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ORIGINAL ARTICLE

Assessing Passenger Comfort in Compartments of Long Distance Conventional Trains: A Case Study

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ABSTRACT

In developing countries where conventional trains are still in use, passengers endure lengthy hours on board. These passengers could opt for air travel, which offers a much shorter duration. Therefore, environmental factors significantly contribute to the overall comfort of passengers and the modal share of railways. In this cross-sectional research, a questionnaire has been developed to quantify passenger evaluations of factors such as light, temperature, noise, and vibrations. An 11-hour journey between Tehran, the capital of Iran, and the second major city is selected, along with two trains (five-star and four-star). Passengers responded to paper questionnaires, and 382 fully completed ones were collected and analyzed. Satisfaction from light was highest while thermal comfort was lowest. A statistically significant difference was observed between the comfort levels of passengers on the two trains. The results also indicated that certain personal or health conditions affect passenger feelings. For example, individuals suffering from low blood pressure tend to feel cold, or those who wear reading glasses are not satisfied with the illumination. Furthermore, older individuals are more sensitive to vibrations, but those traveling with their families are less sensitive to it. The findings of this research can assist in better compartment allocation for passengers and enhance overall passenger satisfaction.

KEYWORDS: *passenger comfort, environmental factors, railway, quality of traveling*

INTRODUCTION

Passengers, as the primary customers of the railway industry, play a crucial role in mode choice. (Dis) comfort during travel is a significant barrier to choosing railways (Blainey et al., 2012). In long-distance travel, passengers spend extended hours on trains, making environmental factors such as noise, vibration, light, and temperature extremely important. Conventional trains with lower speeds (below 200 km/h), which primarily operate in developing countries, usually have lower standards in this regard compared to modern high-speed trains. This topic appears to be understudied in the literature and requires more attention to prevent a modal shift toward cars and airplanes for sustainable transport. This is particularly important for developing countries that often face challenges in improving the quality of their transportation networks, and investment might not be easily available or feasible.

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Literature Review

Passenger satisfaction directly influences the financial sustainability of transportation companies and mode choice (Lai and Chen, 2011). Several review papers have been published on related topics, including human factors in railways (Wilson and Norris, 2005, Wilson and Norris, 2006), (Wilson, 2007), thermal comfort for car passengers (Walgama et al., 2006), and air passenger comfort (Hiemstra-van Mastrigt et al., 2017, Ahmadpour et al., 2016). However, the literature lacks a recent comprehensive paper regarding railway passengers.

One of the early works on passenger comfort was conducted by Richards et al. (1978a), who categorized contributing factors into "motion, sensory, and seat," while Kogi (1979) used "physical, mental, and environmental" categories. It's not just the absolute levels of environmental factors that affect perceptions of comfort, but also the personal characteristics of passengers are determining factors (Richards et al., 1978b).

Research on passenger ride comfort in railways can be categorized into two major groups:

1. Mechanical aspects such as noise and vibration, acceleration, and suspension, which are well-studied in the literature (Powell and Palacín, 2015, Xu et al., 2018, Gerlici et al., 2007, Kumar et al., 2017, Ripamonti and Chiarabaglio, 2019, Hardy and vibration, 2000). There are also standards such as ISO 2631-1 to specify various aspects of it.
2. Thermal comfort (Ampofo et al., 2004, Konstantinov and Wagner, 2016, Ivanescu et al., 2010, Ye et al., 2004, Katavoutas et al., 2016, Deb et al., 2010).

As summarized above, researchers have mainly focused on a single aspect of passenger comfort. Few studies have taken a comprehensive approach: Mohammadi et al. (2020) developed a model that quantifies overall passenger comfort by considering "Thermal, air quality, vibration, lighting and noise" in urban rail transit. Huang and Shuai (2018) and Eboli and Mazzulla (2011) quantified passenger comfort by considering both objective and subjective indices. Han et al. (2016) used the Likert scale to measure the comfort of passengers using the Seoul metro based on their perceptions of "thermal, air, light, acoustic" conditions.

However, urban rail travels are much shorter than long-distance intercity ones; hence passengers deal with these issues for much longer time. In developed countries, research has been done on factors that affect the thermal comfort of railway passengers on high-speed trains with the aid of heat cameras and manikins such as the type of ventilation - whether it is done from the ceiling or floor (Schmeling and Volkmann, 2020), or displacement ventilation (Schmeling and Bosbach, 2017). Previous studies have shown undesirable working conditions for train drivers in Iran (Adel et al., 2015), hence it would be interesting to assess the situation for passengers. These facilities do not exist in many developing countries and this study is one of its first kinds that considers overall comfort of passengers by surveying passengers regarding temperature, light and noise during their long-distance railway journey. Moreover, it considers the impact of personal and health conditions such as age, wearing glasses and suffering from blood pressure on evaluations of passengers.

METHODOLOGY

This research was conducted in Iran, which is among the top 10 countries according to road fatalities (World Health Organization, 2018). Furthermore, Iran is a vast country, and the speed of 4-passenger compartment trains does not exceed 140 km/h, making travel between major cities a lengthy journey. The most crowded route in Iran (Tehran-Mashhad) was chosen for the case study. This route is approximately 926 km long, and it takes trains about 11 hours on average to travel this distance. By plane, this would be just a one-hour journey. Due to cheap fuel prices in Iran, many even choose to travel this route by car. Therefore, ensuring the comfort of railway passengers during their journey is important from both the viewpoint of railway companies and the sustainability of transport. To conduct this research, the authors developed a questionnaire which was distributed on two of the most popular trains, Zendegi and Sepehr. These are respectively ranked as 5-star and 4-star trains according to national railway regulations (shown in Figure 1).

The level of satisfaction and comfort regarding environmental factors (specifically light, noise, and temperature) was examined using self-designed questionnaires. Light meter and sound meter software were also utilized to accurately measure the conditions on the trains involved in the case study.

Along with the questionnaire, specialized devices for measuring light, sound, and temperature were employed. The questionnaire was designed after reviewing previous studies and research. Subsequently, using the opinions of railway industry experts, environmental factors and parameters affecting passenger comfort inside the train were identified, and the questionnaire was designed accordingly. It was edited by experts, and

Five-star Zendegi train Four-star Sepehr train

Figure 1. Trains of the case study (Raja company, 2021)

the final version consisted of five sections:

The first section pertained to demographic questions such as gender, age, educational level, and job.

The second section was about the respondent's current trip (final origin and destination, purpose of trip, travel companion, and seat location).

The third part included several 5-scale Likert questions on passengers' opinions about the temperature, light, and vibration of the train.

The fourth section asked questions about the passenger's physical condition and health. These were mainly focused on illnesses that may affect passengers' opinions on the aforementioned environmental factors such as high/low blood pressure, diabetes, and allergies. Finally, the last part consisted of open questions to seek suggestions for improving passenger comfort.

Temperature, light, and vibration in different sections of the train were measured by one of the authors to compare them with standard values and match them with passengers' opinions.

In this study, a voluntary sampling method was employed. The appropriate sample size was calculated to be 384 using Cochran's formula (equation 1) (Kotrlik and Higgins, 2001). In the formula, 'n' represents the sample size, 'N' is the size of the target society, and 'Z' represents the value of the normal variable at the confidence level of 95% (which is 1.96). The questionnaire was distributed among train passengers in September 2019. A total of 400 filled questionnaires were collected, but after excluding partially filled ones, 382 questionnaires were used for statistical analyses using SPSS software.

$$n = \frac{\frac{Z^2pq}{d^2}}{1+\frac{1}{N}\left(\frac{Z^2pq}{d^2}-1\right)}$$

The validity of the questionnaire was verified by a panel of university professors from Iran University of Science and Technology and experts at Raja Passenger Trains Company. There are several methods to analyze the reliability of the questionnaire. In this research, Cronbach's alpha method was used. The Cronbach's alpha value (at a confidence level of 95%) in this study was 0.730, which is within an acceptable range according to Cortina (1993).

RESULTS

The respondents consisted of 187 males (49%) and 195 females (51%). About 10% of respondents were under 18, and 16% were over 55. Approximately 14% of respondents belonged to the 18-25 age group, both the 26-35 and 36-45 age groups equally comprised 20.9% of respondents, and 18.1% of respondents were in the 46-55 age group. About 71.5% of respondents were married. More than half of the respondents had a graduate degree or higher. Students made up 21.5% of respondents, about 47% were employed, and about 30% were unemployed.

Regarding health conditions, about a quarter of respondents suffered from high blood pressure, in contrast to 6.8% who had low blood pressure. Seasonal allergies affected 21.5% of respondents, arthritis and movement problems affected 7.1%, and diabetes affected 13.4%. Also, almost 40% of respondents wore glasses for reading.

Evaluations from passengers regarding temperature, light, vibration, and noise in different sections of the train are presented in Table 1.

The results indicate that the highest overall satisfaction among passengers was related to lighting, while the lowest was related to temperature. There was a high variation (SD=0.99) in passenger responses, with 23.2% finding the temperature hot or too hot and 35.3% finding it cold or too cold. Despite the questionnaires being distributed in September, a relatively warm month in Iran, it appears that the air conditioning may have been overworking. This assumption is later confirmed for the four-star train in Table 6. Unfortunately, passengers on neither of these trains can customize the temperature of their compartments.

The T-test was used to compare people with low blood pressure and others, showing that those with low blood pressure are more susceptible to feeling cold (t=3.533, Sig=0.001). The T-test was also used for people who need to wear glasses and others, revealing that these individuals are not comfortable with the compartment lighting (t=2.088, Sig=0.037).

The ANOVA test was used to compare different age groups and their sensitivity to vibration. The results indicate a significant difference between groups, with elderly individuals being more sensitive than others (Table 2). The ANOVA test (Table 3) also showed that people traveling with their family are less sensitive to vibration (most likely paying less attention) than those traveling alone or with friends or colleagues.

No significant differences were observed between different age groups regarding their thermal comfort or satisfaction from compartment light. Seating positions did not affect thermal comfort or discomfort from vibration. No significant differences were observed between genders regarding their opinions on light, vibration, and compartment temperature. Table 4 summarizes the relevant tests and their results.

As previously mentioned, questionnaires were completed by passengers on two types of trains on the route of the case study. To identify differences between environmental factors of these two trains, the T-test was utilized. Table 5 reveals a significant difference in passenger viewpoints regarding temperature, light, noise, and vibration. Furthermore, the values of these factors were measured in each train and compared to the standard values recommended by the Iran Health Administration, International Union of Railways (UIC), WHO, and EPA (Table 6). The five-star train complies with all standards, while improvements in compartment light and temperature are necessary for the four-star train.

Major suggestions mentioned in response to open-ended questions by passengers included the provision of temperature adjustment options for passengers, the implementation of sound-proof compartments, improved illumination in the W.C., and overall upgrades to train conditions.

Table 1. Results of passenger evaluations from environmental factors

			Temperature				
	Mean	S.D	Too Hot	Hot	Temperate	Cold	Too Cold
ompartment Temperature	2.85	0.999	5.8	17.5	41.4	26.7	8.6
orridor Temperature	3.13	0.673	4.5	13.9	74.3	4.7	2.6
			Light				
	Mean	S.D	Very Good	Good	Moderate	Bad	Very Bad
ompartment Light	4.40	0.706	51.6	38	9.7	0.5	0.3
orridor Light	4.42	0.716	54.5	34.8	9.4	1.3	0
oilet Light	4.48	0.694	58.1	32.5	8.4	1	0
			Noise and vibration				
	Mean	S.D	Very Good	Good	Moderate	Bad	Very Bad
rain Vibration	3.32	1.165	17	30.6	26.2	19.4	6.8
assenger's voices	3.89	0.999	30.1	40.1	21.5	5.2	3.1
entilation noise	3.98	1.009	35.6	38.7	15.7	7.9	2.1

Table 2. ANOVA test for age groups and vibration

	Sum of Squares	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	35.303	4	8.826	3.296	0.011
Within Groups	1009.493	377	2.678		
Total	1044.796	381			

Table 3. ANOVA test for number of accompanying persons and vibration

	Sum of Squares	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	3.080	4	0.770	2.575	0.037
Within Groups	112.713	377	0.299		
Total	115.793	381			

Table 4. Major hypotheses that were rejected

Hypothesis	*Type of test*	
Difference between thermal comfort of different age groups are statistically significant	ANOVA	F= 0.616 Sig=0.652
Difference between satisfaction from compartment light for different age groups are statistically significant	ANOVA	F= 0.878 Sig= 0.477
Difference between thermal comfort of various seat positions and thermal comfort are statistically significant	ANOVA	F= 0.557 Sig= 0.694
Difference between satisfaction from vibration and various seat positions are statistically significant	ANOVA	F= 0.353 Sig= 0.842
Difference between thermal comfort and groups with different travel companions are statistically significant	ANOVA	F= 0.653 Sig= 0.625
There is statistically significant difference between thermal comfort of both genders	T-test	T= 0.297 Sig= 0.767
There is statistically significant different between satisfaction from compartment light of both genders	T-test	T= -1.436 Sig= 0.152
There is statistically significant different between satisfaction from vibration of both genders	T-test	T= -0.810 Sig= 0.418

Table 5. T-test results for difference in passenger evaluations of environmental factors at five-star and four-star train

T-test Results	*Temperature*	*Light*	*Noise and Vibration*
t	-3.659	2.477	-2.292
Sig.	0.00	0.014	0.022

Table 6. Comparison of actual measurements of environmental factors and relevant standards

Factors	*Wagon Numbers*	*Measured Value*		*Standard*	*Result*
		Sepehr Train	Zendegi Train		
Compartment Light	1	520	123	<=400 (Iran Health Administration)	Sepehr Train☒ Zendegi Train☑
	5	494	133		
	11	471	-		
Corridor Light	1	481	163		
	5	508	160		
	11	438	115		
Compartment Noise and Vibration	1	63.6	62.9	55-75 Decibel (UIC)	Sepehr Train☑ Zendegi Train☑
	5	63.5	59.2		
	11	67.5	-		
Corridor Noise and Vibration	1	68.5	62.5		
	5	74.6	57.6		
	11	71.9	58.5		
Compartment Temperature	1	26.5	24	20-26 (WHO, EPA)	Sepehr Train☒ Zendegi Train☑
	5	27	24		
	11	27	-		
Corridor Temperature	1	30	26		
	5	29	26		
	11	32	26		

CONCLUSION

In developing nations, transportation is also evolving and may not yet be at its ideal level. If the satisfaction and comfort of passengers are not adequately addressed, they may transition to more comfortable but potentially less sustainable options. Significant upgrades in the railway industry, such as increasing train speeds or improving rolling stock, may not be feasible in the short term. However, by paying more attention to environmental factors in long-distance trains, higher passenger satisfaction can be achieved at much lower costs.

T-test results confirm a significant difference between passenger evaluations of environmental factors in five-star and four-star trains. Therefore, higher-class (and inevitably more expensive) trains provide a more pleasant journey for passengers. This is not merely subjective; comparisons with existing standards confirm that the five-star train in the case study complies with them more than the other train.

Passengers expressed the highest satisfaction with illumination, while thermal comfort was rated the lowest. Health conditions can influence perceptions of comfort. For instance, T-test results show that respondents who identified as having low blood pressure (6.8% of respondents) felt colder than others. Passengers with reading glasses expressed significantly lower satisfaction with illumination. No evidence was found regarding the impact of gender on evaluations of environmental factors in train compartments in the case study.

The findings of this research can assist railway practitioners and policymakers in better planning and operation of trains. By collecting optional data from passengers (such as whether they wear glasses), better services can be provided. For example, compartments with better lighting conditions (higher lux) can be allocated to passengers who wear glasses. As this research showed that older individuals are more sensitive to noise and vibration, wagons with better suspension systems would be more suitable for them.

REFERENCES

ADEL, M., ZEINAB, K., GABRAEIL, N.-S. & SEDIGHE, B. 2015. Quality of Working Life Assessment among Train Drivers in Keshesh Section of Iran Railway. *International Journal of Occupational Hygiene,* 6.

AHMADPOUR, N., ROBERT, J.-M. & LINDGAARD, G. 2016. Aircraft passenger comfort experience: Underlying factors and differentiation from discomfort. *Applied Ergonomics,* 52, 301-308.

AMPOFO, F., MAIDMENT, G. & MISSENDEN, J. 2004. Underground railway environment in the UK Part 1: review of thermal comfort. *Applied Thermal Engineering,* 24, 611-631.

BLAINEY, S., HICKFORD, A. & PRESTON, J. 2012. Barriers to passenger rail use: a review of the evidence. *Transport Reviews,* 32, 675-696.

CORTINA, J. M. 1993. What is coefficient alpha? An examination of theory and applications. *Journal of applied psychology,* 78, 98.

DEB, C., RAMACHANDRAIAH, A. J. B. & ENVIRONMENT 2010. Evaluation of thermal comfort in a rail terminal location in India. 45, 2571-2580.

EBOLI, L. & MAZZULLA, G. J. T. P. 2011. A methodology for evaluating transit service quality based on subjective and objective measures from the passenger's point of view. 18, 172-181.

GERLICI, J., LACK, T. & ONDROVA, Z. 2007. Evaluation of comfort for passengers of railway vehicles. *Communications-Scientific letters of the University of Zilina,* 9, 44-49.

HAN, J., KWON, S.-B., CHUN, C. J. B. & ENVIRONMENT 2016. Indoor environment and passengers' comfort in subway stations in Seoul. 104, 221-231.

HARDY, A. J. J. O. S. & VIBRATION 2000. Measurement and assessment of noise within passenger trains. 231, 819-829.

HIEMSTRA-VAN MASTRIGT, S., GROENESTEIJN, L., VINK, P. & KUIJT-EVERS, L. F. 2017. Predicting passenger seat comfort and discomfort on the basis of human, context and seat characteristics: a literature review. *Ergonomics,* 60, 889-911.

HUANG, W. & SHUAI, B. J. J. O. M. T. 2018. A methodology for calculating the passenger comfort benefits of railway travel. 26, 107-118.

IVANESCU, M., NEACSU, C., TABACU, S. & TABACU, I. The human thermal comfort evaluation inside the passenger compartment. World Automotive Congress, Budapest, Hungary, 2010. 196-209.

KATAVOUTAS, G., ASSIMAKOPOULOS, M. N. & ASIMAKOPOULOS, D. N. J. S. O. T. T. E. 2016. On the determination of the thermal comfort conditions of a metropolitan city underground railway. 566, 877-887.

KOGI, K. J. E. 1979. Passenger requirements and ergonomics in public transport. 22, 631-639.

KONSTANTINOV, M. & WAGNER, C. Flow and thermal comfort simulations for double decker train cabins with passengers. Proceedings of the Third International Conference on Railway Technology: Research, Development and Maintenance, 2016.

KOTRLIK, J. & HIGGINS, C. 2001. Organizational research: Determining appropriate sample size in survey research appropriate sample size in survey research. *Information technology, learning, and performance journal,* 19, 43.

KUMAR, V., RASTOGI, V. & PATHAK, P. M. 2017. Simulation for whole-body vibration to assess ride comfort of a low–medium speed railway vehicle. *Simulation,* 93, 225-236.

LAI, W.-T. & CHEN, C.-F. J. T. P. 2011. Behavioral intentions of public transit passengers—The roles of service quality, perceived value, satisfaction and involvement. 18, 318-325.

MOHAMMADI, A., AMADOR-JIMENEZ, L. & NASIRI, F. 2020. A multi-criteria assessment of the passengers' level of comfort in urban railway rolling stock. *Sustainable Cities and Society,* 53, 101892.

POWELL, J. & PALACÍN, R. 2015. Passenger stability within moving railway vehicles: limits on maximum longitudinal acceleration. *Urban Rail Transit,* 1, 95-103.

RAJA COMPANY. 2021. *Description of trains and on-board services* [Online]. Available: https://www.raja.ir/ [Accessed 05/04/2021].

RICHARDS, L. G., JACOBSON, I. D. & KUHLTHAU, A. J. A. E. 1978a. What the passenger contributes to passenger comfort. 9, 137-142.

RICHARDS, L. G., JACOBSON, I. D. & KUHLTHAU, A. R. 1978b. What the passenger contributes to passenger comfort. *Applied Ergonomics,* 9, 137-142.

RIPAMONTI, F. & CHIARABAGLIO, A. 2019. A smart solution for improving ride comfort in high-speed railway vehicles. *Journal of Vibration and Control,* 25, 1958-1973.

SCHMELING, D. & BOSBACH, J. 2017. On the influence of sensible heat release on displacement ventilation in a train compartment. *Building and Environment,* 125, 248-260.

SCHMELING, D. & VOLKMANN, A. 2020. On the experimental investigation of novel low-momentum ventilation concepts for cooling operation in a train compartment. *Building and Environment,* 182, 107116.

WALGAMA, C., FACKRELL, S., KARIMI, M., FARTAJ, A. & RANKIN, G. 2006. Passenger thermal comfort in vehicles-a review. *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering,* 220**,** 543-562.

WILSON, J. R. 2007. *People and rail systems: human factors at the heart of the railway*, Ashgate Publishing, Ltd.

WILSON, J. R. & NORRIS, B. J. 2005. Rail human factors: Past, present and future. *Applied ergonomics,* 36**,** 649-660.

WILSON, J. R. & NORRIS, B. J. 2006. Human factors in support of a successful railway: a review. *Cognition, Technology & Work,* 8**,** 4-14.

WORLD HEALTH ORGANIZATION 2018. Global status report on road safety 2018: Summary. World Health Organization.

XU, J., YANG, K. & SHAO, Y.-M. 2018. Ride comfort of passenger cars on two-lane mountain highways based on tri-axial acceleration from field driving tests. *International Journal of Civil Engineering,* 16**,** 335-351.

YE, X., LU, H., LI, D., SUN, B. & LIU, Y. 2004. Thermal comfort and air quality in passenger rail cars. *International Journal of Ventilation,* 3**,** 183-192.