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Human Factors Analysis for Railway Coach and Bogie Maintenance Using AHP

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Abstract

There are innumerable reasons behind train accidents or postponement. Proper functioning and maintenance in the coach and bogie section of a train for railways, in general, and Indian Railways, in particular, which faces maximum public interaction, is an important factor for attaining safety and punctuality. Out of many factors, analysis of human factors affecting the performance of the staff responsible for coach and bogie maintenance is one of the most important research issues, which needs an in depth investigation and study. In this research work, AHP has been applied to study performance of personnel working on coach and bogie maintenance hence, to identify the most important criterion or factor to improve their efficiency . It is found that out of seven very important factors, working environment in the coach and bogie maintenance shed is the most important factor affecting the performance of employees.

Keywords

Coach and bogie, Human factors, Analytical Hierarchy Process (AHP), Judgment matrix.

1. Introduction

Catering to a vast population of about 125crore, the Indian Railways (IR) has become the lifeline of Indian traffic in terms of economic growth and sustenance of social and cultural integration. Apart from different components of the rolling stock of railways, coach and bogie is treated as the main section, as it is designed to carry passengers as well as goods with prerequisite safety and comfort. Depending on the different types of trains, such as superfast, express, mail, passenger, and freight, goods carried, and the purpose of transit, there are various kinds of coach and bogie systems used varying hugely in their design, make, operations, and maintenance factors. Thus, each of these systems is gigantic and complex as far as operational and functional activities are concerned.

Maintenance of coach and bogie system is very important and crucial as it is directly linked to safety and security of the passengers [Baek et al., 2010; Kim and Yoon , 2013]. After closely studying the maintenance activities, both preventive and corrective, for a significant period of time, it is observed that human factors, having many attributes, are integrally related to safety and punctuality of the railway system [Thorsten and Bernhard, 2012; Baysari et al., 2008; Belmonte et al., 2011]. Factors affecting human performance are multi-criteria-based and multi-faceted, also varying immensely among people, working environment, culture, system of working, and many more.

Safety and satisfaction of the customers being the main objective of the service, the various factors to increase the efficiency of the workers become one of the most important parameters to improve the system [Belmonte et al., 2011]. In this context, it is worth mentioning that even though the number of passengers using the system daily keeps on increasing, the number and the quality of employees recruited, have not been improved as per the requirement of IR. It may also be stated that due to the real-life critical situation, work life balance of maintenance personnel in many cases is hampered. As the safety and efficiency of such kind of a vast government sector, serving people is directly dependent on the efficiency and the work quality of the workers. Hence, studying the various human factors becomes an essentiality.

In this regard, several attributes may be taken into account while studying human factors, selection of which is taken as the first step of such an analysis. In order to improve the service of the employees, the parameters affecting their performance needs to be identified and studied. [Ivan et al., 2014]After extensive research and analysis two levels emerged having seven key human factors like working environment, socio economic factors, work zone safety, work load schedule, working skill, job satisfaction , roll of information technology and subsequent nineteen sub factors like interpersonal relation, basic amenities, family background, present financial condition, peer culture etc. Several of these factors are not easy to evaluate because of their intangible, overlapping and complex nature.

In this context, decision making methods are an important tool to identify the most important factor affecting human performance by weight analysis of each of them. The prime necessity, in this process, is to reduce inconsistencies while comparing the various sub-factors which are not always compatible in nature. Since this study involves numerous parameters as well as options varying widely as weights are attributed to the factors, identifying the most important factor hence becomes a complex and tedious job. Such kind of a problem requires multi-criteria evaluation models based on either quantitative data collection method or qualitative judgment matrix. Multiple criteria decision making (MCDM) is a process that helps to identify the preferred option for prioritizing the given alternatives, generally conflicting in nature [Hwang and Yoon, 1995].

It is already stated that human performance and the chances of making errors is uncertain in nature and hence, sometimes quantization of the factors is difficult. Keeping the complex nature of the problem in mind and its multiple attributes, Analytical Hierarchy Process [Lee and Park, 2008; Lee and Tseng, 2009] a popular MCDM technique, is recommended so that the qualitative and quantitative aspects are combined and analyzed by converting them into a series of simple problems by downward depth profile analysis. This is a common method applied for evaluation and analysis of complex systems, where the parameters are mostly intangible in nature. The basic logic behind AHP, developed by Saaty [Saaty, 1980] is to break down a very complex problem into various factors and sub factors which are then hierarchically grouped.

Formulation of a judgment matrix to quantify qualitative parameters by keeping in mind all related and interrelated factors is the key application of AHP. Indian Railways, because of its vastness and variety is not only a very critical and complex system for analysis the performance of the system is completely dependent intricately on human performance. Study of human performance and the factors on which they are dependent are mostly intangible and qualitative in nature, analysis of which is of utmost importance to increase the efficiency of the workers, thereby improving the service of the sector.

The paper is organized in the following sections- Section 2 deals with maintenance of coach and bogie. Section 3 briefly discusses AHP method, in section 4 the problem is solved using AHP and in section 5 result and discussion is given followed by section 6 where the conclusion is stated.

2. Maintenance of Coach and Bogie System

In this section the first part deals with the basic structure of coach and bogie system, while the second part describes the maintenance practices in brief.

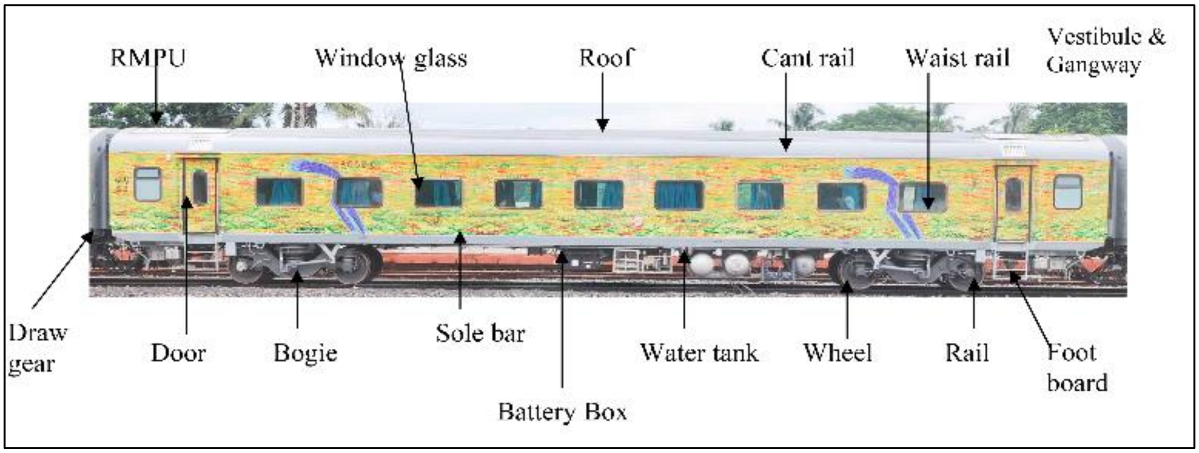

Figure 1. Structural Details of Coach

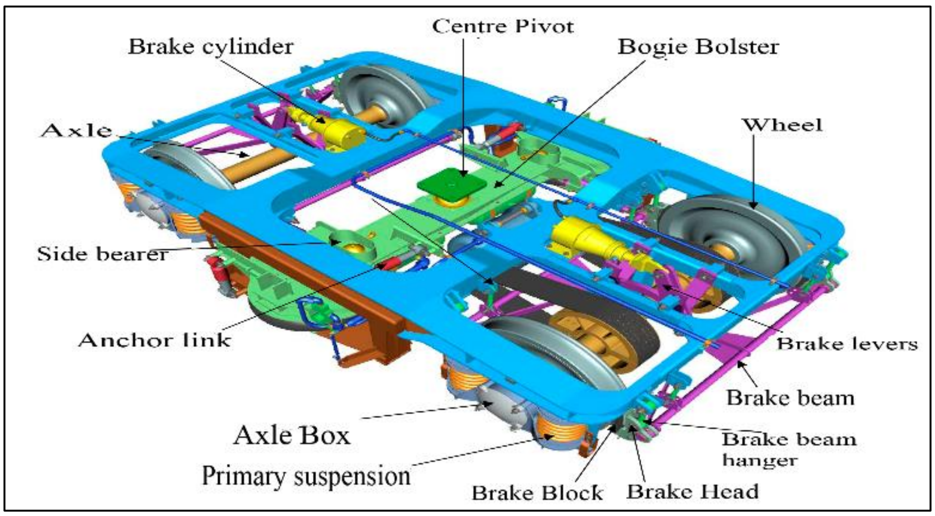

Figure 2. ICF Bogie Layout

The rolling stock of IR mainly consists of the coach and bogie section of the trains. The coach is a piece of railway rolling stock that is designed to carry passengers and goods. The coach stock, in general, divided into 2 categories, Passenger Coaching Vehicles (PCV) and Other Coaching Vehicles (OCV) i.e. service vehicles like pantry cars, parcel vans, mail vans etc. The coaching stock is assembled on a chassis or framework or modular subassembly of wheels and axles known as bogie. Based on load carrying capacity of an axle, the conventional bogie frames are grouped into two types- 13ton bogie frame used in non-AC main line coaches, and 16ton bogie frames for all AC coaches, power cars and diesel multiple unit train coaches.

The bogie serves a number of purposes
1. Support of the rail vehicle body,
2. Stability on both straight and curved track,
3. Ensuring comfortable ride by absorbing vibrations and minimizing impact of centrifugal forces when train runs on curves at high speed.

The bogie can be divided into the various subsections-
bogie frame, bogie bolster, center pivot pin, wheel set assembly, roller bearing assembly, brake beam assembly, brake head, brake blocks, brake levers, brake cylinder, primary suspension which include: dashport arrangement, spring seating, problem of oil spillage, buffer height adjustment, and secondary suspension which include: lower spring beam, equalizing stay rod.

As vital parts of a train like wheel set assembly, brake set, axle set, lodging and accommodation of passengers and crew is catered by the coach and bogie section, proper functioning and maintenance is of primary importance.

After studying the standard railway maintenance manual as followed by South Eastern Railways (SER) of IR for their coach and bogie section, it is observed that the maintenance personnel at different levels follow to address 25 types of failures during the preventive maintenance activities. These practices are achieved by manual settings and different test rig. Moreover, at the time of breakdown along with preventive maintenance practices various corrective maintenance policies are followed as per the need of the situation.

3. AHP Method

Analytical Hierarchy Process (AHP) is a multi-objective decision making technique which takes care of both qualitative and quantitative analysis. It was developed by an American scientist Saaty [Saaty, 1980].Formation of the judgment matrix is the most important factor in AHP. Basic feature of human reliability analysis is the quantitative analysis of the qualitative problem [Büyüközkan and Çifçi, 2012; Hadad and Mehrez, 2000; Lee and Park, 2008; Lee and Tseng, 2009; Lijuan and Shinan, 2011; Dragomir et al, 2014].

Basic Steps of AHP

Application of AHP is based on following steps:

Step1: The problem and its scope are identified before analyzing relations between the factors. This step signifies the key aspect of the entire process because the reliability of final result is directly related to the correctness of the logical relations as mentioned.

Step2: The layer structure and a matrix, say A, are established. The factors involved in each layer are made definite because matrix A will be the sticking point of this step. The difference between the factors is compared based on the criterion mentioned in the Table given below:

Table 1. The significance of 1-9 scales

Scale	Meanings
1	Comparing the two factors which are of same importance
3	The later is more important than the former
5	The later is important than the former
7	The later is less important than the former
9	The later is extremely less important than the former
2,4,6,8	The middle value between the above results
Reciprocal	If the degree of importance between the factors “i” and “j” is “bij”, then comparing “j” and “i” is “bji”- which is equal to 1/bij.

The Eigen Vector or the Weight Vector is computed. The weight of each factor based on the matrix A and the vector sum of each column are computed. A new weight matrix, matrix B, is then constructed in the following manner:

$$Hj = \sum_{i=1}^{n} a_{ij},\ j=1, 2, 3\ldots m; \tag{1}$$

$$bij = \frac{a_{ij}}{H_j},\ i=1, 2,\ldots,m,\ j=1,2,\ldots,m \tag{2}$$

where, a_{ij} is the evaluate factor of matrix A based on the Table1.

H is the sum of each column of A, W_k is the weight vector of each judgment matrix, k is the correlate number of each judgment matrix.

$$W_i = \sum_{j=1}^{m} b_{ij},\ i=1, 2\ldots n; \tag{3}$$

$$W_k = \frac{W_i}{\sum_{i=1}^{n} W_i} \tag{4}$$

$$\lambda max = \sum_{i=1}^{n} \frac{(Aw)_i}{nw_i} \tag{5}$$

$$CI=\frac{\lambda max-n}{n-1},\ CR=\frac{CI}{RI}, \quad (6)$$

where, CI is the deviation degree in matrix A, which is called the consistency index of matrix A,CR is the consistency ratio, RI is the random ratio of consistency that is changeable with the number of factors (see Table 2). λmax is the consistency index after being normalized. When the CR<0.1, the result is considered to be reasonably good.

Table 2. The RI changeable with the number of factors

N	1	2	3	4	5
RI	0	0	0.58	0.89	1.12
N	6	7	8	9	10
RI	1.26	1.36	0.58	1.41	1.46

Computation of the combined weights based on the Table3.

Table 3.The calculation of combined weight

Layer R / Layer C	R1 R2 … Rm r1 r2 … rm	Order of Layer C
C1	C11 C12… C1m	∑rjc1j
C2	C21 C22… C2m	∑rjc2j
…		
Cn	Cn1 Cn2… Cnm	∑rjcnj

Table 4. The hierarchy module

First Level	Second Level	Third Level
Human Factors	Working environment or ambience(R1)	Inter-personal relation(C1)
		Basic amenities (C2)
		Outsourcing activities (C3)
	Socio-economic factor (R2)	Family background (C4)
		Present financial condition (C5)
	Work zone safety (R3)	Preventive & corrective maintenance (C6)
		Up gradation of existing machines (C7)
		Vigilance (C8)
	Work load Schedule (R4)	Time(C9)
		Manpower (C10)
	Working skill (R5)	Education (C11)
		Training (C12)
		Experience (C13)
	Job satisfaction (R6)	Peer-culture (C14)
		Performance analysis (C15)
		Salary and Bonus (C16)
		Appreciation and awards (C17)
	Role of Information Technology (R7)	Documentation and Manuals (C18)
		Communication (C19)

4. Solving the problem using AHP

Various circumstances are responsible to impact the safety and security of the railway coach and bogie system. One of the major factors that affects the safety of the railway system is the performance of the employees i.e. human factors working in the concerned workplace [Vanderhaegen, 2001; Anjum 2013]. Due to the vastness in every aspect of the railway system, catering the basic needs of the employees of the railways, is of utmost importance. Factors like political influence, recruitment policies, union policies and government policies are excluded from the domain of present analysis, but other essential factors are analyzed. Employees from all the strata were divided into groups and interviewed for the collection of primary data and analysis. Table 4 shows various important human factors (R1-R7) and their sub factors (C1-C19) based on which the judgment matrices are made and final conclusion is obtained.

5. Result and Discussion

After several visits to the railway workshops and continuous interaction with the employees starting from the ground level maintenance workers to the top notch higher officials, the essentiality of the work regarding human factor analysis was felt by the research group. To make the research extensive and exhaustive, method of detailed primary data collection was identified.

In this context, an expert panel comprised of six members viz. one senior level railway executive with post-graduate qualification and twenty years of experience, one mid-level railway executive with graduate qualification and ten years of experience, one junior-level executive with diploma and ten years of experience, and three academic persons, two with Ph.D degree and one with post graduate degree was formed. The research team has explained in detail the objective of the present work and methodology used.

Based on the structured and semi-structured interviews, views of these experts and their opinion in terms of guidelines provided in Table1, the judgment matrix is formed and presented on the basis of the methodology, as described in Section 3, the calculations are made and also presented in Tables 5 to 12.

Table 5. Weight analysis R-E judgment matrix

E	R1	R2	R3	R4	R5	R6	R7	W	NW
R1	1	2	4	4	3	6	5	3.120	0.352
R2	1/2	1	3	3	3	4	3	2.068	0.233
R3	1/4	1/3	1	1	1/2	3	1	0.742	0.084
R4	1/4	1/3	1	1	3	3	3	1.121	0.126
R5	1/3	1/3	2	1/3	1	5	1	0.864	0.097
R6	1/6	1/4	1/3	1/3	1/5	1	1	0.368	0.041
R7	1/5	1/3	1	1/3	1	1	1	0.579	0.065
∑	2.697	4.57	12.33	9.99	11.7	23	15	8.862	

λmax = (2.697*0.352) + (4.57*0.2333) + (12.33*0.084) + (9.99*0.126) + (11.7*0.097) + (23*0.041) + (15*0.065) = 7.363

CI = $\frac{7.363-7}{6}$ = 0.0605

CR = $\frac{0.0605}{1.35}$ * 100 = 4.48%

Since the value of CR is less than 10%, the data collected is reasonably consistent.[Saaty TL 1980]

Table 6. Weight analysis R1-C judgment matrix

R1	C1	C2	C3	W	NW	λmax	CI	CR
C1	1	1/5	1	0.585	0.144	3.0128	0.0064	1.2%
C2	5	1	5	2.893	0.712			
C3	1	1/5	1	0.585	0.144			

Table 7. Weight analysis R2-C judgment matrix

R2	C4	C5	W	NW	λmax	CI	CR
C4	1	1/5	0.447	0.166	1.9956	negative	Undefined
C5	5	1	2.236	0.833			

Table 8. Weight analysis R3-C judgment matrix

R3	C6	C7	C8	W	NW	λmax	CI	CR
C6	1	1	1/3	0.694	0.201	3.003	0.0015	0.288%
C7	1	1	1/3	0.694	0.201			
C8	3	3	1	2.065	0.598			

Table 9. Weight analysis R4-C judgment matrix

R4	C9	C10	W	NW	λmax	CI	CR
C9	1	5	2.236	0.833	2.0016	0.0016	Undefined
C10	1/5	1	0.447	0.167			

Table 10. Weight analysis R5-C judgment matrix

R5	C11	C12	C13	W	NW	λmax	CI	CR
C11	1	1	5	1.701	0.496	3.104	0.052	9.9%
C12	1	1	2	1.257	0.367			
C13	1/5	1/2	1	0.468	0.137			

Table 11. Weight analysis R6-C judgment matrix

R6	C14	C15	C16	C17	W	NW	λmax	CI	CR
C14	1	2	1	5	1.778	0.368	4.0656	0.021	4.1%
C15	1/2	1	1	5	1.257	0.260			
C16	1	1	1	5	1.495	0.309			
C17	1/5	1/5	1/5	1	0.299	0.062			

Table 12.Weight analysis R7-C Judgment Matrix

R7	C18	C19	W	NW	λmax	CI	CR
C18	1	9	3	0.901	1.991	negative	Undefined
C19	1/9	1	1/3	0.099			

CI and CR are consistency index and consistency ratio respectively which are parameters to judge consistency of the results. If the consistency ratio is less than 10% the result is supposed to be consistent and acceptable. Lesser CI better is the chance of CR to be less than 10% as value of RI is within the range of (0.52 to 1.49) for no. of parameters (3 to 10) respectively. [Saaty TL, 1980] As for less than 2 parameters RI value is considered to be zero, hence in tables 7, 9 and 12 CR values are undefined. Here we have got all the results with consistency ratio less than 10%, which validates the effectiveness of the results.

The results show that working environment, socio-economic factor and work load schedule are three vital human factors for proper maintenance of railway coach and bogie system. The weight matrix clearly shows that working environment is the most important factor whose relative weight is almost double than socio-economic factor and three times the work load schedule. From experts point of view it reflects that working environment which involves basic amenities like canteen, rest rooms (both for men and women), proper sitting area etc. has got maximum contribution behind the motivation and dedication of human beings working in the coach and bogie maintenance shed which directly affects the safety and punctuality of the Railway system. It is also found that out of all factors job satisfaction and role of information technology are the least important factors contributing to the safety of coach and bogie system, out of which job satisfaction is least, which involves peer culture, performance analysis, salary, bonus and appreciation. After analyzing the results it can be concluded that being a government sector service provider railway employees are reasonably happy with their pay packages, they are not very keen to use information technology to maintain the safety of railways whereas working environment, which includes inter personal relation amongst employees, basic amenities, socio-economic factors are more important factors as far as safety measures of railway coach and bogie system is concerned.

6. Conclusion

This paper has presented a generic methodology to identify critical human factors, working in industrial area, in general and railway system, in particular. One of the important MCDMs i.e. AHP has been applied on the personnel of coach and bogie maintenance depot of SER in IR. Six persons have participated to collect the primary data. It is observed that working environment and ambience is the most important factor out of seven factors which are , socio-economic factor , work zone safety , work load Schedule , working skill , job satisfaction and role of information technology.

AHP being a multi criterion decision making tool has been effectively applied and judiciously used to solve the complex intangible problem dealing with human factors and efficiency. The most important factor affecting human performance has been identified using the tool keeping in mind the overall safety and performance of IR which is the main objective of this research work.

However it is felt that apart from these seven factors, as mentioned, some other factors may also be included, such as political issues, other stakeholders interest and government policies. The same procedure may also be applied to other zones and sections of IR to justify and standardize the results and outcomes of the present study. It may be recommended that other MCDMs and modeling techniques can also be applied to get better results.

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