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Implementation of Six Sigma methodology using DMAIC to achieve processes improvement in railway transport

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Abstract
The provision of quality transport services is a prerequisite for the creation of an efficient organization that can meet the expectations and requirements of both the enterprise itself and its customers. From the railway enterprise's point of view, it is necessary to pay attention to the increasingly demanding requirements of its customers in railway passenger transport. This article focuses on identifying defects in rail transport processes that negatively affect ordinary operations. One of the most serious bottlenecks affecting railway transport reliability is the train delay, which fundamentally affects the perception of railway transport. At the same time, it emphasizes the need to apply individual tools according to the DMAIC cycle in order to achieve continuous improvement. The aim of the implemented Six Sigma methodology in railway enterprise is disciplined application of statistical problem-solving tools to recognize the gaps in the transport process and set out individual steps for their gradual removal.

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1. Introduction

Passenger transport is generally considered as an effect of where people are in the exact time and their transport request to the correct location is met (Vojtek et al., 2017). Passenger demand is geared towards providing services in the required time frame with desired quality. The most relevant way of assessing quality of passenger railway transport is considered the concept examining selected quality indicators which are very significant and means decisive factor for the traveling public (Dedík et al., 2017). The transport enterprises have to make an effort to improve their service portfolio with quality tools according to a vision and strategy. Depending on the existence of the process approach in the enterprise, an effective qualitative approach can be progressively introduced.

The Six Sigma methodology is considered an integral part of quality management whose principles can be applied in railway transport processes (Štefancová et al., 2017). This quality approach can be used in service organizations just as effectively as in manufacturing with using five step DMAIC repeating cycle positively affecting existing processes (George, 2003). The Six Sigma according to DMAIC cycle helps enterprises identify the problems in their processes and reduce the defects that are costing them time, money, competitiveness, and customers (Brue, 2005). The DMAIC process is aided by the several quality tools such as Ishikawa's diagram, flowchart, control chart, histogram, Pareto diagram, Bubble and scatter diagram (Bedi, 2006). It consists of these individual steps as Define, Measure, Analyze, Improve and Control. This systematic framework allows to identify problems, understand how processes work and propose solutions to insufficient processes according to the appropriate tools and techniques. In the first phase, there are describe process requirements from the enterprise and customer perspective as well. At the same time, Six Sigma team members will be assigned and their responsibilities redistributed to achieve the desired results. The next phase focuses on identifying the current process capability through measured discrete or continuous data. The analytical phase leads to the deeper specification of root cause of the problem that is inhibiting enterprise performance. Subsequently, the Improve phase takes

into account the ideas of experts in the field using the principle of brainstorming to identifying potential solutions and selecting the most suitable. In the final phase, recommendations are made to achieve stable processes with final standardization (Morgan et al., 2016). The following figure shows the DMAIC cycle with its most basic tools for continuous process improvement.

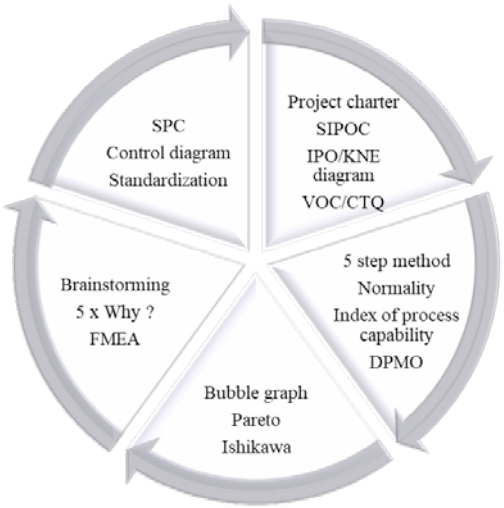

Fig. 1. DMAIC cycle

The structured DMAIC cycle is a basic procedure for improving processes according to Six Sigma metrics. The project charter specifies the boundaries of the improvement project and also there are assigned competencies of the particular team members. Process mapping will be based on the SIPOC and IPO KNE diagrams in which the links between the process, its inputs and outputs as well as the relationships between suppliers and customers are determined. The primary source of information in determining key performance indicators is the requirement set by the customer's voice (VOC) transformed into a requirement marked as the critical to quality (CTQ). Furthermore, it is necessary to determine exactly what will be measured, which employee will be it in charge and in which period. These procedures will be described in detail in a 5 steps method. Most statistical tools work with a normal distribution and therefore it is necessary to verify the normality condition for further analysis. Based on the discrete or continuous data analyzed, the process is evaluated either by the capability index or by the number of faulty units by the DPMO formula. In the next phase, the acquired process capability is analyzed through various tools and diagrams for deeper assessment of the severity of the problem. Bubble, Pareto and Ishikawa diagram are among the most widely used and reflected the need to focus on the most serious areas. In the case of setting the most fundamental reason for the lack of process capability, it is necessary to consult the obtained results with practitioners and propose solutions. The tool 5x Why means a simple procedure to find root cause through five follow-up questions. Failure Mode and Effect Analysis (FMEA) is a more complicated risk identification tool that compares three factors (meaning, occurrence, and detection). Statistical Process Control referred to as SPC is used for quality control in production, but can also be used in the area of service quality analysis (Sygut et al., 2017). It also includes regulation diagrams that allow enterprise to continuously monitor and control the process status over time and intervene in time.

2. Identification of defects in railway transport processes

As a result of increasing quality management, there is a trend to implement various quality approaches to businesses. However, the successful implementation of a quality methodology should be based on a dedicated strategy and management support in order to define key processes in order to improve their performance rather than the pressure of society and the external environment of its insignificant implementation.

The variety of perceptions of rail service quality means a problem in the actual evaluation of the provided service. Since quality is closely related to meeting customer expectations, it is necessary to define key processes and identify the decisive quality characteristics that passengers require from transport services. Establishing acceptable boundaries of individual aspects of quality based on customer voice recognition is the basis for continuous improvement.

In the case of implementation of the Six Sigma methodology, defects should be defined that indicate problems and impair process capability.

Possible areas of its application are described as follows:

- insufficient capacity of railway infrastructure
- lack of information and provision of relevant data for passengers
- train delays
- planned closure activity
- negative impact on the environment
- insufficient reliability of the rail sector

The applied methodology will serve the needs of the infrastructure manager to achieve stable processes and, in conjunction with the management of railway undertakings, to achieve satisfaction with the provided transport services for the end customer, who is a passenger in rail passenger transport. To achieve the desired results, it builds on the assumption of possible improvements in rail transport processes and allows customers to translate expectations into measurable and comparable indicators. Depending on the nature of the process and the parameters monitored, it allows the selection of appropriate qualitative tools to evaluate process capability in order to understand in detail and ensure their gradual improvement.

3. Legislation regulating train delays

The issue of train delays in the Slovak Republic is regulated by an agreement between infrastructure manager and rail passenger carriers, which deals with the common measures to ensure the quality of transport on the railway. On the basis of the concluded agreement, the train delay is monitored and evaluated on arrival at the destination station on the railway

network. The fulfilment of train timetable represents the main indicator for assessing the quality of the provided transport services.

UIC 450-2 is valid for all UIC members. The main objective of the Decree is to establish uniform procedures and processes for measuring and obtaining information on the reliability of international rail passenger trains and rail freight trains. Its output is a unified system of coding the causes of delays and non-provided services. The Decree also lays down uniform procedures and methods for analysing information, recording methods and their transmission. Part of the UIC 450 - 2 is a basic code table, which is an overview of the causes of delays attributed to the infrastructure manager.

4. Results and discussion

The aim of the transport operators in the field of infrastructure manager and railway undertakings is to provide transport services for the traveling public safely, economically and especially on time. The timeliness of trains is a key factor in the choice of passenger transport mode.

The punctuality of trains is measured by comparing the planned time schedule of a train with the actual driving time according to its identification number (Čamaj et al., 2016).

Table 1. Comparison of the most frequent reasons for train delays for selected international and national trains

International train	National train
Other railways	Increased frequency
Rail connection	Exceeding train travel times
Other railways	Electric traction equipment
Delay caused by following company	Locomotive destruction
Turnover of train	Weather effects
Increased frequency	Accident events
Locomotive destruction	Train connection

One of the most used tools in determining the most important causes of delays is the Pareto principle. Through it they were compared national trains as well as trains of international importance. The data was obtained from the information system of infrastructure manager and reflects the actual situation on railway network.

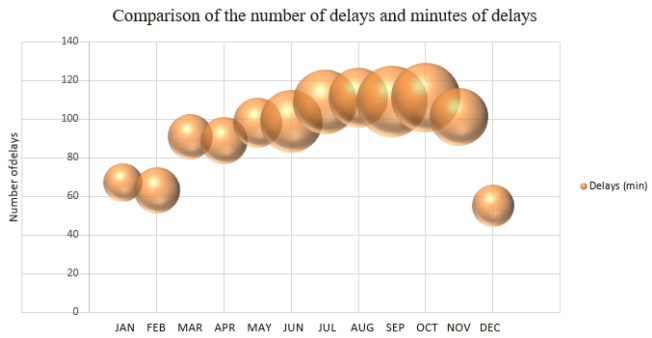

Fig. 2. Bubble graph of train delays

The Bubble Diagram allows transport enterprise to capture the interaction of different factors and compare the continuity of multiple variables like the number of delayed trains, date and weather. It allows them to continuously monitor the providing the transport services. Figure 2 shows the train delays in number and delayed minutes during each month of the year. Although it was assumed that the largest delay was in winter months due to bad weather, the real situation was different. In the analysis of the national train delays, the most frequent delays were recorded in the summer months due to another circumstances, namely the planned track closure.

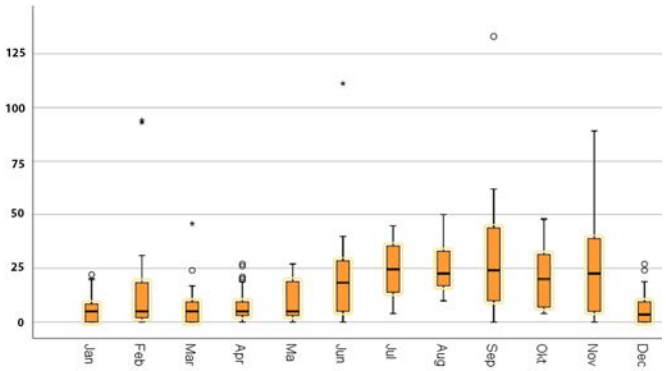

Fig. 3. Delay variability expressed by Boxplot

In case of train delays it is appropriate to analyse the given situation from the point of view of the operation itself, management, means of transport, accidents, influence of human factor as well as external environment. By using brainstorming with experts in the field, the necessary information about the possible origin of the negative effect is collected and the necessary measures are formulated.

The article focuses on the implementation of the methodology in the railway transport processes and the introduction of a new perspective on the monitoring of the variability of individual processes and the closely related quality of the provided transport services. It presents a clear guide to the continuous monitoring of processes through a structured cycle dealing with chronologically defining the problem up to its continuous control.

5. Summary and conclusion

One of the possible ways to constantly improve the company's performance while fulfilling customer expectations is to implement the Six Sigma philosophy in the day-to-day business processes of individual process management. It focuses on changing corporate culture and gradually redesigning processes from strategic planning to operational processes.

Process improvement through Six Sigma methodology is carried out on a step-by-step basis by selected projects as a continuous targeted improvement process leading not only to a quantified benefit to a transport company, but in particular to increase passenger value, maintain and acquire new passengers. The strategic goals set by the transport company

will be met by implementing Six Sigma projects with the goal to improve existing processes in a systematic way. It is necessary to find out which characteristics of transport process are critical for passengers and determine which factors most influence the satisfaction with provided transport services. The structured cycle of DMAIC represents the basic means of improving processes within the Six Sigma methodology, and it can be used for the gradual improvement of railway transport processes. It is an acronym expressing five chronological steps to optimize existing processes in rail transport. The aim of this article is to propose the development of an efficient and functioning system for monitoring and evaluating the quality of rail passenger services, which will enable problems to be solved in everyday operations.

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使用DMAIC实施六西格玛方法，以实现铁路运输的流程改进

關鍵詞
六西格玛方法论
DMAIC循环
铁路运输
火车延误
运输服务

摘要
提供优质的运输服务是创建有效组织的先决条件，可以满足企业自身和客户的期望和要求。从铁路企业的角度来看，有必要关注铁路客运对客户的要求越来越高。本文的重点是识别铁路运输过程中对普通运营产生负面影响的缺陷。影响铁路运输可靠性的最严重的瓶颈之一是列车延误，这从根本上影响了铁路运输的感知。同时，它强调需要根据DMAIC周期应用单个工具，以实现持续改进。在铁路企业中实施六西格玛方法的目的是严格应用统计问题解决工具，以识别运输过程中的差距，并为逐步消除这些差距制定各个步骤