AN INVESTIGATION OF THE ADVANTAGES AND DISADVANTAGES OF PARALLELISM OF THE HIGH-SPEED INTERCITY PASSENGER RAIL WITH FREEWAY

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Abstract— The importance of railway industries is an inevitable subject, which has raised several debates among scholars. In this research, by reviewing, the projects implemented in the past, and considering the advantages and disadvantages of how they were examined, we tried to reveal disciplines and ideas for the future research on this notion. So that, future researchers can adopt these results to their problem of study and use it in a way that is appropriate to their problem conditions. This research will discuss about the possibility of implementation of high-speed railway tracks in parallel with highway or freeway routes, and evaluate this proposal's pros and cons.

Index Terms— High-Speed Intercity Passenger Rail, Freeway, ROW, Advantages of Parallelism.

1. INTRODUCTION

The dramatic growth of technology has changed the world of communication. Increasing the speed in railway transportation systems is one of the achievements of this technology, which obtained by designing new power converter topologies in electric and high-speed trains. The authors in [1] proposed a new combination of power converter topologies which can increase the efficiency as well as the reliability of traction motors. Besides, researchers in [2], [3] could present enhanced control methods to drive the traction motors of electric and high-speed trains using power electronic converters. Such advanced control strategies yield high-quality output powers and does not apply any harmful harmonics to the overhead contact system (OCS).

Nowadays, the rail transportation system as the safest communication system has gained more popularity. During the research on Western European countries, it was observed that high-speed railways run parallel to highways in many parts of the country, which raised questions that yielded interesting results through surveys and analyzes [4]. In addition to these results, in terms of operation, travel time and energy consumption are reduced and the field of real and continuous advertising is provided to attract road passengers to the railway system [5], [6].

In recent decades, in parallel with the developments that have taken place in various fields of industry, rail transport has also witnessed major developments, including reducing the headway of trains, increasing capacity and, most importantly, increasing the speed of trains [7], [8]. The operation of the first high-speed train in Japan in 1964 marked a turning point in the world's passenger rail transport, which led to the expansion of high-speed lines in Japan and other developed countries, including France and Germany. The development of high-speed rail transport is an important development to achieve the important role of railways in passenger transport [9], so that in many cases, and some airlines are in crisis.

High-speed railway is expanding around the world and as a healthy, safe and sustainable transportation, the system has proven its role in the social and economic development of the nations that use it [10]. Railroad and highway construction are typically studied independently. However, it has been observed in many countries that high-speed passenger railways run parallel to freeways [11]. A railway next to the highway has many merits and drawbacks, in this article; tried to explore this issue. The railway authorities and officials of the Islamic Republic of Iran have considered the feasibility study of the current freeway routes as the primary proposal in the design of railway tracks. This research will mention to high-speed passenger lines in comparison with airplanes and other means of transportation and mention its benefits [12]. (Fig. 1)

Fig. 1. An ICE 3 high-speed train on the Cologne-Frankfurt route parallel to the freeway.

A. A. The origin of the idea of the parallelism in construction B. of railway project along to freeways:

Mainly, due to high bandwidth on highways and freeways, it is necessary to acquire large tracts of land (according to the road area) in order to build highways on-site [13]. Freeways and highways are defined as a road with at least four lanes whose return routes are separated [14] and usually the passage of vehicles such as bicycles, motorcycles and the like is prohibited and for communication between important and crowded centers [15], [16].

However, these routes may also be used to some extent for the passage of commercial goods. Intersections on this route are mostly uneven and have a high design speed. According to the above definition and also the definition of highway-right- of-way, it seems reasonable and possible that by considering a geometry limitation for railway lines, it would be possible to construct such this plan, in other words, railway tracks beside a freeway [17], [18].

This will be useful because it is necessary to acquire the route and its land possession for any route, whether road or railway, and at the same time we can see the necessary preparations for the construction of two transportation routes. Because the issue of land possession will leave a lot of delays and challenges in the completion of the project [19], some of which are mentioned below [20]:

- Increasing the cost of immunization project
- Inflation effects on land prices, real estate
- A decrease in the value of budget allocated for land acquisition
- The cost of creating temporary roads
- Wasting and idling equipment during the land possession
- Increase material costs during the project

In this stage of the feasibility study, the question can be asked at this stage why the railway is only along the highway and cannot be along the main road? The answer given to this matter is related to the aim of a highway and main road construction. Highways are mainly built between two main areas in terms of various cases (commercial, population, trade union, etc.). While the main roads between the two cities are relatively important in terms of population attention is being constructed.

In fact, the highway can pass through several cities without interrupting the process and reducing the speed of passing vehicles; In other words, in highways, they are mainly built from origin to destination, and communication with it, as mentioned, is done through non-level intersections. Therefore, due to the speed of the route, the importance of the highway, a significant number of people use it [21].

The presence of a passenger train along the road can create benefits such as proper service through the road to the railway and the possibility of joint use of single buildings in the sections crossing the rivers, or in some tunnels can be used by road and rail [22]. One of the most important and costly parts of building a road is its heavy construction; and for two separate routes from a river, the construction of two bridges will cost a lot, while for the deck of a bridge, it costs less than the construction of a separate bridge which can be seen in Fig. 2 [7], [23].

Fig. 2. George and King Bridge, including a railway bridge beside a road bridge.

The point that can be mentioned here is the increase in traffic due to different work, treatment issues, education, trade, etc. A clear example of which in the current world is such as France, Belgium, England, Germany, Switzerland, Italy, Spain, and the Netherlands, as well as Japan can be seen. The principle that makes the aforementioned European countries think of building a network of railway along highways or freeways is becoming more and more felt and they are trying to improve and expand their lines. So that now this network of important cities such as Paris, Lyon, Madrid, it connects Amsterdam, Brussels, London and Cologne [24]. Due to the remarkable speed of this network, safety, and reduction of travel time, more attention is being paid by the general public (workers, traders, etc. [25].

b. Comparison of high-speed railway Right-of-Way with freeway

The size of the railway stations is determined by the station committee according to the type of station, whether passenger, freight, or organizational, and the amount of traffic and geographical location [26]. Right of way for high-speed railway tracks is determined up to 20 meters from each side in the 394 instruction Fig. 3). Likewise, properties of road-right-of-way in Iran Highway Geometric Design Code which is determined in table1.

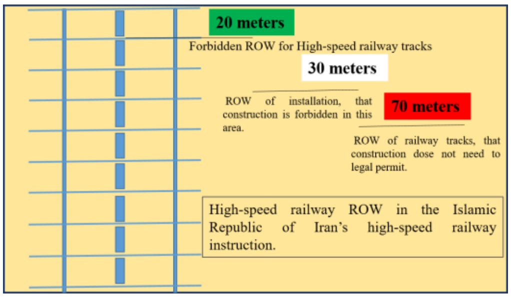

Fig. 3. High-speed railway ROW in the Islamic Republic of Iran's High-Speed railway instruction.

Types of road	Distance(meter)
Freeways	60 meters
Highways	38 meters
Main Roads	22.5 meters
Diversion Road	17.5 meters
Rural Roads	12.5 meters

Table 1. Properties of ROW for types of roads in Iran

c. Reduce land occupation and be environmentally friendly:

The traffic volume transferred by a high-speed railway train is more than the traffic volume transferred by the airport or the highway, and according to the required space. For example, the construction of 1,300 kilometers of new lines across a corridor will cover about half of the area required for the construction of a new airport. Transportation capacity to the occupied land area is an important indicator for comparing land transportation methods. This indicator has been compared in high-speed and freeway railways. As it turns out, this indicator is 3 times freer on high-speed rail (Fig. 4) [27].

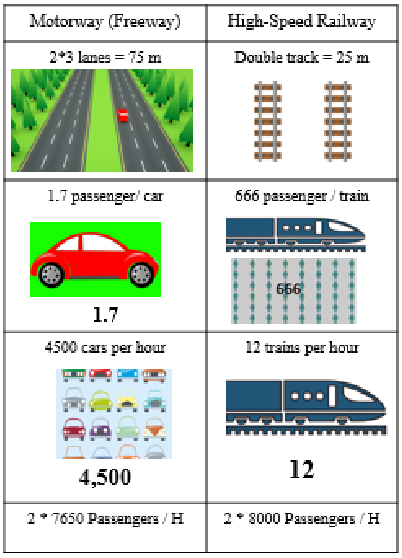

Fig. 4. Relationship of infrastructure volume and productivity

2. DISCUSSION

In the Iranian regulations, the maximum slope and ascent of highways is mentioned up to about 9%, which can continue at different lengths, but the maximum length of the ascent will be up to 3000 meters. Of course, these values are a limitation for a heavy vehicle and not a problem for a light vehicle. In general, regulations have tried not to reduce the speed to at least 20 kilometers per hour so as not to slow down the movement of other vehicles.
In [11] the maximum slope value on highways is 6 to 7%. In English regulations, the maximum slope is limited to 6%, which is mentioned in [11]. Restrictions are applied to the maximum length of these slopes so that the minimum speed of light vehicles does not decrease from the design speed during that length and to maintain the capacity of the highway at the above sections, an extra width may be considered. In any case, a slope limit of 6% or 7% will also be useful for railways. Considering to aforementioned restrictions, the possibility of constructing railways tracks along freeways and highways will not be a problem. Although in some areas the roads and railways will not be able to move perfectly side by side, the distance will not be too great.
Apart from the above, the radius of the arches can also be considered. This is one of the most important issues that can limit the speed and parallelism of railway with highway. In the usual ways for various reasons, including low design speed, arches with a smaller radius can be used, but on highways to maintain the necessary speed and capacity, this value should remain within a certain range. For example, in Iranian regulations, the minimum radius of arches in the amount of 120 meters with a transverse slope of 8% is equivalent to the maximum transverse slope in high-speed trains. Of course, the radius of the arch in trains is preferred to be considered much higher than the above value, so that the optimal radius of the arc is 1000 meters (if we want to maintain the desired speed), but the arrival of trains that can add an angle to Trains that are called in Tilting, reduces this amount.

Using the tilting train (Fig. 5) that has an additional angle change of about 8 degrees. In the routs that have specific arc radius, by using the tilting technology, the train can move in a smaller radius. Also, according to the CEC Alstom, it is possible to travel at a speed of 110 km / h using a tiling train within a radius of 350 meters, while without the possibility of tilting, it can remain at a speed of 95 km / h.

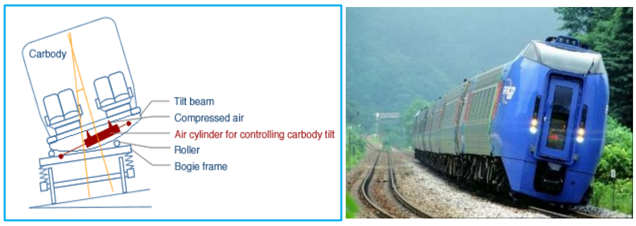

Fig. 5. Tilting train mechanism

In a higher radius, this value increases so that in a radius of 1000 meters, with the possibility of tilting the speed of 190 and without it, the speed of 160 km / h is possible. This technology increases the coefficient between 15 to 20 percent totally, and is intended for trains with tilt of 6 degrees. In any case, according to the speed of the project, it is possible to move in different curves and the adaptation of the railway to the highway will not be a problem [28].
Due to the proximity of the existing criteria and regulations in the routing of highways and railways, it seems that the optimal route for the highway is very close to the optimal railway route.
Therefore, choosing of parallelism proposal of railway with the highway as the base route for designing the passenger railway route can be useful and remarkable. There are other benefits to the implementation of railroad next to a freeway or highway, including the following:

- Relative reduction of cost and time of feasibility study and route selection [29].
- Adequate opportunities to buy land cheaper and easier
- Relative reduction of funding and allocation budget
- Relative reduction of cost and time of preparing executive drawings
- Relative reduction of execution time and cost (especially infrastructures like bridges, tunnels, trenches, …)
- Reduction of construction costs of joint terminals (bus, subway, etc.) (Fig. 6)
- Continuous advertising to attract passengers to the railway section. (Fig. 7) [30]

- More ease in preparing a comprehensive and detailed plan of cities and satellite towns
- More ease of maintenance activities and higher safety
- Increasing the speed of mutual assistance in terms of accidents or natural disaster [31].
- The better psychological effect of safety speed for the passenger
- Less harmful effects on the environment [32].
- Quick and easy access and use of road equipment in collecting railway accidents

However, in special cases, due to the limitations, it is possible to break up the parallelism with the highway to the extent necessary to satisfy these limitations.

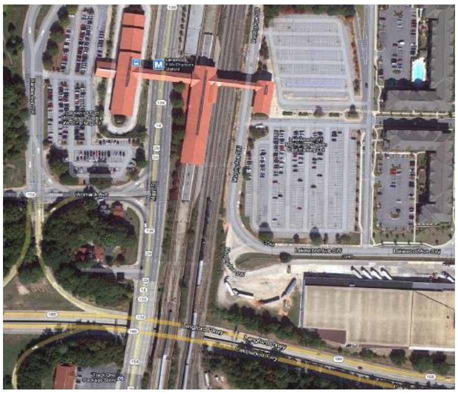

Fig. 6. Example of creating joint stations in Florida, USA (Using Google earth pro software).

Among the disadvantages that can be considered for the implementation of this project can be mentioned as follows:

- The high cost of implementing an intelligent control system [34].
- Increasing the possibility of collisions and accidents in this proposal if maintenance is not controlled continuously, also do not use protective walls for clearing the freeway and railroad right-of-way.(See Fig. 8)

Fig. 7. Endless advertising to attract passengers to the railway sector (Wikipedia: The WCML running alongside the M1 at Watford Gap) [33].

Fig. 8. Use of sound absorbing walls along railway routes

Experience the world in the parallelism of high-speed railways with freeways or highways: In this part, a large part of the parallel projects of high-speed railways with freeways and some highways, such as China, Germany, France, etc., are discussed, and as an example, the geometric design specifications of some of them are mentioned:

1. China

In [11] has mentioned that, the Shanghai Maglev works within the center (See Fig. 9) and along the north side (See Fig. 10) of Yingbin Freeway, and within new and other highway ROW for a share of the 30 km route with a maximum speed of 430 km/h between the Pudong Airport and Shanghai.

Country	China
Length of rout	30 km
Percentage of parallelism	90 %
Travel time	8 minute
Type of track	Maglev
Speed	430 km/hour
Inclination(per thousands)	2

Fig. 9. Aerial image with longitudinal profile in Shanghai and specifications of the parallel path geometric design (Using Google earth pro software)

Fig. 10. A side view of a railway and highway parallel project in Shanghai, China

1. Germany

In Fig. 11, The Cologne-Frankfurt ICE route involves dominantly of a new, dedicated track, and 140 km of the route (71% of the total route) parallels the A3 autobahn. (International Union of Railways, 2010). A new high-speed track suggested between Wendlingen and Ulm, Germany, would also possess a plethora of segments adjacent to the A8 autobahn. (See Fig. 12, Table 2) [11].

Fig. 11. Parallel high-speed rail with the Autobahn in Germany (Cologne-Frankfurt ICE route) [4].

Fig. 12. A view of parallel projects in Germany (right of Cologne Frankfurt, left of Wendlingen–Ulm) (Using Google earth pro software).

Table 2. Geometric characteristics of the parallel route of railway next to the freeway in Germany

Name of rout	Wendlingen and Ulm	Cologne-Frankfurt
Length of rout	30km	140 km
Percentage of parallelism	60%	71%
Type of track	Ballasted track	Ballasted track
Speed	300 km/hour	320 km/hour
Slope and ascent (per thousands)	40	8

2. France

The first TGV route (the Paris Sud-Est) started operation in the early 1980s and runs between Paris and Lyon parallel to existing highways for only 14% (60 km) of the total path. Increasing worries regarding the land use and environmental impacts of new HSIPR lines led to a soar percentage of French TGV routes operating within or parallel to the existing motorway, railway, or abandoned railway corridors. Operational since 1989, the TGV-Atlantique follows existing ROW, for instance abandoned and existing rail ROW or motorway ROW, for approximately 60% of its length from Paris to Courtalain (Streeter, 1992). (See Fig.12) The Paris to Lille TGV Nord route that began operation in 1993 operates parallel to motorways for 41% (135 km) of the total route length (International Union of Railways, 2010). Another railway track operates parallel to A432 (See Fig. 13, Table 3) [11].

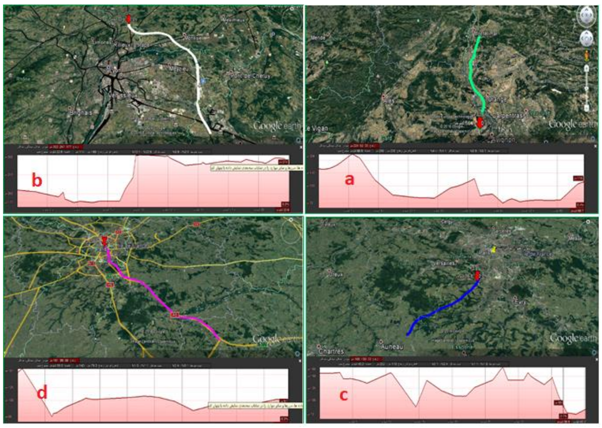

Fig. 12. A view of parallel projects in France (Using Google earth pro software)

Fig. 13. (a) Two-way TGV lines adjacent to the A432 highway, (b) Parallel high-speed railway with the A1 motorway on the route from Paris to Lille in France

Table 3. Geometric characteristics of high-speed railways close to highways in France

Fig.	a	b	c	d
Rout	Montela to Avignon	Near to Lyon	Paris to Courtalain	Paris and Lyon
Length of rout	66	16.5	42	60
Percentage of parallelism	85	12	60	14
Type of track	Ballasted	Ballasted	Ballasted	Ballasted
Speed (km/h)	320	270	300	280
slope and ascent (per thousands)	12	41	6	12

3. United Kingdom

To make available a faster corridor from London to the Channel Tunnel, a channel tunnel rail connection, currently managed by High Speed 1, was fabricated and originated HSIPR operation in 2003. For much of the distance, the rail link is adjacent to the M20 motorway and the A20 trunk road. A total of 60% of the track (55km) is within present road or rail transportation corridors. (Fig. 14) [11].

Fig. 14. HSIPR (High Speed 1) in the UK.

5. Italy

To decrease land acquisition and environmental influences, the Italian HSIPR organization predominately functions adjacent to existing motorways. For example, 71% of the Milan (Milano) to Bologna HSIPR route parallels the A1 autostrada for 130 km (about 80 miles) (International Union of Railways, 2010). Fig. 15 shows the Milan-Bologna HSIPR tracks within proximity of the highway. The Turin to Milan line segment runs adjacent to the A4 autostrada.

Fig. 15. The Milan–Bologna high-speed railway track, beside the Autostrada del Sole, in the municipality of Pieve Fissiraga (Wikipedia)

3. CONCLUSION

The problem of the railway parallel to the freeway can be considered as a primary route for the design of the railway route result in its advantages. Due to the proximity of standards and regulations related to freeways and railways, the optimal route for railways (especially passenger railways) can be compatible (and parallel) with the freeway route. At the same time, in special cases, due to the limitations, it is possible to move away from the parallel of the freeway to satisfy these limitations. It is possible that the implementation of the parallel plan and placing the parallel benefits quantitatively in the objective function when navigation of the railway and freeway can be in the direction of transportation studies and development, either in terms of reducing the cost of feasibility studies and construction, or in terms of continuous promotion. Rail transport will play an important role. Therefore, studying the possibility of parallelism in other parts of the country can be considered an effective step in the implementation of high-speed railway tracks along freeways.

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