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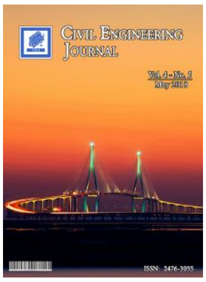

Selecting an Appropriate Express Railway Pavement System Using VIKOR Multi-Criteria Decision Making Model

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Abstract

A gigantic evolution has been brought about in the railway transportation by the emergence of the expressways as the most efficient method of carrying passengers within short and medium interurban distances. Various types of expressway pavements have been offered during the recent years. A considerable amount of the repair and maintenance costs in railroad sector is allocated to the constituents forming the pavements. No thorough and precise research has been so far conducted on the railroad expressways featuring traffics with speeds over 250 km/h and the extant information have merely been trivial changes in the procedures existent for speeds below 200 km/h and these are not deemed of much use and applicability. Thus, the current research paper is devoted to the investigation and selection of express railways pavement system design using VIKOR method. The evaluations indicate that the commencement of the first high-speed train work in 1964 in Japan marked a turning point in the railroad passenger transportation in the world. The development of the high-speed railway transportation is enumerated as an important revolution helping the railroads retake their crucial role in passenger transportation in such a way that it is found overtaking the roadway and aerial transportation and even exposing some airlines to real crisis. The high-speed railroad is undergoing an intensive expansion worldwide and as a safe, sound and sustainable transportation system, it has well proved its role in the social and economic development of the nations.

Keywords: Railroad; Express Train; Fuzzy Logic; VIKOR Method.

1. Introduction

Railroad is the oldest and the first method of public transportation and it was unrivalled until the full-scale development of the roadway transportation in early 20th century in such areas as land transportation of cargos and passengers. After the WWII, the tremendous improvement in the production of the automobiles, autobahns and delivery of aerial services provided a greater many of the people with access to the other means of transportation by The passenger railroad has been less competitive in the US because the government has been, in the first place, concentrated on the aerial and roadway transportation and, secondly, in such countries as the US featuring a vast area and low population density the development of the passenger railroad and that of the high-speed type is not envisaged cost-effective [1].

Essentially, passenger railroad can act competitive where there is a high population density or when the fuel costs are expensive. At present, a few number of the passenger trains consume gasoline or other fossil fuels around the globe and the majority of them work with electricity but the power plants supplying their energy consume gas and/or coal [1]. The main goal of any industry related to transportation has always been to use the minimum available resources to enjoy the maximum benefits of the system and provide the most services to the users of that transportation system; therefore,

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high profitability and efficiency are the main objectives of any company or organization. One of the problems of construction of high-speed rails is their huge cost over conventional rails, which is far higher than the direct revenues being generated. Hence, from the point of view of business enterprises, the justification for investing in such large projects is usually weaker than the justification for conventional plans. However, even the policies that do not pay much attention to the transportation issues are not interested in the implementation of high-speed rail technology. Yet by choosing the right method and reducing costs on the high-speed rails, it has been possible to make policymakers welcome the new high-speed rail technology [2].

The transportation sector in general, and the high speed rail in particular are of great importance due to their direct and major impact on the economic and social development of countries and facilitation of the traveling. High speed rail transportation is an important and strategic way to compete with other modes of transportation, and in recent years, its development has been of great importance in all countries [3]. High speed rail technology is usually developed as a result of the advancement of conventional rail technology providing greater speed as well as safety for users of this network. In addition, it is a fast and efficient way to meet the demands of travelers who want a shorter trip with a higher quality [4].

2. Literature Review

It is not possible to finance the high speed rail projects using public funds; the construction of high-speed rails requires the participation and attraction of capital along with the participation of other ministries. The attitude towards the investor in this section is different from other plans. In some countries, privatization is used to finance the high costs of this type of rails. Furthermore, many researchers have investigated the privatization of high-speed rails in many countries [5]. The arrival of high speed rail technology requires a comprehensive and integrated approach of government authorities and an incentive to attract investors in this sector. Strategic studies and the formulation of a general policy, as well as the prioritization of the implementation of high-speed projects, can be useful in making decisions [6]. In order to achieve sustainable economic development, proper use of the factors of production and planning is of particular importance because it increases productivity in the condition in which the country's economy is faced with limited production factors [7].

The reports of the International Union of Railways (UIC) also indicate the link between rail operations, speed lines and some costs in the European rail network [8]. Also, many studies have considered the difference between high-speed railways and air transport and have carried out economic investigations for this purpose [9-12]. In addition, various sources based on economic assessments in high-speed rail projects often focus on the project-oriented economic analysis and do not provide comprehensive information on the general state of the high-speed rails. Although they contain some organized economic information on high-speed rails and networks, they have not paid much attention to the issue of speed [13, 14]. The speed indicator is one of the most important indicators for a variety of modes of transportation, including high speed rails. Line Speed is a technical parameter related to the infrastructures [15].

The assessment of high-speed rails in Europe shows that, despite the financial difficulties, the high-speed rail system is considered as an important option regarding the global environmental concerns and the need for a rapid and safe transportation. It has also been proven that the implementation of high-speed railways, with an increasing access to the urban areas, leads to imbalances between major cities and marginal areas [16]. The impact of these rails on travel, encouragement to travel and its distribution is dependent on parameters such as the existence of conventional rail ways, air lines and the number of built stations. In addition, factors such as population coverage, budget constraints, the origin and destination of travels affect the provision of the rail network's extension model [17]. Regarding this issue, the decision to build new high-speed rails is made from the point of view of the impact on the environment, the historical features, the state of natural disasters, government policies for servicing specific areas, and the amount of allocated funds [18].

The emphasis on the efficiency leads to the formation of a high-speed network, the main purpose of which is to optimize the connection of important economic centers to each other; however, this approach will have a negative impact on the development, as it leads to an intensification of the polar pattern in spatial development; therefore, the richer cities become more beneficial and smaller cities inevitably fall into less favorable conditions [19]. However, there is now a relative consensus that the design of a high-speed network should take into account both equality and efficiency [20]. In 2015, Bachok et al. explored the sustainability indicators of transportation in Malaysia and considered indicators such as average travel time, land use and air and noise pollution [21]. In 2015, Bozasi et al., introduced sustainability indicators in the assessment of urban transport systems as well as their categorization; he included indicators such as taxes and shipping costs, air pollution costs, average travel time, environmental costs, and social and economic considerations [22].

The investigations on ballast in express trains show that the lack of paying attention to the ballast causes the loss of elasticity property, line stabilization and dirtiness of the ballast. Therefore, according to the substantial role played by ballast in the quality of the entire line and preservation of the safety and comfort of the trains movement, making investment in selecting the type of the masonry and the implementation method as well as the maintenance is greatly necessary [23]. The proper selection of the railroad's pavement system provides for its becoming the focus of the economy planners as a safe and cheap means of passenger and cargo transportation for the long routes to the extent that it is recounted as one of the factors accelerating the development and even the infrastructure of the countries' development [24]. The proper selection of the pavement implementation method in this type of trains causes reduction of noise and shake, increase the safety and reduction of human resources dangers during the project execution phase, lower repair and maintenance needs and the reduction of derailment risk in the express railways [25].

In view of implementation, ballast-free pavement is classified into three sets of in-situ, precast and combinational pavements each having their own specific advantages and disadvantages. The cost and the time required for performing repair and maintenance of the ballast-free lines is considerably lower than the cost of the ordinary railroads. The issue presents this system as an economically competitive method during the whole life of the railroad in contrast to the traditional systems [26]. The investigations also demonstrate that the ballast pavement system is an old but customary one and it is better to employ the ballast-free pavement systems according to the high ballast pavers' repair and maintenance costs. Also, the subgrade coupled pavement system has been experienced in Iran but it is found less cost-effective hence it is better to make use of a substitute pavement system called RHEDA [27]. According to the fact that about 90% of the express train costs pertain to the construction of appropriate substructures, the selection of a proper system for the express trains can, meanwhile reducing the costs, provide for the social comfort [28]. Case study of the express trains in European and East Asian countries demonstrated that the selection of the pavement implementation system preceded by an investigation of the various methods of express railways are mostly done via concentration on the economic issues and the other factors have been given lesser weights [29].

The investigations performed in the express trains in India are reflective of the idea that the exertion of certain changes in the existing railroads can render them utilizable as express railways [30]. The evaluation of the properties of the express trains made it clear that the express railways are recognized and employed as highly efficient mechanisms in intra- and interurban transportation in the developed countries as well as in a great many of the developing countries. These types of trains are not only environment-friendly due to their absence of aerial and acoustic pollutions but they are also more favorable to the passengers with their speeding of the destination arrival, reduction of driving accidents, high capability of transporting the passengers and lower levels of energy consumption [31]. Therefore, these types of trains can be envisioned as a good choice for the sustainable development that is in need of precise planning and codifying strategies [32].

Considering the enhancement of the traditional railroads along with paying attention to the role of the cities positioned in the midway of the path from a source to a destination travelled by an express train is enumerated as an optimum solution that is currently being executed in countries like Spain and France [33]. Aerodynamic, land and environmental conditions as well as the rail response to the vibrations and its load-bearing considerations are among the most important risks taken into account in selecting express train railway pavement system [34]. The issue turns more significant when very soft clay is used in the implementation of express train railway pavement [35]. Using ABAQUS software for the investigations of the vibrations in implementing various methods of pavement construction in regard of the express train railways made it evident that the failure in selecting a proper method, meanwhile increasing acoustic pollution, causes a larger deal of train shakes as a result of which the passengers lose their feeling of safety and comfort followed by faster destruction of the railroads [36]. Moreover, there are other researchers carried out using analytic hierarchy method to determine the appropriate systems of express train railway pavement construction that have indicated that the pavement systems with D-traverse of the buried block in the concrete slab are the preferred choice [37].

Khalili and Assadi evaluated high speed trains and stated that the high cost of construction, operation and maintenance of high-speed railway lines and its development is more justifiable in countries that have high population density and travel demand [38]. Based on the research of Khakbaz and Fattahi, regarding different methods of implementing high speed trains in Australia and overcoming its geotechnical problems, it was determined that the correct choice of pavement method in the high-speed rails would reduce the structural height, maintenance costs, the risk of wheel slide, and increase travel comfort due to reduced vibration and noise of the rails [39]. Alimoradi et al. analyzed the economic costs of high-speed railways and found that the total cost of the railway shows the least cumulative costs, taking its various parts into account and the approximate range of 250 km/h. In addition to the issue of speed, factors such as transportation policies, geographic conditions and topography of the regions, the economic conditions of countries, and the type of pavement execution system affect the cost of high-speed rail lines [2]. Fadakar Masouleh and KeyMansheh explored the costs of construction and maintenance of high-speed railroads and announced that the high-speed rails, being the advanced generation of normal vehicles, are able to save the costs and time. This transportation system is in competition with other transportation systems such as airlines because the five categories of safety, convenience, access, time savings and costs are very important for the users as well as the constructors and operators who, aside from the four primary issues, take the issue of cost seriously. The quality of each transportation system, with regard to the competitive ability of each, is evaluated with other systems in the intercity transportation [40].

Barikani et al. explored in their research the new methods of launching ballast in high speed trains, and stated that due to the high importance of ballast as a significant component of the pavement in line performance, it is necessary to conduct researches in this regard. Concerning the heavy maintenance costs of the line- the main costs are related to the ballast- the use of a durable ballast and more stable stability with a certain uniformity can save a large part of these costs. Slag ballast is one of the materials being evaluated as ballast [41]. The research of Saheb Azamani on intelligent pavement system in high speed railways revealed that the selection of a suitable system for high-speed railroads increases reliability and quality, reduces installation time and noise pollution as well as maintenance costs [42]. More frequent and faster trains will also have a positive effect on economic growth in the area. The construction of HS2 will result in Birmingham being as close to London as is Cambridge, in terms of travel time [43]. Jing et al., studied the ballast on fast trains, and it was realized that the effective factors in the selection of ballast are high speeds, the velocity of ballast particles and the ratio of mass to volume; therefore, to implement a proper pavement system, one must, already, examines the shape, volume, grading, and connectivity of the ballast [44].

3. Methodology

In the present research, a qualitative analysis was performed descriptively and the method of implementation of high-speed railways' pavement system was analyzed. Then, four commonly used high-speed railways' pavement systems were evaluated and compared by experts in order to choose the best operating system. These systems include the Shinkansen concrete slab system, the ERC buried railing system, MRT rheda System, and the IPA system. The reason for choosing these systems is their frequent use in high-speed rail projects. Library studies were used and a questionnaire was prepared with the help of specialists, individuals and organizations that directly deal with the choice of the type of construction system in order to identify the effective measures in selecting the type of proper pavement system; the input data required for the VIKOR procedure were obtained. Meanwhile, the questionnaires were distributed to seven groups, including contractors, employers, advisors, project directors, investors, university professors and the experts and specialists reaching to a total of 123 individuals. The questionnaire was scored based on Likert's 9-point scale.

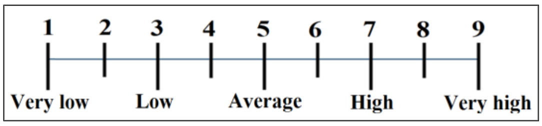

Figure 1. Likert's 9-Point Scale

It was made clear in an evaluation of the questionnaires that the required scales include the ease and pace of implementation, implementation costs, repair and maintenance, domestic implementation experience and the contractors and consultors' competencies and there was made use of Likert's 9-point scale to quantify these scales to tangible figures. Finally, according to the data and output of the VIKOR method, pavement systems of high-speed rail were categorized in terms of priority (Figure 2).

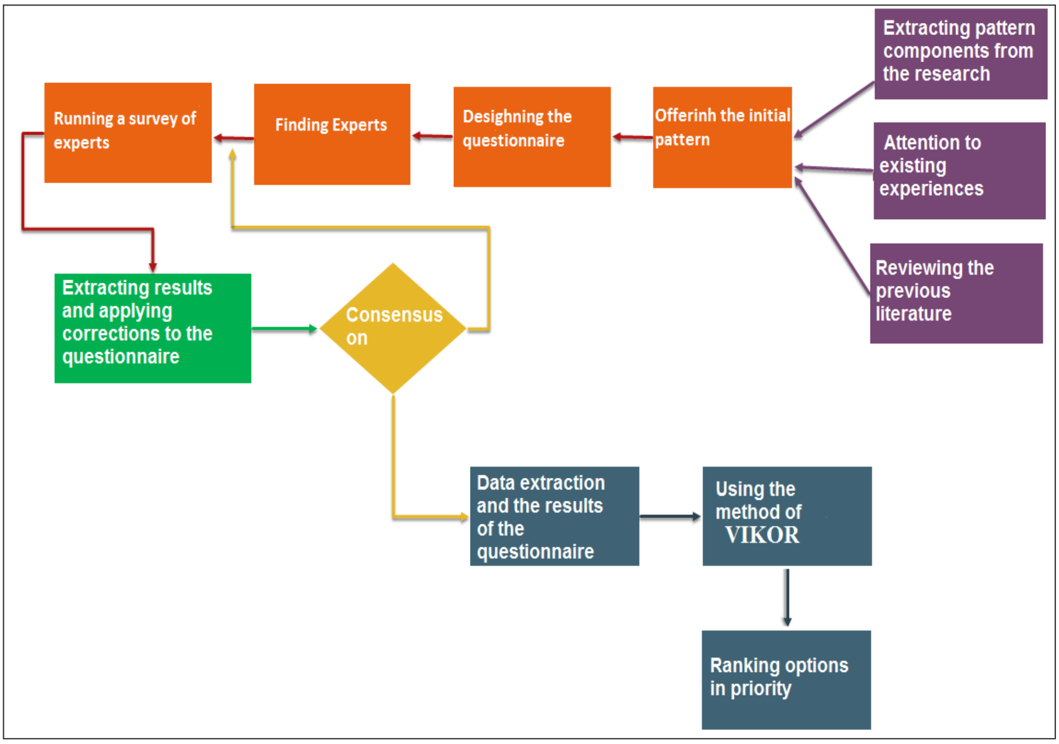

Figure 2. Flowchart of the study method stages

4. VIKOR Method

The term VIKOR (Vlse Kriterijumsk Optimizacija Kompromisno Resenje) was presented by Opricovic and Te-Zang in 1988 being developed during 2002-2007. This methodology is based on the consensus planning of multi-criteria decision-making issues, evaluating issues that are inappropriate and incompatible. When a decision maker is unable to identify and express the superiority of a problem at the time of its initiation and design, this method can be used as an effective tool for decision making.

The purpose of this method is to focus on the ranking and selection of a set of variables in an issue with conflicting criteria, which ultimately result in a consensus ranking list and one or more consensus solutions. The consensus solutions is a viable solution being closest to the ideal solution. An agreement or consensus means an answer based on the mutual agreement between the criteria. The target space between the two criteria is shown as an example in Figure (3) [45].

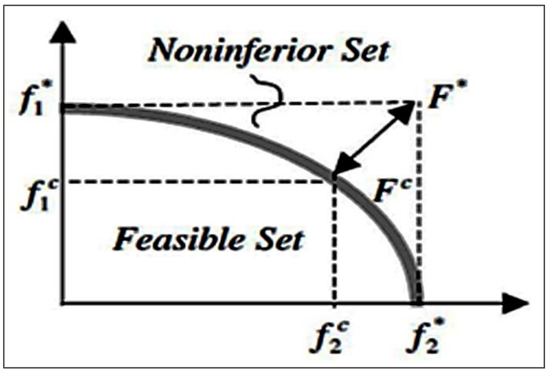

Figure 3. The target space between two criteria in the VIKOR method [45]

4.1. The Advantages of VIKOR Method

The advantage of the VIKOR method is that it doesn't necessitate the use of experts' opinions to evaluate options on the basis of criteria, but it can use raw data. For example, to evaluate for instance which village has favorable conditions in the "communication path" the distance between the communication path and the village can be measured and entered into the model without requiring an expert assessment instead of scoring by experts. This is the main difference between this model and hierarchical and network analysis being based on paired comparisons of criteria and options, while in this model there is no comparison between criteria and options, but each option is evaluated independently based on each criterion [45].

This assessment can be based on raw data or based on expert opinion. Thus, the main purpose of this model is to determine the weight and value of each option and it's ranking [45].

5. Introducing the Common Express Railway Pavement System Implementation

5.1. Shinkansen Slab Track System

The use of Shinkansen slab track dates back to the bitter experiences of exploiting 516 km Tokaido railway put to work in 1964. The railroad was firstly furnished with a ballast structure and the emergence of the great many of the problems governing the system led to the innovation and development of a railway by means of precast concrete slabs. The system was operationalized in 1970 on a 21 km railroad and it is known to be of several kinds. Although they are different in some respect, they are all drawn on a common fundamental idea and their differences only lie in their details, especially according to the place where they are going to be mantled [46].

Figure 4. A sample of implemented Shinkansen slab track [46]

5.2. ERC Subgrade Railroad Design

The ERC subgrade railroad design possesses continuous rail abutment consisted of a composite material such as the combination of cork and polyurethane. The rails are infirmed in their places by an elastic composite material in the entire profile except for the railroad ferrule. There is no need for using additional elements for fixing the line width and this is the most specific characteristic of this system. The method is applicable in a range of railroads from those used for lighter trains to even express trains. The connection system properties are as stated below [46]:

- Continuous abutment of the railway is built on an elastic strip
- Rail's guidance by the use of elastic anchors to a slot
- Top-down alignment and arrangement of the rails
- Stabilization of the rail profile location by the assistance of a composite material.

Optimum designing of the slot dimensions, elastic segments and the strips underneath the rail in line with providing for specific elasticity required by the line system are illustrated in Figure 5.

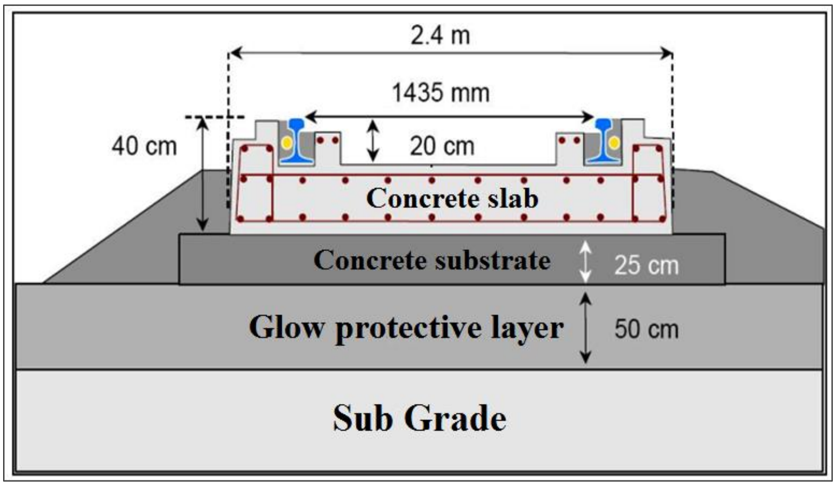

Figure 5. Cross-section of the ERC subgrade railroad design [47]

5.3. RHEDA MRT System

The term RHEDA ballast-free railway dates back to 1972 in the construction of Rheda Wiedenbrück train station in Germany. The Rheda system structure and the various kinds derived thereof include an in-situ constructed reinforced concrete plate in which the pre-stressed concrete railroad tie are employed as the elements keeping the rail track fixed in its position. In the process of construction and manufacturing of these structures, a collection encompassing rail's complete span consisted of the track and the connected pre-stressed railroad tie and rails are mantled inside the concrete. The use of the pre-stressed concrete railroad tie as part of the final concrete slab makes it ascertained that the rail connection bonds to the railroad tie are not influenced by the cracks created in the concrete slab. Due to the lack of integrity in the final concrete slab, micro-cracks, usually not devastative, are usually developed uniformly in the periphery of the railroad ties [46].

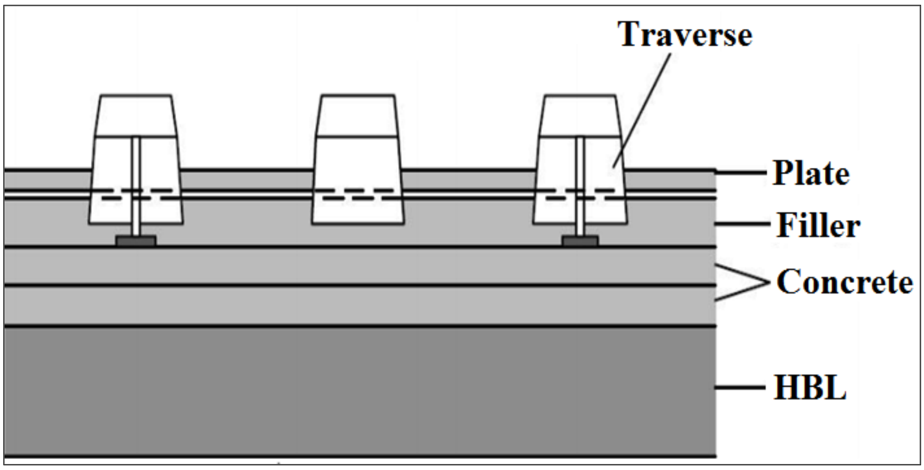

Figure 6. Rheda System [46]

5.4. IPA System

The system was originally developed by Italy's government Railroad Network and it is the result of railroad technology transferring from Japan to them. The system embraces pre-stressed and precast concrete slabs that are assembled on a concrete foundation featuring a layer thickness of 50 mm made of asphalt concrete. The installation of the ballast-free line incorporates the placement of the basic flat concrete slabs and then the superimposition of the pre-stressed concrete slabs, 5 meters in length, 2.5 meters in width and 160 mm in thickness, reaching to a weight of more than 5.2 tones. A semicircular protruding section has been built on the ending part of every concrete slab so as to stabilize the slabs and it also serves the prevention of their longitudinal and lateral movements. In addition, a combination composed of asphalt concrete, 50 mm in thickness, is grouted on-site in the clearance between the precast slab and the concrete foundation. This gives an elastic layer (900 newton per millimeter) capable of providing for a better elasticity in the subsection of the track than the ordinary ballasted lines [46].

Figure 7. IPA System [46]

5.5. STEDEF VFB Design

This system is the most well-known ballast-free design widely used in France and very similar to express TGV lines constructed in the tunnels and it is comprised of two elastic surfaces. The first elastic surface is supplied by means of pads made between the rail and the reinforced concrete blocks. The railroad is placed on the blocks through being fastened by the use of elastic anchors' bolts (of the NABLA elastic anchors). The layer is served to absorb the high frequencies (800-1000 Hz) and the vibrations stemming from the rail-wheel contact. Therefore, the rail pad is capable of preventing the transferring of these vibrations to the railroad tie blocks. The second elasticity surface carries out the duty of the ballast in the customary lines [46].

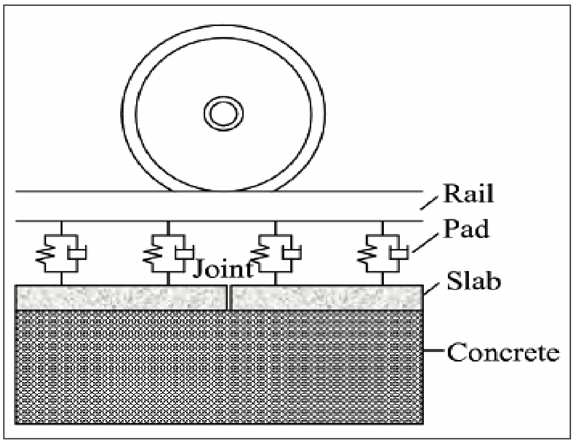

Figure 8. STEDEF System [46]

5.6. PACT (Paved Concrete Track) Concrete Slab System

The system incorporates a continuous reinforced concrete slab that is implemented on-site. The substantial advantages of the system are [46]:

- The humid conditions have no special effect on the role-playing of this system and there is no risk of the line buckling due to its high lateral rigidity.
- The finished height of the pavement is smaller than the ballast state and its improved geometry eliminates the risk of derailment as a result of the line irregularities.
- The layer beneath the rail track can be used in a continuous manner so as to provide for a higher rate of smoothness and larger absorption of the vibrations.

5.7. SATO Design

The first design pertinent to the supportive layers in singular unburied ballast-free systems was proposed by SATO, a German term meaning Study Group for Asphalt Pavements (Studien gesellschaft Asphalt-Oberbau). The specialty of SATO design is its use of Y-shaped steel railroad ties equipped with the double rail abutments. In order to make the railroad ties bound in both orthogonal and horizontal directions, they are welded to a broad steel plate, named Nelson anchor (Rawlplug) as shown in Figure 9 so as to create an appropriate fixed support as a result of the anchor's placement in the asphalt layer [46].

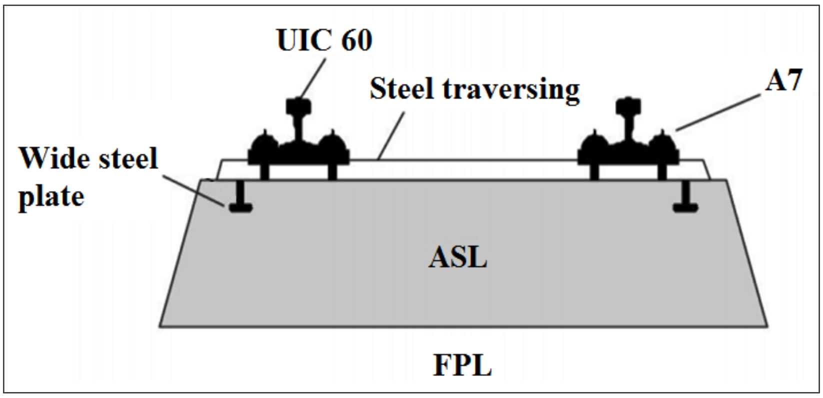

Figure 9. Cross-section of SATO design [46]

6. VIKOR Multi-Criteria Decision Making

6.1. Step One: Converting the Qualitative Quantities to Quantitative Values Using Likert's 9-point Scale

Due to the fact that the questionnaire gathers the data in a qualitative manner, there was made use of Likert's 9-point scale to convert the qualitative quantities to quantitative values. Table (1) presents the decision matrix.

Table 1. Quantitative decision matrix

Option \ Scale	Implementation speed and ease	Implementation cost	Repair and maintenance	Domestic implementation experience	Contractors and advisors Competency
PACT	7	5	7	5	7
Shinkansen Slab Track System	9	7	7	7	9
IPA System	7	7	7	7	7
STEDEF VFB Design	7	7	5	7	7
RHEDA MRT System	9	9	7	9	9
SATO Design	5	5	5	3	5
ERC Subgrade Railroad Design	9	7	7	9	9
Total	53	47	45	47	53

6.2. Step Two: Normalized Decision Matrix

Table 2 gives the normalized decision matrix obtained from every column's total sum of squares and dividing it by that value [47].

Table 2. Normalized decision matrix

Option \ Scale	Implementation speed and ease	Implementation cost	Repair and maintenance	Domestic implementation experience	Contractors and advisors Competency
PACT	0.344	0.277	0.408	0.270	0.344
Shinkansen Slab Track System	0.442	0.387	0.408	0.378	0.442
IPA System	0.344	0.387	0.408	0.378	0.344
STEDEF VFB Design	0.344	0.387	0.291	0.378	0.344
RHEDA MRT System	0.442	0.498	0.408	0.486	0.442
SATO Design	0.245	0.277	0.291	0.162	0.245
ERC Subgrade Railroad Design	0.442	0.378	0.408	0.486	0.442

6.3. Step Three: Calculation of the Positive and Negative Ideal Spots

For every scale, the best and the worst of each will be determined amongst all the options denoted by fj* and fj-, respectively [47].

$$f_j^* = \text{Max } f_{ij}$$
$$(i = 1, 2, \ldots, m., \; j = 1, 2, \ldots, n) \quad (1)$$
$$f_j^- = \text{Min } f_{ij}$$

6.4. Step Four: Calculation of the Utility and Regret Values of Each Option

For every scale, the best and the worst of each will be determined amongst all the options denoted by fj* and fj-, respectively [47].

$$L_{1.j} = S_i = \sum_{j=1}^{n} w_j \times \frac{f_j^* - f_{ij}}{f_j^* - f_j^-} \quad (2)$$

$$L_{\infty.i} = R_i = Max \left\{ w_j \times \frac{f_j^* - f_{ij}}{f_j^* - f_j^-} \right\} \quad (3)$$

Where S denotes the relative distance of the i-th option from the positive ideal solution (the best combination) and R_i designates the maximum discomfort of the i-th option for its distantness from the positive ideal solution [47].

6.5. Step Five: Calculation of VIKOR Index for Each Option

$$Q_i = V\left[\frac{S_i - S^*}{S^- - S^*}\right] + (1 - V)\left[\frac{R_i - R^*}{R^- - R^*}\right] \quad (4)$$

Wherein, we have:

V= the weight for the maximum group utility

$S^- = Max\ S_i$

$S^* = Min\ S_i$

$R^- = Max\ R_i$

$R^* = min\ R_i$

The amount of index for each option has been given in Table (3).

Table 3. The amount of VIKOR index for each option

Option \ Scale	Q-value
PACT	0.741
Shinkansen Slab Track System	0.317
IPA System	0.454
STEDEF VFB Design	0.504
RHEDA MRT System	0.000
SATO Design	1.000
ERC Subgrade R1ailroad Design	0.275

6.6. Step Six: Option Ranking Based on S, R and Q Values

The options are ordered in three groups, from small to large, based on S, R and Q values. The best option possesses the lowest Q value provided that the following two condition hold:

Condition One: if the option A_1 and A_2, among m options, are ranked first and second, then the relation (5) should hold between them:

$$Q(A_2) - Q(A_1) \geq \frac{1}{m-1} \tag{5}$$

Condition Two: the option A_1 has to be ranked superior at least in one of the R or S groups. If the first condition is found not holding true, then both of the options are to be considered as the best. If the condition two is found not holding rue, both options, A_1 and A_2, are selected as the best choice [47].

Table 4. Ranking of the methods of express railway pavement implementation methods

Based on S-value		Based on R-value		Based on Q-value	
RHEDA MRT System	0.000	RHEDA MRT System	0.000	RHEDA MRT System	0.000
ERC Subgrade Railroad Design	0.110	ERC Subgrade Railroad Design	0.110	ERC Subgrade Railroad Design	0.275
Shinkansen Slab Track System	0.193	Shinkansen Slab Track System	0.110	Shinkansen Slab Track System	0.317
IPA System	0.408	IPA System	0.125	IPA System	0.454
STEDEF VFB Design	0.508	STEDEF VFB Design	0.125	STEDEF VFB Design	0.504
PACT	0.602	PACT	0.220	PACT	0.741
SATO Design	1.000	SATO Design	0.250	SATO Design	1.000

According to Table 4, the option that is recognized as the superior choice in all of the three groups is selected as the best option. As it is observed, Rheda MRT system has been selected as the best option in terms of the three S, R and Q indices. To introduce this option as the superior choice, there is a need for its two prerequisites to be investigated.

Condition One:

$$0.275 - 0.000 \geq \frac{1}{7-1} \rightarrow 0.275 \geq 0.167$$

Thus, the first condition holds.

Condition Two:

The option A_1 should be realized as the superior option at least in one of R or S groups. If the first condition is not found holding true, then both of the options are considered as the best. If the second condition is not found holding true, both of the options will be selected as the superior choice. We have:

Rheda MRT system has been selected as the superior option in terms of all three indices, i.e. R, S and Q. Hence, the second condition is also found holding true.

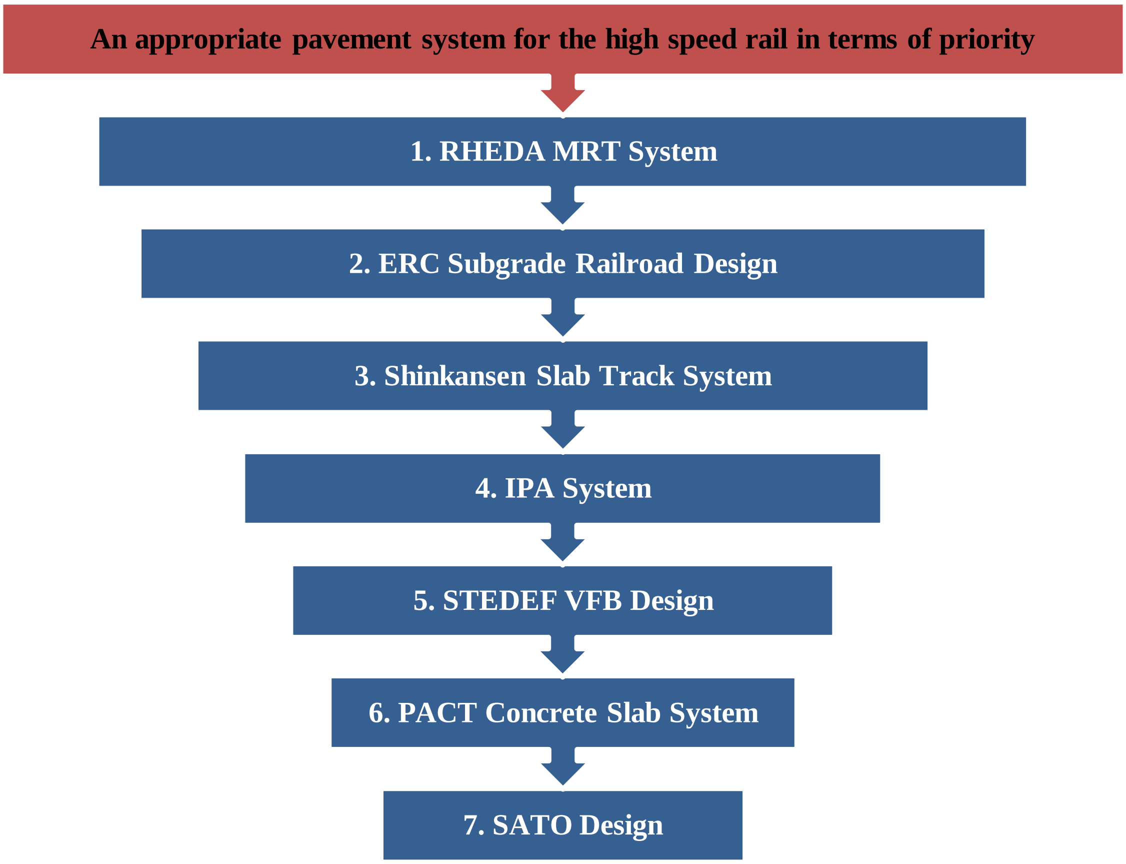

Figure 10. An appropriate pavement system for the high speed rail in terms of priority

7. Conclusion

The development of the railroad transportation, especially express railway, needs precise planning and codification of strategy for its being characterized by such advantages as very low pollution, high transit competencies, reduction of driving accidents, a very high capability in transportation of the passengers, offering more comfort and safety and reduction of energy consumption. Since the most important duty of a railway pavement system is the safe guidance of the railroad transportation fleet and preservation of the required sustainability against being repeatedly loaded with orthogonal, lateral and longitudinal loads during its exploitation period, the stability level of the railway track should be to the extent that no destruction and disruption can be caused in the geometry and structure of the line. The sustainability of a railroad pavement system largely depends on its constituent components, tonnage and the speed of the passing load, quality of the repair and maintenance operations and an array of the other environmental factors like the temperature and so forth.

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