TRAVEL AND LAND-USE IMPACTS OF THE MUMBAI–AHMEDABAD HIGH-SPEED RAIL IN THE MUMBAI METROPOLITAN REGION

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The Working Paper series is a continuation of the formerly named Discussion Paper series; the numbering of the papers continued without interruption or change. ADBI's working papers reflect initial ideas on a topic and are posted online for discussion. Some working papers may develop into other forms of publication.

Abstract

Mumbai is the financial capital of India, where the commuter share of suburban rail and city bus systems is greater than 70%. With only one metro line, 11.4 kilometers (km) long (Versova–Andheri–Ghatkopar), being operational at present, a large network i.e., about 230 km of metro system has been planned to ease the commuting across the entire Mumbai Metropolitan Region (MMR) by 2025. The initial 65 km stretch of the proposed high-speed rail (HSR) from Mumbai to Ahmedabad falls under the jurisdiction of MMR and includes the three proposed HSR stations at Bandra, Thane, and Virar. This study examines the travel and land use impacts of the introduction of HSR in MMR by applying a four-stage travel demand model. This model has been developed incorporating all the proposed land use and transport network developments across MMR till 2041, replicating the existing travel behavior. An equilibrium between highway and public transit assignments is achieved in the state-of-the-art transportation planning software CUBE. The HSR corridor with all its intricate details has been coded on to the MMR network, and the variations in the ridership of metro, suburban rail, bus, and other public transport systems with and without HSR have been studied. Due to high land use prices inside MMR, more and more people are moving to the outskirts, which is also supported by government schemes relating to providing affordable housing for all. One of the locations chosen for this housing scheme is at the Boisar area, just outside the MMR, which is the next HSR station after Virar. The improvement in accessibility of such peripheral areas due to the proximity of an HSR station and the associated impact on the current intense activity areas of the region have also been studied and reported.

Keywords: high-speed rail, accessibility, public transport, Mumbai Metropolitan Region, travel demand modeling

JEL Classification: L92, R41, R58

Contents

1. INTRODUCTION

India has a wide network of rail routes spread across the country. The Indian rail system is the fourth largest in the world by size, covering around 68,000 km of route length. Based on the sanctioned speeds, rail lines are classified into four categories, A, B and D, whose details are given in Table 1. Even though the sanctioned speeds for these lines are good enough, the actually realized journey speeds are very low.

Table 1: Classification of Indian Rail Lines

Line Classification	Sanctioned Speed	Realized Journey Speed
Group A	160 km/hr	80–100 km/hr
Group B	130 km/hr	65–75 km/hr
Group D	110 km/hr	55–65 km/hr

Note: Suburban sections of Mumbai, Delhi, Chennai, and Kolkata are classified as Group C lines.

High-speed rail (HSR) is a type of rail system that operates significantly faster than the traditional rail system. After its first inception by Japan in 1964, many economies have adopted this emerging technology, including the People's Republic of China (PRC); France; Germany; the Russian Federation; the Republic of Korea; Taipei,China; Turkey; the United Kingdom (UK); and the United States. The PRC has the biggest network of HSR in the world. In fact, in Europe, HSR crosses international borders. In India also, the National High Speed Rail Corporation Limited (NHSRCL) has undertaken the task of implementing an HSR corridor, popularly called the "Bullet Train", between Mumbai and Ahmedabad with the help of Japan International Cooperation Agency (JICA). The Mumbai–Ahmedabad bullet train will run at an average speed of 320 km per hour and at a maximum speed of 350 km per hour, covering the 508 km stretch in less than 3 hours. It will stop at 12 railway stations on the route, but only for 165 seconds each.

Civil aviation in India is the third largest in the world and is growing at the rate of 17%–22% per annum. But, considering the fact that HSR railway stations are usually built closer to city centers than airports are, the HSR has a travel time advantage over planes for distances less than 1,000 km (Givoni 2006). Thus, there is a possibility that many air passengers will shift to the Mumbai–Ahmedabad HSR for commuting purposes. Evidence from five existing European HSR plans demonstrates that around 30% of the HSR demand is the shift from air, 15% from road, 30% from conventional rail, and 25% from induced traffic (Preston et al. 2013). A similar trend is expected to be followed in India as well.

Due to overcrowded mass transit systems and congestion on the roads coupled with the higher financial status of people in Mumbai, it is expected that a considerable number of commuters will shift to HSR. This will cause peak hour relief for the mass transit systems, but it will also affect business travelers who want to travel from Mumbai to Ahmedabad. Thus, this study has tried to examine the variation in the ridership of metro, suburban rail, bus, and other public transport systems in MMR due to the introduction of HSR. People's decisions to purchase houses are based upon social infrastructure, travel time to workplaces, and affordability. However, when housing is excessively expensive in core city regions, individuals are compelled to either travel long distances from rural/suburban areas or to live in compromised slum-like situations inside the core metropolitan area. Due to high land use prices inside MMR, more and more people are moving to the outskirts, and this is also being supported

by government schemes like "Pradhan Mantri Awas Yojna." This study evaluates the improvement in accessibility of such peripheral areas due to the proximity of HSR stations and the associated impact on the current intense activity areas of the region.

2. LITERATURE REVIEW

One of the main objectives of this study is to determine the improvement in accessibility in the peripheral region of MMR due to the introduction of HSR. Hansen defined accessibility as the opportunity which an individual at a given location possesses in order to take part in a particular activity or set of activities, i.e., a facility connected to a large number of commercial, residential, and industrial places will have high accessibility (Hansen 1959).

Construction of the HSR requires a huge economic investment and hence is expected to produce more economic development. For this to happen, an improvement in accessibility and other measures conducive to economic growth are required (Banister and Berechman 2000). For this reason, preliminary analyses to assess the accessibility impact of HSR have been done by a number of researchers. Martínez Sanchez-Mateos and Givoni (2012) used travel time to London as a primary criterion to measure the accessibility of HSR stations in the UK. Cao et al. (2013), Kim and Sultana (2015), Wang et al. (2016), Jiao et al. (2017), and Yu and Fan (2018) used the weighted average travel time (WATT) and potential accessibility indicators. The weighted average travel time gives the accessibility in terms of travel time, while the potential accessibility describes the ease with which travel can be done from origin to destination in terms of friction in distance. Xu et al. (2018) combined a connectivity indicator with Hansen's accessibility in order to evaluate the impact of HSR in terms of connectivity and accessibility. The formulation of Hansen's accessibility is very similar to the potential accessibility. In addition to that, while considering the deterrence function, the travel time component can also be taken into consideration. Thus, considering geographic spread, the alignment of the Mumbai-Ahmedabad HSR, and the availability of data, Hansen's accessibility can be a very good measure for the present study. Also, majority of these studies have been done at an aggregate level with the complex HSR network being considered. No study to evaluate the improvement in the accessibility of a small region due to a single HSR line was found during the literature review for this study. Jiao et al. (2017) concluded from their study that HSR in the PRC has definitely helped to improve the connectivity of the cities. Kamga (2015) reported that in the US, HSR could complement aeroplanes, conventional rail, and cars, and help rebalance these modes so that each mode is used in the most efficient and suitable niche. For Mumbai–Ahmedabad, Pal (2013) estimated that 39% of the HSR demand would be from classic rail, 39% from bus, 13% from air, and only 9% from car, assuming no generation or changes in modal shares due to other factors (such as income growth). However, looking at existing travel between Mumbai and Ahmedabad, it is hard to believe that there will be no induced travel due to the introduction of high-speed rail. This study, to some extent, will help future researchers to re-examine this assumption by considering the impact of HSR on metro and suburban rail in MMR.

3. STUDY AREA

The area of interest for the current study is the Mumbai Metropolitan Region (MMR), a metropolis in the state of Maharashtra, consisting of the financial capital of India,

Mumbai, which is also the state capital. The MMR region is the biggest urban conglomeration in India and one of the most populous metropolises in the world. Spreading over an area of 4,355 square kilometers (1,681 square miles), it comprises eight municipal corporations and fifteen smaller municipal councils. In addition, it spreads over five districts of Mumbai City, Mumbai Suburban, parts of Thane, Raigad, and Palghar. With a population of more than 22 million and a forecasted population of 34 million by 2031 (Figure 2), the region has witnessed an unprecedented economic development in the past. This has laid the foundations for the growth to continue in the future mainly due to the presence of the financial capital of India, its strategic location giving it an advantageous access to the western world, and the flourishing growth centers and special economic zones (SEZ) that are on the rise in the region.

Population and employment growth in the past and the future forecast for the MMR are represented in Figure 1.

Figure 1: Population and Employment Trends in MMR
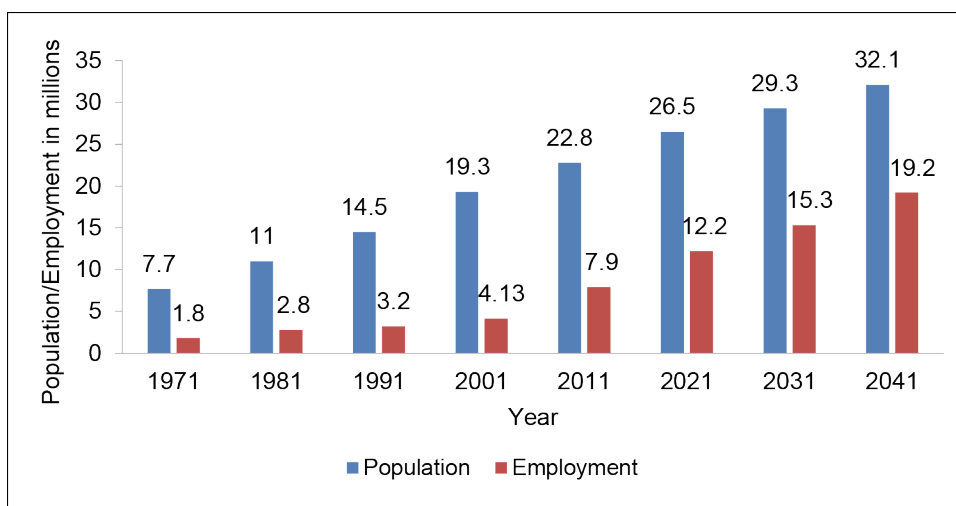
Source: CTS, 2008; Mumbai Metropolitan Regional Development Plan, 2016.

The continuous large-scale immigration of people into MMR has taken its toll on the transportation infrastructure of the region. The suburban network, the lifeline of the city, is already operating at a super-dense crush load, carrying over 8 million passengers per day. Brihanmumbai Electricity Supply and Transport (BEST), which is the primary bus service in Mumbai, has a fleet of 3,600 buses carrying 2.5 million passengers over 445 routes. There are also some other public bus services like Thane Municipal Transport (TMT), Navi Mumbai Municipal Transport (NMMT), Kalyan-Dombivali Municipal Transport (KDMT), and Mira-Bhayandar Municipal Transport (MBMT), which make traveling convenient in Mumbai. Auto-rickshaws and taxis provide last mile connectivity and also act as feeders to public transit. The metro network in Mumbai is planned to be built in three phases over 15 years. With only one metro line, 11.4 km long (Versova–Andheri–Ghatkopar) being operational at present, a large network, i.e., about 230 km of metro systems, has been planned to ease the commuting across the entire Mumbai Metropolitan Region (MMR) by 2025.

4. METHODOLOGY

The objectives of this study are twofold: First, assessment of variations in the ridership of metro and suburban rail systems with and without HSR; Second, evaluation of improvements in accessibility due to the introduction of HSR. In order to achieve these objectives, a robust travel demand model is the prime requirement. Hence, a four-stage travel demand model for MMR is developed in the state-of-the-art CUBE voyager platform. This model is based on the Comprehensive Transportation Study (CTS) conducted by Mumbai Metropolitan Region Development Authority (MMRDA) in 2008.

4.1 Travel Demand Modelling

The methodology adopted for developing the four-stage model and its application for estimating the ridership on various public transit systems including HSR is described in the following four steps:

- Base year OD matrices generation and validation

- Travel Demand Model Development

- Travel Demand Forecasts for horizon year 2041

- Estimation of Metro and suburban corridors' ridership with and without HSR.

The following sections briefly describe each of these steps.

4.1.1 Base Year OD Matrices Generation and Validation

2018 has been considered to be the base year for this study. The base year travel pattern has been obtained by utilizing the available travel demand model which was developed by MMRDA. Population, employment, and vehicle ownership are the planning variables used for the base year in trip generation analysis. These OD matrices, obtained after applying the trip distribution and mode choice models, are then validated using the traffic volume count data on selected links of the study area.

4.1.2 Travel Demand Model Development

The internal passenger travel of the MMR region is obtained using recalibrated trip end models using planning variables and the validated base year OD matrix obtained from step one. For trip distribution, a single gravity model is recalibrated with the help of validated trip ends and generalized cost skims. Generalized cost skims are obtained as initial values from the assignment process. Revision of cost skims is done after successive iteration of modal split and traffic assignment in order to calibrate the gravity model. In order to find the share of public transport and private vehicles, a basic logit model is used. The logit model mainly consists of transport system attributes. Person trips by private vehicles such as cars and two-wheelers are included in the Private Vehicle (PV) matrix. Person trips by public transit such as bus, rail, auto and taxi are included in the Public Transport (PT) matrix. Calibration of the mode choice model is done based on cost skims obtained from trip assignment. During the assignment step, the peak hour PT matrix is assigned on the public transport network. The PT network consists of (i) all bus routes of BEST, NMMT, TMT, and KDMT buses, (ii) Intermediate Public Transport (IPT) routes coded on the road network, (iii) the railway network, which includes suburban rail and metro with all the existing links. The generalized time is the basis of public transport assignment, which is mainly derived from the waiting time (WT), in-vehicle travel time (IVTT), number of transfers (TR), level of discomfort, and fare in

time units. The Stated Preference (SP) survey approach is adopted to obtain the above parameters of generalized time.

Public transport trip assignment mainly consists of path building and trip loading on these paths. Path building is the process of identifying all reasonable paths between all origin–destination pairs and gives associated generalized travel time information. The path and generalized time information obtained from the path building step is used in the loading step to obtain the proportion of trips using each path. The maximum share of trips is loaded on to the path with the smallest generalized time between any pair of zones. Paths with a relatively higher generalized time will be conversely loaded with a very small number of trips. The generalized time-based logistic choice function is used to find the proportion of trips that need to be loaded on each path. The modal share assigned by public transport assignment should reflect the actual observed modal share. In order to achieve the observed modal share, the stated preference survey is conducted which gives parameters of generalized time that are used in the model. The assigned flow across screen-lines from the model after assignment is checked with the observed flows from the survey to simulate the actual traffic condition.

Similar to public transport assignment, highway assignment is carried out for peak hours. The highway network is preloaded with peak hour public transport and commercial vehicle flows. Peak hour public transport flows are obtained from the daily public transport flow factored with the ratio of peak hour flow to daily flow. As public transport and commercial vehicle flows are preloaded on the network in terms of the Passenger Car Equivalent (PCU), the passenger flows obtained need to be converted to PCU using an appropriate Passenger-to-PCU conversion ratio. Now the obtained peak hour public transport (PT) and commercial vehicle (CV) flows are preloaded on the highway network before loading the private vehicle OD matrices. Similar to public transit, private vehicle matrices are converted into peak hour PCU units by utilizing the conversion factors for passenger–PCU and regional peak hour ratios. These factors are obtained from the occupancies observed at screen-lines during the survey. In the case of private vehicle assignment, the user equilibrium procedure is followed, which is based on the generalized cost (sum of operating cost of vehicle, time cost and toll, if any). After assigning private trips, the public transport network also needs to be revised with the speeds. On the revised network, the assignment of public transport is performed and again the next iteration of private vehicle assignment is carried out, considering preloads of public transport. The whole iterative process between private and public transport is repeated until no considerable change is observed in the link loadings and link costs. The updated highway time and highway cost skims obtained from the loaded network are further used for calibration of the gravity model and the mode split model, distribution, modal split and trip assignment is repeated until the OD matrices become stable. The above recalibration process is described with the help of the flow diagram in Figure 2.

4.1.3 Horizon Year Travel Demand Forecasts

The recalibrated base year Travel Demand Model is used for forecasting the horizon year (2041) loadings on each public transport mode on all the links. The planning variables for the horizon year are forecasted based on demographics and inputs from planning agencies. The planning variables thus forecasted form the input to the Travel Demand Model along with the future highway network and proposed metro corridors. The base year highway skims are used to estimate trip ends. Trip ends thus obtained are fed into the calibrated gravity model along with the base year highway skims. The OD matrix forms input to the mode split model which gives the output in terms of mode-wise OD matrices.

**Figure 2: Travel Demand Model Development Flowchart**
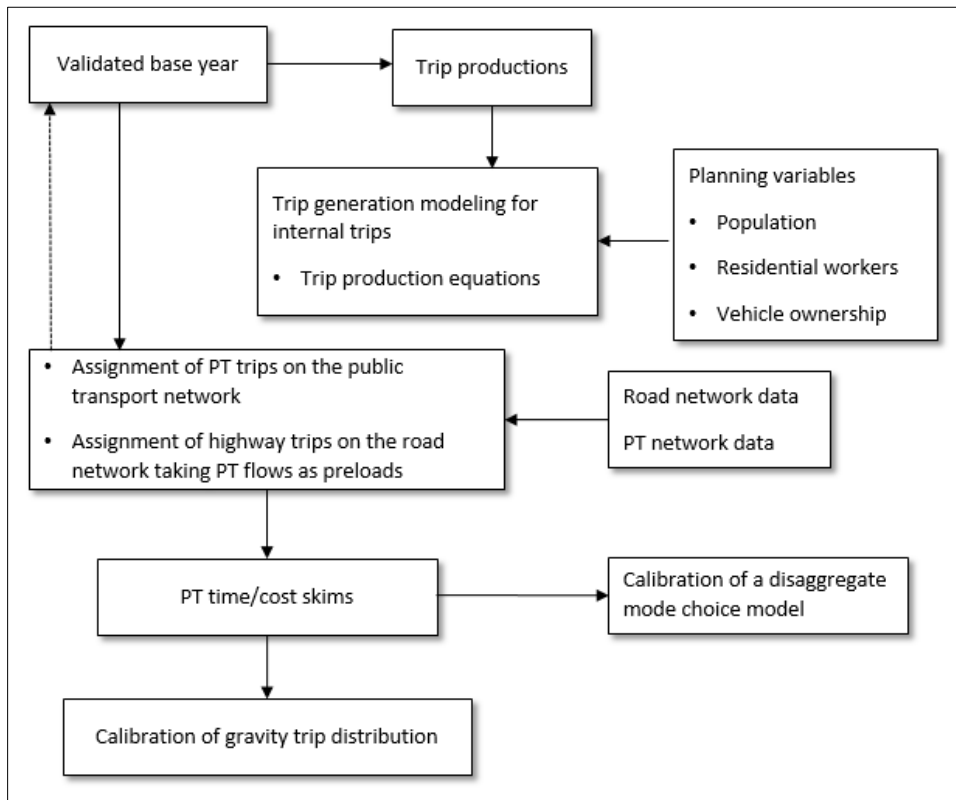
The internal portion of the OD matrix thus obtained is added to the external passenger OD portion, as well as commercial vehicle trips which are estimated by the Furness method. The combined total OD matrix obtained consists of daily trips. The daily trip OD matrix is converted into a peak hour OD matrix. The peak hour OD matrix is loaded on both the PT and highway network. The updated highway and time skims obtained during the assignment process are taken as input in the gravity model, and trip redistribution is done. From the updated skims, mode-wise OD matrices are estimated and loaded on the network, and again the whole cycle is repeated until stable skims are achieved. The flowchart of the procedure followed is displayed in Figure 3.

4.1.4 Ridership Estimation of Metro and Suburban Corridors With and Without HSR

To examine the travel and land use impacts of HSR in the MMR region, coding of HSR is restricted to the MMR region with the inclusion of one external node. The estimated ridership for this HSR corridor is obtained from the "Preliminary Study on the Formation of High-Speed Railway Project in Western India" (JIC 2013), and is shown in Figure 4. From this ridership data, the number of passengers commuting to and from MMR by HSR are obtained and directly assigned to this external node. This data has also been used for recalibration purposes, as the earlier model was built without considering HSR. Now, this model with and without HSR has been applied in the CUBE voyager platform to obtain ridership variations in the metro and suburban rail.

Figure 3: Horizon Year Travel Demand Forecast Methodology
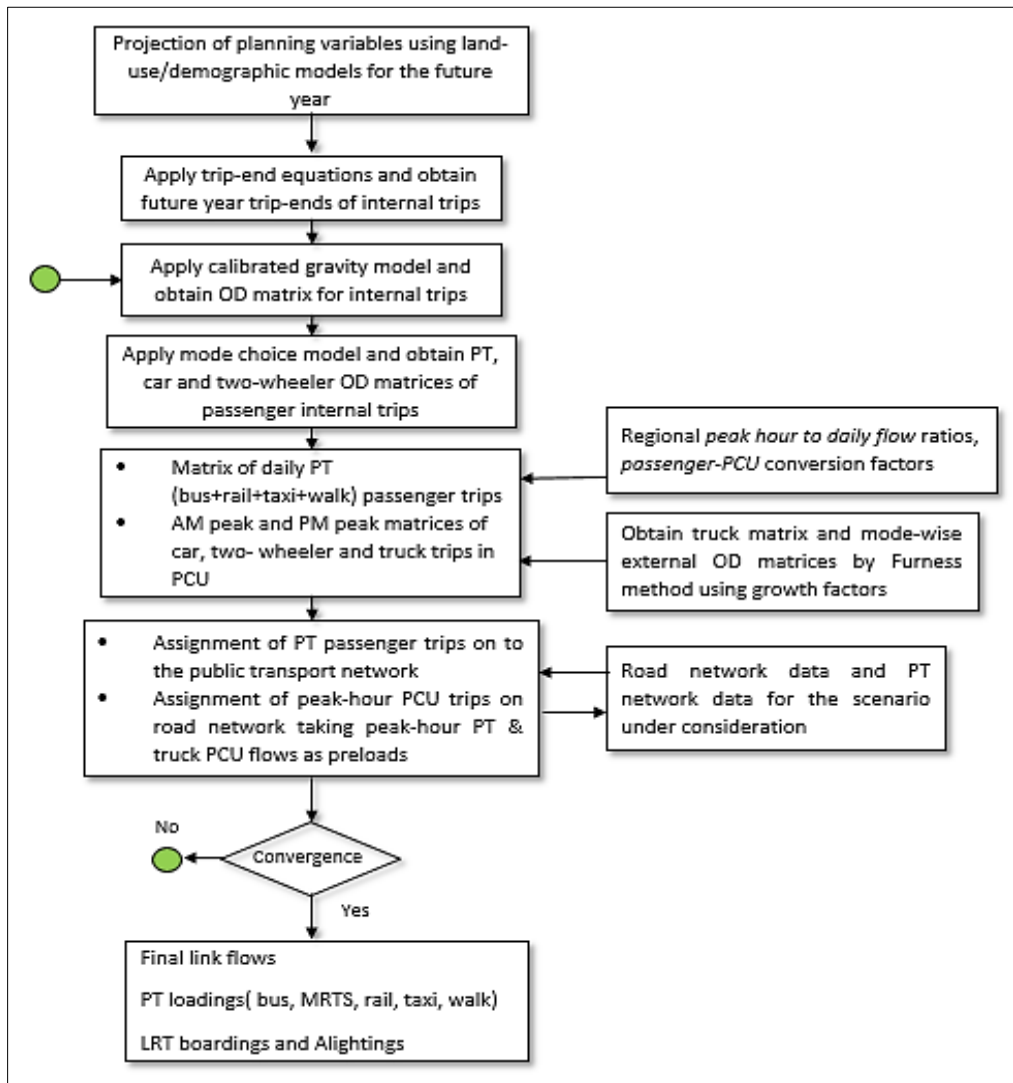
Figure 4: Estimated Daily Ridership of Mumbai–Ahmedabad HSR in 2050
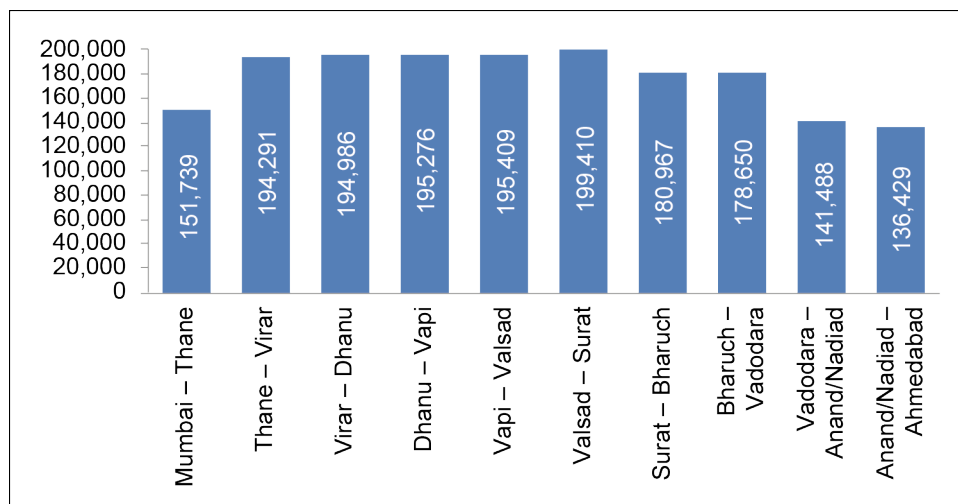
Source: Preliminary Study on the Formation of High-Speed Railway Project in Western India (JIC 2013).

4.2 Accessibility

To evaluate the improvement in accessibility due to the high-speed rail, different indicators have been used by different researchers. In this study, Hansen's accessibility has been used. Hansen's accessibility considers opportunities available to residents of the study area in order to conduct a particular activity or set of activities. The general form of Hansen's accessibility is given in Equation (1):

$$A_i = \sum_j B_j f(c_{ij}) \qquad (1)$$

Where B_j is the opportunities at zone j for a given purpose, C_{ij} is the travel cost from i to j and $f(\ )$ is a deterrence function representing a resistance to travel.

The most famous form of Hansen's accessibility considers the deterrence function as the inverse of the travel time and the opportunity available as employment. Thus Hansen's measure used in this study is given by Equation (2):

$$A_i = \sum_j E_j \Big/ t_{ij}^a \qquad (2)$$

where E_j is the employment at zone j and t_{ij} is the travel time from zone i to zone j.

Many researchers have previously used a potential accessibility indicator which is very similar to Hansen's accessibility. For potential accessibility, typically, in international and national-scale analyses the value of α is taken as 1, whereas at a regional level, a higher value of α is used. However, in the majority of these studies, α has always been taken as 1 (Wang et al. 2016). Even CTS also suggests the value of α to be 1 and hence the same is adopted for this study.

The Hansen's accessibility of 1,030 zones of MMR with and without HSR has been calculated using the forecasted employment data of 2041 and the travel time skims obtained from the four-stage travel demand model.

5. RESULTS AND DISCUSSION

5.1 Variations in Ridership of Metro and Suburban Rail

Initially, the ridership on the metro and suburban rail systems for horizon year 2041 without HSR was obtained using the travel demand model developed. Then, HSR is coded onto the 2041 transit network and the ridership is re-estimated on the metro and suburban rail systems. The observed change in the ridership in the peak hour is represented in Table 2. The major change in the suburban ridership is observed on the western suburban rail since the HSR is running almost parallel to it.

Table 2: Ridership Variation in Western Railway and Metros

Passengers in Peak Hour	Western Railway	All Metro Corridors
Without HSR (in thousands)	747	972
With HSR (in thousands)	701	1,022
Difference (in thousands)	–46	+50

From Table 2, it can be observed that there is a significant decrease in the ridership on the western railway, which is generally extremely overcrowded in peak hour. This could be attributed to the fact that the Bandra station of the western railway and the Bandra-Kurla-Complex (BKC) station on the HSR lie in close proximity and the case is similar for the Virar stations of both, so suburban commuters from Bandra to Virar are likely to switch to the HSR due to its speed advantage. On the other hand, the metro shows a substantial growth in the ridership. The reason might be that the metro acts as a feeder for long distance commuting through the HSR. The greatest growth in metro ridership is observed on Metro lines 2B, 3 and 6.

Metro lines 2B and 3 have a common station with HSR at BKC. Thus these lines act as direct feeders to the HSR. Metro 6 acts as a feeder to metro 3, which in turn carries the passengers to the HSR's BKC station. Even though there is a reduction in the ridership for some other metro lines, there is an overall growth in metro ridership.

The BKC node is proposed to be a metro station in the near future. It is also proposed to be the first station on the HSR (from Mumbai). Hence, a large interchange of passengers is observed from the travel demand model. It is estimated that the number of passengers using the proposed BKC station during peak hour will be about 15,000 and 39,000 for HSR and Metro (Line 2B and Line 3) respectively. This huge passenger demand needs to be considered during the design of the BKC station.

5.2 Impact on Accessibility

Hansen's accessibility measure has been utilized to compute the accessibility of each of 1,030 zones for the scenarios with and without HSR. Zones which lie near to the northern peripheral region of MMR, i.e., near the HSR's Virar station, have experienced significant improvement in accessibility. Also, there is an increase in the accessibility in some of the other zones of the MMR near BKC. However, the increase is not as great as in Virar area (Table 3).

Table 3: Accessibility Changes in HSR Station Area

	Hansen's Accessibility		
HSR Station	**Without HSR** (in thousands)	**With HSR** (in thousands)	**Increment**
Virar	226	284	25.5%
Boisar	156	186	19.6%
BKC	589	605	2.7%

The zone containing Virar station has a 25.5% increase and the region near to Boisar station has a 19.6% increase in Hansen's accessibility. Thus, the introduction of HSR will promote rapid development in these developing regions.

6. CONCLUSION

This study has primarily focused on the assessment of variations in ridership of the metro and suburban rail systems, and the improvement in the accessibilities of different regions of the MMR due to the introduction of HSR. A significant decrease in the ridership on the western suburban rail and an increase in the ridership of some of the proposed metro lines in 2041 is observed from the application of the travel demand model developed during this study. The decrease is due to the fact that the HSR is running almost parallel

to the western suburban rail and a shift in suburban commuters to HSR is very likely due to its speed advantage. Hence, it can be said that a peak hour relief to the congested western suburban rail is likely due to the introduction of HSR. The increase in metro ridership may be considered to be the result of the metro systems acting as feeder services to long distance commuting through HSR within MMR (Bandra–Virar).

Earlier, the Vasai–Virar region was not a part of the MMR. Since the suburban lines were extended to these regions, rapid development has been observed, and the same is evident with the increase in population, from 0.69 million in 2001 to 1.54 million in 2016. "Pradhan Mantri Awas Yojna" is an affordable housing scheme with more than 2.4 Lakhs housing units sanctioned for construction. The accessibility of the peripheral areas of MMR near Virar station is reported to show considerable growth due to the introduction of HSR. An underdeveloped Boisar region near Virar, which has housing prices way below the rest of the MMR (Table 4), will benefit extensively from the HSR.

Table 4: Land Prices in MMR

Location	Land Prices (INR per square feet)
Greater Mumbai	50,000–70,000
Western Suburban	22,000–55,000
Eastern Suburban	14,000–38,000
Thane	9,000–18,000
Vasai–Virar	3,000–5,200
Boisar	1,200–2,800

Source: https://housing.com/dsl/heatmaps/mumbai/buy.

It is known that the MMRDA is planning to include Boisar in MMR and convert it into a CBD area similar to the existing CBDs in MMR. With the inclusion of Boisar in MMR, coupled with the vital connectivity provided by the HSR, a similar trend of rapid development to that of Vasai-Virar is expected. The increase in accessibility combined with low prices is expected to change the existing travel scenario within MMR and hence people may start to reside in such peripheral areas and commute via the HSR.

REFERENCES

Banister, D., Berechman, J. 2000. Transport Investment and Economic Development. *UCL Press,* London.

Cao, J., Liu, X. C., Wang, Y. and Li, Q. 2013. Accessibility impacts of China's high-speed rail network. *Journal of Transport Geography* 28: 12–21.

Givoni, M. 2006. Development and impact of the modern high-speed train: A review. *Transport Reviews* 26(5): 593–611.

Hansen, W. G. (1959). How accessibility shapes land use. *Journal of the American Institute of planners*, *25*(2), 73–76.Japan International Consultants for Transportation Co., Ltd. (JIC) 2013.

Jiao, J., Wang, J. and Jin, F. 2017. Impacts of high-speed rail lines on the city network in China. *Journal of Transport Geography* 60: 257–266.

Kamga, C. 2015. Emerging travel trends, high-speed rail, and the public reinvention of U.S. transportation. *Transport Policy* 37: 111–120.

Kim, H. and Sultana, S. 2015. The impacts of high-speed rail extensions on accessibility and spatial equity changes in South Korea from 2004 to 2018. *Journal of Transport Geography* 45: 48–61.

Martínez Sanchez-Mateos, H. S. and Givoni, M. 2012. The accessibility impact of a new High-Speed Rail line in the UK – a preliminary analysis of winners and losers. *Journal of Transport Geography* 25: 105–114.

Mumbai Metropolitan Region Development Authority (MMRDA) 2008. *Comprehensive Transportation Study (CTS) for the Mumbai Metropolitan Region.*

———. 2008. *Mumbai Metropolitan Regional Development Plan.*

Pal, S. 2016. High Speed Rail in India: Selection of Corridors and Impact of Emissions. TERI. 2 May http://iced.cag.gov.in/wp-content/uploads/2016-17/NTP%2003/SP.pdf.

Preston, J., Albalate, D. and Bel, G. 2013. The economics of investment in high speed rail. *Public Administration Review* 30(3): 336–349.

Wang, L., Liu, Y., Sun, C. and Liu, Y. 2016. Accessibility impact of the present and future high-speed rail network: A case study of Jiangsu Province, China. *Journal of Transport Geography* 54: 161–172.

Xu, W. (Ato), Zhou, J., Yang, L. and Li, L. 2018. The implications of high-speed rail for Chinese cities: Connectivity and accessibility. *Transportation Research Part A: Policy and Practice* 116: 308–326.

Yu, M. and Fan, W. 2018. Accessibility impact of future high speed rail corridor on the piedmont Atlantic megaregion. *Journal of Transport Geography* 73(September): 1–12.