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Willingness to pay for reduced travel time: Case study of Mumbai - Ahmedabad High Speed Railway

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ABSTRACT

India is constructing its first High Speed Railway (HSR) corridor between Mumbai and Ahmedabad, which is expected to reduce inter-city travel times significantly. However, the affordability of these reductions in travel time is still questionable for a developing country like India. This study analyses the existing conventional train travellers' Willingness to Pay (WTP) for reduced travel time due to HSR. A questionnaire-based combined RP-SP survey was conducted in Mumbai to capture respondents' travel details, socioeconomic status and Stated Preference choices. The modified open-ended contingent valuation method and binary logistic regression modelling methods were used for data collection and modelling, respectively. Differential Utility Weighted Mean WTP was calculated for multiple socioeconomic cohorts. It was found that travellers are willing to pay an average INR 300 (as on March 2020) over and above their current travel cost for every hour of travel time saving. The ideal fare range that travellers are willing to pay is between INR 3.25/km to INR 5.25/km. Low-income travellers, occasional travellers, those travelling in a group, and those on social trips had the lowest WTP values in their cohorts. On the contrary, regular business travellers with high incomes had the highest WTP. Analysis showed that the WTP of individuals decreases with the increasing no. of co-passengers and with the increasing comfort of competing modes. The future HSR in India needs a group ticket discount of 10% and an average 25% subsidy on monthly passes to make HSR more attractive for commuters and those travelling with families. This research would help draft the HSR operational policies for subsidies, stronger inter-modal competition, loss minimisation for conventional trains and ridership forecasts.

1. Introduction

The first corridor of the Indian HSR network is under construction between Mumbai and Ahmedabad. The HSR is often considered a booster to local, regional and national economic growth and productivity (Fan et al., 2022a), as it virtually shrinks the space–time geography of the connected region (Chen and Hall, 2011). This capability of HSR to bring cities closer to each other comes through its 'leap of speed' property that decreases inter-city travel times. These steep reductions in travel time favour a chain of developments on the ground. The reduced space–time distance between Chinese cities has also led to increments in income and poverty alleviation (Fan et al., 2022b). However, it has been argued that sometimes these speed increases and subsequent time gains are too costly for society to accept and accommodate (Crozet, 2017). It is said that "*knowledge about the product's willingness to pay (WTP) on behalf of its potential customers plays an important role in pricing decisions*" (Breidert et al., 2006). The values of WTP can vary significantly with different socioeconomic conditions (such as income and age) and travel characteristics like trip length and purpose. Especially in developing nations like India, it becomes crucial to understand the type of travellers willing to pay higher for the travel time savings by HSR and the types of trips they are ready to pay for.

This makes the study of current travellers' willingness to pay for the future HSR corridor in India a necessity. However, the existing literature worldwide lacks the focus on the willingness to pay for HSR, with no studies for India and other similar developing nations. This study's motivation is to fill this gap in the literature with empirical evidence from India's upcoming HSR corridor. This study focuses on the existing conventional rail travellers on the Mumbai - Ahmedabad route of Indian Railways. Hence, the study also contributes to finding Indian Railway

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users' perceived value of saved travel time. This detailed analysis of willingness to pay for various sub-categories of conventional train users would be beneficial for defining the HSR ticket fare policies, decisions on railway operations, and revenue management strategies for HSR and conventional rail in India and other developing countries aspiring HSR.

2. Literature review

Willingness to pay is well-studied in transportation sciences by both direct and indirect methods, mostly measuring the hypothetical WTP. The research on Willingness to Pay in transportation sciences primarily deals with the savings in travel time due to increased speed, frequency, and ease of transfer. Several studies calculating WTP for improvement in the quality of service are also available in the literature. Literature also includes studies on the effects of crowding in transit systems (Li and Hensher, 2011; Basu and Hunt, 2012) and activities during travel (Varghese and Jana, 2018) on travellers' WTP for a service. However, the literature lacks studies on the willingness to pay for HSR services. Though the literature on intermodal competition between HSR and air transport discusses the value of travel time savings (Zhang et al., 2022), only a few studies have focused on the willingness to pay for HSR.

The Contingent Valuation Method is among the most widely used methods in WTP studies. A study from the UK analysing public attitude towards the HSR used a closed-form Contingent Valuation. Two options of current travel time and two hypothetical HSR travel times were posed to the respondents, and they were asked to respond with an adequate fare from a set of options (Harvey et al., 2014). The study showed the maximum WTP to be only 23% more than the current fare for travel time reduction from 90 min. to 30 min. on London - Birmingham HS2 route (Harvey et al., 2014). A revealed preference survey of current HSR users of the Madrid - Barcelona corridor in Spain was conducted with a sample size of 378 respondents to find the travellers' value of travel time savings and corresponding WTP (Román et al., 2014). The mean WTP was calculated as weighted averages of individual WTP values using choice probabilities as weights. The variability in WTP was analysed for trip frequency and trip purpose (Román et al., 2014). A study of customer loyalty for 300 km long Turkish HSR showed the relationship between customer satisfaction and willingness to pay more using structural equation modelling on the data collected from current HSR users (Dölarslan, 2014). The willingness to pay for business class seats in Taiwanese HSR was studied using the data of 309 HSR travellers at Taipei station (Jou et al., 2013). The variations of WTP were analysed based on trip frequency, purpose and income. The study used the Double Bound Dichotomous Choice method asking two questions with binary (yes or no) answers (Jou et al., 2013).

The Double Bound Dichotomous Choice method is one of the most widely used Contingent Valuation methods. In this method, the second question is asked to the respondent, depending on their answer to the first question. A study of modal competition between HSR and Low-Cost Airlines and willingness to pay for HSR for a proposed HSR corridor in Thailand used the Double Bound Dichotomous Choice method formulated by Hanemann et al. (1991) for the WTP calculations in the binary choice environment (Chantruthai et al., 2014). The end-to-end WTP analysis was done for two destinations from Bangkok, concluding the fare to be USD 0.055/km for the proposed southern corridor of Thai HSR (Chantruthai et al., 2014). The study of willingness to pay for the proposed HSR corridor in Indonesia also used the binary logistic regression with conventional train and HSR as two options. The mean willingness to pay was calculated as the mean of individual willingness to pay values. Data collected from 177 respondents were used for the analysis, and end-to-end average WTP for various scenarios was calculated to be USD 14.88 to USD 16.65 for a 142 km long HSR corridor, making the fare close to USD 0.1/km. The scenarios focused on HSR frequency and its last-mile connectivity (Putri and Widyastuti, 2019).

In the context of India, the only study of the upcoming HSR corridor in India was carried out by Japan International Cooperation Agency. Respondents were posed with a dichotomous question for four closed-form fare scenarios with travel time fixed at 2 h for an HSR journey from Mumbai to Ahmedabad. The study proposed that HSR fares higher than the fare of AC first class but lesser than the airfare would result in 40% of the current AC train travellers switching to HSR. The study also proposed that the per km HSR fare should range between USD 0.08 to 0.14 (i.e. INR 4.72 to 8.85 as per 2015 rates) with fare at INR 2,305 for 500 km long Mumbai - Ahmedabad route (JICA, 2015). Table 1 summarises the existing literature on Willingness to Pay for HSR across the world.

3. Research gap and motivation

The literature includes few studies dealing with improvement in the existing HSR service, and others study the WTP for the proposed HSR corridor. However, existing studies lack a detailed analysis of variations in WTP across multiple socioeconomic and travel characteristics-based sub-groups. Moreover, most of these studies have considered only the end-to-end travel for calculating the WTP and proposed fare ignoring the intermediate stations and the variation of WTP with the destination. The literature on WTP for HSR lacks an understanding of variation across different market segments. In this study, we intend to fill this gap in the literature by analysing the variations of WTP across multiple socio-demographic and economic cohorts. Along with this, the paper intends to augment the literature with empirical evidence of willingness to pay for India's first proposed HSR corridor. Most existing studies use closed-form dichotomous questions in surveys with fixed travel time and cost levels. This approach is advantageous in determining the maximum willingness to pay and the extent of the modal switch. However, it prevents us from understanding the respondents' True Willingness to Pay. One of the intentions of this study is to understand and analyse train users' True Willingness to Pay for the proposed HSR without considering the constraints on HSR travel cost and time. For this purpose, the study uses the data collected through a choice experiment format with options based on an answer to an initial open-ended question. Further, a new strategy has been adopted for calculating the weighted average WTP of each sub-group. The study intends to capture the True WTP for HSR and its variation for multiple socioeconomic groups and classes to help design future HSR fare policies.

4. Study area

The Mumbai - Ahmedabad region was the study area for the questionnaire-based survey. Fig. 1 shows the upcoming HSR corridor and existing conventional railway lines.

The HSR corridor is being constructed parallel to the existing route of Indian Railways operating more than 60 high-occupancy daily trains between Mumbai and Ahmedabad. This upcoming corridor will connect cities like Mumbai, Surat, Vadodara, and Ahmedabad with a faster

Table 1
Summary of the existing literature on WTP for HSR.

Study	Country	Methodology	Findings
Román et al. (2014)	Spain	A weighted average of individual WTP	Air and HSR travellers have a high Value of Time
Harvey et al. (2014)	UK	Contingent Valuation Method	Maximum WTP of 23% premium over current fares
Jou et al. (2013)	Taiwan	Double Bound Dichotomous Choice	Travellers have low WTP for business class seats in HSR
Chantruthai et al. (2014)	Thailand	Double Bound Dichotomous Choice	End-to-end WTP of USD 0.055/km for the proposed HSR corridor
Putri and Widyastuti (2019)	Indonesia	Stated Preference survey	Average WTP of USD 0.1/km for the 142 km proposed corridor

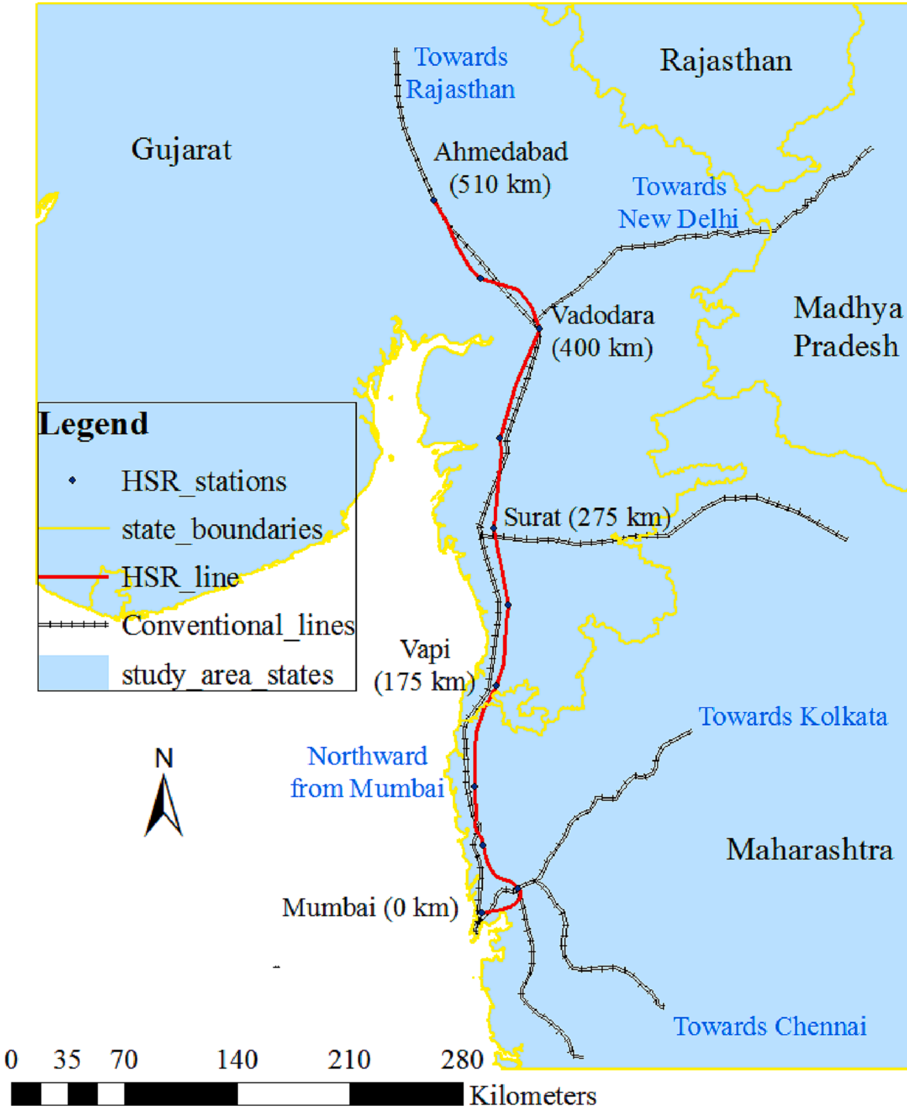

Fig. 1. Future HSR corridor and existing conventional rail lines.

alternative. Among these, Mumbai is the largest metropolis with a population of over 23 million (Demographia, 2020), making it the most critical node of this corridor. The air connectivity between Mumbai and other cities is weaker than the rail connectivity, with only 15 daily flights from Mumbai to Ahmedabad and three each from Mumbai to Surat and Vadodara. Moreover, domestic flights in India carry less than 150 passengers per flight (Airports Authority of India, 2020), whereas the Indian railway passenger trains carry more than 1500 passengers per train on average (Ministry of Railways, 2020). Considering the significantly higher proportion of train travellers, the target population for the survey was set as current conventional train travellers between Mumbai and Ahmedabad.

Conventional trains operating between Mumbai and Ahmedabad consist of premium trains like Shatabdi Express and Rajdhani Express that are fully air-conditioned with AC seating and AC sleeper coaches. Non-premium intercity trains have both AC and non-AC coaches. All premium and non-premium trains originating and terminating on three major terminals of Mumbai, namely *Mumbai Central Terminus*, *Dadar Western Terminus*, and *Bandra Terminus,* halt at *Borivali* station in North Mumbai, where a large number of passengers aboard and alight. Hence, the *Borivali railway station* was chosen as the location for the questionnaire-based survey for this study.

5. Methodology

This study uses the combination of contingent valuation and the stated preference method. A questionnaire-based survey was conducted among the conventional train travellers in the study area. The questionnaire was designed to use the combination of an open-ended Contingent Valuation Method (CVM) and Choice Experiment (CE), both in the backdrop of initial Revealed Preference (RP) questions. The method ensured that the questions and corresponding options posed to the respondents were not divergent from their perception of HSR travel time and HSR travel cost. The RP part gathered information about the respondents' current travel patterns and socioeconomic status, whereas the CVM and CE part gathered information on the perception of travel time and fare of HSR to their destination.

Survey Design: The questionnaire for the survey was designed to collect information on.

(i) Details of respondents' Revealed Preference (RP), i.e. conventional rail travel
(ii) Overall socioeconomic status (income, age, the preferred mode of travel)
(iii) Perception of HSR's travel time and corresponding ticket cost they are willing to spend

(iv) Stated Preference (SP) for multiple HSR travel time and cost scenarios.

The first part of the questionnaire includes questions about the current or last journey details such as destination, ticket price, travel time, class of travel, and travel purpose, followed by their age, income and place of residence. The term 'Current Journey' represents the respondent's immediate last or immediate next journey, as the survey was conducted at a railway station. These variables are considered crucial for deciding the pricing policy of the passenger rail transport system (UNESCAP, 2001). After this, respondents were asked if they knew about the High Speed Railway and India's 1st upcoming HSR corridor between Mumbai and Ahmedabad. Respondents were then asked to state their perceived HSR travel time for said destination. Following this, respondents were asked to quote an amount in INR that they were willing to pay for their stated HSR travel time. This amount was considered the baseline value (TC_{base}) for the travel cost options in the choice experiment.

Choice Experiment: Following the question on perceived HSR travel time and corresponding travel cost bidding (TC_{base}), 5–6 SP cards were shown to each respondent with different HSR travel times and costs. Each SP choice card had two options, (i) the conventional rail with travel time and cost as of the Current Journey and (ii) HSR with specific travel time and cost. The combinations of HSR's hypothetical travel time and travel costs were chosen using the fractional factorial design method from 16 combinations of four travel cost levels and four travel time levels. Taking the baseline value of travel cost to be the minimum willingness to pay for perceived HSR travel time, the four travel cost levels for each respondent were:

(1) $1.0*TC_{base}$
(2) $1.5*TC_{base}$
(3) $2.0*TC_{base}$
(4) $3.0*TC_{base}$

As the respondents had different destinations between Mumbai and Ahmedabad, the corresponding travel time levels for HSR should be different. Hence, the travel time values at four levels for every destination were set using four levels of HSR travel speed. The first proposed HSR corridor in India would have two types of High Speed Trains, viz. rapid trains and all-stop trains, with average speeds of 250 km/h and 170 km/h, respectively (JICA, 2015). Along with these two HSR speed levels, two other levels were set considering the average operating speeds of various HSR systems worldwide. So, the travel time values for four levels were set considering HSR speeds as 300 km/h, 250 km/h, 200 km/h, and 170 km/h and normalised to the nearest 15 min or 10 min multiple. The hypothetical travel time values for different destinations are shown in Table 2.

The fractional factorial combinations were selected dynamically for every respondent depending on their perceived HSR travel times. The SP card options with travel times lesser than the perceived HSR travel time included only the higher travel cost. On the other hand, for options with higher travel times, the travel cost value equal to TC_{base} was shown on the SP card.

Table 2
Travel time values for different destinations at multiple levels.

HSR's speed (km/hr)	Destinations (Distance from Mumbai in km)			
	Ahmedabad (510 km)	Vadodara (400 km)	Surat (275 km)	Vapi (175 km)
300	1 hr 45 min	1 hr 15 min	45 min	30 min
250	2 hrs	1 hr 30 min	1 hr	40 min
200	2 hr 30 min	2 hrs	1 hr 15 min	50 min
170	3 hrs	2 hrs 15 min	1 hr 30 min	1 hr

Sampling strategy: The socioeconomic characteristics and corresponding population proportion of current rail travellers on the Mumbai - Ahmedabad route has not been studied in the existing literature. To ensure a proportional representation of all socioeconomic groups, the sampling strategy used was simple random sampling. The sample size for data collection was determined from Cochran's formula (Eq. (1), owing to a lack of information about the population.

$$n = \frac{Z^2 * p * q}{e^2} \tag{1}$$

where 'n' is the sample size, Z is the Z-score corresponding to the confidence interval, p is the population estimator, q is $1 - p$, and e is the tolerance level, i.e. acceptable error margin. The required sample size is maximum for the maximum variability, i.e. when the value of p is 0.5. Thus, the value of p was taken as 0.5 and q was calculated as $1–0.5 = 0.5$, considering maximum variability. The acceptable margin of error was fixed at 5%, and the suitable confidence interval considered was 90% giving the corresponding Z value to be 1.645. With this, the required sample size came out to be 271 individuals.

Data Collection: The survey was conducted around the premise of *Borivali railway station* in the northern part of Greater Mumbai. The data were collected during January and February 2020 on weekdays and weekends. The survey was conducted during day hours from 10:30 AM to 7:30 PM to target the day travellers. Passengers travelling long distances towards Ahmedabad were randomly picked for the survey. The response rate for the questionnaire survey was high due to face-to-face interaction. Twenty-seven more individuals above the required sample size were collected, considering the possibility of inconsistent and logically incorrect responses.

Modelling Method: This paper uses the binary choice models to estimate the attribute values of parameters with the two choices of Conventional Rail and High Speed Railway. The values of 'willingness to pay (WTP)' and 'willingness to pay extra per hour of travel time saved (WPE/hr.)' were calculated for multiple cohorts from the estimated attribute values using a weighted mean approach. The modal choice probabilities or modal utilities were used as weights for weighted mean WTP calculations in the literature (Román et al., 2014; Putri and Widyastuti, 2019). This study uses the difference in the utilities of HSR and conventional rail (i.e. $U_{HSR} - U_{train}$) as the weights. The utility differences were used as weights due to the following reasons: (a) The extent of the willingness of modal shift is better depicted by the utility difference, and (b) In the binary choice environment, the choice probability of chosen mode is always greater than 0.5 even for the instances with a minimum difference in the utilities of two modes. Hence, using choice probabilities as weights give a relatively higher weightage to the lowest modal shift possibility. The individual WTP values were multiplied by these weights of utility value differences, and the weighted mean and variance were calculated for various socioeconomic subgroups.

6. Data description

After deleting samples with incomplete information or logical discrepancies, a total of 260 responses were left for further analysis in this paper. The logical discrepancies were found through cross-verification questions and factual evidence. A total of 1532 binary choice sets were generated from the stated preference (SP) choice experiments. The responses were classified into multiple cohorts based on respondents' Current Journey and socioeconomic status.

Ahmedabad and Surat were found to be the most favoured destinations. Most of the trips of respondents were social trips followed by work and business trips. Asserting to this, most of them had at least one accompanying person. Two third of the Ahmedabad passengers were between 25 and 60 years of age, earned less than INR 1 Million/year and travelled by AC coaches. The average age of the respondent came out to be 39 years. The distribution of this data in eight different cohorts is described in Table 3.

The collected data was analysed in the binary choice environment. The details of the model and estimation are given in the following section.

7. Model estimation

The two choices of binary logistic regression were conventional rail and High Speed Railway. Multiple parameter combinations were examined in the NLOGIT software, and the values of coefficients of significant parameters forming the final model are tabulated in Table 4.

The utility equation for the two modes is as follows:

$$U_{mode} = -1.26*TravelTime_{mode} + 0.00023*TravelCost_{mode} + 1.54*Distance - 0.13*TravelClass + 0.09*No.ofcopass - 0.07*Income \quad (2)$$

The model's prediction success was 89.22%. The six significant variables were:

(i) Travel time: The travel time coefficient is comparatively huge, with a negative sign suggesting that the utility of a mode would increase by 1.26 units for every 1 h of travel time reduction.
(ii) Distance from Mumbai: The high positive value for the coefficient of 'destination distance from Mumbai' shows that the utility of HSR increases for longer trips.
(iii) Travel Class: The relatively small negative impact of travel class shows that the utility of the mode for given travel time and cost slowly reduces for respondents travelling by higher classes of conventional train currently, i.e. AC seating and AC sleeper.
(iv) Co-passengers: The small positive coefficient of the number of co-passengers displays that group travellers and families have higher utility towards HSR than single travellers.
(v) Income: The smaller negative coefficient of income indicates that the utility of a mode gradually decreases for a given travel time and travel cost as the traveller's income increases.

Table 3
Data description.

Classification	Nos.	Percentage
Destinations of Current Journey		
Ahmedabad	108	41.53
Vadodara	43	16.53
Surat	81	31.15
Vapi to Billimora	28	10.76
Travel purpose		
Visiting relatives	141	54.23
Returning home	56	21.54
Business/Official	44	16.92
Other	19	7.31
No. of accompanying persons		
Travelling alone	74	28.46
With one person	75	28.85
With two or more persons	111	42.69
Travel class of Current Journey		
AC chair car	72	27.69
AC sleeper classes	73	28.09
Non AC classes	115	44.23
Income		
Less than 10 LPA	165	63.46
10 to 20 LPA	68	26.15
More than 20 LPA	27	10.39
Frequency of travel		
Weekly and more	37	14.23
Monthly	76	29.23
Quarterly	49	18.84
Twice a year	48	18.46
Once a year or less	50	19.23
Advance booking		
Same day/previous day	101	38.84
A week or two ago	90	34.61
A month ago or earlier	69	26.55
Age		
Less than 25 years	45	17.30
25 to 40 years	111	42.69
40 to 60 years	87	33.46
Above 60	17	6.54

Total sample = 260 individuals.

Table 4
Model Estimations (N = 1532).

Attribute	Coefficient	Std. Error	p-value	Confidence level
Travel Time	−1.25959	0.04914	0.0000	99.9%
Travel Cost	0.00023	0.000095	0.0151	98%
Distance from Mumbai	1.53756	0.09298	0.0000	99.9%
Travel class	−0.13497	0.06711	0.0443	95%
No. of co-passengers	0.09067	0.05152	0.0784	90%
Income	−0.06882	0.03396	0.0427	95%

Note: Log-likelihood = 1109.68, Chi-squared: 228.59.

Travel Cost Coefficient: The travel cost coefficient is relatively small and has a positive sign, which does not obey the logical assumption of 'lower the cost, higher the utility'. This inverse effect results from respondents quoting much higher amounts that they would like to pay for HSR than their current conventional train fare. The HSR fare quoted by the respondents for their perceived HSR travel time was 2 to 3 times their current rail travel fare (Fig. 2). On the contrary, most respondents perceived HSR's travel time to be only half to 0.3 times their current travel time by conventional rail (Fig. 3). This indicates that respondents were ready to pay three times their current train ticket to reduce their travel time by just 50%. The SP-based choice experiment had even higher travel cost options, which the respondents generously selected.

Due to highly subsidised conventional rail in India, the conventional rail option in many SP cards was significantly cheaper than the HSR option (Tiwari, 2016). Despite that, HSR was the preferred mode by most respondents for a large set of SP experiments. This pushed the travel cost coefficient towards a positive value, as people were choosing a much costlier option among the two. Moreover, the travel time levels were determined using average HSR operating speeds across the world, which are significantly higher than the conventional rail speed in India. Hence, the designed binary choice model was not exposed to the scenarios of equal travel time for both modes. The small magnitude of the travel cost coefficient compared to travel time arises due to units in which these quantities are measured, i.e. travel time in hours and travel cost in Indian rupees.

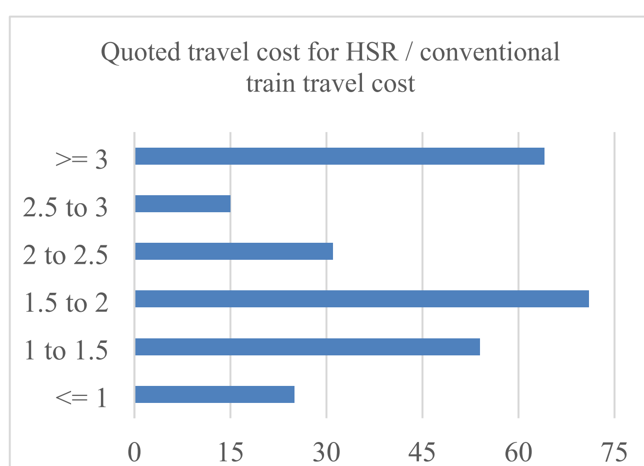

Fig. 2. Travel cost ratio (HSR quote/train).

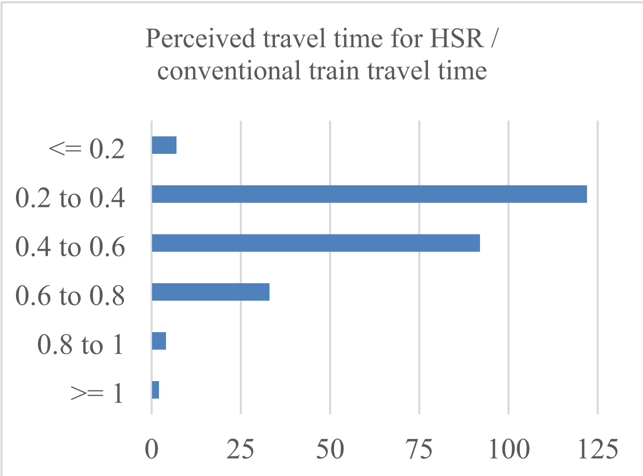

Fig. 3. Travel time ratio (HSR perceived/train).

Higher-than-real WTP: Misquoting the actual travel cost by the respondent is a critical problem in stated preference surveys. Many researchers have discussed the measures to handle these possible biases, such as qualitative questions and improving realism (Cherchi and Hensher, 2015). This study uses an optimal design of choice sets to avoid direct bias in stated WTP. For this purpose, all price options in the choice sets were kept higher than or equal to the initial quoted price i.e. TC_{base}. This ensured that the respondents with higher than real WTP initially, would either select HSR option with the same price, or would select the conventional rail as their preferable option. However, knowing the 'high-quality image' associated with the HSR (Ureña et al., 2009), it is likely for respondents to quote higher-than-real WTP, even after bias correction through survey design.

These results and corresponding utility values were used to estimate the weighted average WTP and weighted average WPE/hr. for all the respondents and their socioeconomic groups.

8. Willingness to Pay (WTP) Estimation

The mean Willingness to Pay Extra per hour of travel time savings (WPE/hr.) and mean Willingness to Pay (WTP) are calculated using the modal utility values. We use the differences in the utilities of HSR and conventional train (i.e. $\Delta U = U_{HSR} - U_{train}$) as weights to calculate the weighted mean and standard deviations. The weighted mean WTP and WPE/hr. are calculated for all cohorts defined by either socioeconomic conditions or travel characteristics. The weighted mean value of WPE/hr and WTP were calculated as shown in Eq. (3) and Eq. (4), respectively.

$$\frac{WPE}{hr.} = \frac{\sum\left(\Delta U^{*}\frac{\Delta TC}{\Delta TT}\right)}{\sum(\Delta U)} \tag{3}$$

$$WTP = \frac{\sum \Delta U^{*} TC_{HSR}}{\sum \Delta U} \tag{4}$$

Since the natural relation between Travel Time (TT) and Travel Cost (TC) is in inverse proportion, it was hypothesised that the relation between the ratio Travel times of HSR and conventional trains is inversely proportional to the ratio of travel costs of HSR and conventional trains. It is provided in Eq. (5).

$$\left(\frac{TC_{HSR}}{TC_{Train}}\right) \propto \frac{1}{\left(\frac{TT_{HSR}}{TT_{Train}}\right)} \tag{5}$$

The constant of proportionality is calculated as the utility difference weighted mean as per Eq. (6).

$$k = \frac{\sum \Delta U^{*}\left\{\left(\frac{TC_{HSR}}{TC_{train}}\right)^{*}\left(\frac{TT_{HSR}}{TT_{train}}\right)\right\}}{\sum \Delta U} \tag{6}$$

The values of WPE/hr., absolute WTP, and the proportionality constant for various cohorts and the results have been summarised in Table 5.

Travel time savings in hours and distance in kilometres were used as normalising factors to avoid the bias of higher fare differences for longer distances.

9. Results and discussion

The values of three parameters and their variation across the socioeconomic groups provide insights into the behavioural aspects of travellers and their future travel patterns.

1. Individuals travelling by AC coaches would pay higher than those travelling by non-AC coaches. In correlation to this, travellers with higher incomes are willing to pay more than those from lower-income backgrounds. Passengers travelling in AC seating coaches are willing to pay more than those travelling in AC sleeper coaches due to the additional sleeping comfort of AC Sleeper, which is absent in the HSR and AC seating.
2. The value of saved travel time reduces with an increase in the number of co-passengers. Respondents travelling alone were willing to pay higher than those accompanied by one person who would pay higher than group travellers. Respondents with more than one co-passenger were willing to pay 10 to 12% less than single travellers. This is due to (a) the burden of paying a higher amount for multiple

Table 5
Willingness to pay estimations.

Cohorts	WPE/hr. (in INR)		Absolute WTP (in INR)		Constant (k)
	Mean	Std. dev.	Mean	Std. dev.	
Destinations					
Ahmedabad	247.9	253.9	2085.4	1168.6	0.94
Vadodara	326.8	243.4	1885.7	1257.2	1.13
Surat	337.3	423.4	1100.5	770.7	1.48
Vapi to Billimora	246.7	296.3	653.0	587.9	0.91
			WTP (in INR/km)		
Travel class					
AC chair car	378.9	385.5	5.16	2.70	0.92
AC sleeper classes	253.5	268.7	4.73	2.57	0.80
Non AC classes	234.9	230.8	2.97	2.05	1.40
Accompanying persons					
Travelling alone	317.5	306.1	4.50	3.01	1.16
With one person	282.0	261.4	4.11	2.40	1.07
With two or more person	252.7	306.6	3.97	2.55	1.02
Income					
Less than 10 LPA	256.7	266.2	3.70	2.32	1.21
10 to 20 LPA	298.0	354.3	4.53	2.73	0.86
More than 20 LPA	311.7	268.3	5.00	2.93	0.92
Purpose					
Business/Official	387.4	354.6	5.32	3.54	1.32
Visiting relatives	255.5	291.5	3.97	2.37	1.02
Returning Home	246.1	208.6	3.58	1.83	0.99
Travel frequency					
More than monthly	305.0	219.6	4.26	2.07	1.06
Monthly/Quarterly	312.1	339.8	4.34	2.72	1.13
Less than quarterly	216.1	238.4	3.81	2.58	0.98
Age					
Less than 25 years	163.5	197.7	3.35	1.81	0.73
25 years to 40 years	280.8	254.7	4.09	2.06	1.09
40 years to 60 years	301.6	357.8	4.46	3.22	1.17
More than 60 years	287.7	264.1	4.00	2.67	0.95

tickets and (b) the altruistic factors determining 'non-use values' (Chang, 2010), such as the added value of social interaction in a group.

3. Individuals travelling for business and official purposes value the savings of travel time much more than passengers on a social trip. This can be seen in association with three properties. People on business or official trips (a) mostly travel alone, (b) prefer travelling by AC coaches, and (c) belong to the higher income group. On the other hand, travellers going back home and those travelling to visit their relatives are willing to pay 25 to 30% lesser than business travellers.
4. The relationship between travel frequency and willingness to pay for reduced travel time is not monotonous. The least frequent and the most frequent travellers have WTP lesser than the medium frequent. The least frequent travellers are expected to have the lowest unit value of travel time saving. However, as the most frequent travellers primarily travel for work purposes, their WTP reduces due to a large number of monthly trips.
5. The respondents between 25 and 60 years of age were willing to pay the highest, as most business and official travellers belong to this age group. Respondents below 25 years were willing to pay the lowest, as most were financially dependent on elders.
6. The natural relation of 'more the distance, higher the fare' is observed in destination-based classification. In the case of Ahmedabad, other options, such as overnight trains and flights, reduce the Willingness to Pay Extra (WPE) for the HSR.

A fare structure for the proposed HSR for a distance of 150 km and more was determined from the average WTP. The formulation is shown in Eq. (7).

$$FareinINR = 1612.5^{*}\{\log_e(DistancefromMumbaiinkm)\} - 7897.8 \tag{7}$$

The variability of fare is capped between the corresponding maximum and minimum WTP, as shown in Fig. 4. The maximum WTP and corresponding fare structure is calculated from the absolute WTP of AC chair car travellers, whereas the minimum fare corresponds to non-AC passengers. The average fare structure, fitting with Eq. (7), was obtained from the average Absolute WTP for all travellers for their destinations (refer to Table 5). The logarithmic trend best fits the fare structure, considering the low WTP for the shortest and longest distances.

The range of optimal HSR fare in the Indian scenario, derived from this study, is between 0.04 USD/km to 0.08 USD/km (i.e. INR 3/km to INR 6/km). This range is closer to the unit fare value of Chinese HSR (0.07 USD/km) and Turkish HSR (0.045 to 0.05 USD/km). However, the Indian HSR fare range is significantly lower than that of Japan (0.23 to 0.3 USD/km), France (0.16 to 0.18 USD/km), Taiwan (0.16 USD/km) and even South Korea (0.12 to 0.145 USD/km). Fig. 5 compares the HSR's unit fares around the world.

Moreover, the calibrated unit fare of Indian HSR is close to proposed fare structures in other developing nations like Thailand (0.055 USD/km) and Indonesia (0.1 USD/km), as discussed by Chantruthai et al. (2014) and Putri and Widyastuti (2019).

The optimal unit fare of HSR in India is lesser developed and industrialised world but similar to the countries with medium to low per capita income, most of them in the prospect of HSR in the coming future. Nevertheless, the HSR fare normalised with per capita GDP (in Purchasing Power Parity, i.e. PPP terms) is found to be in the same range across the globe, with Japan being a notable exception. Table 6 lists the global cities with HSR connections to compare their unit HSR fares and per capita GDP (in PPP terms) with the calculated fare for Mumbai - Ahmedabad HSR.

Most countries with operational HSR services are developed, industrialised countries with higher per capita income (more than USD 40,000), except China and Turkey. However, most countries planning or constructing HSR are developing countries with low per capita GDP (less than 20,000 USD), except the USA and Australia. Table 8 shows the major HSR countries with existing HSR networks, those expecting HSR in the future, and the difference in per capita GDP.

As the future of HSR lies in developing countries from Asia, Africa and South America, they need special attention in HSR studies. The results of this study show that the unit HSR fare expected by travellers in India is similar to existing and proposed HSR fares in other developing countries. Due to the socioeconomic inequity in developing countries, it is essential to compare the future HSR cities instead of future HSR countries. Table 9 indicates the future HSR cities from developing countries with their per capita GDP in PPP terms.

Among these future HSR cities worldwide, cities like Rio de Janeiro, Johannesburg, Hanoi, Mexico City, and Tehran have per capita GDP values closer to Mumbai, while other cities like Jakarta, Ho Chi Minh City, Bangkok, Casablanca have per capita GDP in the range of Ahmedabad. The willingness to pay for Mumbai - Ahmedabad HSR is globally significant, considering this socioeconomic similarity between the future HSR cities. Apart from the developing countries, the study holds importance for international agencies funding new HSRs worldwide.

10. Policy implications

Fare is one of the most critical factors determining the modal share and financial viability of a newly introduced mode of public transport.

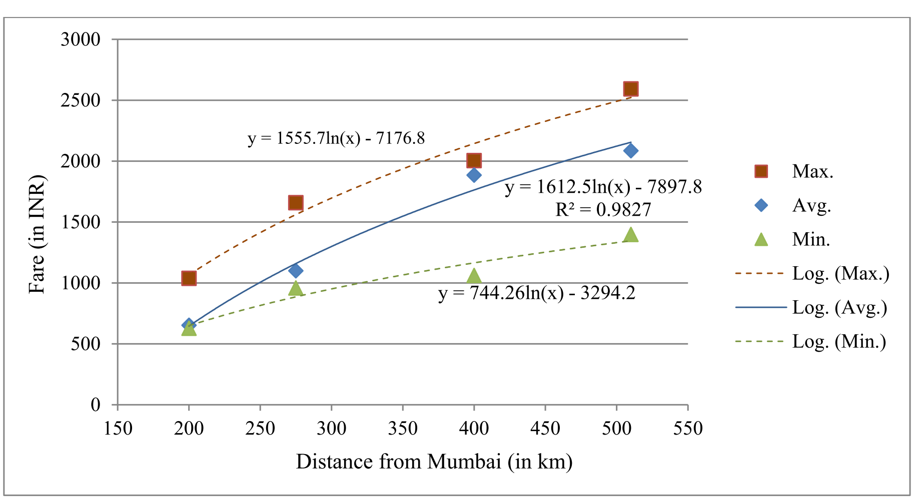

Fig. 4. Fare structures from calculated WTP values.

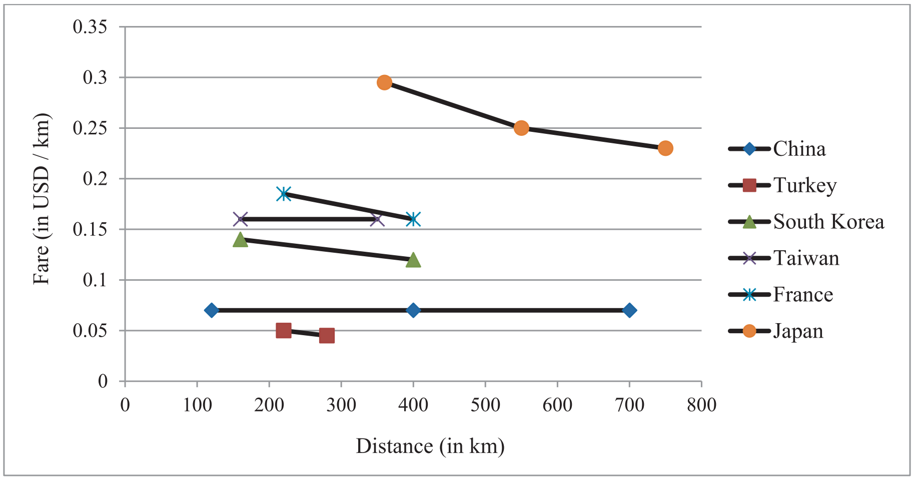

Fig. 5. HSR fare structure in other countries (Source: JICA (2015)).

Table 6
Unit fares in HSR countries across the world with per capita GDP.

Country	Important HSR cities	GDP per capita (PPP) in 1000 s of USD	Unit fare for 500 km (USD/km)	500 km fare as % of per capita GDP
India	Mumbai	26.9	0.055	0.102
China	Beijing	22.1	0.07	0.159
	Shanghai	22.7		0.154
	Guangzhou	29.4		0.119
Turkey	Ankara	20.0	0.045	0.125
	Istanbul	22.6		0.100
South Korea	Seoul	43.0	0.12	0.140
	Busan	50.9		0.118
France	Paris	65.3	0.16	0.123
	Lyon	54.2		0.145
Japan	Tokyo	53.5	0.26	**0.243**

*Sources: Global city GDP estimations for 2025 by PWC (PriceWaterhouseCoopers, 2009) and city population estimates for 2025 by the United Nations population division (*Department of Economic and Social Affairs, 2019*).*

The HSR demands heavy financial investment due to its fixed infrastructure and operations. Hence, estimating the ridership and usage of the mode by different sections of society is essential. The willingness to pay studies can provide fare policies for optimum revenue generation. The results of this study have the following policy implications for fare design, subsidy calculations and discount provision for categories of travellers.

1. **Policies for ownership:** The Indian Railways (IR), a Government body owned by the Railway ministry in the Union Government of India, has long been the only operator of conventional trains in India. In recent years, the Indian railway network has been opening up for privatisation in train operations. However, no clear decision has been made on the public or private operations of future HSR in India.
   The results of this study show that Indians are willing to pay 0.1% of their average income for a single journey of 500 km by HSR, whereas other HSR countries except Japan have single HSR fares for 500 km as 0.1 to 0.17% of their per capita GDP. In the case of Japan, the number is as high as 0.24%. Even for developed countries like France and South Korea, with per capita GDP similar to Japan, their unit HSR fare is significantly lesser than Japan's. This is due to the subsidised Government operated HSR in South Korea and France (KORAIL and SNFC, respectively), whereas the Japanese HSR is

Table 8
Comparing GDP per capita of HSR countries with countries expecting HSR.

Countries with existing HSR network	Per capita GDP (PPP) in USD	Countries planning or constructing HSR for future	Per capita GDP (PPP) in USD
Germany	56,052	India	7,034
France	49,435	Morocco	7,826
Saudi Arabia	48,908	Vietnam	8,374
United Kingdom	48,709	Egypt	12,250
Italy	44,196	Indonesia	12,301
Japan	43,235	South Africa	12,999
South Korea	43,028	Iran	14,535
Spain	42,214	Brazil	15,258
Turkey	27,875	Thailand	19,228
China	16,784	Mexico	20,410
		Australia	53,320
		United State	65,118

*Sources: Countries' current GDP data by the World Bank (*Bank, 2019*) and HSR network data by UIC (*International Union of Railways, 2020*).*

Table 7
Fare Scenarios with marginal and average cost pricing.

Station	Distance	Shatabdi (AC seating)		Rajdhani (AC sleeper)		WPE per hr	High Speed Rail			
		TT	TC	TT	TC		TT	MCP 1	MCP 2	ACP
	(km)	(hrs)	(INR)	(hrs)	(INR)	(INR/hr)	(hrs)	(INR)	(INR)	(INR)
Vapi	200	1.5	530	1.33	800	246.7	0.66	737	965	653
Surat	275	2.5	630	2.33	940	337.3	1	1136	1389	1100
Vadodara	400	4	850	3.75	1100	326.8	1.5	1667	1835	1885
Ahmedabad	510	6	1025	5.25	1300	247.9	2	2017	2106	2085

Table 9
GDP per capita of future HSR cities of the world.

Country	Future HSR corridor	Length (km)	Important cities	City's per capita GDP (PPP in 1000 s of USD)
India	Mumbai - Ahmedabad	500	Mumbai Ahmedabad	26.9 16.0
Indonesia	Jakarta - Bandung	142	Jakarta Bandung	19.9 19.6
Vietnam	Hanoi - Ho Chi Minh city	1600	Hanoi Ho Chi Minh City	23.9 18.5
Thailand	Southern HSR	976	Bangkok	21.2
Iran	Tehran - Isfahan	410	Tehran	25.9
Morocco	Rabat - Casablanca	88	Casablanca	17.0
Egypt	Alexandria - Luxor	910	Alexandria Cairo	18.6 14.3
South Africa	Johannesburg - Cape Town	610	Johannesburg Cape Town	30.7 36.2
Brazil	Rio de Janeiro - Campinas	511	Rio de Janeiro Sao Paulo	29.2 34.0
Mexico	Mexico city - Queretaro	210	Mexico City	32.7

Sources: Global cities' GDP estimations for 2025 by PWC (PricewaterhouseCoopers (PWC) 2009), city population estimates for 2025 by United Nations population division (Department of Economic and Social Affairs, 2019) and future HSR lines data from UIC (International Union of Railways, 2020).

operated by a group of 7 'for profit' private companies - the Japan Railways (JR) group. Non-subsidised private player operation for any public transport system results in relatively higher unit fares. The results of this study can be used to draft a policy for the extent of private ownership in HSR operations in India.

2. **The fare policy:** The formulation of fare structure and the variation of unit fare with distance calculated through travellers' True Willingness to Pay for HSR is a critical finding of this study. The two parameters calculated from the collected data, viz. Willingness to Pay Extra per hour of saved travel time, and Absolute Willingness To Pay, were used to formulate three different fare structures. The first and second fare structures use Marginal Cost Pricing (MCP), whereas the third use Average Cost Pricing (ACP). The Marginal Cost Pricing is calculated by adding the marginal (extra) cost travellers are willing to pay for savings in their travel time, to the original fare. Thus, the formulation of MCP is:

$$MCP = Fare_{conventionaltrain} + WPE*TravelTime_{saved}$$

The cost of saved travel time was added to the existing fare of two premium trains, Shatabdi Express (AC seating) and Rajdhani Express (AC sleeper), to calculate the MCP 1 and MCP 2, respectively. Table 7 summarises the three fare scenarios for HSR.

Marginal cost-based fare structure has higher fares for shorter distances than average cost-based fare structure. However, the fares are equivalent and comparable for longer distances. These results can be used directly to draft a ticket pricing policy for India's first HSR corridor and the future planned corridors. Fig. 6 shows the possible fare structures for future HSR in India using MCP and ACP methods, along with the baseline fares of conventional trains.

The Government run conventional rail currently uses a linear fare structure for all its passenger services. However, the results of this study suggest the logarithmic fare structure to be ideal, considering the effects of competition with airways and overnight sleeper trains for longer distances. This factor can be incorporated into the new fare policy. Currently, conventional long-distance train tickets in India are heavily subsidised, with the Government bearing up to 43% of the ticket cost for every passenger (Tiwari, 2016). The study results can help determine the extent of subsidies required to run the HSR with optimum patronage levels, provided it is to be run by Government-owned agencies. In other cases, results can help private operators of Indian HSR define their operation strategies for revenue maximisation.

3. **Subsidy for regular travellers:** The results of this study show that regular travellers and those travelling for work trips are willing to pay lesser compared to non-frequent travellers and significantly less than business travellers. Paying multiple HSR trips monthly would result in higher travel expenses to income ratio. The concept of monthly/quarterly passes or season tickets is often discussed to tackle this issue for regular travellers. Currently, the Indian Railway provides a Monthly Season Ticket (MST) to regular passengers, costing 15 single trips on the same stretch (Railways, 2011). The results of this study can assist HSR operators in determining the

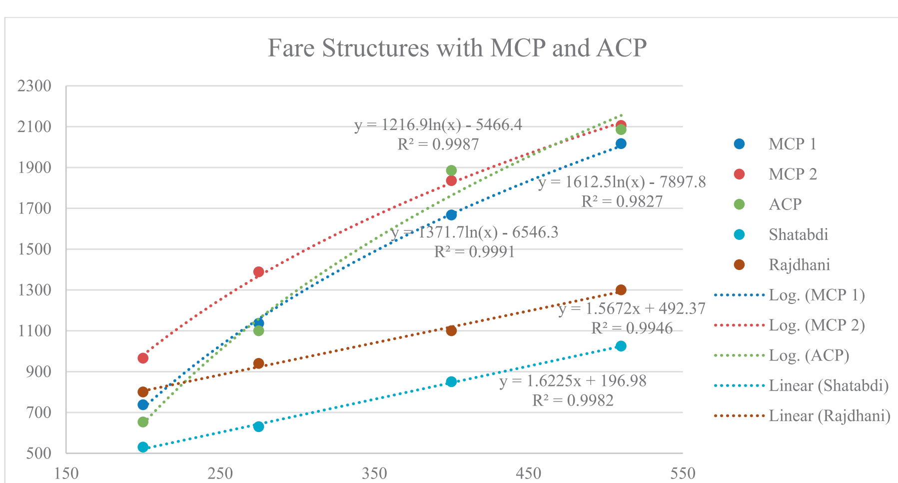

Fig. 6. Fare structure with MCP and ACP.

optimum fare ratio for such season tickets and thereby design policies to attract more frequent travellers and commuters towards HSR.

4. **Group ticket discount policies:** Variations of WTP with the number of co-passengers have been analysed in this study to find that group travellers were willing to pay 10 to 12% less than single travellers. A study of Spanish HSR showed that the provision of discounts on group ticket booking significantly boosted the ridership on HSR, especially for social trips like tourism (Moyano et al., 2016). A similar discount can be provided in the case of Indian HSR. The results of this study quantify the extent of such discounts and hence help draft the group ticket discount policies.
5. **Student concession policies:** The results of this study show that the WTP for young travellers, predominantly students, is 25% lesser than others. High HSR fares can result in HSR becoming socially exclusive for the earning population of India. Future HSR operators in India can utilise this result to decide the concessions on HSR tickets for students. Currently, Indian Railways provide a flat 50% concession on Monthly Season Tickets (MSTs) for students under the age of 25 years (Railways, 2011). A similar concession policy can be drafted for Government operated HSR using the results of this study. Apart from the traveller's direct willingness to pay, the policy can also consider the social benefits of access to better schools and quantify the subsidy accordingly.
6. **Policy for balanced competition:** The study shows that many conventional rail passengers are willing to use HSR even for significantly higher fares. This modal shift will reduce the conventional trains' ridership for inter-city travel leading to the loss of revenues by Indian Railways. This study makes a peculiar observation of travellers' willingness to pay for distances longer than 400 km. The availability of overnight sleeper trains influences the WTP of passengers travelling more than 400 km. Conventional trains with AC sleeper coaches will be more attractive than future HSR for journeys above 400 km in India. These results help draft a scheduling policy for Indian Railways for minimal revenue loss to a new alternative, HSR.

11. Conclusions

This study gives empirical evidence of consumers' willingness to pay for the first HSR corridor in India. A modified open-ended contingent valuation method was used for data collection, and the weighted mean WTP for different cohorts were calculated with weights as increments in the corresponding utility. The conclusions and findings of this study are as follows:

a) Indians are willing to pay INR 300 (as of March 2020) above the conventional train fare for every hour of travel time saved by the HSR.
b) The average willingness to pay values as HSR fare varies from INR 3.25/km (USD 0.043/km) to INR 5.25/km (USD 0.07/km) for different socioeconomic classes travelling for varied purposes.
c) The willingness to pay varies significantly with trip purpose, travel frequency, age and income. It also shows variations with the current class of travel, number of co-passengers and the destination.
d) The average speed elasticity of WTP lies between 0.9 and 1.2, showing that conventional rail travellers pay more for HSR in the same proportion of the increase in travel speeds.
e) The HSR fare policy in India must have a subsidised Weekly or Monthly Season Ticket option for more frequent travellers on work trips, as they are willing to pay 25–30% less for the same travel time savings compared to less frequent travellers with other trip purposes.
f) Future HSR operators in India should provide 10 to 15% discounts on group tickets of more than two travellers to attract more social trips to HSR.
g) The pricing policies for the upcoming HSR corridor can be determined through marginal and average cost pricing. The fare structure developed with marginal cost provides higher fares for shorter distances, whereas for longer distances, they are equivalent to the fares from average cost pricing.
h) Indian Railways must operate overnight AC sleeper trains to strongly compete with the future HSR above 400 km on the conventional rail network.
i) Air travel as a competing mode from Mumbai to Ahmedabad is vital in limiting the WTP for an HSR trip to Ahmedabad. One of the most commonly quoted statements by the respondents travelling to Ahmedabad was, "if the HSR ticket price is beyond INR 3000, then we would prefer to take flight".

Limitations and Future Scope: A relatively smaller sample size and the unavailability of secondary data are two significant limitations of this study. The dataset can be expanded to other modes, such as flight and bus and can be modelled as a multinomial choice instead of binary. Quoting higher-than-real WTP by the respondents is another critical limitation of this study. This study can be expanded to understand the effects of in-travel activities with ICT (Varghese and Jana, 2018) and last-mile connectivity High Speed Rail on the Willingness to Pay. The WTP for commuting from these and Mumbai's peripheral locations can be analysed with the help of a Mumbai suburban crowding study (Basu and Hunt, 2012). Moreover, an exclusive study can be done on the competition and equilibrium between conventional overnight trains and the upcoming HSR between Mumbai and Ahmedabad.

CRediT authorship contribution statement

Omkar Deepak Karmarkar: Methodology, Data curation, Visualization, Investigation, Formal analysis, Writing - original draft. **Arnab Jana:** Supervision, Conceptualization, Methodology. **Nagendra R. Velaga:** Supervision, Conceptualization, Methodology.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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