COMPARISON OF HSR LINES IN TURKEY AND THE WORLD AND THEIR SPATIAL IMPACT: A CASE STUDY OF THE ANKARA–KONYA HSR LINE

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ABSTRACT

High-speed train services have been implemented in many different countries of the world since it was first introduced in Japan in 1964. High Speed Railways (HSRs) are it extremely attractive for countries due to rapid travel with high speeds among long-distance settlements. HSR investments have increased in recent years in Turkey after the determination of HSR developments as a national policy by the Turkish Government. 888 km HSR lines were constructed between Ankara-Eskişehir, Ankara-Konya and Ankara-Istanbul from 2002 to 2014.The aim of this study is to find out how HSR lines effect the distribution of population, labour capacity, time efficiency as well as urban sprawl in the Ankara-Konya region. To explore the impact of HSR lines, a new model is developed to satisfy the former goals, model computes the data not only from the statistical part also estimation of the future activity distributions. Basically, there are two main components in the developed model. First is to calculate the accessibility of HSR in the region. The second to figure out HSR's spatial impact in the city. A utility function has been composed and interviews have been conducted with HSR passengers. Besides, public transport system also examined in terms of accessibility in the second part of the model. In addition, the study reveals the socio-economic and spatial effects of HSR lines to Ankara-Konya region, which is the first implemented line as a new one in Turkey.

Keywords: high speed train, accessibility, spatial impact.

1 INTRODUCTION

So far HSRs are the basic dominant transportation modes for the last decades not only for developed countries also for developing countries in terms of making connections between regions and cities. In addition, by the HSR systems, railways can compete with other transportation modes and make corridors to enhanced regional development. As seen in Table 1 could be realized, railway future is as brightly as it never happens before since 19th century. Today, HSR systems are completed, under construction or planned in 39 countries and whole length of railway lines are 89,347 km (Table 1).

Since the inception of high-speed train service in Japan for the first time in 1964, it has been the subject of discussion of many scientific studies and reports. These studies are commonly arranged from the point of economic view; infrastructure and costs [1]–[3] engineering services, deploy, performance and fertility [4]–[7]. Besides, there are also some studies which are about the social, cultural and spatial impact of high speed railways (HSR) such as [8]–[15]. Most of these studies argue that HSR systems have a significant transform effects on the time distance, spatial development and social convergence. On the contrary, there are also some studies which show that HSR systems have some disadvantages from the point of spatial equity [16] or some small cities suffer by not being in the HSRs network [17].

HSR issues were discussed in Turkey simultaneously with the other countries. For instance, HSR systems were discussed in the Second National Plan meetings in 1968 [20]. However, the first HSR line construction was started in 2005 and run in 2009 between Ankara and Eskişehir in Turkey. There was a conventional line in the same route until the HSR service run between the cities. Moreover, another new line also constructed between Ankara-Konya and there wasn't a railway service since HSR line constructed in this route.

WIT Transactions on The Built Environment, Vol 176, © 2017 WIT Press
www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/UT170471

Thus Ankara-Konya HSR service is the first, modern and terminologically the first HSR line in Turkey and it was started to run in 2010.

In substance, this study aims to show how HSRs effect the selection of transportation modes, enhance accessibility, distribution of population in a city and spatial choice. To show the impact of HSR lines, a model has been used to satisfy the former goals, model computes the data not only from the statistical part also estimation of the future activity distributions. Basically, there are two main components in the model. One is to calculate the accessibility of HSR in the city and region. The second one is figured out the spatial impact in city. A utility function has been composed and interview made with the passengers of HSR.

Table 1: HSRs; run, under construction and planned lines according to countries [18], [19].

Country	Run	Under construction	Planned	Total
Australia	0	0	1749	1749
Austria	48	218	0	266
Bahrain-Qatar	0	0	180	180
Estonia, Lithuanian, Latvia	0	0	740	740
Belgium	209	0	0	209
Brazil	0	0	511	511
Canada	0	0	1590	1590
China	23914	10730	1525	36169
Czech Republic	0	0	890	890
Denmark	0	56	0	56
Egypt	0	0	1210	1210
England (UK)	113	0	543	656
France	2142	634	1786	4562
Germany	1475	368	324	2167
India	0	0	4630	4630
Indonesia	0	0	730	730
Iran	0	425	870	1295
Italy	981	67	221	1269
Japan	3041	402	179	3622
Kazakhstan	0	0	1011	1011
Malaysia-Singapore	0	0	350	350
Mexico	0	0	210	210
Morocco	0	183	480	663
Netherland	120	0	0	120
Norway	0	0	333	333
Poland	224	0	1127	1351
Portugal	0	0	596	596
Russia	0	0	2978	2978
Saudi Arabia	0	453	0	453
South Africa	0	0	2390	2390
South Korea	657	120	49	826
Spain	2871	1262	1327	5460
Sweden	0	0	740	740
Switzerland	144	15	0	159
Taiwan-China	354	0	0	354
Thailand	0	0	2877	2877
Turkey	888	599	1334	2785
USA	362	483	1029	1874
Vietnam	0	0	1600	1600
Total	37543	16079	36109	89731

2 COMPARISON OF HSRS IMPLICATIONS IN THE WORLD AND IN TURKEY

2.1 Current circumstances in HSRs in the world and in Turkey

There isn't a unique explanation of high speed train (HST) even it defines mostly exceed 250 km/h speed [21]. In terms of this explanation Shinkansen is the first HST services which was firstly managed in 1964 although the speed was achieved 200 km/h in 1903 and in France, 331 km/h in 1955. However, these speeds are not the operating speeds [8], [22].

Narrow or wider gauge couldn't allow to make high speed such as 250 km/h or more, so modern HSRs lines need to run into standard gauge. In some countries, new HSR lines are constructed apart from the conventional lines as Japan, Spain, Turkey. Therefore, HSRs investments are so much expensive because of construction costs and high land price. On the other hand, as Givoni cited French TGV systems also reduce the construction cost by using the conventional lines in city centers [23]. This shows that HSRs and conventional lines also could be run together. Moreover, German ICE managed a mixed-use line, namely it is used for both passenger and freight transport [8]. By this way, basic expensive construction cost argument of HSR eliminated.

China's HSRs systems need to be mentioned in apart. As of 2007, there is no HSR line in China. However, just in last decades more than 23,000 km HSR lines constructed and half of this number is under construction. After all constructions accomplished, total length of China's HSR lines will be 36,169 km and this is almost half of whole length of HSR lines in the world. China's main aim is to connect all provincial cities with other big cities and make a HSR network connection. This connection enhances the accessibility of cities conspicuously [24]. Additionally, HSRs investments are found to have a strong and positive effect on national and economic growth and social welfare [7].

The construction of Ankara-Eskişehir line, which started in 2003, was completed and run in 2009. Before the construction, there was another conventional line in the same route. Basic improvement for HSR line is to reduce time between cities. By HSR line it reduces 1 hour 25 minutes from 2.5 hours. However, even the line updated use a tilting mechanism as suitable for high speed train, herewith the line didn't construct newly. All curves, gauge and other technical notions is suitable for conventional line. So terminologically it isn't true to call this line as HSR line.

Second HSR line was constructed between Ankara-Konya. This line has some differences compare to Ankara-Eskişehir line. First of all, there wasn't a railway between the cities since HSR line constructed. Thus, whole route is designed for high speed trains. The line construction was ended in 2010 and run in 2011. Total line is 306 km and it takes only 1 hour 15 minutes from Ankara to Konya. It is extremely important for Konya due to time reduce. Before HSR line, it takes nearly 3.5 hours by bus and 2 hours by car.

According as the TCDD Annual Report 2015 total length of HSR lines is 888 km. Moreover, 405 km of Ankara-Sivas and 194 km of Ankara-Afyonkarahisar HSR lines are under construction. Ankara-Eskişehir, Ankara-Konya, Ankara-İstanbul and Konya-İstanbul lines are in operation in order of 2010, 2011 and 2014. Total passenger number is more than 23 million and total income from passengers is nearly 500 million TL (150 million $).

2.2 New horizons for HSRs

HSR systems make a big deal with shaping of cities, discontinuous spaces and time reduces. Besides, it is creating strong polarizations around the station and in the city. In most of the

cases, HSRs are good opportunities for cities to change the relationship between the city and region as well as infrastructure [25]. Today, HSR systems more than a transportation mode. It played an active role by cities and regions through government intervention [22].

While HSR lines are being constructed, technological and mechanical systems also have been improved. In terms of speed, the MAGLEV (Magnetic Levitation) technology is an upgrade of high speed train. The technology based on electromagnetic forces to cause the vehicle to hover above the track and move forward at theoretically unlimited speeds [8]. As Takagi cited from EU Research "Although there are, no doubt, some who dream of trains achieving even higher speeds, this is not a realistic prospect. Noise, vibration, the cost of maintaining the track and rolling stock, and energy consumption (up by 50% for an increase in train speed from 300 km/h to 360 km/h) would all increase excessively for just a marginal time-saving" [26]. The manner still carries on and it needs some new prospects to balance the cost and benefit.

After a successful privatization and division of Japanese National Railways (JNR) in 1987, many EU countries privatized their railways in the 1990s [26]. Same process is going to be continue for Turkish State Railways (TCDD). TCDD's administration is divided into 2 groups: one is responsible for infrastructure and other is going to manage the travels and

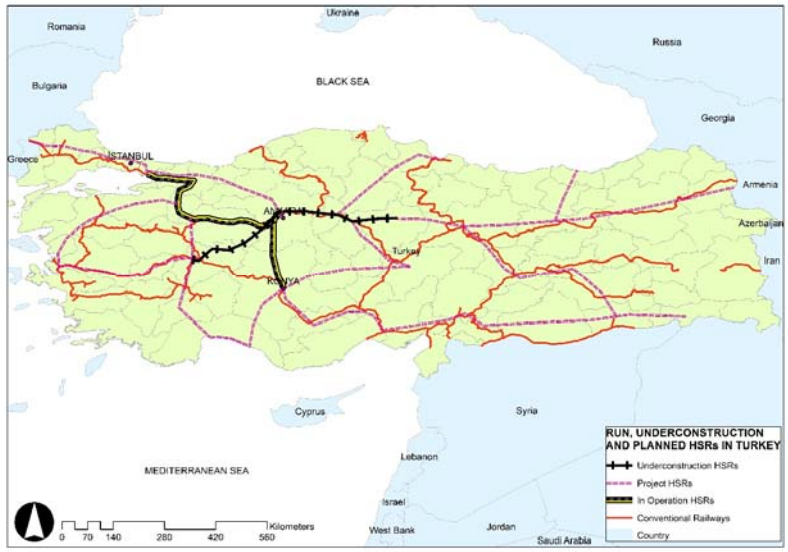

Figure 1: Railways map in Turkey. (*Source: Map is drawn by authors by using TCDD (Turkish State Railways) data and annual reports.)*

Table 2: Total passenger numbers annually carrying by Turkish HSRs [18].

HSR Lines	2010	2011	2012	2013	2014	2015
Konya-Ankara	0	406,636	1,371,369	1,744,605	1,890,320	1,437,291
Konya-İstanbul	0	0	0	0	30,776	527,604
Ankara-İstanbul	0	0	0	0	992,098	1,564,249
Ankara-Eskişehir	1,889,666	2,149,879	1,978,155	2,264,394	1,924,431	1,019,845
HSR Total Passenger	1,889,666	2,556,515	3,349,524	4,207,324	5,085,697	4,548,989

Note: 2015 data is as of 19th October of 2017.

other stuffs. It is expected that in a few years, second part of TCDD, which is called TCDD Taşımacılık A.Ş. today, will be privatized same as Japan and other EU countries. Main important thing in HSR investments is expensive construction costs. Except China, it looks hard to construct a HSR line without state subsidies. In a near future, other developing countries may try to use the same method as Japan or EU countries. Likewise, there is a big improvement on the other transportation modes. Especially in air transportation, flying cars could be change all our thoughts [27]. Perhaps, it seems to use it so far in a short time but as we know that, railway investments once constructed, it is used more than hundred years. During this process, all indicators must be evaluated in terms of using effective public sources.

3 CASE STUDY

3.1 General information about case area

The first settlement in Konya was settled in Catalhöyük in south-east part of Konya 8000 years ago. Thus, Konya has a long historical heritage from the point of archaeological evidence. Therefore, the city was the capital of Anatolian Seljuk Empire. As a result of this, there are so many historical place and monuments in the city. So, it makes the city a tourism hub in the center of Anatolia. Nearly 1.3 million tourists visit the city annually. Today, more than 2 million people live in Konya. Moreover, there are 3 universities in the city and 125,611 students educated in the city (Table 2). Besides the city has 6 industrial zones and more than 100 thousand people work in these zones. On the other hand, the city far from the capital of Turkey-Ankara just 258 km as well as Istanbul is 662 km away from Konya. So far the city Konya located in the crossroad center of Anatolia and it is easy to reach the city from north to south and west to east part of Anatolia. There is an international airport close to city in which there are 9–10 flights in a day according as the different airline companies.

Total settlement area, including commercial, educational, health and other daily facilities, is about 22,457 ha according as land use data. Industrial zone areas are covered 6,532 ha of city (Fig. 1). To sum up total area is 28,989 ha and modelling area is nearly 830 ha (3% of whole study area).

3.2 Survey analysis

3.2.1 Accessibility analysis

HSRs are very efficient in terms of time distance between 250–750 km. Outside of these distance bus, conventional trains, car and air transportations are more efficient compare to railways [8]. The distance of cities in which the accessibility measures are calculated for them are given in the Table 2.

Table 3: General statistical data for Konya [28]–[31].

Years	Population (Person)	Employee (Person)	Student (Person)	Tourist (Person)
2010	2,013,845	389,004	76,166	1,803,375
2011	2,038,555	419,620	84,324	1,926,015
2012	2,052,281	446,286	92,616	1,811,335
2013	2,079,225	455,335	104,153	2,313,293
2014	2,108,808	475,984	111,800	2,298,027
2015	2,130,544	499,531	125,611	2,254,689

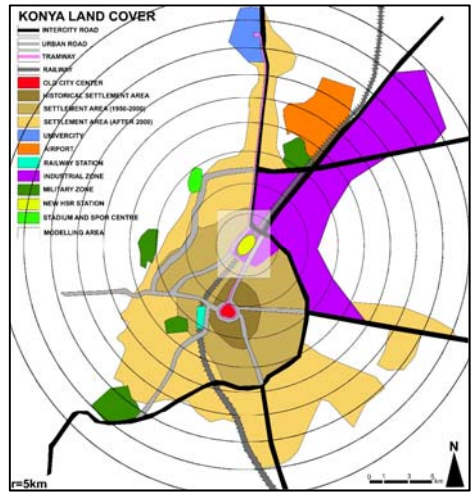

Figure 2: Land cover of Konya. (*Source: Map is drawn by author by using Konya Metropolitan Municipality data and satellite photos.)*

Accessibility analysis is one of the input indicator in order to calculate the utility differences of transportation modes or destinations [32]. Therefore, it has been used in different aspect of travel demand forecasting, location choice and appraisal of land-use changes [33]. Beside as Chandra and Vadali also studied an accessibility analysis of USA Appalachia region; accessibility effects not only from the point of distance also economic activities in the region [34].

In most of the accessibility studies there is a basic equation to calculate the time differences between the cities. To carry out this study, basically there have been calculated three indicators which are duration, distance and population as shown in the eqn 1:

$$A_i = \frac{\sum_{j=1}^{n}(T_{ij}.\ln M_j)}{\sum_{j=1}^{n}(\ln M_j)}, \quad (1)$$

where A_i refers the accessibility of city i, T_{ij} refers to the travel time and M_j refers to the population of city. To eliminate the effects of the population difference and determine the travel time impact, a logarithmic exchange has been made to the number of population.

Accessibility analysis also gives the distribution of population in a city according to their location choice in terms of train station. By this way, not only regional accessibility, also inner-city accessibility is determined to find out the distribution of passengers in the city which is mentioned in spatial analysis part.

For automobile trips speed is 120 km/h in autobahn and 110 km/h for other intercity roads. HSR and airline trips time is calculated from the departure and arrival time from train station and airport. Spending time in the city and other transportation modes don't calculate in the duration. Intercity buses give a break for each 3 hours. Time is calculated according to this data.

Table 4: Distance and duration (minutes) according to the transportation modes between the cities of Konya, Ankara and İstanbul. (*Source: Distance derived from [35]. Durations are calculated by authors according as legal speed limit.)*

Modes	Automobile			HSR			Bus			Airline			Distance (km)		
City	Konya	Ankara	Istanbul	Konya	Ankara	Istanbul	Konya	Ankara	Istanbul	Konya	Ankara	Istanbul	Konya	Ankara	Istanbul
Konya	0	150	435	0	103	278	0	200	545	0	0	70	0	258	662
Ankara	150	0	200	103	0	255	200	0	420	0	0	60	258	0	453
Istanbul	435	200	0	278	255	0	545	420	0	70	60	0	662	453	0

Table 5: Accessibility index. *(Source: Index are calculated by authors.)*

	Ai (Automobile)			Ai (High Speed Train)			Ai (Bus)			Ai (Airline)		
	Konya	Ankara	Istanbul	Konya	Ankara	Istanbul	Konya	Ankara	Istanbul	Konya	Ankara	Istanbul
Konya	0	72.77	211.03	0	53.03	147.59	0	102.97	289.35	0	0	37.16
Ankara	77.23	0	96.79	49.97	0	131.6	93.82	0	216.75	0	0	30.96
Istanbul	224.49	103.21	0	130.41	123.4	0	255.65	203.25	0	37.16	30.96	0

Table 6: Transformation of passenger choice between transportation modes [36].

Transportation mode	Ankara-Konya (%)		Ankara-Eskişehir (%)	
	Before HSR	After HSR	Before HSR	After HSR
Bus	70	35	55	10
Automobile	29	11	37	18
High-speed train	-	54	8	72

When the accessibility index is examined according to the transportation modes, it is clearly seen that high-speed train improved the accessibility between the cities. This makes a big change on the transportation mode choice. As seen in the Table 4, most of the bus and automobile passengers give up their mode and select high-speed train. On the contrary, bus transportation is the most suffer modes between Ankara-Konya and Ankara-Eskişehir. As it is seen in Table 6, opening a new HSR line can affect the demand on the route as well as changing the connections, pattern of network usage and performance [5]. Most of the bus companies, in which work on these lines, decrease their trips and dismiss their employees.

3.2.2 Spatial impact analysis

Over the last 30 years, the spatial modelling systems and programs have been increased so much. Cellular automata was studied in the early 1950s by Wolfram [37] and he called cellular automata; simple to allow detailed mathematical analysis, but complex to exhibit a wide variety of complicated phenomena [38]. Cellular automata are used to analysis the changing of space according as defined cells. At this point, we can simply clarify it; space divided into the cells, these cells define one state of a function for a certain time and all cells are in an interaction between others. Thus, there is transition that drives changes of state in each cell as some function of what exists or is happening in the cell's neighborhood [39]. This is a useful way to make a simulation for future. However, the model doesn't compute

the social behaviors or policies. So, the modelling gives an indicator to forecast the future circumstances.

In the case study, spatial impact analysis has basically two steps. The first step is clarifying the accessibility index of each cells (Fig. 2) according as public transport and private car. Secondly a utility function (eqn (2)) is examined in each cell to find out the utility. Cells are defined into eight categories depend on their functional manners. These categories are: continuous settlement area, discontinuous settlement area, development area, commercial area, industrial area (OIZ, SIZ), green area, recreational area and empty area [10]. Continuous area clarifies the housing place in which the cell is fully settled. Discontinuous area is half of the cell is settled and the other is empty. Development area defines the place where new settlements are going to be constructed. There are two types of industrial zones. One is organized industrial zone (OIZ) and the other is small industrial zone (SIZ) area. Green area defines the park and other open space areas. Recreational area is consisting of the place in which people spend their leisure time such as aqua parks, enjoy facility areas etc.

$$U_t = c_i + W_g + W_r + W_a + W_e + W_t + W_s, \tag{2}$$

where U_t defines the utility of any transportation mode in a cell. c_i shows the tendency of an i person to a transportation mode. W_g shows the personal income. Wr shows the trip reason, Wa is the age of person, W_e ownership of a driving license, W_t shows the spending time for an i person and W_s shows the impact of security on an i person [40].

$$T^{tt}(i, j) = T_O(i, E_i) + T_{IV}(E_i, E_j) + T_D(E_j, j) + \tau p. \tag{3}$$

According to the eqn (3) public transport duration calculated. T_O shows the duration of walking time in which the distance from i point to nearest bus or railway station (E_i). T_{IV} refers to trip time that is spend in the car from station (E_i) to j arrival station (E_j). T_D shows the duration of walking time in which the distance from station (E_j) to j arrival point. τ_p is random variable and shows the unexpected delays or cancels [10].

$$T^a(i,j)=T_O(i, N_i) + T_a(N_i,N_j) +T_D(N_j,j)\,. \tag{4}$$

According to the eqn 4 private car trip duration calculated. T_O shows the duration of walking time in which the distance from i point to car (N_i). T_a refers to trip time that is spend in the car from N_i to N_j point. T_D shows the duration of walking time in which the distance from N_j to j arrival point. There would be roughly no delays or cancels because of car ownership. Thus there is no random variable in the car trip [10].

Modelling area divided into the cells. The size of a cell is 100×100 meters. Main cell is HSR station and all equations are calculated based on this cell. A utility index has examined for each cell by adding accessibility index and utility function results. All cells can turn an upper function which is defined before. In this study, transition of a cell to an upper function defines as [41]: recreational and green area > services (health, education etc.) > commercial area > residential area > industrial area>empty area.

So far, empty area turns into all functions. An industrial area turns into a residential, commercial, service or recreational and green area. Therefore, a residential area also turns into a commercial, service or recreational and green area but never turns into an industrial area. Recreational and green area is a public area and mainly in this study these areas are accepted never turn into another function due to public necessities. HSR station, which is the main cell for our study, effects all cells in terms of accessibility and utility. Zone distance is calculated as a 5 km radius where HSR station locates in the center of study area (Fig. 1 and Fig. 3) [10].

Basically, all transport investments aim to reduce the trip time. In Ankara-Konya route, the aim is achieved and people chose HSR mode. Meanwhile, it is clear that when a HSR service arrives in a city, it effects the economic activities and land use distribution around the station, development of new residential areas and transport demands of passengers [5]. As it happened in the case study area, industrial zones are turned commercial and mix-used zones into. Therewithal, settlement choice of passengers is also directly affected by location of HSR station.

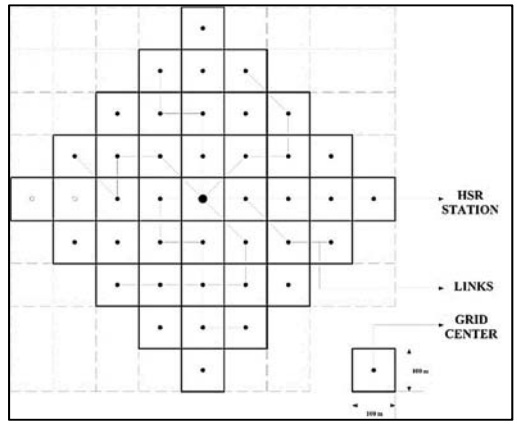

Figure 3: Scheme of cells. (*Source: Scheme drawn by authors.)*

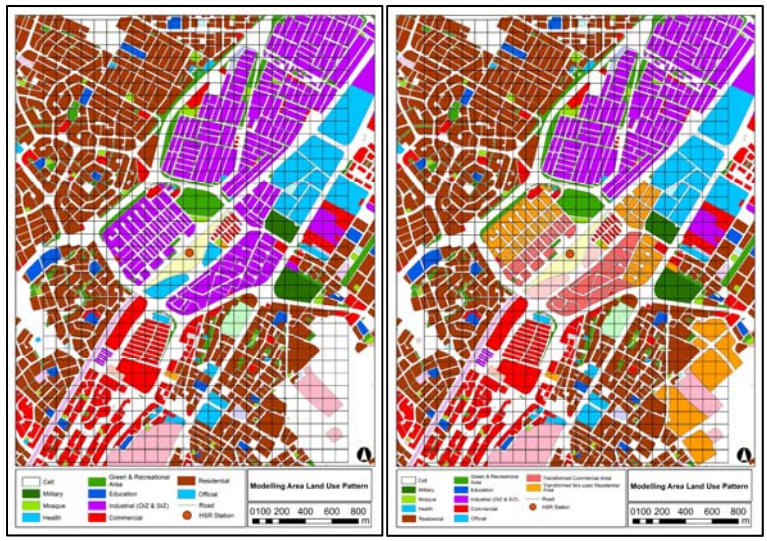

Figure 4: Comparison of scheme modelling area by land use pattern before and after the construction of HSR station. (*Source: Scheme drawn by authors.)*

4 CONCLUSION

There is not much literature about the impact of HSR systems in Turkey due to the fact that high speed train is a new transportation mode. For this reason, our study underlines the need for evaluating the effects of HSR systems from the point of accessibility and spatial impacts. It is clear that the study needs to be examined much detail various data. Especially, spatial analysis is very important to show the differences of land use pattern and functional distribution before and after HSR systems. Thus, the study contributes the literature on HSRs from the point of Turkey HSR investments.

The relationship between HSR station and transportation mode has positive manner. It is easy to say that people choose HSR systems if the ticket price is affordable and the time saving is acceptable. The study shows that how a transportation mode can change the passenger demands and spatial distribution by a public investment. To achieve these aims, whole transportation systems have to be integrated and new settlements and big activity functions must be located according as HSR stations.

Spatial equity is less examined issue in the study. As Kim and Sultana (2015) mentioned HSR systems could be an important element to enhance the spatial equity between the regions [12]. On the other hand, by HSR systems reducing the regional divergence, some other small cities, which are not located in the HSR corridor, can suffer from the polarization of economic and spatial circumstance [17]. At this point, there must be some inner connections to these cities in order to eliminate the negative impact of HSR systems. Besides HSR service can be re-developed around the station by re-producing the land with a suitable function as residential, industrial, commercial, educational, recreational and so on.

There are also much topics needed to be solved in Turkey. One of them is integration of HSR systems to the Europa lines. Endogenously Turkish HSR systems could run in some routes such as Ankara-Konya or Ankara-İstanbul. However, compare the whole HSR projects, it is difficult to claim that it would be as successful as the formers. There isn't enough evidence to prove this claim. Even three of Turkish HSR lines run efficiently, future investments are planned carefully in order to avoid unnecessary constructions because of expensive construction costs. Besides, without Europe and Asia connections, Turkish HSR lines don't make sensible adequate contribution to enhance the spatial equity. At this point, perhaps we need to ask a question; is it possible to connect all HSR lines in the world and what could be the impacts of this situation?

ACKNOWLEDGEMENT

This study was funded during the survey by İTÜ BAP Offices. We here thank the office for their funding.

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