the phase of digitalization, rather than implementing advanced solutions. Any organizational change demands unfreezing and mindset redirection, among both management and executors, which is always challenging, especially in the public sector. This paper aims to explain the preconditions and benefits of digital transition of the train maintenance process, and key challenges in such transformation.

Keywords:
digital transformation, organizational change, business process digitalization, train transport, railway, maintenance, public sector management

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1 Introduction

Rapid changes in the business environment require constant adaptation of all modern organizations since these adjustments have become the only way to maintain competitiveness and achieve satisfactory business results (Kraus, et al., 2021). In parallel, the development of Industry 4.0 has contributed to the fact that digital tools are increasingly used in practically all business spheres, which creates the basis for the introduction of digital transformation (Krivokapić et al., 2023). Digital transformation implies the use of digital technologies to create new or to modify existing business models and processes, and represents support for the transformation of organizational structure, resources, and internal and external relations (Plekhanov et al., 2022).

Digital transformation brings with it many potential benefits. If implemented in an appropriate manner, it is possible to improve the company's performance through:

- More efficient data collection and analysis (Tratkowska, 2019) - digital technologies allow data to be collected more easily and used better, and as such can represent the basis for various types of analysis.
- Better resource management (Hu et al., 2023) - modern technologies enable standardization and centralization of all company's resources, which may lead to better and more accurate records of their spending and perception of accountable employees,
- Improved productivity (Du & Jiang, 2022) - automatization of activities and better coordination of employees' efforts enable jobs to be performed more efficiently which makes final outputs better.
- Adaptation to user needs and better consumer experience (Hoyer et al., 2020) - better understanding of user requirements enable companies to become consumer-oriented.
- Increased agility (Saleh & Saad, 2023) - quick adaptations through multiple cycles allow more innovations in both key and supporting processes.

On the other hand, digital transformation also represents a major organizational challenge (Chaanoun et al., 2022). The use of digital technologies implies a change in the way activities are carried out, which requires the need for employees' education, change in their awareness regarding their roles in the processes, as well as the provision of solutions for overcoming potential resistance (Scholkman, 2021) that might arise due to the fear that all these changes are carrying. Having this in mind, digital transformation must be precisely designed and adapted to the specifics of each company, to generate all potential benefits and to overcome the obstacles as easily as possible.

2 Maintenance Process and Digitalization

Maintenance represents one of the most important processes in every organization with a high amount of fixed assets. Ensuring the correctness, functionality and development of technical systems is one of the prerequisites for continuity of production or provision of services (Todorović, Komazec & Marič, 2020). On the other hand, keeping them functional generates expenditures that usually correlate with their value. Influence on business operations and cost structure (Fontanini & Wollmann, 2021) pushes the management of maintenance activities among the top aspects in generating the business strategy (Barberá, Crespo, Viveros & Stegmaier, 2012). While corrective maintenance is focused on removing the faults with minimal costs and in shortest time whenever they occur, preventive maintenance can be scheduled (Lao, Ellis & Christofides, 2014). Preventive maintenance planning is one of the key activities in the realization of the maintenance process (Kłos & Patalas-Maliszewska, 2013), which is aimed towards detecting the proper elements and assignments for pro-active repairs and confirming that sufficient resources for the operations execution are available (Rosqvist, Laakso & Reunanen, 2009).

Preventive maintenance can be planned at an operational level, but corrective maintenance activities are stochastic. Nevertheless, when it comes to financial planning, costs of both types of maintenance can be predicted with high accuracy, if the organization owns adequate historical evidence about corrective maintenance activities. Additionally, human capacities required for the execution of annual maintenance operations can also be calculated on the base of the suitable maintenance reports from previous years (Todorović, Komazec & Jaško, 2021). Deficiency of data suitable for analytics disables the maintenance process optimization and leads towards cost increase as the organizations strive to ensure the enough resources to secure the systems from failures, sometimes performing more operations than necessary or providing more employees and parts in stock than required (Komazec, Todorović & Jaško, 2015). Organizations tend to define the most effective maintenance plans (Schutz, Rezg & Léger, 2013), but they should also keep an eye on the reporting methods, as they are preconditions for good planning (Jovanović, Mrvić & Todorović, 2020).

3 Research hypothesis and methodology

ICT could be an important tool for reaching efficiency and effectiveness within maintenance (Kans, 2008). ERP solutions can secure operational and financial planning, but also the reporting that generates the base for data analytics and BI in the field of maintenance. This paper will try to explain the process of ERP introduction in the maintenance function and potential accompanying benefits, in the case of a train transportation company. Therefore, we hypothesize that:
Hypothesis: The introduction of ERP system in the maintenance function improves various aspects of the maintenance process.

As a research method we use case study, a standard tool in management consulting practice (Bosilj Vukšić, Pejić Bach & Popović, 2013) for conducting a complete analysis and report of an individual subject with respect to specific phase of its totality (Krishnaswamy, Sivakumar & Mathirajan, 2006). All data presented in the paper were generated during the 8 months of consulting project in a rail transport company. The research concluded documentation analysis, process mapping, direct observation and interviews. All the authors of this article were members of the consulting team. Situational analysis of the observed case of rail transport company and key research findings will be provided in separate chapters, followed by the concluding remarks.

4 Situational Analysis

To effectively implement the digitalization of the maintenance process, it is necessary to map the current process flow, especially around creating and validating the maintenance work orders, and the issues that appear because of inadequate process organization. The company introduced the SAP system into its operations some time ago, along with its plant maintenance module. However, during the implementation, the adaptation of the system to the process was not carried out in the best possible way, i.e. vice versa, the process was not sufficiently optimized, so that it can take all the advantages and opportunities that SAP, as such a system, provides.

After bringing the vehicle to the workshop, the Train Driver initiates the maintenance process by fulfilling the Maintenance Request form, on paper, and handing it over to the one of the engineers from the Maintenance Department. In the Maintenance Request, the Train Driver manually writes the reason for handing over the vehicle to the workshop, which can be regular inspection or emergency repair. One Maintenance Request very often includes one of the regular inspections and one or more emergency repairs, where the Train Driver specifies the type of inspection that needs to be done, and all the repairs that he considers necessary to bring the vehicle into driving condition.

The next step, which is anything but logical from the aspect of responsibility and process control, is that the engineer from the Maintenance Department, in the role of maintenance planner, enters the Maintenance Request into SAP system, to later create a specific Work Order based on that same request. This leads to certain problems when entering data into the system. First, maintenance requests are very often illegible, due to the poor handwriting of those who filled them in, and the person who enters them into the system sometimes must presume what the Train Driver was thinking of when filling out the form. Secondly, maintenance requests are filled out in a non-standardized way, in a free form, where each Train Driver fills in the request in his own unique way. This results in requests for the repair of the same parts or assemblies not being filled in the same way by different Train Drivers, and even by the same Train Driver, but on a different date. In addition, Train Drivers write down specific failures that they suspect, but they are not expert enough to be able to recognize them all, so they can mislead maintenance planner and maintenance workers, where they may focus on a misrepresented problem, instead of primarily investigating what could be the real problem.

Every fault reported by the Train Driver, the maintenance planner must enter the system by selecting the appropriate item from the predefined list of faults in the system. After creating the Maintenance Request in the system, the maintenance planner approaches the creation of the Work Order, which is referenced to the Maintenance Request and takes over the same title, which he previously entered in free form, based on the items written down by the train driver. The biggest process irrationality is that work orders are often issued retroactively, that is, at the end of the maintenance process. Maintenance workers carry out maintenance activities based on the received Maintenance Request on paper. After the completion of the maintenance operations, they write down what has been done and finally the maintenance planner enters it into the system and creates a Work Order. In doing so, the maintenance Supervisor will only write down the completion time of the Work Order, i.e. the time of handing over the vehicle back for the drive, while not recording the actual duration of the maintenance operations, nor which of the employees performed the operations.

The maintenance planner, when entering data into the system, creates a Work Order based on the opened Maintenance Request, to which he adds the planned maintenance operations, which the maintenance workers have already performed and very poorly recorded on the Maintenance Request, in free form. In the existing system, for regular inspections there is a predefined menu from which it is possible to select the type of inspection, while there is none for emergency repairs. Each emergency repair must be entered manually into the system. Because of this, a situation arises where the same emergency repairs are entered under different titles, and it is very difficult to perform any analysis related to emergency repairs conducted in the past.

An additional problem arises in the process of confirming the realization of the Work Order. In the case of work orders that contain regular inspections, the execution time durations that are entered are equal to the planned, i.e. normed duration of operations. This means that in any analysis of work orders in the system, planned times and actual working hours are equal. Moreover, actual working hours are not even entered according to the profession and qualification of the employees who did the work. Instead of that, the entire normed time for the realization of work order activities is entered in total hours, which the system then divides according to the set parameters and displays the number of employees who worked on the work order, which coincides with the norms. This means that it is impossible to determine the real maintenance costs, based on the analytics from the system, because neither the duration of activities, nor the structure of the employees who performed those activities are realistic. Whether an engineer or a technician worked on the Work Order is not relevant in the current system.

As a result of the inadequately organized process of creating and confirming the realization of work orders, many problems arise related to later analytics of work orders, such as following statements:

- The unstructured titles of the work orders significantly complicate any analysis regarding the number of breakdowns of specific assemblies or parts on vehicles.
- Work orders realization times do not deviate from the planned duration due to entering planned working norms when confirming the maintenance operations execution for regular inspections.
- In case of confirming the duration of operations for emergency repairs, it is estimated by the maintenance planner or the maintenance Supervisor, if the maintenance planner asks for his opinion.
- Emergency repairs have no standardized maintenance operations, so in connection with that, the duration entered for the same operations in different work orders will also differ in the planning settings of work orders, because they will also be entered by the maintenance planner based on estimation.

It is impossible to determine the real costs incurred by the work order, because specific employees, or at least groups of workplaces participating in maintenance, are not recorded. The system works by dividing the total maintenance work time equally between the average number of people defined in the maintenance norms and the average hourly cost of maintenance workers. The information that employees whose hourly price is more expensive or cheaper than the average hourly price worked on a certain Work Order is completely lost. Therefore, it is impossible to calculate the real costs per Work Order, which according to the data do not deviate from the planned ones, because they were entered in an identical way.

4 Results and Discussion

Digitalization of key processes, such as maintenance, especially in large state-owned enterprises, implies that certain prerequisites for adequate implementation, and subsequent use of the information system, have been met (Todorović, Komazec & Marić, 2020). There are rare examples where the current situation found in state-owned enterprises is good enough for the almost immediate implementation of an information system that would digitalize a certain process. Based on the mapped situation in the railway transportation company, the necessity of process reengineering is evident, and based on that, certain changes in the organizational structure of the company, which would accompany changes in the responsibilities and duties of certain participants in the maintenance processes. Technological advances often cause changes in the organizational structure (Todorović, Čudanov & Komazec, 2012). In this case, under the reengineering of the maintenance process is considered a change in the way of creating, recording, and confirming the realization of work orders for the maintenance of train vehicles. Changes refer to the order and method of activities execution, the workplaces responsible for their conduction, as well as the inputs of certain activities, that is, the documentation used in the process. Potentials for additional improvements through further digitalization of the maintenance process have also been recognized and noted.

First, changes were made in the way the process is carried out, where now the person who creates the maintenance request is responsible for entering it into the system, which is the Train Driver. Data entry into the system is standardized, in such a way that arbitrary entry of the title of the Maintenance Request is not possible.

Changes in the organizational structure, conditioned by the redesign of the process, are reflected in the design of adequate job gradation levels for each work position in the operational part of the Maintenance Department, as well as the revision of the job descriptions of the workplaces in the company. Adequately defined gradation of workplaces is of great importance when assigning employees to the realization of specific Work Orders, from the point of view of the price of an employee's hour of work and the subsequent analysis of maintenance costs. With new job descriptions, it was important to precisely define the duties and responsibilities of employees at workplaces, as a starting framework for the assignment of employees to specific work orders and the realization of maintenance activities.

In addition to the redesign of the organizational structure, it is necessary to review the list of standard maintenance operations and defined norms. The situation analysis revealed that there are work norms for operations of regular inspections, while they do not exist for operations of emergency repairs. However, during the review of the work norms for regular inspection operations, it was determined that in a certain number of cases they are not realistic. They were either given by the manufacturer during the procurement of vehicles or were determined at some point by an unknown method and under working conditions that used to be valid in the time of setting norms, and now they may have changed. Therefore, their audit was an integral part of the maintenance digitalization process. On the other hand, the list of emergency repair operations does not exist, nor do the work norms for the operations. From the current system and way of recording Work Orders, it is very difficult to conduct any analysis, and even that it would be wrong as such. In this connection, a list of emergency repairs was defined, where the most expert employees from the company in collaboration with external experts gave their estimates regarding the norms of certain operations The list and norms were adopted as preliminary and will be as such until their validation is shown through future use of the system. As a result of the work norming process, defined up-to-date lists of operations for regular inspections and emergency repairs should form the basis for planning every Work Order for the train vehicles maintenance.

In addition to the revision of the norms and the definition of the list of emergency repair operations, the list of malfunctions was also revised, i.e. the logic according to which malfunctions are reported by the Train Driver. The new defect list now contains two levels of decomposition, which are *assembly* and *part* (one *assembly* consists of several *parts*). On the Maintenance Request it is possible to select the *assembly* and/or *part* suspected of having a problem from the predefined list, and anything else the Train Driver has to say can be written in an additional comment.

With the introduced process changes and added functionalities to the system, the process of creating and confirming the realization of Work Orders has been improved, which is now carried out in the following way. The Maintenance Request is opened by the Train Driver in the system, after bringing the train to the workshop for maintenance. By changing the responsibility of opening this document in the system, it is ensured that there is no gap between what the Train Driver wants to report and what is entered into the system. Also, predefined lists now prevent arbitrary entry of Maintenance Request titles, which contributes to the standardized filling of documents in the system, which is later suitable for various types of analytics. The maintenance planner creates a Work Order that is referenced on the open Maintenance Request and assigns planned activities to it from the list of regular inspections operations or emergency repairs, in consultation with the maintenance Supervisor. Upon receipt of the Work Order, the maintenance Supervisor determines a team of workers who will conduct maintenance and begin operations. If, during maintenance, it becomes apparent that additional operations need to be performed, the maintenance Supervisor informs the maintenance planner to add certain activities to the Work Order. After the implementation of the planned maintenance activities, maintenance Supervisor records the specific executors of each individually defined operation on the Work Order, as well as the accurate working hours that employees spent on their realization. The completed Work Order is then submitted to the maintenance planner, who confirms the real durations and maintenance participants in the system for each Work Order activity. Selecting the specific executor of the operation in the system retrieves data about the work center (employee), i.e. his hourly price, which gives precise information about the costs of the employee who performed that operation for the time shown.

Adequate entry of data into Work Orders ensures precise calculations of actual working time for each activity and Work Order as a whole, which enables the possibility to compare planned and realized working time for each. Such data are of great importance when calculating the real labor costs per Work Order, where it is possible to see the difference between the planned and actual maintenance labor costs, where that difference arose, and to optimize maintenance costs. After a while, it will also be possible to compare realization of Work Orders of the same title through time and make conclusions. In this way it is only possible to create the basis for future precise analyzes regarding the reality of maintenance norms and the eventual need for norm corrections. Considering that ERP introduction in a described way has positive effect on maintenance planning, reporting and costs, the results indicate that digitalization of the maintenance process improves various aspects of the maintenance process, which confirms our hypothesis.

5 Conclusions

Digitalization of maintenance process enables precise monitoring of work performance down to the level of specific operators of activities, where for each employee the actual working time spent on the realization of specific activities would be recorded and compared with the normed time required for the execution of the activity. It creates quantitative and transparent bases that can be used for assigning employees by gradation levels within the same workplace and incentive rewarding of employees, based on achieved and recorded work performance. On top of that, the bases have been set for:

- Accurate record of planned and realized maintenance activities, in the digital format suitable for analysis.
- Continuous review and revision of maintenance norms, based on a comparison of planned and realized operations execution times.
- Systematization of all relevant data related to maintenance of specific vehicle and decision making according to that.
- More accurate records and allocation of labor costs, based on actual work hours of specific employees in the process.
- Capacity analysis and utilization of the maintenance resources.
- Process analysis and decision making regarding the improvement of the organization and work methods in the Maintenance Department.

Following successful implementation, after a certain period, a review of what has been done is required. The established work standards would, over time, accumulate a history of data for comparative analysis and potential modifications. New work norms could be defined, aiming for even greater precision compared to the initially set standards. The findings can be used as guidelines for digitization of any process, but especially those containing wide sets of operations and executors. Key directions for future research may involve investigating the impact of process digitalization on the productivity of employees engaged in maintenance tasks and possible ways for introducing more sophisticated digital processes through various tools and methods.

References

Barberá, L., Crespo, A., Viveros, P. & Stegmaier, R. (2012). Advanced model for maintenance management in a continuous improvement cycle: integration into the business strategy. International Journal of System Assurance Engineering and Management, 3(1), 47-63.

Bosilj Vukšić, V., Pejić Bach, M., Popović, A. (2013), "Supporting Performance Management with Business Process Management and Business Intelligence: a case analysis of integration and orchestration", International journal of information management, Vol. 33, No. 4, pp. 613-619.

Chaanoun, J., Rahmouni, A., & Alaoui, M. (2022). Literature review on organizational change and digital transformation. International Journal on Optimization and Applications, 2(3), 14-22.

Du, X., & Jiang, K. (2022). Promoting enterprise productivity: The role of digital transformation. Borsa Istanbul Review, 22(6), 1165-1181.

Fontanini, C., & Wollmann, D. (2021). Model for Simulating the Financial Viability of a Just-in-Time Maintenance Program in an Agribusiness Company. Management:Journal Of Sustainable Business And Management Solutions In Emerging Economies, 26(3), 1-12.

Hoyer, W. D., Kroschke, M., Schmitt, B., Kraume, K., & Shankar, V. (2020). Transforming the customer experience through new technologies. Journal of interactive marketing, 51(1), 57-71.

Hu, C., Wu, C., & Yu, L. (2023). Challenges and Opportunities of Digital Transformation in Enterprises. Accounting and Corporate Management, 5(12), 1-9.

Jovanović, M., Mrvić, J. & Todorović, I. (2020). Organizational Restructuring through Downsizing Based on the Analysis of ERP System Data. In Proceedings of the XVII International Symposium of Organizational Sciences: Business and Artificial Intelligence, pp.429-436.

Kłos, S. & Patalas-Maliszewska, J. (2013). The impact of ERP on maintenance management. Management and Production Engineering Review, 4(3), 15-25.

Komazec, S., Todorović, I. & Jaško, O. (2015). Model for planning preventive maintenance of the power transmission system elements. In Vasić, B. (Ed.) Proceedings of the 40th scientific conference OMO 2015. Institute iipp, Belgrade, Serbia, pp. 409-419.

Kraus, S., Jones, P., Kailer, N., Weinmann, A., Chaparro-Banegas, N., & Roig-Tierno, N. (2021). Digital transformation: An overview of the current state of the art of research. Sage Open, 11(3), 21582440211047576.

Krishnaswamy, K.N., Sivakumar A.I., Mathirajan M., (2006): Management Research Methodology: Integration of Methods and Techniques, Delhi, India: Dorling Kindersley, p. 352.

Krivokapić, J., Milosavljević, M., & Spasenić, Ž. (2023). Organizacioni aspekti digitalne transformacije. Zbornik radova - XIV Skup privrednika i naučnika SPIN' 23: Digitalni i zeleni razvoj privrede. Belgrade, Serbia.

Lao, L., Ellis, M. & Christofides, P. D. (2014). Smart manufacturing: Handling preventive actuator maintenance and economics using model predictive control. AIChE Journal, 60(6), 2179-2196.

Plekhanov, D., Franke, H., & Netland, T. H. (2022). Digital transformation: A review and research agenda. European Management Journal.

Rosqvist, T., Laakso, K. & Reunanen, M. (2009). Value-driven maintenance planning for a production plant. Reliability Engineering & System Safety, 94(1), 97-110.

Saleh, M. A., & Saad, M. (2023). Digital Transformation Impact on Agility and Strategic Risk Management. Journal of Business, 11(1), 63-82.

Scholkmann, A. B. (2021). Resistance to (digital) change: Individual, systemic and learning-related perspectives. Digital transformation of learning organizations, 219-236.

Schutz, J., Rezg, N. & Léger, J. B. (2013). An integrated strategy for efficient business plan and maintenance plan for systems with a dynamic failure distribution. Journal of Intelligent Manufacturing, 24(1), 87-97.

Todorović, I., Čudanov, M. & Komazec, S. (2012). Interrelationships of Changes in Organizational Structure and Technology. In Ferjan, M., Kljajić Borštnar, M., Marič, M., Pucihar, A., Bernik, M. (Ed.) Quality, Inovation, Future: Proceedings of the 31st International Conference on Organizational Science Development, Moderna organizacija, Kranj, Slovenia, pp. 1264-1271.

Todorović, I., Komazec, S. & Jaško, O. (2021). Data Model for Information System that Optimizes Human Resource Engagement on Technical System Maintenance. Proceedings of the YU INFO 2021 - 27th Conference on Information and Communication Technology. Kopaonik, Srbija, March 7-10, 2021.

Todorović, I., Komazec, S. & Marič, M. (2020). Organizational Preconditions for Turning Maintenance Planning into Smart Automated Process. In Proceedings of the XVII International Symposium of Organizational Sciences: Business and Artificial Intelligence, pp.437-444.

Tratkowska, K. (2019). Digital transformation: theoretical backgrounds of digital change. Management Sciences. Nauki o Zarządzaniu, 24(4).