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Towards Optimal TMS Integration Scenario Based on HRM and SWOT Analysis

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Abstract: To meet the collective goal of providing an efficient, sustainable, and safe transportation system, motorway managers are oriented toward establishing an optimal traffic management system (TMS). However, there are no straightforward guidelines through which to deploy the optimal integration scenario for traffic control centers (TCCs). An important component of TMSs is traffic control decisions, implying that human resources represent a critical feature of a TMS. In this study, we introduce human resource management (HRM) into the process of selecting the most appropriate integration scenario, which is achieved by developing a model to determine the number of employees. We formulated the problem as the mixed integer nonlinear programming problem based on the analysis of traffic incidents and road infrastructure data, considering also the employee voice and some HRM specificities in incident situations. Combining these findings with a SWOT analysis of the possible integration scenarios in Slovenia, we propose the most suitable scenario, in which TMS is organized as a cloud service. Moreover, this study predicts TCCs' space requirements and identifies threats of neglecting HRM in TMS design. This paper can serve as a guideline and a baseline of expertise for motorway managers to create an effective and sustainable TMS in their region.

Keywords: traffic management system; motorway traffic control center; SWOT analysis; human resource management; least squares method; traffic incident

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1. Introduction

Increasing mobility demands are resulting in the setting of a collective goal of providing efficient, sustainable, and safe transportation systems. A crucial role that must be established to achieve this goal is a good traffic management system (TMS) with traffic control centers (TCCs)/traffic management centers (TMCs), which integrate and coordinate a wide range of traffic management strategies. TCCs are responsible for monitoring and managing traffic flow and for providing traveler information by using a wide range of intelligent transportation system (ITS) technologies. A local (private) telecommunication network within TCCs ensures hierarchic connections with the individual components, i.e., traffic counters, video cameras, variable message signs, etc.

This study is, in particular, concerned with the organization of TMSs with respect to motorway networks. The two basic organizational structures of the TMS are the centralized and decentralized models [1]. More recently, distributed traffic management systems [2] are also worth considering when designing system architecture. The choice of the organizational model is not straightforward and presents many challenges [3]. Although it does not concern a motorway network, which certainly has its own specificities, a comparative study on centralized and decentralized controls for urban traffic control [4] and a comprehensive review of railway traffic management [5] provided insights into coordination, control, and organization questions, as well as the overall possible effectiveness of decentralized systems. Moreover, the validity of a decentralized simulation-based system of urban roads was shown in [6]. Some of the advantages and disadvantages of centralized, decentralized, and distributed network managements were highlighted in [7].

To keep pace with emerging technologies, the organizational structure of traffic control should not be rigid but rather adaptive enough to accommodate for the future challenges and opportunities caused by the Internet of things (IoT). Intelligent traffic management systems (ITMSs) have become one of the main applications of intelligent transportation systems (ITS) [8]. Although knowledge-based (ITMSs) are on the horizon, this type of system may not replace human operators but may act as intelligent assistants that cooperate in the tasks of defining and applying traffic control decisions [9]. Although most motorway managers have already established a TMS with TCCs and traffic control operators, the system should be live and prone to optimization in several aspects. Operators within TCCs represent human resources and play a crucial role with respect to timely, meaningful, and consistent management techniques. Human resource management therefore plays an important part in the organization of a TMS, i.e., in the number of TCCs and in their hierarchy and coordination. Moreover, the two components, i.e., the number of operators and the number of TCCs, are codependent. The organizational structure of TCCs should be taken into account when managing human resources, as well as the abilities and limitations of the operators, when designing a TCC organization. This raises the question of how to conduct human resource management (HRM) in TCCs.

HRM is concerned with all aspects of how people are employed and managed within various types of organizations, and it has been a field of extensive research [10–14]. A recent comprehensive review on sustainable HRM can be found in [15], where sustainable HRM was identified as an emerging concept worldwide. Moreover, emerging technologies may increase the role of HRM. The authors of [16] found that HRM is to take a more active role in contributing to the era of digitalization. Moreover, the authors of [17] discovered that strategic resource management practices and artificial intelligence significantly mediate the relationship between organizational learning and sustainable organizational performance on the one hand, and corporate social responsibility on the other.

However, in the field of traffic management, HRM is still largely underresearched. The authors of [18] highlighted the importance of strategic management, including HRM, for the purpose of sustainable road traffic management. Some research can be found in railway [19] and air traffic management [20] fields. The related areas in road traffic management are, for example, the allocation of human resources in sustainable traffic management to obtain a day-to-day manpower allocation schedule [21], emergency response resource allocation [22], and the mathematical model for efficiency optimization by determining the best number of employees for an logistics task [23]. Those studies have a common point; the right number of employees affects the effectiveness of a system. With investments in communication networks, road infrastructure, smart vehicles, and cross-border agreements for traffic management, society will take a significant step closer to achieving the "vision zero" carbon footprint, hazard, and accidents for rational costs, which are all indicators of sustainability. The optimization of HRM in TCC for the mentioned investments is very important, as it is bringing the efficiency aspect of the sustainable transport system.

The present study contributes to the literature in several ways. First, we present a SWOT (strengths, weaknesses, opportunities, and threats) analysis [24] for three scenarios regarding the organization of a TMS for a motorway network. While some of the Ss, Ws, Os, and Ts can be summarized from previous research [4,7], others are identified based on the experience and knowledge obtained from the work of TCCs in Slovenia and neighboring countries and guidelines regarding the implementation of TMS infrastructure. This study is also concerned with the HRM within TCCs, which represents a commonly unaddressed or unpresented issue. In the case of Slovenia, we introduce a model for determining the number of traffic control operators and other employees in TCCs based on historical traffic flow and incident data. Using the developed model, we assess the analyzed scenarios of the organizational development of TCCs. When managing human resources, employees and employee voice play a fundamental role for sustainable HRM [25–27]. When designing the statistical model, the factor of employee voice was not overlooked, and when overload was detected through formal/informal communication channels and/or identified through data entry delay, employee voice was also considered when designing the statistical study. Moreover, the difficulties in performing the work assignments in the case of only one operator per shift, regardless of the actual workload, was also taken into account. Thus, this study contributes to the body of knowledge by emphasizing the role of HRM in TMSs. Moreover, the findings of the present study provide theoretical and practical implications for TMS organizational management in terms of enhancing sustainability performance.

The paper is organized as follows: Section 2 contains the description of the scenarios of integration of TCCs in Slovenia, the SWOT analysis of the scenarios, and the theoretical background for the development of a model to determine the number of employees in TCCs; Section 3 presents the number of employees for each scenario; Section 4 discusses all the results and proposes the optimal scenario; and Section 5 summarizes the findings of this paper.

2. Methodology and Assumptions

2.1. Scenarios of Integration of TCCs on National Level

In most developed countries, including Slovenia, TMSs are established for national motorway networks. In order to determine the extent of the actual situation, an inquiry was conducted with the motorway operators in the EU. Motorway operators from Austria, Italy, Portugal, and Greece responded to the inquiry and were willing to cooperate further [28]. Currently, TMSs are organized via regional TCCs, and they are hierarchically divided into four levels (Figure 1). The top level is the coordination level. In Slovenia, the main traffic control center (mTCC) is meant to take this level; however, such a center is not yet fully established on the Slovenian motorway network, and a similar situation is also the case for most of the motorway networks in the neighborhood. The role of this operational level is the overall control of the system of the motorway network of each country/motorway manager. At the second level, there are regional traffic control centers (rTCCs) that monitor and implement traffic management measures on corresponding motorway segments or on regional subsystems. Through mTCCs and rTCCs, the TMS for the motorway is connected to other organizations and systems in the country and neighboring countries [29]. Most motorway managers plan to keep this hierarchy in the future. With local ("private") telecommunications networks, TCCs are hierarchically connected to the individual components of TMSs (traffic sensors, surveillance cameras, variable message signs, etc.). However, the possibility of system enhancements in terms of the number and integration of the TCCs represents an open question, especially with the technological future in mind (which is known to be oriented toward automation and integration with IoT on the horizon).

Through a comparison to foreign practices, the direction toward a possible reduction in the number of TCCs is being highlighted [30]. The question is whether, and to what extent, the reduction in TCCs is reasonable, i.e., whether it is optimal to establish only one TCC with connection to all TMS components, or it is better to retain a larger number of regional TCCs. Moreover, in the case of a larger number of control centers, it may make sense to reorganize the centers toward achieving even more individual TCCs to enhance the quality of traffic management. In this context, it is necessary to be aware of the advantages and disadvantages of the selected scenarios regarding the development and integration of TCCs, and we must also pay attention to their weaknesses (threats) and the risks associated with them.

We set up a framework for analyzing the various scenarios of development and organization regarding TCCs. This was conducted on the basis of Slovenian and foreign experience and an analysis on the involvement of control centers and corresponding operator workloads in motorway traffic incidents. Within this research, we have analyzed three scenarios of development and organization for TMSs as follows:

- Scenario A: several regional TCCs (rTCCs) that operate independently and are coordinated from one office (Figure 1);

- Scenario B: one main TCC (mTCC) and several smaller rTCCs (subcenters) that are logically connected (Figure 2), and the number of rTCCs is reduced compared to that in Scenario A;

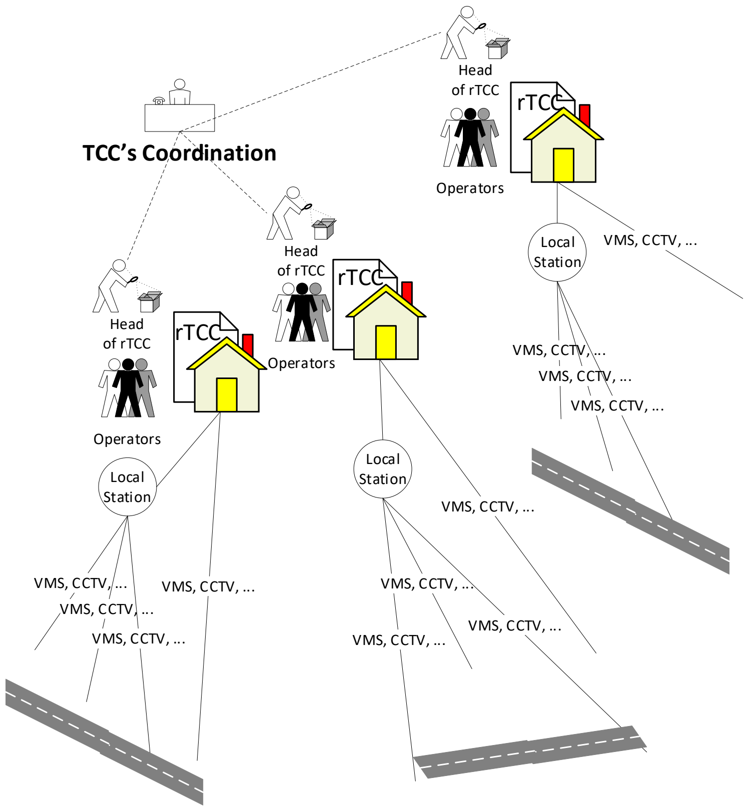

Figure 1. Hierarchy and connections within TMS. Existing System/Scenario A.

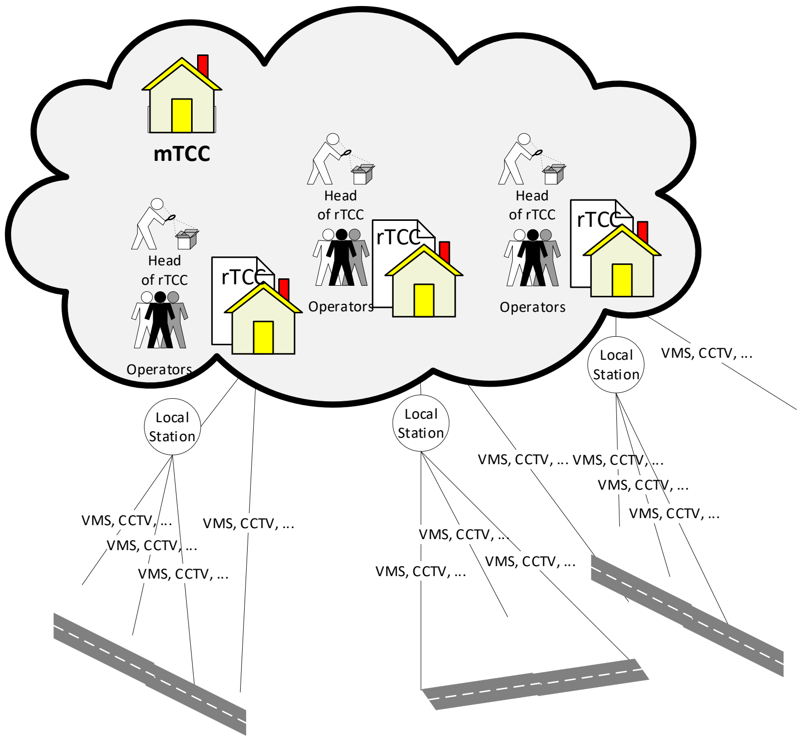

Figure 2. Hierarchy and connections within TMSs. Scenario B.

- Scenario C: one centralized mTCC that manages the whole network (Figure 3).

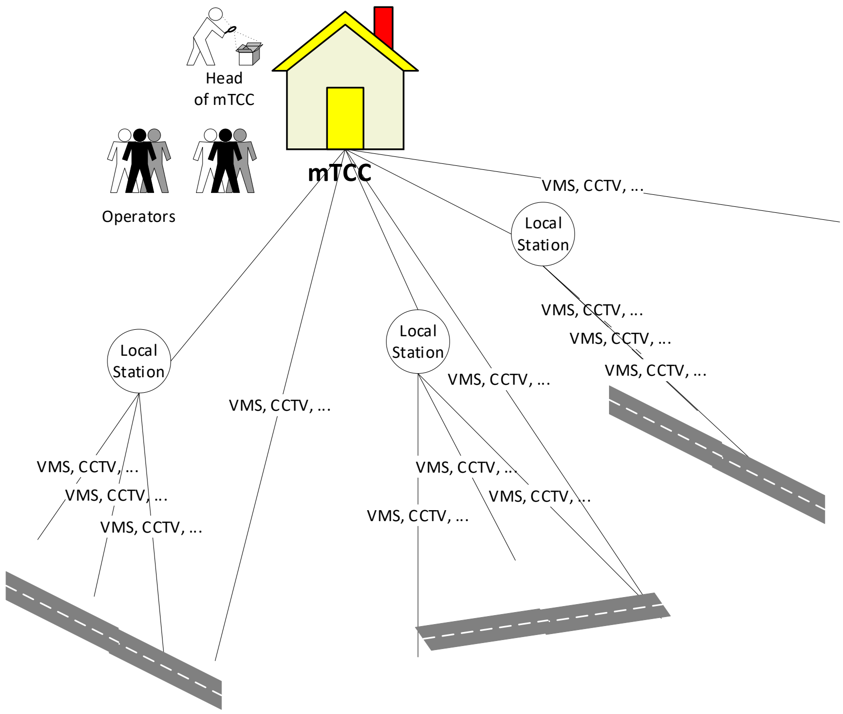

Figure 3. Hierarchy and connections within TMSs. Scenario C.

2.2. *SWOT Analysis of TCC Scenarios*

This chapter analyses the individual scenarios in form of the SWOT (strengths, weaknesses, opportunities, and threats) analysis based on the methodological foundation in [24]. In total, 32 strengths, weaknesses, opportunities, and threats were identified based on the authors' experience and expertise, cooperation with the motorway manager, employee voice, and findings of the previous studies [4,7].

2.2.1. Scenario A: Several rTCCs

The SWOT analysis of Scenario A is shown in Figure 4.

2.2.2. Scenario B: One mTCC and Several Smaller rTCCs

The SWOT analysis of Scenario A is shown in Figure 5.

2.2.3. Scenario C: One Centralized mTCC

The SWOT analysis of Scenario A is shown in Figure 6.

2.3. *Model for Determining Number of TCC Employees*

The aim of this part of the research was to obtain an equation to determine the number of employees/TCC staff of the Slovenian motorway network (which is approx. 600 km of motorways and expressways) based on the available data. Similar problems were, in the main, typically solved with the multiple linear regression method. However, by designing such a model with human resources in mind, certain additional aspects should be taken into account in order to obtain an equation that ensures a high enough number of traffic control room operators to enable quality traffic management, i.e., the equation should avoid overloading employees. Statistical equations were derived based on the data. In our case, we used the traffic incidents database from the information system of the Slovenian Traffic Information Centre for Public Roads (TIC). Due to the additional requirements for traffic management in the regulations [31], the number of tunnels above 500 m was also considered in the analysis.

Within the current implementation of the national TMS, there appear instances of overloading operators. This was partially detected from the data entry delay in the database and partially through formal/informal communication channels. This overload was managed before statistical analysis by artificially modifying the actual data of the operator's workplace number; an additional operator workplace was also considered in the analysis where the overload was detected.

STRENGTHS	**WEAKNESSES**
• A well-established and proper functioning system for traffic control and management of potentially hazardous motorway sections, especially for those with a higher percentage of bridges/tunnels and/or heavy vehicles; • Good knowledge of the motorway network being controlled; • No reorganization required; • No changes to infrastructure and/or TMS software required.	• Workload is unevenly distributed among the TCCs (the online reassignment of available human resources is not enabled); • Possible incompatibility of TMS software and/or user interfaces; • Operation of TCCs can be uncoordinated (as it is without common traffic control and management plans); • Difficulty in the exchange in knowledge and experience (i.e., between the staff in different rTCCs); • Coordination with foreign traffic operators/managers is decentralized.
OPPORTUNITIES	**THREATS**
• In rTCC centers with inadequate staffing, there is an opportunity to introduce/test innovations and to conduct additional training.	• Without mTCC, problems with communication and priorities between centers may arise; • Risk of traffic management problems at the border between operating areas of different rTCCs; • Occasional work overload in individual rTCCs; • Different traffic control and management decisions in the case of similar incidents in different rTCCs.

Figure 4. SWOT analysis of Scenario A.

STRENGTHS	WEAKNESSES
• The established mTCC enables coordination between the rTCCs, allowing the rTCCs to operate in a coordinated manner; • Coordination with foreign traffic operators/managers is centralized; • Coordinated traffic management at the border between operating areas of different rTCCs; • A smaller number of TCCs means fewer border working areas, i.e., there may be fewer problems in traffic management at the border; • Good knowledge of the motorway network being controlled; • Workload can be more evenly distributed between TCCs, and a potentially overloaded rTCC can be supported through remote TCCs (i.e., the online reassignment of available human resources is enabled); • Enables external access to rTCCs for software maintenance purposes, thus allowing coordinated and unique software and user interfaces.	• Changes required to infrastructure and software in rTCCs and mTCCs; • The knowledge or experience required for the mTCC to temporarily take over rTCCs could be insufficient; • Difficulty in sharing knowledge and experience (i.e., among the staff in different rTCCs), thus resulting in insufficient coordination; • Complex equipment and skills, as well as questionable economic justification, required the intertwining of functions; • In the mTCC, and partially in the reorganized rTCCs, the knowledge of the motorway network being controlled could be insufficient; • Partial restructuring of current rTCCs would be required.
OPPORTUNITIES	**THREATS**
• Uniform workload across all rTCCs provides an opportunity for a more consistent management of all TCCs; • Opportunity to control and manage the traffic outside rTCC boundaries; • Opportunity to change (reduce) the number of operators per shift and/or to relieve the workload of present operators during less traffic-intensive periods; • Control and management function outside rTCC boundaries provides an opportunity to reassign work to another rTCC (e.g., to introduce or test innovations, etc.).	• Risk of less efficient/inconsistent traffic management when functions intertwine; • Unfamiliarity with the network when taking over the network outside of the parent rTCC; • Unfamiliarity with the network when controlled by the mTCC.

Figure 5. SWOT analysis of Scenario B.

STRENGTHS	WEAKNESSES
• The coordination with foreign traffic operators/managers is centralized; • The centralized system enables a consistency of traffic management throughout the network, i.e., there is no rTCC; • Operator workload is evenly distributed; • The entire infrastructure for maintaining all rTCCs would no longer be required (i.e., rTCCs would not exist); • All hardware and software in the same location (easier maintenance, no software incompatibility, etc.); • Effective exchange in knowledge and experience between employees; • An easier establishment of the information system; • There is no risk of overlapping functions between the rTCCs and the mTCC; • Centralized database.	• Establishment and investment in the mTCC (the highest set-up cost of all scenarios); • Changes in mTCC software and TMS infrastructure are required; • Distance between the mTCC and the tunnels requires better organization to achieve adequate responsiveness in the case of system outages; • Clear and unambiguous organization and division of tasks is required; • Knowledge of the motorway network under control may be inferior; • High technological complexity to establish such a system, i.e., high-performance IT systems are required; • Questionable feasibility and effectiveness regarding implementation; • Major reorganization required.
OPPORTUNITIES	**THREATS**
• The centralized system provides an opportunity for a good coordination of traffic management within the country and in the international environment; • Opportunity to change (reduce) the number of operators per shift and/or relieve the workload of present operators during less traffic-intensive periods.	• With possible rapid growth in the number of incidents and the related larger number of subsystems and/or with increased operator employments, space requirements can grow substantially, which can lead to lack of space in the mTCC; • Significantly increased/changed workload for the allocated personnel; • Knowledge of the foreign language used in the mTCC (without rTCCs in vicinity of national borders) can be insufficient, which can lead to communication errors with foreign controllers and to dangerous, wrong decisions; • Performing multiple functions in the same room may be distracting.

Figure 6. SWOT analysis of Scenario C.

The selected function form was the following:

$$N_{OP} = aN_I + bT + c, \tag{1}$$

where N_{OP} is the number of traffic control room operator (TCC operator) workplaces in the rTCC, N_I is the number of incidents in the database in a year, T is the number of tunnels longer than 500 m, and c represents an integer that is greater than or equal to 1. The latter requirement is due to the specificity of human resources. The physical explanation for the TCC that had no tunnel network in the case of low traffic showed that even when there is a low number of incidents, the network should not be uncontrolled; therefore, at least one TCC operator is still needed.

To determine the parameters a, b, and c, we used the least squares method, i.e., we solved the mixed integer nonlinear programming problem of finding the line of best fit for a set of data points by reducing the sum of the squares of the offsets of the points from the line. The task therefore resembles the multiple regression method, with the exception of the integer requirement for the coefficient c.

3. Results

By solving the mixed integer nonlinear programming problem, we obtained $a = 0.000169$, $b = 0.0840$, and $c = 1$; this gives us the model for determining the number of TCC operator workplaces:

$$N_{OP} = 0.000169N_I + 0.0840T + 1. \tag{2}$$

Practically, this means that for any TCC with no tunnel control functionality, one TCC operator workplace per shift is needed until the number of incidents reaches approx. $N_I = 3000$. If the equation delivers a result that is greater than 1.5, then two TCC operators per shift are required. On the other hand, in the case of a small number of incidents, an additional TCC operator workplace is required in the case of six or more tunnels above 500 m. Combinations of the two variables also apply (e.g., one thousand five hundred incidents and three tunnels). We should note that if the result of the equation for an individual TCC is one, then another specificity should be considered. However, difficulties in performing the work assignments in the case of only one TCC operator per shift can arise since incidents are unpredictable, unevenly distributed over time, and some may require immediate intervention. This means that one single TCC operator per shift may not be able to safely and functionally perform certain unpredictable and urgent tasks, nor would they be enough to ensure an optimal performance in all TMS situations. Therefore, for the best traffic management quality, at least two TCC operators per shift should be in each TCC.

This model can calculate the required number of TCC operators in each scenario. Table 1 shows the expected number of operators in TCCs for each scenario, which is calculated by Equation (2) considering the predicted values of the incidents and the tunnels for the planning period of 15 years (e.g., 2038).

Table 1. Expected requirements for TCC human resources.

	No. rTCC + mTCC	TCC Operator Workplaces	Head of TCC Workplaces	Total Workplaces
Scenario A	5 + 0 [1]	14 + 0 [1]	3 × 1 + 0 [1]	18
Scenario B	3 + 1	12 + 1	3 × 1 + 1	17
Scenario C	1	12	1	13

[1] Not an mTCC, only a coordination office.

Table 1 shows the human resources/employee requirements, including the heads of the TCC for different scenarios: Scenario A requires, in total, 18 workplaces, Scenario B 17 workplaces, and Scenario C 13 workplaces.

4. Discussion

The present research considers the different aspects in the scenarios of integration for the TCCs in Slovenia. SWOT analysis was performed for each analyzed scenario. While some of the Ss, Ws, Os, and Ts are consistent with those of the centralized/decentralized systems [4,7], others are more specific. One example is the communication problem because of the not speaking the foreign language in the case of reorganizations of TCCs. A major part of this is specific to the geographical feature of Slovenia; because the country is relatively small, changes in motorway network coverage by a specific center can easily mean bordering another country.

The SWOT analysis showed that both scenarios, which differ from the existing Scenario A, offer more advantages for the development of the TMS. In addition, logically connecting rTCCs and the mTCC provides more benefits than a separate rTCC infrastructure. However, centralization in a single mTCC center presents a challenge that can lead to multiple weaknesses and threats while not necessarily being more beneficial. Reducing the number of TCCs has a whole range of advantages in terms of both the organization of work in the rTCC and the operation and maintenance costs of the rTCC systems.

After this, different scenarios were assessed from the perspective of human resources and the total number of workplaces. The results showed different requirements for human resources between the different scenarios, which indicates a strong dependency of human resource management on the organizational structure of the TCCs. Although Scenario A is the only scenario without an mTCC—meaning no workplaces in the mTCC are therefore required for it—the total number of workplaces is bigger due to additional rTCCs, which results in covering fewer motorway sections with proportionally reduced coverage of incidents. One should note that by considering the human resources for incident specificities, also highlighted by the employee voice, two operator positions are required in these TCCs, even for those theoretical cases with such a low workload that it does not require the capability of one TCC operator. Clearly, human resource specificities in terms of the abilities and limitation of operators in incident situations play a role in providing efficient, safe, and sustainable traffic management systems and should not be neglected. This clearly shows that the employee voice is a crucial part of sustainable HRM, which complies with the findings of [27]. Furthermore, the integration of HRM into the process of selecting the TMS organization model is crucial for fostering a more sustainable TMS.

Considering these findings, we propose a reasonable reduction in the number of rTCCs in the current implementation in Slovenia (contained in Scenario B), such that each rTCC requires at least two TCC operator workplaces at all times. Due to a higher incident density during the day, this usually means at least three workplaces during the day and two workplaces on the night shift. We must note that the number of positions does not equal the number of employees, as five employees are needed for each operator workplace (to provide a continuous 24/7 service). This means that the actual number of employees is dependent on working week duration of the employees. Another factor that could potentially affect the required number of employees is education and practical experience of the operators, which is known to significantly affect the performance. However, a good TMS should not allow for potentially unqualified workers; therefore, sufficient required education level as well as regular employee training are the basis of the quality TMS.

It is worth mentioning that by calculating the future requirements for the number of employees, we also obtain some prognosis of the space requirements in any new/reorganized TCCs.

The number of incidents that require some degree of action from the operator is dependent on the size of the motorway network, the extent of major engineering structures (tunnels and bridges), and traffic volumes. To estimate the number of required TCC operators in the future, we considered the planned state of the motorway network and engineering structures, the forecasted traffic volumes, and the current incident rate (derived from the number of incidents, length of road sections, and their AADTs). The incident growth in recent years acts in a similar manner as do predictions using the aforementioned technique. However, the number of incidents that are reported and entered into the information system of the motorway operators can also be dependent on the incident detection and reporting service, which can involve different levels of automatization and participant involvement on the road towards the ITMS in which the artificial intelligence domain plays highlights the importance of the detection process [32]. Therefore, other motorway operators with different incident reporting services, information systems, and traffic management regulations should not directly use the derived equation; however, the technique itself is certainly suitable for practical applications. Moreover, in the future, the number of reported incidents may grow rapidly on the one hand (e.g., each vehicle could report the same problem), and the operator workload to manage one incident may decrease significantly on the other hand (e.g., automated handling of several instances of the same incident reports). Therefore, if the model is used for the same purpose in the future, the involvement of the number of conflicts should be critically evaluated with respect to any changes in the incident reporting and handling techniques.

To summarize both the SWOT analysis and the work in the field of HRM, it is reasonable to propose Scenario B as the future TMS development plan in Slovenia. This approach combines reducing the number of rTCCs with establishing logical connections between all the TCCs and thus developing the TMS as a cloud service with physically separated rTCCs.

5. Conclusions and Future Directions

This paper highlights the importance of human resource management in TMSs and introduces certain practical implications for TMS organization, i.e., it provides guidelines and expertise regarding the integration of TCCs with human resource management. The introduction of HRM into the process of selecting the most suitable scenario of integration for TCCs can emphasize certain possible threats in the inappropriate organization of TMSs (e.g., lone operators in incident situations). Moreover, the introduction of a model for determining the number of employees for future scenarios may also lead to a better prediction in the future space requirements for any new/reorganized TCCs.

To support society moving to a more sustainable future regarding the "vision zero" carbon footprint, hazard, and accidents, the efficiency aspect of the sustainable transport system is an important factor. Questions arise about the automation, liability risks, and functionality issues. On the other hand, systems such as TMS can operate autonomously to a certain level, but they still require human involvement for development, supervision, ensuring responsible and also ethical use, e.g., the priority in traffic. This highlights the importance of HRM in TMS also in the future.

The organizational structure of the TMS should be able to accommodate the future challenges and opportunities that are caused by the Internet of Things (IoT). Scenario B, which combines the findings from the SWOT analysis and the integration of HRM, is also a reasonable choice from this point of view, as it represents a cloud service with physically separated rTCCs and combines some of the advantages of centralized and decentralized systems. However, the adaptability of organizational structure to adjust to the technological future (which is known to be focused on automation and integration with IoT on the horizon) is certainly vague and indistinct. Therefore, the possibility of improving the system in terms of the number and integration of TCCs remains an open question and represents the main subject of further research.

Many modern vehicles are already connected to the "cloud" with cellular technologies including personal communication devices, RDS-TMC broadcasting receivers, or short-range communication devices, enabling them access to information on traffic conditions ahead. Indeed, the future of traffic control systems is expected to be highly influenced by the integration of data from mobile devices and vehicles. This integration would lead to an interactive system architecture known as TMS 2.0+ [33]. The deployment of 5 G networks and other wireless communication technologies has the potential to significantly enhance the efficiency of traffic control centers, not just in Slovenia but throughout Europe [34–36]. For example, by fostering new approaches to European interoperability, the C-Roads platform sets milestones by the provision of fundamental guidelines as the base for deployment, evaluation, and assessment of service architecture on more than 20,000 km C-ITS enabled EU roads [37]. As previously mentioned, we anticipate the introduction of new services and enhanced data delivery capabilities between the actors involved in the TMS ecosystem (e.g., centers, users/vehicles etc.). These services will require stringent communication parameters [38]. The advancements in technology would enable a more interconnected system where vehicles and infrastructure are connected, allowing for a more comprehensive data exchange model. For example, with this increased connectivity, it becomes essential to distinguish between vehicles that are part of a road convoy, incorrectly counted vehicles, or potential vehicle queues, which are today's challenges of traffic surveillance. This advancement in technology offers the potential to significantly improve the characterization of traffic flow and enable more informed decision-making. Consequently, it is conceivable that in the future, it could alleviate the workload of staff in TCCs.

One challenge that may arise with the growing number of input data and parameters is the potential for negative effects if their determination and standardization are lacking. It is crucial to establish unified methods for determining and measuring these parameters to ensure the effectiveness of the decision-making process in TMS.

This evolution (we are not expecting the revolution) would require the active involvement of all stakeholders, along with standardized data collection methods and decision-making criteria to optimize TMS. Until experienced, we can ignore the latest technologies, or we can introduce these technologies step-by-step into the optimization process of HRM in TCCs. With this article, we are bringing the new claim that remains to be proven: "Optimization of HRM in TMS is a time and technology matured-dependent iterative process".

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