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Selection of Light Weight Materials for Railway Vehicles Using WASPAS Method

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Abstract. *This study attempts to determine and assess appropriate lightweight materials for different railway vehicle components, taking into account elements like durability, strength, cost-effectiveness, and production viability. To compile pertinent data on lightweight materials, their characteristics, and their uses in the railway industry, a thorough assessment of the body of current literature and business practises was carried out. Introduction: Modern transport networks depend heavily on railway carriages to transfer people and commodities across large distances. The emphasis on enhancing the performance and lowering the environmental effect of railway vehicles is expanding as the need for effective and environmentally conscious transportation rises. The use of lightweight materials in their design is a viable strategy to meet these goals. For railway cars, using lightweight materials has a number of benefits. First of all, it can help people lose a lot of weight, which increases energy efficiency and lowers fuel usage. Less energy is needed by lighter cars to accelerate and maintain speed, which lowers operating costs and lowers greenhouse gas emissions. Reduced weight also makes it possible to carry more payloads and maybe travel at faster speeds. Research significance: The importance of choosing lightweight components for railway vehicles lies in its potential to increase payload capacity, decrease environmental impact, improve efficiency and safety, achieve cost-effectiveness, spur technological advancements, and guarantee regulatory compliance. For the railway sector to advance towards effective and sustainable transport systems that serve society as a whole, this study issue is essential. Method: A decision-making process called the Weighted Aggregated Sum Product Assessment (WASPAS) method is used to assess and rank a group of options based on several criteria. Without plagiarising, it uses a multi-criteria decision analysis (MCDA) technique to take both quantitative and qualitative aspects into account when making a choice. Alternate parameters: Dual Phase, DP600, Transformation Induced Plasticity, TRIP700, Twinning Induced Plasticity, TWIP, Aluminium, Al6005 T6, Aluminium, Al6082 T6, Porous Structure (Al—Closed cell). Evaluation parameters: Yield Strength, Tensile Strength, Young's Modulus, Density, Price. TRIP700 got 1st rank, TWIP got 2nd rank, DP600 got 3rd rank, Al6082 T6 got 4th rank, Al6005 T6 got 5th rank and Porous Structure (Al—Closed cell) got 6th rank. TRIP700 is got the first rank with less compensation.*

Keywords: *Light Weight Materials, Railway Vehicles, WASPAS, Tensile Strength, Yield Strength.*

1. INTRODUCTION

A major problem in the railway industry is lowering the weight of railway equipment. A small automobile reduces the amount of mould, which has a positive financial impact. Drive vehicles and the expense of railway maintenance. A weight loss effort is also made when using high-speed trains. You may access a number of light rail vehicles. There are three ways to reduce the number of components: choosing lightweight materials, making design changes utilising optimisation techniques, and taking use of their various roles [1]. Compared to a car, space, and It is thought that the railway and maritime sectors are slower to incorporate lightweight materials (mainly FRP composites) into their constructions. The main obstacles to the widespread use of FRP Composites are their high cost, poor fire performance, and maintenance problems in a railway environment and throughout the course of the vehicle's lifespan. However, by lowering the number of parts, assembly steps, and assembly time, the mix design can lower production costs (from the standpoint of life-cycle costs) [2]. In order to provide weight reduction in transport equipment train bodies, several design techniques (i.e., applications of light-weight components or design modifications) are required. The Rail body's weight is crucial to weight loss Rolling stock, as the rail system has a significant impact. Rolling stock structures are at the higher position and contribute to the vehicle weight. Other train-related structures, such the bogie, suspension, etc., as well as the traction systems, become lighter if the train's overall weight is decreased [3]. Traditional railcar constructions are often made of welded steel assemblages and frequently have a thin, non-structural fibreglass covering. As a

result, they are rather heavy. Additionally, modern carriage designs frequently have too many pieces and a dispersed use of materials. This is due to the fact that they must adhere to a number of requirements, including as proof loading, safety in crashes, missile defence, aerodynamics, and insulation. Costs for assembly are substantial, and there is limited functional integration. In contrast to the future vehicle outlined in this work, the goal was to exploit the capabilities for design integration provided by sandwich material technology to produce a lightweight structure that realises structural, crash, aerodynamic, and isolative functions in a cohesive bundle [4]. Not all designs that are lightweight focus on strength. The state of the materials to be employed, but it's also how their properties interact with loads, geometry, production technique, and prices. Cost is usually a significant consideration when choosing products, and the rectangular sample profiles already touch on this subject. Comparing comparable material costs is necessary. For high- and high-strength steels with weight, magnesium, aluminium, and composites reinforced with fibres irons. The benefits over lightweight alloys and compositions are based on manufacturing costs rather than just raw material costs [5].

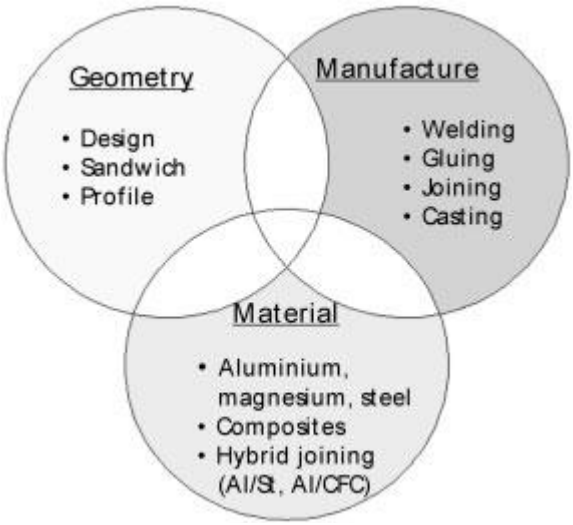

FIGURE 1. Light Weight Design Concept

As of right now, the only thing that matters is the usage of abstraction fibreglass in a matrix of polyester fractions of quite little volume. However, engineers are becoming more prevalent and are aware of the potential combinations constructed with continuous fibres high in aramid, glass, and carbon given the high volume fractions an opportunity to build a foundation Highly durable materials ratios of stiffness to weight. Therefore, it is a blueprint for ongoing development work in high-performance compound environments [6]. The outcome reveals Lightweight car bodies vibrating Frequencies of sampling took place in the high sensitivity range. Railways result in uncomfortable rides for those travelling. Hence, the applicable quality standards are several types of railway cars. According to UIC 5664 and EN 12663, 5 and more, different countries have different frequency specifications for instance, an automobile body's initial vertical curve frequency compounds [7]. The network is strained as a result of this heavy rolling stock. As a result, the track's damage increased Infrastructure, upkeep, and exorbitant prices update. They are produced when the motivation to act increases Likely to raise along with operating expenses High CO2 emissions during the life cycle of energy generation Moreover, there is a lot of demand makes graded traction and braking systems possible [8]. The Life Cycle Assessment, or LCA, technique is a systematic and exhaustive way to assess the environmental effects of a system, process, or product throughout the course of its full life cycle. It is a well-known and frequently used methodology that takes into account the cradle-to-grave viewpoint, including all phases from raw material extraction and production through consumption, disposal, and eventual recycling or reuse. Informed decision-making and the recognition of potential improvement areas are made possible by life cycle evaluations, which offer a comprehensive understanding of the environmental profile of a system or product. LCA is frequently used by businesses, governments, and academics to evaluate and contrast various goods or procedures, direct eco-design tactics, promote environmental labelling, and provide information for policymaking [9]. The actual utilisation of these materials circumstances shows that epoxy plastic is better weathering resistant. Due to plastic's usage in the manufacture of boilers and tanks, GRP's resilience to aggressive loads, low thermal conductivity, and appropriate bulk as compared to steel Mechanical strength at substantially less weight, operating costs may be significantly decreased its mass storage in turn by using it to heat the boiler Each vehicle can have a 35% improvement in effective load capacity thanks to fibreglass construction. And because of its great purity, softness, and low internal humidity, it should be made of fibreglass reinforced plastic. Less

transported items have soiled the wall's surface the most cost-effective and efficient Certain automobile types with adequate technological and economic features are needed for transportation. Depending on the specifications and automobile design for a very long period, modern freight car design was created. Currently, goods carriages are in use on all major railway systems. On various fronts, goods vehicles were upgraded. Transporting various sorts of goods, as well as improving circumstances for handling and equipping automobiles, were all taken into consideration while designing cars with high carrying capacities and fitted designs automation and mechanisation mechanisms [10]. In South Korea, interest in using structural composites in railway wagons has increased. In this area, the Railway Department was a pioneer. Manufacturing, design, structural strength, ageing and material deformation, deformation behaviour, and numerical modelling have all have been the subject of several thorough and successful investigations [11]. Major applications for fibre are-Glass fibre-reinforced plastic (GFRP) is often used for interior and exterior components in the rail vehicle industry because to their complicated geometries and low mechanical demands. Reinforced plastics have thus far mostly been used in these applications. It is not currently common practise to manufacture substantial structural elements of rail vehicles out of CFRP. The first comprehensive baseline studies of the CFRP lightweight design methodologies for rail cars have shown that they are technically feasible and economically advantageous over the course of their service lives [12]. The recommended light structural design must be precisely specified in order to be used in optimisation process lightweight answers. Initial answers found using the suggested optimisation the technique is further examined and improved while taking productivity and economics into account. Features choosing materials based on the primary loading scenarios anticipated for use. the main parts of a vehicle Bending loads are applied to the structure. Therefore, better material possibilities must exist. It is believed that the particular kind of light is a rigid beam [13]. High-speed trains are now being created in order to regulate power in a more efficient and compact manner. On the roof, communications cables, passenger power supplies, and PIS (Passenger Information System) wiring are more complicated electrical cabling and wiring for both low and high voltage purposes. They traverse the roof, such as the vehicle's electrical cabinet, side compartments, and low- and high-voltage junction boxes. A source of electromagnetic radiation is any kind of cable. Such sources' electromagnetic radiation might harm passengers' health or interfere with sensitive railway equipment has implantable medical equipment. Additionally, they could significantly affect how safely high-speed trains operate [14]. In the past, a design's weight was typically used to determine its commercial worth. Experience suggests that smart weight is less, leading to increased design process efficiency. To be respected It's crucial to comprehend the fundamentals of lightweight design Based on and proven by statics and historical factors the demands of contemporary design are not met by the idea of power. Based on a dynamic idea, these viewpoints need to be modified their work to do [15].

2. METHODOLOGY

WASPAS Method: This study proposed a mixed-methods approach. The approach is referred to as Weighted Aggregate Product Assessment (WASPAS). It uses two models: WSM (Weighted Sum Model) and WPM (Weighted Product Model).utilised to evaluate the negative impacts of project risks. When compared to independent approaches used for alternative ranking, this method has a larger capacity and more accuracy. WASPAS approach is a novel multi-index decision-making approach was adopted and used in many different contexts [16]. The WASPAS approach is quite effective. Accuracy plays a significant role in both practicality and ranking. The WSM and WPM advantages are used in the WASPAS approach. The ranking precision of WASPAS Alternatives is improved by combining WSM and WPM [17]. The WASPAS technique provides very reliable assistance in evaluating and ranking options. Numerous choice issues have been addressed using this strategy many fuzzy theories [18]. The alternatives are given in value order integrated optimality standards. However, by running a sensitivity analysis within its own function, the approach can regulate consistency in alternate ranks [19]. The WASPAS technique is typically the most well-liked solution to different MCDM issues. In numerous research works, a review of the application of WASPAS methodologies was offered. The simplicity and stability of WASPAS can be used to explain its popularity. The criteria weights were established using the direct subjective criterion weight estimate approach [20]. WASPAS was chosen to look into the issue. Loss of aerial images is related to how well compression is done. Previous studies described the WASPAS method's applications. Many MCDM problems are solved using the WASPAS technique. Because it is stable and straightforward, this approach is well-liked [21]. WASPAS or Weighted Aggregate Product Assessment has three optimisation criteria form the basis of the approach. The Weighted Sum Model (WSM), a widely used measure of optimality, is used to determine the first criteria: In order to normalize the initial decision matrix,[22]

$$\overline{x_{ij}} = \frac{x_{ij}}{max_i x_{ij}} \quad , \quad \overline{x_{ij}} = \frac{min_i x_{ij}}{x_{ij}}$$

In order to guarantee equitable growth in European Union countries, the WASPAS approach is applied [24].Qi represents the total optimality value determined by below equation .The combined optimality coefficient is ([0,1]). L is equal to 0.5 if the Weighted Sum Model and Weighted Product Model methods have an equal impact on the combined optimality criterion [19].

$$Q_i = \lambda Q_i^{(1)} + (1 - \lambda) Q_i^{(2)}$$

The main criteria for optimality in the WASPAS approach are related to the WSM scheme. It has widespread acceptance and popularity. MCDM method for numerical option estimation varied criteria for decision-making [24]. The Fuzzy WASPAS technique prioritises options based on the WPS and WSM results for the combined optimality criterion. Consistency of the ranking of alternatives is verified using fuzzy WASPAS compared to other MCDM approaches, it takes less time to do a sensitivity analysis [25].

Alternate Parameters

1. A form of advanced high-strength steel (AHSS) known as DualPhase (DP) steel has a distinct microstructure that combines the properties of both the ferrite and martensite phases. DP steel is extremely ideal for automotive and other structural applications because of its great mix of strength, ductility, and formability. The DualPhase steel grade known as DP600 has a minimum tensile strength of 600 megapascals (MPa). The minimum yield strength of DP600, which is normally exceeds 600 MPa, is indicated by the "600" in the acronym. DP600 steel is excellent in applications that need outstanding structural integrity and crashworthiness because of its high strength level.
2. Transformation Induced Plasticity (TRIP) is a phenomenon that occurs in some high-tech, advanced steels, where the austenite-to-marten site transition is induced by deformation, improving the material's ductility, strength, work-hardening, and fatigue resistance. TRIP steels are very sought-after for vehicles where better crash-worthiness and absorption of energy are crucial aspects because to their special characteristic.
3. In high-manganese steels, a deformation process known as twinning induced plasticity (TWIP) occurs when twin boundaries develop and migrate, improving the material's rigidity, strength, work-hardening ability, and formability. TWIP steels are used in a variety of sectors, with the automobile industry being one of the more significant ones because of its resilience to impact and crashworthiness.
4. Due to its high tensile strength, superior formability, and resistance to air corrosion, Al6005 T6 is frequently used in structural applications such as building, transportation, and renewable energy. Due to its qualities, it may be used for parts that need to be strong yet lightweight, which aids in the creation of effective and environmentally friendly designs.
5. A particular type of aluminium alloy called Al6082 T6 has undergone heat treatment to produce improved mechanical characteristics. It has undergone solution heat treatment, followed by artificial ageing, which has increased its strength, hardness, and toughness, as indicated by the "T6" classification.Al6082 T6 is frequently employed in applications that call for strength, including building materials, aircraft components, and automobile frames. It is appropriate for challenging locations and industries thanks to its lightweight and high strength combination.
6. A substance or item with interconnected spaces or pores is referred to as having a porous structure. Al—Closed Cell designates a particular class of porous structure composed of aluminium with closed-cell geometry, in which the pores are not linked to one another. This kind of porous structure has advantages including lightweight construction, a high strength-to-weight ratio, thermal insulation, and it may find use in filtration systems, aerospace, and the automotive industries.

Evaluation Parameters

1. A material's yield strength is defined as the highest stress or load it can withstand before starting to irreversibly deform or experience plastic deformation. It is a characteristic of materials, especially metals and alloys, and it denotes the point at which the material changes from elastic to plastic deformation, where it retains a permanent deformation even after the load is removed. Elastic deformation allows the material to return to its original shape after the load is removed.
2. The amount of stress that a material can endure before breaking or failing under strain is known as its tensile strength. It evaluates the material's capacity to withstand dragging forces and is a crucial

characteristic in figuring out how durable and structurally sound it will be. Standardized testing procedures, such as the tensile test, when a specimen is put through increasing axial loads until it fractures, are commonly used to assess tensile strength.

3. The elastic modulus, commonly referred to as Young's modulus, is a measurement of a material's stiffness or rigidity. It calculates the stress to strain ratio within the material's elastic range, indicating how resistant the material is to deforming under a given load. Young's modulus is frequently used in engineering and material choice processes to compare the physical characteristics of various materials.
4. A substance's density is a physical characteristic that indicates how much mass there is per unit volume. It measures how closely the molecules or particles are packed together within a substance. Density is frequently used to describe and contrast the weight or lightness of distinct substances and is essential for many every day, scientific, and technical applications.
5. In a market-based economy, price is the monetary value given to a good, a service, or a resource. It displays the exchange rate at which a buyer is prepared to pay and a seller is ready to accept payment for the requested good.

3. RESULT & DISCUSSION

TABLE 1. Selection of Light Weight Materials for Railway Vehicles

MATERIALS	YieldStrength (Y.S.),MPa	TensileStrength (T.S.),MPa	YoungsModulus (GPa)	Density (kg/m3)	Price US$/kg
DualPhase, DP600	410	700	200	8050	0.55
Transformation Induced Plasticity, TRIP700	520	800	200	8050	0.55
Twinning Induced Plasticity, TWIP	750	1000	200	8050	1.5
Aluminium, Al6005-T6	240	260	69	2700	1.9
Aluminium, Al6082-T6	250	310	70	2700	1.9
Porous Structure (Al—Closed cell)	20	30	12	1000	46

Show the Table 1Selection of Light Weight Materials for Railway Vehicles using WASPAS method. The alternatives are DP600, TRIP700, TWIP, Al6005-T6, Al6082-T6, Porous Structure (Al—Closed cell). The evaluation parameters are Yield Strength, TensileStrength, YoungsModulus, Density and Price.

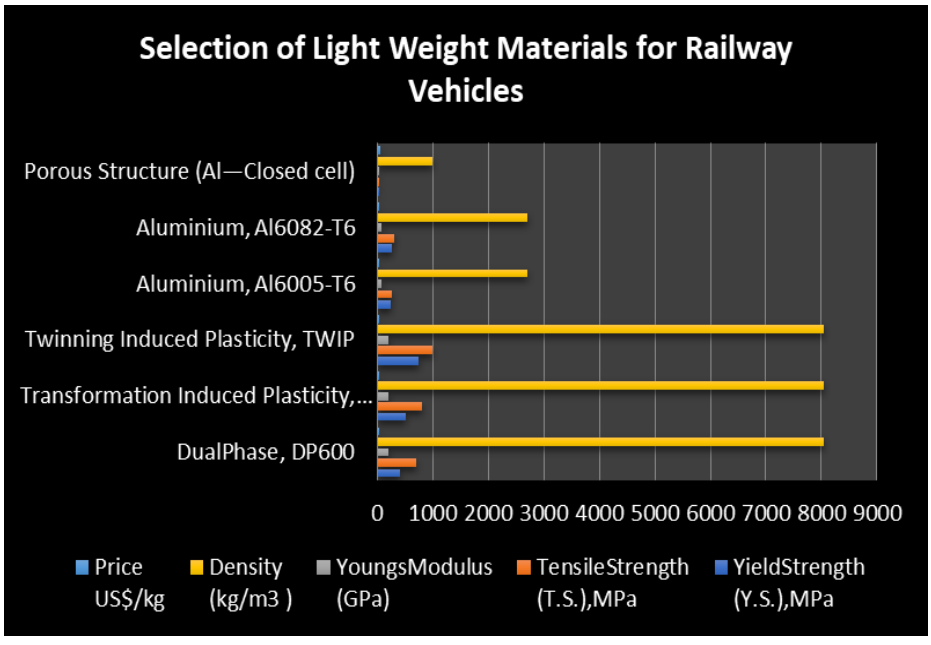

FIGURE 2. Selection of Light Weight Materials for Railway Vehicles

TABLE 2. Normalized Data

	YieldStrength (Y.S.),MPa	TensileStrength (T.S.),MPa	YoungsModulus (GPa)	Density (kg/m3)	Price US$/kg
DualPhase, DP600	0.5467	0.7000	1.0000	0.1242	1.0000
Transformation Induced Plasticity, TRIP700	0.6933	0.8000	1.0000	0.1242	1.0000
Twinning Induced Plasticity, TWIP	1.0000	1.0000	1.0000	0.1242	0.3667
Aluminium, Al6005-T6	0.3200	0.2600	0.3450	0.3704	0.2895
Aluminium, Al6082-T6	0.3333	0.3100	0.3500	0.3704	0.2895
Porous Structure (Al—Closed cell)	0.0267	0.0300	0.0600	1.0000	0.0120

Table 2 shows the Normalized Data of Selection of Light Weight Materials for Railway Vehicles using ASPAS method. All the Alternate Parameters and Evaluation parameters are mentioned above.

TABLE 3. Weights

Weightages				
0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2

Table 3 shows that all the evaluation parameters has same weight.

TABLE 4. Weighted normalized decision matrix (WSM)

Materials	weighted normalized decision (WSM)				
DualPhase, DP600	0.1093	0.1400	0.2000	0.0248	0.2000
Transformation Induced Plasticity, TRIP700	0.1387	0.1600	0.2000	0.0248	0.2000
Twinning Induced Plasticity, TWIP	0.2000	0.2000	0.2000	0.0248	0.0733
Aluminium, Al6005-T6	0.0640	0.0520	0.0690	0.0741	0.0579
Aluminium, Al6082-T6	0.0667	0.0620	0.0700	0.0741	0.0579
Porous Structure (Al—Closed cell)	0.0053	0.0060	0.0120	0.2000	0.0024

Table 4 shows that weighted normalized decision matrix (WSM) for all the Alternate parameters.

TABLE 5. Weighted normalized decision matrix (WPM)

Materials	weighted normalized decision (WPM)				
DualPhase, DP600	0.88623	0.93115	1	0.6589	1
Transformation Induced Plasticity, TRIP700	0.92937	0.95635	1	0.6589	1
Twinning Induced Plasticity, TWIP	1	1	1	0.6589	0.8182
Aluminium, Al6005-T6	0.79621	0.76383	0.8083	0.8198	0.7804
Aluminium, Al6082-T6	0.80274	0.79117	0.8106	0.8198	0.7804
Porous Structure (Al—Closed cell)	0.48439	0.49593	0.5697	1	0.4126

Table 5 shows that weighted normalized decision matrix (WPM) for all the Alternate parameters.

TABLE 6. Preference Score (WSM&WPM)

Materials	Preference Score(WSM)	Preference Score(WPM)
DualPhase, DP600	0.6742	0.543757
Transformation Induced Plasticity, TRIP700	0.7235	0.585662
Twinning Induced Plasticity, TWIP	0.6982	0.539132
Aluminium, Al6005-T6	0.3170	0.314512
Aluminium, Al6082-T6	0.3306	0.32939
Porous Structure (Al—Closed cell)	0.2257	0.056464

Table 6 shows that Preference scores for all the Alternate parameters by using WSM and WPM.

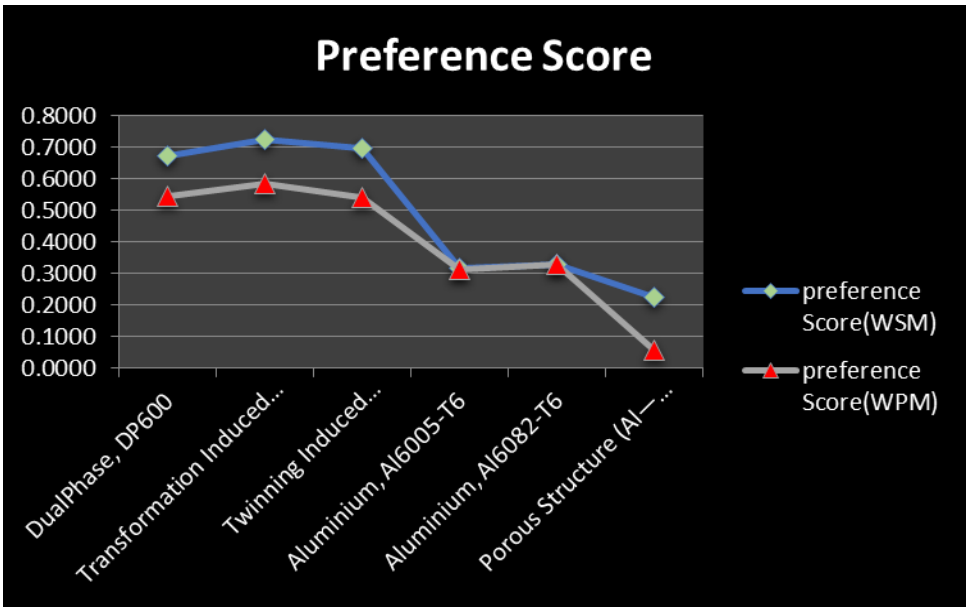

FIGURE 3. Preference Score by WSM and WPM

TABLE 7. WASPAS Coefficient & Rank

Materials	WASPAS Coefficient	Rank
DualPhase, DP600	0.60897	3
Transformation Induced Plasticity, TRIP700	0.65459	1
Twinning Induced Plasticity, TWIP	0.61866	2
Aluminium, Al6005-T6	0.31574	5
Aluminium, Al6082-T6	0.33001	4
Porous Structure (Al—Closed cell)	0.14109	6

Table 7 shows that WASPAS Coefficient for all the Alternate parameters and TRIP700 is got the first rank.

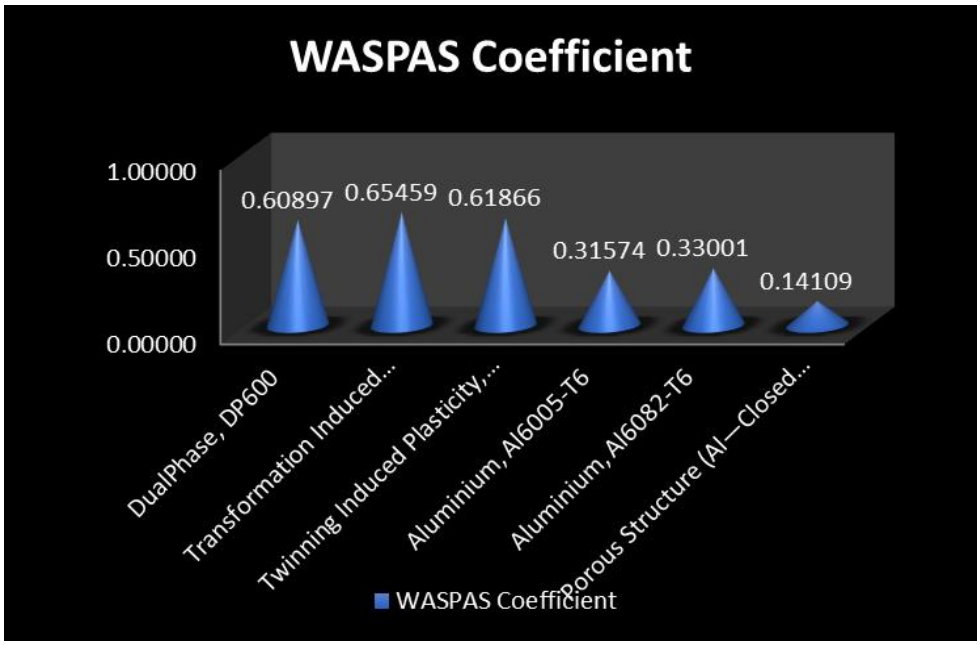

FIGURE 4. WASPAS Coefficient.

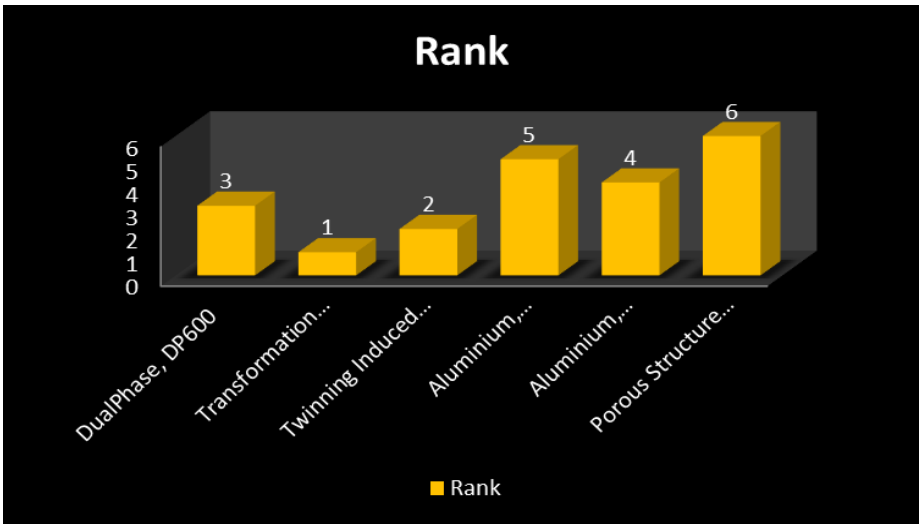

FIGURE 5. Rank for 1Selection of Light Weight Materials for Railway Vehicles using WASPAS method

Figure 5 shows that the TRIP700 got 1st rank, TWIP got 2nd rank, DP600 got 3rd rank, Al6082-T6 got 4th rank, Al6005-T6 got 5th rank and Porous Structure (Al—Closed cell) got 6th rank.

4. CONCLUSION

A major problem in the railway industry is lowering the weight of railway equipment. A small automobile reduces the amount of mould, which has a positive financial impact. Drive vehicles and the expense of railway maintenance. A weight loss effort is also made when using high-speed trains. You may access a number of light rail vehicles. There are three ways to reduce the number of components: choosing lightweight materials, making design changes utilising optimisation techniques, and taking use of their various roles. In order to provide weight reduction in transport equipment train bodies, several design techniques (i.e., applications of light-weight components or design modifications) are required. The Rail body's weight is crucial to weight loss Rolling stock, as the rail system has a significant impact. Rolling stock structures are at the higher position and contribute to the vehicle weight. Other train-related structures, such the bogie, suspension, etc., as well as the traction systems, become lighter if the train's overall weight is decreased. WASPAS was chosen to look into the issue. Loss of aerial images is related to how well compression is done. Previous studies described the WASPAS method's applications. Many MCDM problems are solved using the WASPAS technique. Because it is stable and straightforward, this approach is well-liked. TRIP700 is got the first rank with less compensation.

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