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OUTLINE OF A METHOD FOR ALLOCATING RAILWAY SHIFT WORKERS ACCOUNTING FOR THE DIFFICULTY OF WORK

Summary. At present, shift work is evaluated from the carriers' perspective as employers. Therefore, the purpose of the article is to outline the characteristics of an innovative software application that would enable human resource managers to take railway workers' satisfaction or the difficulty of a job into account when creating shift plans. This article includes an overview of the prevailing methods of handling railway shift worker scheduling and a list and description of the empirical methods for creating shifts. Next, the consideration given to the interests and preferences of employees regarding shift types is described. We then outline possible changes, especially changes utilising mathematical formulas. These patterns and considerations are verified through actual shifts and questionnaires distributed to a select group of employees. An actual shift of conductors at the Czech national carrier České dráhy is chosen for the case study. Finally, a proposal of a software system that takes employee preferences into account and permits the scheduling of blocks of free days is described. From the development point of view, the aim of this software is to achieve maximum satisfaction after subjective requirements are considered, thus ensuring, from the human resource management perspective, a higher degree of railway employees' satisfaction, leading to better quality services and improved rail transport.

1. INTRODUCTION

For more than 160 years, railway transport has had an irreplaceable position in the transportation market in Europe and the world. For a long time, it has evolved in all areas of its activities – technical, operational, and organisational – and in the way personnel are managed. Today, under novel conditions of the creation of a single European market, the railroad industry is undergoing a process of transformation as it gains a new impetus and undergoes further development [20].

Information and communication technologies are an increasingly important part of everyday life, as they facilitate many activities, mainly in the world of work but also in scientific research and education [17]. In practice, people most often encounter information systems as users and less often as designers and planners. At present, informatics is one of the fastest-growing sectors of the national economy [16]. This development has had a significant impact on the process of improving the quality of transportation

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and transportation processes because the basic pillars of the development of information technology are the demands to increase operational safety and streamline management and control activities in companies [31]. In rail transportation, existing information systems are being improved gradually [45]. The current trend involves using information systems that can communicate and share and use information and data from other systems [56]. In addition to information processing itself, an important part of modern information systems is the storage and analysis of information. Information systems and technologies are utilised to ensure the competitiveness of companies [35]. In the field of railway transportation, information systems are used mainly to optimise the use of means of transport and staffing, streamline operations, increase safety and productivity, and reduce costs [10]. From the point of view of the management of transportation and transportation processes in railway operations, it is necessary for managers and designers to set operational requirements for information and communication systems that are a necessary condition for knowledge of operational processes and information flows [24].

2. LITERATURE REVIEW

The problem of work shift evaluation has been examined in different fields and disciplines of science, some of which are in the medical/biomedical and health sciences area. A major area of study in the evaluation of work shifts is the assessment of the impact of shift work on the health of patients, as well as on the health and workplace performance of workers in particular, is medical doctors and nurses [33]. For example, Keller et al. investigated the problem from the perspective of patient safety, productivity, and the health of shift workers, mainly nurses [32]. Another example comes from recent research according to which the deaths of more than 250,000 US citizens were reported to be due to medical errors [39]. If compared with other research, this finding confirms that among a variety of reasons for medical errors, some can be caused by extended shift work [4]. Of course, it might seem that the cases presented above are not related to management sciences; however, by analogy, for management purposes, some questions can be formulated based on the above medical cases [12]. For instance, it can be asked what impact shift work has on the performance of business activity and the health of shift workers, and inversely, whether the shift scheduling satisfies workers because their health, including their satisfaction, is a powerful determinant of work performance. It can also be asked whether managers know how many of the errors made by shift workers result from work shift scheduling misalignments or if there are any management methods and tools that managers can utilise when creating scheduling assignments that are the most agreeable to the workers and heighten worker morale and increase their motivation. The human aspect of the above questions indicates that their answers should be sought within the management discipline known as 'human resource management', which, in addressing shift work, explores these questions in research areas such as work evaluation and compensation, employee performance, ergonomics and workplace health and safety [13]. However, mentions of shift work can also be found in general textbooks on management, such as 'Jobs that have rotating work shifts make it difficult for people to have stable sleep patterns' [21]. Such works indicate the importance of corporate social responsibility, which is understood as the exercise of managerial responsibility for workplace health, safety and working conditions, and, thus, the responsibility for worker satisfaction [44]. The shift work management sub-discipline deals in particular with the problem of shift work's impact on employees, especially on their job performance, compensation, occupational safety and health, and social and family life [51]. These research problems are essential for understanding every area of economic activity, including the railway transportation sector. The literature features some interesting readings related to shift work problems in railways that can be classified into four research areas. The first is the impact of shift work on the health of railway workers. The second area is the validation of railway shift workers' fatigue and its impact on the risk to railway transportation safety. The third involves assessments of railway workers' satisfaction with different shift arrangements. The fourth research area investigates methods and tools of railway crews' shift scheduling optimisation.

A representative example of the first category of problems are the results of research performed on a sample of 149 rail workers, including permanent day (non-shift) workers, as a reference group, three-shift and other irregular working employees of the Spanish Railways, mainly stationmasters, train engineers and conductors. Questionnaire results, analysed by statistical methods (ANOVA, Student's t-tests and Chi-squared test), revealed that the health was reported as 'poor' more often by the roster workers than by the reference group day workers, including digestive, respiratory, and osteoarticular problems, as well as symptoms of anxiety and insomnia. The variance between the two groups appears to be statistically significant [1]. Other examples of research on problems in this category can be found in the articles by Härmä et al. and Holzinger et al., who focused on the effect of an irregular shift system on sleepiness at work in train drivers and railway traffic controllers [23] and a sleep coaching seminar on work and life quality in shift workers employed in an Austrian railway company [27].

An interesting example of the second research category mentioned above is an empirical study based on observations of each separate work shift for each day of a 12-month period from 11 traffic control centres of Belgian railways. This research focused on verifying the traffic controllers' fatigue caused by their shift work and the related risk of errors they could commit because of the fatigue. Based on more than 11,000 statistically tested work shifts, the obtained results showed that individual characteristics such as gender, age, and full- or part-time work had no significant effect on fatigue and, thus, no effect on railway traffic errors. These findings were contrary to those concerning day-of-week effects, which were reported as significant, identifying Saturday as having a 6% higher risk of errors [47].

The third research category mentioned above is the most closely related to the problem(s) presented in this article (i.e. the assessment of railway workers' satisfaction with various shift systems). Satisfaction can be treated as the reverse of the difficulties railway workers suffer if they are unable to adjust to shift work. For example, a comprehensive work involving an analysis of 3889 completed questionnaires filled out by Great Britain railway signallers and train controllers and processed by SPSS statistical software demonstrated that the respondents suffered problems with shift work [47]. This, in turn, induced the authors to undertake a more detailed study whose results showed that the signallers were significantly more satisfied with a 12-hour work shift than with any other rotating schedule system, especially the eight-hour schedule, but no significant difference was found between a forwards or backwards work schedule. Regarding the effect on the signallers' satisfaction with the worker's age, the speed of rotation, and the number of the same consecutive shifts, 'The analyses suggested that the younger rail workers (44 years and under in this study) prefer intermediate speeds of forwards rotation (five to six consecutive nights) and faster backwards rotation (either four or fewer, or five to six consecutive nights). The older rail workers (45 years and over in this study) seemed to prefer faster forwards rotation (four or fewer consecutive night shifts) and slower backwards rotation (five or more consecutive night shifts)' [48].

Regarding the fourth research area (i.e., the methods and tools of railway crew shifts' optimisation), a large number of papers can be found, especially in the operational research discipline of management sciences and including some propositions formulated by applied mathematics and IT. An overview of the methods and tools used to address the problem of railway crew shifts' optimisation can be found in 'Freight Railway Crew Scheduling: Models, Methods, and Applications' [2]. Another look at the state of the art of operations research models and techniques used in passenger railway transportation was presented by Huisman et al. [29]. An updated review of this problem is included in the article written by Heil et al., where models, methods and applications were classified according to heuristic, column generation, and meta-heuristic approaches [25]. In the literature, some case studies on concrete solutions can also be found. For instance, an interesting case of a train team scheduling system named TrainTRACS, in wide use by UK train operating companies, was analysed by Kwan [36]. The main aim of the system is to allocate crews with irregular work schedules to trains in the best way possible, especially according to time and cost criteria. The software was tested successfully in such UK train operators as ScotRail, Northern Rail, Arriva Trains Wales, Southern Railway, National Express East Coast, Virgin West Coast, Arriva CrossCountry, London & South Eastern Railway, London Midland, and London Overground, Virgin West Coast Co. and Southern Railway [36].

Other examples of the methods and tools used for the optimal allocation of shift-working rail workers, especially the heuristic and integer linear program column generation methods, were presented by Frish et al. [19] and Nishi et al. [42]. Because of the numerical methods used to optimise the scheduling of the shift-working railway employees, the main criteria used in these methods were numerical values, usually costs, and the number of duties and units of idle or busy time. Some suggestions for the usage of text (qualitative) variables were recommended for further research.

An important complement to the above literature review is an analysis of research projects related to the problem of the evaluation of railway shift work. Three projects financed by European Commission were found, all of which addressed the impact of shift work on the physiological health of employees from a strictly medical point of view, so they are not quoted in this paper. The EC research project that comes closest to the issue of railway shift work is titled 'New forms of work and their impacts on traffic (Preliminary study)' [57]. This study focused on the identification and impact estimation of new forms of work, for instance, part-time work, flexible work, telecommuting, video conferences and remote maintenance, on the movement of passengers and goods. The authors concluded that the new forms of work extend the flexibility of the existing transportation capacity. Therefore, the study only implicitly touched on questions related to shift work.

The above-reviewed literature indicates that the problem of shift work exists on a multitude of levels and in several dimensions that are analysed in different fields and disciplines of science. The actual state of knowledge, especially with respect to railways, shows that although only a few studies have thus far been undertaken, they have provided a set of important relations between variables affecting railway workers (fatigue, risk of errors, satisfaction, and age) and the character of railway shift work (type, speed, rotation, and consecutiveness) have been identified, and their impacts have been assessed. The obtained results are limited regarding the number of variables identified, especially from the perspective of railway workers' satisfaction or difficulties, when working according to shift plans. Questions such as what makes rail workers satisfied or what makes shift work difficult, when investigated using methods supported by tools, particularly in the form of software, allow for an exploration of the difficulties faced by management when dealing with the problems that shift work causes for railway workers. Answers to such questions are yet to be found. Based on this conclusion, the results of the studies in the literature presented above are extended by the following theoretical and practical background.

3. BACKGROUND

3.1. Management

A prerequisite for successful entrepreneurship is a creative activity that follows a well-chosen strategic management aimed at constantly improving the quality of outputs [14]. As passenger requirements are steadily increasing, service providers need to change the old paradigm, develop a new strategy, and focus on continually optimising processes, thus improving overall quality [41]. The business environment opens up space for perceiving problems as new challenges and coming up with new solutions that will create a better working environment for staff and provide more attractive services to customers [22]. The introduction of process management in enterprises is now considered to be self-evident and results in the creation of a functioning organisation capable of flexibly responding to a changing environment [38]. The next step is to prioritise and implement a quality methodology from a wide range of qualitative approaches [46].

In terms of success in the transportation market, every railway company will inevitably be forced to devote all their investment capital efforts to improving the quality of their services in a continual quest to satisfy the needs of their customers, which can be effective only when grounded in a solid, comprehensive knowledge of both the market and railroad transportation customers [58]. Since passenger rail services have been marketised (i.e. they have been opened to market competition), private transportation entities have had the opportunity to participate in railway transportation operations, thereby creating opportunities to compare service portfolios [55]. The new environment created by liberalisation has produced additional conditions and environments, most notably those which dramatically undermine the hitherto unassailable, erstwhile monopoly position of state-owned railway carriers by giving opportunities to other railway transport operators [30]. For this reason, any transport undertakings should be focused on providing customers with better services and favourable travelling experiences. This leads to more competitive pressure, making it necessary to properly connect managerial skills and apply the marketing concept of business in striving to attract customers to purchase transport services [18]. Fig. 1 shows the enterprise structure with applied process management and the Lean Six Sigma quality approach [28].

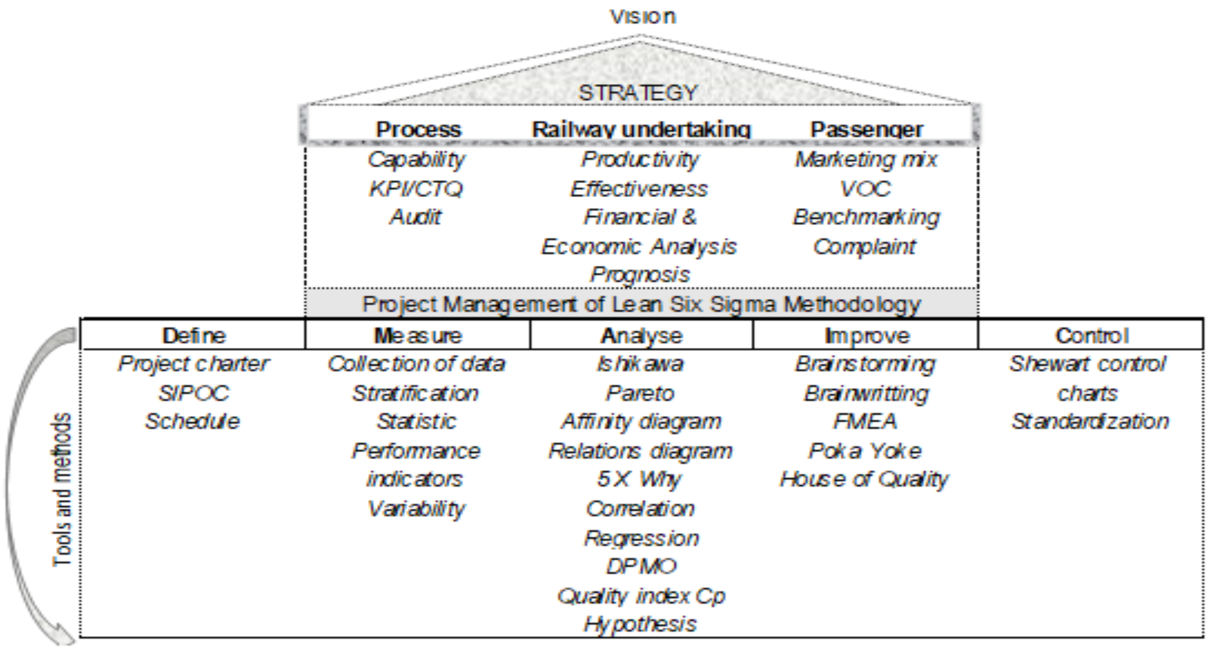

Fig. 1. Implementing a quality approach to business process management [28]

Fig. 1 also documents a set of approaches suitable for improving processes and overall strategy in relation to railway undertakings. The methods are broken down by define-measure-analyse-improve-control (DMAIC) steps. It is a quality improvement procedure and a data-driven quality strategy used to improve processes. All methods and approaches in DMAIC can be considered part of process improvement within the Six Sigma philosophy. One of the most important steps is the correct identification of key performance indicators and the key attributes of a product or service that customers have defined as being critical to quality. All measures must be taken regarding the voice of customers – that is, they must be based on customer needs. It is very convenient to use the suppliers-inputs-process-outputs-customers (SIPOC) map as a chronological representation of the most important events in the process. As Six Sigma also relies heavily on statistics, the defects per million opportunities calculation can be used to monitor process discrepancies. In the improvement phase, failure mode and effect analysis (FMEA) or a house of quality (quality function deployment) methods can be used.

At the outset, every transport undertaking should set a vision and define an accurate strategy for the future direction of its processes. When considering the most appropriate strategy, it is necessary to conduct a market survey and forecast developments in the transportation market. Depending on the determination of competitive power through the method known as benchmarking, it is possible to choose a market segment and a portfolio of services and then apply qualitative methods. At present, one of the most preferred methods is the Lean Six Sigma methodology, which can also be applied to railway transportation processes. It reduces defects in processes and provides organisations with tools to improve the capabilities of their business processes. Before subjecting normal business operations to its principles and embarking on qualitative projects, it is important to train staff according to the right level of management [50].

Lean Six Sigma is a structured approach and provides a comprehensive set of tools and methods within the DMAIC cycle, which can be used to achieve improvements. It is considered a systematic way to enhance existing processes or concepts related to the future situation, and to design new processes, including transport services, for example. The five phases of the DMAIC cycle are used as a helpful framework to solve the proposed problem, with the first step being the definition of the exact wording of the project and determining competencies and purposes in the project documentation. This concept focuses mainly on satisfying customer needs, so it should be precisely described as critical to quality and should be used to turn results from the transformation of the 'voice of the customer' into measurable requirements. The SIPOC diagram helps to visualise the relationship between process, supplier, customer, and input and output, which, in the case of the transport market, means the relationship between the infrastructure manager, transportation undertakings, and passengers [14].

The measure phase focuses on collecting adequate data in order to analyse the actual productivity and effectiveness of a company and the capability of its processes. Accurate data enables the quantification and verification of company performance and determines process variability based on discrete or continuous data [11]. Depending on the complexity of the data processing needs and the interpretation of the data, sophisticated statistical software is utilised. This can be the case when using correlation and regression analysis or when analysing a very large amount of data. This methodology encompasses a wide range of tools that can be used across phases and, therefore, depends only on the transportation company employing the tools that are the most beneficial and are able to improve the quality of services. The Ishikawa diagram presents a simplified fish-skeleton plot illustrating where the causes of problems are assigned to the key effect. One of the most appropriate tools used to identify the most serious problem areas in a business is the Pareto diagram, which illustrates the relative importance of causes at a ratio of approximately 80:20. After generating ideas for solving problems by brainstorming or brainwriting, these are gradually grouped into an affinity diagram according to natural relationships. The FMEA is considered to be a risk management method that an enterprise can use to analyse possible errors and their future consequences and subsequently propose corrective actions (Michalak et al., 2020). During the last control phase, the use of Shewhart control diagrams is advised for the indication of the range of variability and for comparing the analysed processes at its end [54].

Lean Six Sigma features an approach that can be used to deepen the understanding of the defects in processes and, through its five steps, attains a higher quality of the services offered in railway passenger transport. Achieving the required status is based on the accurate knowledge of the chosen tools, as well as their correct application inside a given transport company. Railway companies should use only those tools that are appropriate to achieve improvements. The aim of this approach is to focus not only on the profit of the company but also on the requirements of its customers. At the same time, the requirements of employees should not be neglected, nor should building an appropriate system for employee performance [26].

3.2. Employees

When it comes to employees, their performance differs according to their shifts. Shift compilation is also a complex problem. However, the creation of shifts generally depends on the circulation of railway vehicles. The principles applicable to the circulation of railway vehicles can also be applied to the shifts of operating staff, which will be shown in specific cases. The circulation of sets is used to determine the number of train sets that are needed to accommodate the timetable (i.e. the departure of each connection listed on it) [34].

The term 'circulation of sets' means the sequence of individual connections in time, which determines the coverage of the given connections by sets [59]. The circulation of sets is divided into individual days. It shows the sequence of connections to which a given set passes on a given day and also the sequence of individual days. During the circulation of the sets, all necessary technological tasks are considered, such as loading fuel, operational cleaning, replenishing water, and emptying sewage tanks [60]. Set circulation is a basic tool for calculating the running of sets for a period of one day, week, month, and year. However, the values of the run of the sets are always calculated as an average, as the individual sets travel different numbers of kilometres per day. Nevertheless, by maintaining the circulation, it is ensured that after a certain period (i.e. the total number of rotating days), all sets have the same number of kilometres. The circulation of sets must be handled separately for each day, subject to timetable restrictions [37]. It is also necessary to ensure a smooth transition of sets between individual days, even if it is switched between several circulations, which are subject to restrictions. The circulation of sets also shows whether the set is running individually or if two sets are running together on one train [8].

When compiling fixed circulations, the prescribed maintenance of rolling stock is considered. The combination of different types of railway vehicles in one circulation group is not allowed, except for a locomotive with the same or similar traction properties. When compiling the circulation of railway vehicles, it is necessary to have available technological procedures of work in the relevant railway station (e.g. technological times of travel to and from the train or local shifts). The planner submits a form in which they note the circulation of the locomotive according to the train numbers for the relevant station where the locomotive joins the trains, departs from the trains, or handles trains; a written request for the submission of technological travel times to and from the train station; and each case of boarding or disembarking at a given station. The time before the departure of the train must include the running time of the train (i.e. the ride on a railway vehicle from the border of the station or from the railway station parking place, further possible shunting, the time of preheating the train from the locomotive, and down time at the station). Similarly, the time after the arrival of the train must include the indicated technological times [3].

All trains are incorporated into the circulation of rolling stock. Furthermore, all other regular services are incorporated into the circulation, such as spills, pushing, and station shuntings. The operational treatment, in the case of the loading of fuels for diesel engine locomotives and in the case of electric-powered wagons and units, operational cleaning will be incorporated into the circulation and marked [6]. It is forbidden to incorporate operational treatment into the circulation of rolling stock if this would increase the total need for vehicles. In this case, the in-service treatment is performed by replacing the vehicle. If several pieces of rolling stock are joined to the train at the same time, the planner is responsible for the correct incorporation of the order of the rolling stock in the train. During the assembly of circulations, the requirements of the station for the time to (dis)connect vehicles to/from trains must be respected. In any case, when the time between the arrival of the train at the station and the departure of the train is equal to or longer than the sum of the specified technological times, the train is considered to be fully compliant [52].

The issue of the circulation of railway vehicles, as well as the shifts of the employees operating the vehicles, can be solved by various mathematical methods, but the most-used solution for this issue is to transform it into the so-called assignment problem [9]. Due to the strong degeneracy, special methods have been developed for such tasks, such as the Hungarian method, the name of which is derived from the fact that the principle of the method is based on the theorem of Hungarian mathematicians König and Egerváry [7].

The appropriate compilation of shifts in the requirements of rail passenger transportation is an important task of transportation technology. The aim of the set is to minimise the number of requisites required and ensure their maximum use. In doing so, many restrictive conditions must be met. By solving the assignment problem, time losses can be minimised, which represent differences between arrivals and departures of trains at a given station where the vehicles transfer to another train. Minimising time losses leads to a solution by which many different trains can be assigned to one train. This assignment represents the passage of the set between these trains [5]. Various software tools can be used to solve the assignment task. For example, MS Excel can solve the assignment problem as a task of linear programming, but with only a limited number of elements of the input matrix; thus, it is necessary to use more advanced software tools to obtain a more complex solution.

4. EVALUATION OF DIFFICULTY AND PREFERENCES

4.1. Shift evaluation in terms of difficulty

Nowadays, when trying to evaluate the shifts from the perspective of the carrier, as well as of the employee, the human factor should be considered using several methods and tools for evaluation of shift's difficulty and preferences. Difficulty is evaluated only by the total time spent on the job and, more specifically, the length of the shift. However, this might be very misleading because, from the employee's point of view, there are other criteria. We propose a new type of calculation using several criteria based on a questionnaire distributed among the conductors of the Czech national carrier, České dráhy. The criteria marked with Greek letters are in Table 1, together with their maximum values.

The criteria serve as input data for our proposed formula and can be ranked from 1 to 10 depending on how important they are to the employees (the carrier can change it). For the actual value of the number for specific shifts, it is not important how recent it is; what is important is its real value, which is calculated depending on the input data given by a carrier. The maximum values of the input were stated based on average shifts and were subject to change.

Table 1

New criteria for shift difficulty (source: authors)

Criterion	Symbol	Maximum value of the input
Total shift length	α	48
Total length of interruptions	β	35
Total length of night work	γ	35
Number of sleep interruptions	δ	1
Number of conductors in one train	ε	3
Number of allocated cars	ζ	5.67 (17 for one train)
Number of passengers	η	600 (3400 for one train)
Position	θ	1

The criterion 'number of sleep interruptions' can be either 0 for a normal shift or 1 for an overnight shift. The criterion position indicates whether the employee has a shift as a regular conductor (0) or a team leader (1).

$$\alpha' = \frac{\alpha}{\alpha+\beta+\gamma+\delta+\varepsilon+\zeta+\eta+\theta} \tag{1}$$

As seen in Equation (1), the value of each criterion must be subsequently recalculated by dividing it by a sum of all the criteria values. We use this standardised value for the purposes of the new presented formula.

$$H = 100 \cdot \left(\alpha' \frac{a}{Max_a} + \beta' \frac{b}{Max_b} + \gamma' \frac{c}{Max_c} + \delta' \frac{d+1}{Max_d+1} + \theta' \frac{h+1}{2} + \varepsilon' \frac{1}{e} + \zeta' \frac{e \cdot Max_f}{f} + \eta' \frac{f \cdot Max_g}{e \cdot g \cdot Max_f}\right) \tag{2}$$

The full formula is presented in Equation (2). It uses the inputs marked with Latin letters, which were given by the carrier. This is necessary because this mandatory information differs from the criteria judged by the employees. The resulting quantity is called 'shift intensity', which is denoted by the letter H and is calculated using the following criteria: (a) total shift length, marked by the symbol α; (b) total length of interruptions, marked by the symbol β; (c) total length of night work, marked by the symbol γ; (d) number of sleep interruptions, marked by the symbol δ; (e) number of conductors at one train, marked by the symbol ε; (f) average number of passengers on the train; (g) number of passengers per train crew member (f/e), marked by the symbol ζ; and (h) train driver/conductor classification, marked by the symbol η. The maximum values of the input data were determined in this way according to the shifts and after consultation with the employees of the railway company. However, the functional relationship was designed so that the weights of the criteria, input data and their maximum values were taken as input variables. Therefore, these data can be adjusted (except for the input data 'classification', for which there is a value of 1 for the train driver and 0 for the driver). This formula is a new option for the evaluation of shifts in terms of difficulty. However, it must be noted that the values of the criteria would probably have to be determined by questioning the employees and comparing the results with their opinions.

4.2. Design of a software solution for deploying shifts

According to the previous chapter, it would be possible to evaluate shifts by their actual difficulty. The next step is to assign planned changes to specific employees (i.e. to create a specific shift plan for a given period). Differences in the perception of specific shifts may also vary between employees. Some prefer shorter, more demanding shifts, while others prefer longer but less demanding ones, even at the cost of having less time off between them. Theoretically, each employee should have their shifts designed according to their personal shift plan, but railway operations are very specific, and due to individual requirements and numbers of employees without a routine, stable shift plan (floating), it is necessary to create different plans for each month. We suggest that each employee could enter into the system a preference for specific changes. The system would take this data into account if it necessitated decision-making (e.g. when choosing which of two employees to allocate a particular shift day, it would assign it, if possible, to the employee who states a higher preference for it. Fig. 2 shows an example of the interface for entering preferences.

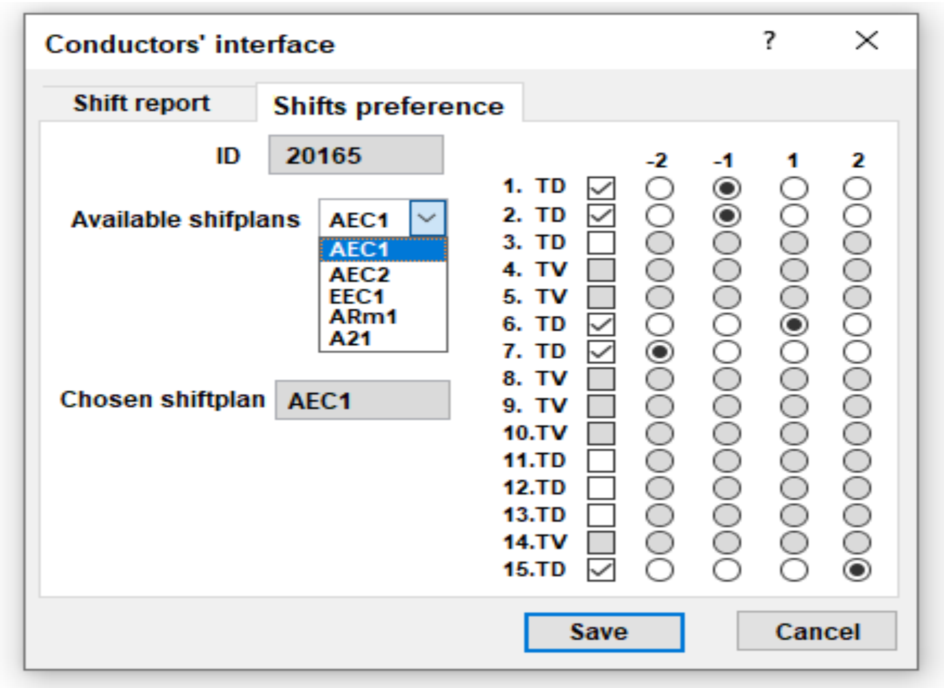

Fig. 2. Design of an interface for creating a database of preferences by employees (source: authors)

The system would first create a fictitious plan for the ideal unattainable case, which means that all shift employees go to work according to their shift plan. Subsequently, it would delete shifts as needed (e.g. incapacity for work, holidays, leave requirements) while continuing to gradually allocate unoccupied shifts to employee floaters according to the above algorithm. If an employee is not available at a glance, it would choose an employee of another shift-plan group who has a day off. In the case of unexpected changes (e.g. employee injury, sudden inability to work, overlong delay), it would be necessary to quickly assign the train/shift to an alternate employee. Furthermore, it would be able to automatically generate a list of available employees, speeding up the search and oversight of employees, for example, the employee's leave time or incapacity for work. This can reduce unnecessary downtime and allow these emergencies to be resolved more quickly. Not only can it lead to shorter delays but also to better travel quality from the customer's point of view [53].

Another unnecessary weakness of creating a specific shift plan for a certain time is the fact that employees block free time for individual days as a whole, while shifts in rail transport are diverse and have different start and end times throughout the day and night. An employee who needs time off only in the morning, for example, due to a visit to the doctor, is forced to unnecessarily report free time for the whole day. Another proposed interface (presented in Fig. 3) would allow the employee to block time off for specific hours, or it could also be used for holidays and other requests, which is currently done through incompatible software tools or by accessing the human interface. Such programs would make it possible to reduce the number of superiors who currently allocate changes (commanders or engineers) to a minimum, thus bringing rail transport closer to greater sustainability by reducing costs.

5. DISCUSSION

Solving vehicle circulation and train staff shift plans using selected mathematical methods is a necessary step to optimise them. Mathematical methods are the basis of information systems, and their correct design and use require knowledge of all the algorithms on which the information systems work. For the outputs of algorithms to be properly understood and interpreted, these information systems must provide users with correct and relevant solutions. The above course of reasoning is a way in which decision-making processes can be simplified and improved in a transportation undertaking, for example, when assigning sets or train requirements to individual connections.

For improving the quality of the service itself, it is necessary to evaluate the shifts of the operation staff by a different method because currently, only the shift length is counted. The proposed formula provides a better way to devise shift plans. Furthermore, a shift preference for each employee could lead to shorter delays, happier staff, and happier customers.

For research to be of good quality, it must be compared with similar research in this sector. As mentioned in the literature review, there are many studies on this topic. Apart from them, when comparing our research with other ones already presented, we can mention, for example, a study on Austrian railway shift workers [27]. It is necessary to mention that the issue of shifts concerns not only passenger rail transport but also rail freight, as stated by Olentsevich [43].

However, previous research has only compared the consequences of shifts that have been determined in advance. Differently, our research proposes a completely new formula that can not only consider the consequences for staff but also numerically quantify the intensity of the shift. In addition, our research proposes a system for considering the personal preferences of individual employees, which is not proposed in previous research. In our research, employees are viewed not only from the point of view of the work unit but also as human beings.

There is also no mention in the available literature of an information system for the automatic creation of shifts in such a specific environment as the railway. Therefore, the scientific enrichment of the proposed methodology also lies in the proposal of both the input interface and the methodology of how such a system might work. However, we must state that further research could improve this theoretical proposal. This idea must be subjected to verification in order to confirm that it might be used on a larger scale.

Further research may concern the IT industry and focus on the software of the above-mentioned system. This area can also be considered from the point of view of sociology and surveys of employee satisfaction with the proposed system, both from the point of view of the user and from the point of view of collegiality and relations with co-workers. These aspects can also be examined from the perspective of superiors. It is also important to explore whether the time spent using this system will be considered in the working hours of employees. This leads to another question, in this case, one that concerns how expensive implementation might be. Therefore, subsequent research can also be conducted in terms of corporate finance and employee income.

In addition to the railway sector, this technology is also applicable in several other sectors in which employees work shifts. For example, we can mention other modes of transportation (bus drivers, aircraft pilots, ship crews), non-stop factory operations, delivery services, hospital emergency services, police forces, fire brigades, and even garbage collectors.

To summarise, this paper outlines possible new directions for railway operators in the area of managing rail workers' shift plans. Much further research is needed for full functionality. However, if successfully implemented, this technology can have several positive consequences, including a reduction in a carrier's expenses, an increase in employee satisfaction and, consequently, an increase in the quality of travel. Together, these outputs can create a synergistic effect and, thus, benefit society.

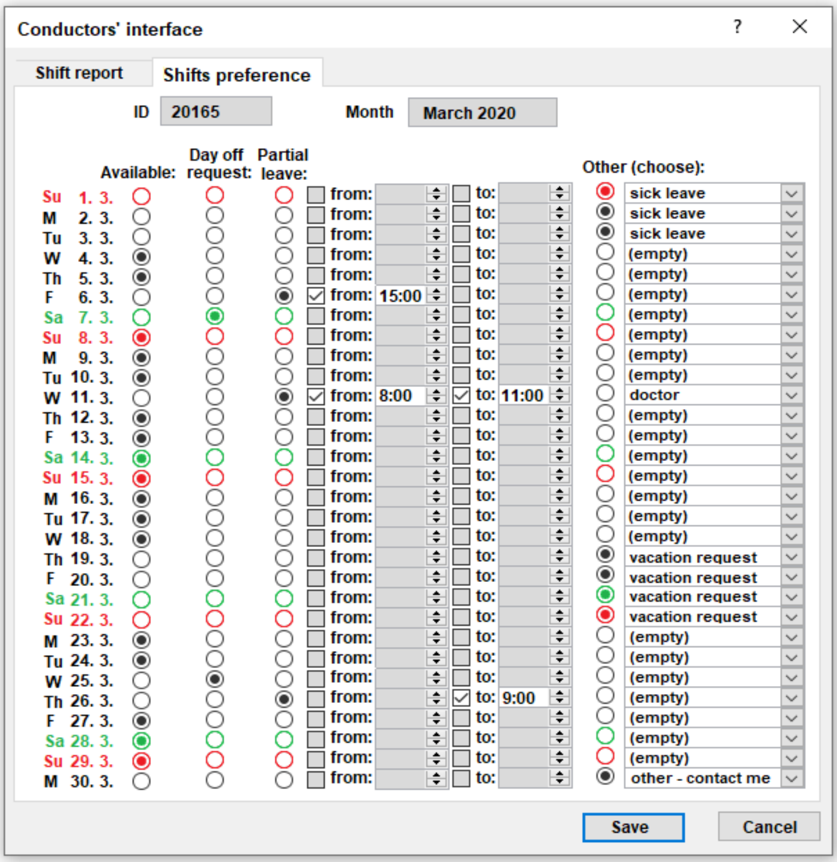

Fig. 3. Design of an interface for reporting free time by employees (source: authors)

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