

# Tehran station improvement and plan for enhancement of medium and high-speed trains

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#### ABSTRACT

One of the latest trends in the transport field is the increasing interest for the rejuvenation of the railway.

Terminals and stations are the junction points between the various lines that constitute the railway network and can simply be described as points of arrival, departure and interchange of passengers or commodities.

The most commonly used indicators that measure the level of their performance are time and cost.

This study aims at exploring possible improvements that could be implemented to the infrastructure and the operation of Tehran station in order to increase the efficiency level.

The study of the station has done in Tehran to get the correct and useful information and data taken from ministry Iranian railway system.

Firstly, drawing upon grounded theory about rail infrastructure and terminal, a description is conducted, followed by a comparative analysis of existing station.

Secondly, the suggested improvements are presented in accordance with application used for more efficiency of station.

The main contribution of this study is to illustrate the high significance of station, acknowledging them as crucial parts of the railway network, because as characterized and demonstrated in this study, their performance are key factors to the whole network performance, making the identification of their critical points and respective possible solutions, the final objective of this paper, in addition to this,

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emphasis is given to the need of improving and developing the existing terminal infrastructure and operations.

And forecasting the passengers growth in future is key factor for design the station.

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## 1) Introduction

Railways are very important in our society and their operation and expansion are incredibly important. They are important, as they allow passengers and freight to be transported across vast distances. Rail networks are complex systems and consist of many different train types, corridors, and services.

The history of rail shows that it can be used as an efficient transportation mode to move goods and passengers.

Building efficient transportation systems, such as railways, can improve both local and global economies by allowing more goods to be transported, reduce greenhouse gas emissions, make highways safer and reduce road congestion. Congestion causes much lost time, and has a significant financial and environmental cost.

Rail terminals and stations<sup>[1]</sup>, are important parts of the railway network because of their function to ensure the mobility of passengers and freight. Indeed, almost all transit times are used for transhipment and shunting operations. Typical processes at these points of the railway network, should be optimised and have to be continuously improved.

This takes an effect on the used trains and terminals, but also offers new chances to develop ideas for a new terminal design.

In the first part of this paper are presented the existing terminal, defining main differences between distribution of trains at the tracks and control the utilization coefficients on application and choose the best value of the coefficient.

For each type, layouts are represented and indicators for objective evaluation in quantitative terms are proposed, being the most commonly used indicators that

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measure the level of their performance, time, and others that contain physical characteristics of the layout as capability, length of operating rails or approximate area.

After describing the different types of distribution of trains and regarding the change of the transported passengers by train, short, medium and long term improvement possibilities are explored in the second part of this paper, in order to outlook aspects of a future terminal.

There is a definite need for transportation systems that meet the needs of increased population sizes.

The importance of railways as a principal transportation mode has been demonstrated and there is a need for more research that facilitates the development of more advanced and efficient rail systems.

Railway station capacity analysis is considered in this thesis. Capacity analysis is necessary to identify the performance of railway networks. If efficient railways are to be designed, constructed and operated, then their performance must be identifiable and their capacity must be transparent. If railways are utilised more efficiently, then more passengers and freight can be transported long distances.

By virtue of this, railways become more desirable as a primary mode of transportation, and hence roads and other modes will be relied upon less, and will be less congested. Congestion causes much lost time, and has a significant financial and environmental cost. This necessary task remains difficult, because the definition of capacity is variable, i.e. it differs from country to country.

Some approaches have limitations, and there are some aspects of the problem that have not previously been examined or included.

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Railway station capacity can be defined in many different ways. The most common definition of railway capacity involves counting the number of trains that can traverse through the network in a specified time. This thesis has considered the concept of operation capacity. operation capacity determines an upper bound on the capacity of a railway station network.

This paper aims to show the using technologies or different methodologies. Because there is no single solution to achieve this goal, the possible solutions will refer to time periods of application and different needs of investment, depending on the characteristics of innovation, latest technologies and different proposed methods.

In particular, with regard to the long term period, the idea about the creation of a unique technologically advanced station that simultaneously handles the transport of passengers is promoted.

## 2) History of Iran Railways

Construction of railway in Iran was a great and national expectation<sup>[2]</sup>, which this national wish came to reality in 1927. October 15, 1927 marked the beginning of constructing the trans-Tehran railway; since the very time the construction of railway was commenced at three points from South – Centre and North.

When the trans-railway was on the verge of completion, the Ministry of Roads and Transportation was committed to construct the other lines; the first line the construction of which started following the trans-railway was the Garmsar – Mashhad line. Construction of the said line was commenced on 15 March 1937, its infrastructure and rail laying up to Shahroud station (315 km) completed in 1941 and its operation began; but the constructional work from Sharoud onwards stopped due to the World War II, till end of war and removal of impediments, once again construction of this line resumed in 1947 by the Ministry of Roads and Transportation and the budget assigned by the Planning and Budget Org., and completed on 7 January 1956.



Figure 1: first rail bridge built in Iran(1942)

## 2.1) Current status of RAI

The Railways of the Islamic Republic of Iran (RAI)<sup>[3]</sup>, is the subset of the Ministry of Roads and Transportation of I. R. of Iran. Currently, RAI has 9864 km of rail lines, 4565 km of which had been constructed before and 5660 km after the Revolution. And for the time being, further 7500 km of rail lines is under construction and based on the Vision 2025 the length of the rail lines in Iran must reach up to 25000 km.

# 2.2) Technical Specifications

The Railways of Iran generally uses UIC 60 rails with, except in some old lines where U33 rails are applied. Concrete sleepers with B70 grade are mostly used with the exception of old lines fitted with wooden and steel sleepers.

# 2.3) Single and double tracks

Of the whole network 81.6% of the main lines are single track and 18.4% are double tracked.

# 2.4) Main lines constructed:

- Mashhad –Sarakhs (North-South): 180 km in length
- Khorramshahr-Shalamcheh: 16 km in length
- Second line of Tehran-Mashhad: 703 km in length.
- Aprin-Bam: 31 km
- Double tracking Tehran-Qom: with the length of 284 km
- Ardakan-Chador malou: 219 km in length
- Kerman-Bam-Zahedan: 535 km in length
- Bafq-Mashshad: 800 km in length
- Esfahan-Shiraz: 500 km in length
- Branches: 81 km in length
- Amir Abad Port-Rostam Kola: 20 km in length



Figure2: Iranian railway map

# 2.5) Infrastructure key rail projects

Many infrastructure projects are being carried out by RAI to develop new railway lines and to supply the rolling stocks; upon realization of these projects Asia will be connected to Europe that could bring many advantages to the Middle-East countries and the region as well. Below are just some internationally important projects:

1-Construction of Qazvin – Rasht – Astara (372 km) is considered as the key route on the North – South corridor and is among the heaviest rail projects of Iran. Construction of this line has got around 70% progress.

2-Construction of Gorgan- Inchehbrun (82 km) along rail connection of Iran – Turkmenistan – Kazakhstan (East of Caspian Sea – 928.5 km) as an alternative to the North – South corridor, 700.5 of which is inside the territory of Turkmenistan, 82 km inside Iran and 146 km in Kazakhstan. This new route passes through Gorgan (Iran) Atrak, Berekat, Kyzilgaya (Turkmenistan) and Uzen (Kazakhstan). The route in territories of Iran and Kazakhstan is already complete and the section in territory of Turkmenistan is planned to be finished in October 2014. 3- Connection to Iraq through two projects:

- Short-term project of Khorramshahr Basra (51 km); operational work has been commenced by Iran with 16 km of length and the studies for the route in Iraq is in the final phase;
- Long-term project of Arak Kermanshah Khosravi-Qaneqin (536 km);
   sub-structuring from Arak to Kermanshah is underway.

4- Construction of Sangan – Herat (191 km), is aimed at connecting Afghanistan to the rail networks of Iran, Central Asia, Middle-East, Europe, also accessibility of Afghanistan to the Persian Gulf and the Oman Sea. Substructure of two sections in Iran is complete and substructure of third section in Afghanistan is underway by the Government of Iran.

5-Double-tracking the Mianeh – Bostanabad – Tabriz route (202 km), upon completion of this project Mianeh - Tabriz will be shortened about 200 km. Furthermore, this route will increase the speed as well as the transportation capacity on the East – West transit corridor.

6-Chabahar Port-Birjand-Mashhad project (1330 km) aims to make a rail link from Sarakhs to Chabahar in the south to connect CIS countries to the Persian Gulf. Executive operations are already started.

7-High speed double track railways of Tehran-Qom (140 km)

8-High speed electrified railway of Tehran – Mashhad (940 km)

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9-Tabriz-Azarshahr electrification (48 km). The project was launched and became operational on 13 Oct. 2012.

- 10- Electrification of Bafq-Bandar Abbas (600 km)
- 11- Electrification of Garmsar-Gorgan (404 km)

## 2.6) Opening for International Transit

In the northwest of Iran a line from Sharaf Khaneh on Lake Orumieh over Qotur was opened in 1977 linking Iranian railways to international standard gauge network. It has great importance in view of huge amount of merchandise and great number of passengers that are annually transported from Iran to Turkey and Europe and vice versa. In 1993 Bafq-Bandar Abbas branch was opened providing a link to this important Iranian port on the Strait of Hormoz. With the opening of the Mashad-Sarakhs branch in 1996 as part of the silk road railway a new transportation facility to Central Asian countries (Turkmenistan, Uzbekistan, Tajikistan, Kasachstan) and China was added.



Table1:Key infrastructure projects of Iranian Railways

# 2.7) Railway electrification in Iran

Railway electrification in Iran<sup>[4]</sup>, describes the past and present electrification systems used to supply traction current to rail transport in Iran with a chronological record of development, a list of lines using each system, and a history and a technical description of each system.

The project is sometimes abbreviated to RAIELEC, in which *RAI* is the abbreviation of Islamic Republic of Iran Railways

## 2.8) Early electrification: TabrizJolfa

After initial negotiations in 1969, railway electrification in Iran started in 1975, with a contract with USSR to electrify the Tabriz to Jolfa route in East Azarbaijan Province near the border with the former Soviet Union.

The work would include a Bogie exchange facility. The Tabriz-Jolfa line was originally established in 1916(before the main network in 1938) with the wide gauge 1,524 mm (5 ft) and was changed to standard gauge after connection of Tabriz to the national network. Tabriz-Jolfa is a single line rail track 146 km long with nine stations in between.

The maximum grade is 2.8% and the minimum curve radius is 400m. The catenary voltage is 25kV with booster transformer.

Three substations exist: in Tabriz, Marand and Jolfa with 4 or 3 single phase transformers from Alstom each having 15 MW of capacity supplying the power. The 8 locomotives used on this line with BoBo configuration have been built by

ASEA from Sweden based on RC4 type from SJ Rc family.

## 2.9) Electrification specification

The electric line voltage is 25 kV, 50 Hz, (25 kV AC railway electrification) with substations in Tabriz, Marand and Jolfa fed by 132 kV from the national grid. The end substations have three 15MW transformer and the Marand substation has four transformers.

Rank	c	Year	Orig.	Dest.	Dis.	Voltage	power,	Speed.,	Height.,	Block I.,	Wire	Tens.,
	_					,	IVIVV	NIIMI			1001°2	NII
1	<del>i i u</del> n	1985	Tabriz	Jolfa	146	25	15	100	5.2	1200	100	1500
2	İran	1997	Tehran	Karaj	35	2′25	63	140	5.2	1200	120	1500
3	Iran	2010	Tabriz	Az arshahr	46	25	15	140	5.2	1200	100	1500
4	<u>Iran</u>	2012	Tehran	Mas hhad	926	2′25	50	250	6.2	1300	120	2000
4	Iran	2014	Tehran	Tabriz	630	2′25	25	250	6.2	1300	120	2000

Table2:Railway electrification in Iran(source ,www.wikipedia.com)

## 2.10) Tehran station

Unique international railway station of Tehran Metropolis<sup>[5]</sup>, is one of the oldest buildings of Iranian railways. The station built in 1927 on southern lands of Tehran, with approximate area of 174 hectares and concurrent with construction of Iranian national railways. It has registered as one of the national monuments of Iran.

This station is railway transportation center of Iran because for most passengers exiting from the station means entering the capital, it acts as a gate; therefore, the area should be proper proportional to the city and act in a systematic and safe way to be suitable for presence and pause of passengers.

To beautify and increase visual effect of the hall and exterior view of the station alongside creation harmony in space of Tehran railway station, the operations of repair and reconstruction were done in 2015 and design of interior and exterior space of the station changed. By improvement of Tehran station enclosure, project of studies on qualitative improvement of exterior space of Tehran railway station has defined in an approximate 7 hectares area of Rah-Ahan Square's margins. The structure of railway station, the administrative office next to the station, Rah-Ahan art school and Qomash Building created a harmonic set that has been neglected due to multiple interventions and has been separated from urban-visual space of Tehran. As an area with distinctive identity in Tehran, the restoration of distinctive characteristics of the square through an integrated design and qualitative promotion of space and performance will be done in this project.

ON the other hand, Rah-Ahan Square is the main constructional-spatial element of Tehran city which has been chosen for global registration. Attention to the quality resulting from this structural association and its restoration as the unique railway gate of the capital are other key aspects of this project.



Figure3:Tehran station



Table3: the number of trains from/to Tehran(2016)

#### 3) Mode shift:

Where it is competitive with other intercity transportation modes, high-speed rail can capture a large share of passenger volume. International experience suggests that high-speed rail usually captures 80 percent of air or rail trips, if the travel time by high-speed train is less than two and a half hours (UIC 2010a). Mode shift to rail provides the greatest benefit in regions where road and air capacity is constrained.

High-speed rail systems around the world have experienced excellent safety records. Until a deadly accident in China in July 2011, high-speed rail operations on dedicated tracks had never experienced a single injury or fatality (UIC 2010)<sup>[6]</sup>.

Dedicated high-speed rail services usually operate at greater frequencies than conventional rail, and have fewer delays and better on-time performance than cars and airplanes.

By adding capacity to the railway network, high-speed rail can divert a large share of passenger rail service to new, dedicated tracks, thus freeing up capacity on the conventional rail network for freight and other intercity and commuter rail services.

Economic benefits of High-speed rail's ability to promote economic growth is grounded in its capacity to increase access to markets and exert positive effects on the spatial distribution of economic activity. Transportation networks increase market access, and economic development is more likely to occur in places with more and better transportation infrastructure. In theory, by improving access to urban markets, highspeed rail increases employment, wages, and productivity; encourages agglomeration; and boosts regional and local economies.

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The potential of high-speed rail to promote urban regeneration in conjunction with new or enhanced rail stations is one of its most promising economic benefits.

The experience with land development around high-speed rail stations has been mixed, but one thing is clear: highspeed rail cannot generate growth by itself. High-speed rail can play a prominent role in economic regeneration, but it is difficult to isolate its impacts from other complementary actions that are necessary to stimulate a larger economic development success story.

To take advantage of high-speed rail's potential land development benefits, cities must adopt policies and planning strategies that encourage station-related development and undertake careful planning of the track routing, station location, and intermodal transportation connections.

Significant land development effects have been documented more frequently in places with robust regional economies and linkages with other transportation modes, especially rail transit links to nearby urban centers, and places with public sector support for policies that encourage development.

High-speed rail stations have been located in almost every setting from the highest density centers of major cities to the most pastoral landscapes. In each case, the location reflects a complex interaction of physical, economic, logistical, and political considerations. Similarly, the designs of the stations illustrate rich variety, from the modernization and adaptive reuse of historic buildings to the construction of completely new, purpose-built structures.

It is difficult to generalize across all of these conditions, but existing station suggest a typological framework that may help to guide planning for high-speed rail. In particular, different station locations necessarily create a different dynamic

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between existing concentrations of activities and the increased access provided by high-speed rail. Center-of-city stations can reinforce established concentrations of development.

Their potential to spur further development is often magnified by the connectivity of the existing urban fabric and the extent of nearby transit connections. Edge-ofcity stations can alter the center of gravity of a city's core and spur redevelopment of underutilized areas at the urban periphery. Suburban and exurban stations can create new centers that concentrate growth around the station or enable corridor development between the station and a nearby existing node. In some cases, such stations are located too far from the key regional destinations and fail to attract much ridership or spinoff development. Special purpose stations can either retain their narrow function as intermodal facilities, such as airports, or can develop as mixed-use centers in themselves.

## 3.1) high-speed rail (HSR)

A plans for growing population and mobility needs, many consider high-speed rail (HSR)<sup>[7]</sup>, to be a cost-effective and environmentally friendly alternative to expanding highways and airport terminals.

Indeed, HSR experts agree that Iran has large enough cities spaced at appropriate distances from one another to make HSR viable.

For example, the distance between Tehran and Esfahan along the planned HSR route is about 450 km. This distance is too far to be quickly travelled by car or conventional rail.

At the same time, it is also what many transportation experts consider to be an inefficient distance to be covered by airplane if one accounts for the time spent getting to airports, typically located outside of cities, passing through security, and boarding planes.

People traveling by plane will spend less than an hour in the air, but their doorto-door travel time may be closer to five hours. Given that HSR stations can be located in city centers and knit into densely populated urban districts ,places that are closer to travellers' typical origins and destinations .

HSR can offer quicker door-to-door travel times than airplanes for mediumdistance trips in the 100- to 500-mile range. Since HSR can be brought into city centers and dense urban neighbourhoods, HSR stations tend to be better connected to urban public transit networks than airports. And where travellers' ultimate destinations are neither within a comfortable walking distance nor easily reached by transit from HSR stations, so-called "last-mile" modes such as bicycling, bike share, car share, and taxi can play a meaningful role in bringing

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passengers to and from stations. These reasons, along with the fact that train travel produces far less air pollution and greenhouse gas emissions than plane or car travel, are behind a growing sentiment in transportation planning circles and airplanes are the wrong tool for medium-distance trips. Indeed, this is the logic behind the European Union's Transform 2050 Initiative, which aims to triple the length of Europe's HSR network by 2030 and to ensure that a majority of medium-distance travel is done by rail by 2050.

HSR experts agree that successful HSR corridors satisfy a number of preconditions, including:Large urban centers located along the HSR corridor, spaced ideally between 100 to 500 miles apart. Distances below 100 miles are best covered by conventional rail or car, while distances above 500 miles are best travelled by airplane. The most successful HSR corridors have a number of large cities distributed along a corridor with a total length of 500 miles or less. HSR systems depend heavily on business travel to sustain ridership, and business travel is highest in places with more productive economies.



Figure4: medium distance for different mode of transportation and different time

# 3.2) technology and signalling

Railroad yard throughput and terminal performance directly impact overall network capacity. An important element affecting terminal performance is the efficiency at which railcars are inspected and repaired.

Technologies are being developed to automate railcar inspections that have the potential to improve railroad terminal efficiency as a result of reduced inspection times and improved rail terminal operations.

## 3.2.1) signalling systems

The characteristics of a signalling and automatic train protection (ATP)<sup>[7]</sup> system have a significant impact on the capacity and stability of a railway line.

One way to improve railway infrastructure capacity is to update the signalling or ATP system to one that allows a closer headway between successive trains.

A capacity assessment with respect to the different signalling and ATP variants then reveals how much capacity gains can be achieved. 1 the new state-of-theart European Train Control System (ETCS) has been implemented successfully on various new (high-speed) lines. The European countries are facing the strategic to how, where, and when to install ETCS on conventional railway lines. Different countries might have different reasons for replacing their safety and signalling systems, including interoperability, improved safety, increased capacity, replacing legacy systems at the end of their life cycle, and improved or extra functionality like higher supervised speeds.

## 3.2.2) Signalling and ATP systems

Railway safety systems can be partitioned in four components:

- Track-free detection: detecting the occupation and release of track sections
- Interlocking: setting technically protected routes for safe train movements,
- Signalling: indicating a movement authority to train drivers, and
- Automatic train protection (ATP): guard against driver errors.

Track-free detection devices such as track circuits or axle counters monitor the occupation of track sections. Interlocking systems guarantee that a signal is only released if the route to a next signal is safe, i.e., when the following route requirements are met: all points properly set and locked, conflicting routes locked, flank protection, and tracks clear. Open tracks between station layouts are usually operated by automatic block systems which can be viewed as a simple and automatic form of interlocking. By definition an open track does not contain any points so that signals only have to guard against following and opposing movements. The open track is then partitioned in block sections each protected by a block signal in rear. The block signal spects according to a signalling logic that varies from country to country. Finally, ATP systems have supervision and intervention functions as a fallback to driver errors and again the functionalities differ largely amongst the different systems.

## 3.2.3) Track Circuit

Nowadays for signalling purposes, trains are monitored automatically by means of "track circuits". Low voltage currents applied to the rails cause the signal, via a series of relays (originally) or electronics (more recently) to show a "proceed" aspect. The current flow will be interrupted by the presence of the wheels of a train. Such interruption will cause the signal protecting that section to show a "stop" command. Any other cause of current interruption will also cause a "stop" signal to show. Such a system means that a failure gives a red aspect - a stop signal. The system is sometimes referred to as "fail safe" or "vital". A "proceed" signal will only be displayed if the current does flow. Most European main lines with moderate or heavy traffic flows are equipped with colour light signals operated automatically or semi-automatically using track circuit train detection.

## 3.2.3.1) Track Circuit - Block Unoccupied

This diagram shows how the track circuit is applied to a section or block of track. A low voltage from a battery is applied to one of the running rails in the block and returned via the other. A relay at the entrance to the section detects the voltage and energises to connect a separate supply to the green lamp of the signal.



Figure 5: Track Circuit - Block Unoccupied

# 3.2.3.2) Track Circuit - Block Occupied

When a train enters the block, the leading wheelset short circuits the current, which causes the relay to de-energise and drop the contact so that the signal lamp supply circuit now activates the red signal lamp. The system is "fail-safe", or "vital" as it is sometimes called, because any break in the circuit will cause a danger signal to be displayed.



Figure 6: Track Circuit – Block occupied

## 3.2.3.3. Axle counter system

All of the track circuits described up to this point operate following the closedcircuit principle. Any disruption of the circuit by a train passing along the rails or by power or component failure, "opens" the circuit and causes a stop indication to be displayed by the signal system. An alternative approach to track circuit design uses a "check-in/check-out" logic.

Simply stated, this circuit is based on the principle that once a train is detected or "checked in" to a block, it is assumed to be there until it is "checked out" by being detected in an adjacent block.

The presence of a train may be detected only intermittently at the time when it enters a new block. Axle counters are installed at each edge of the section of track, when the number of axles counted at the entrance to the section is the same as the number of axles counted at its exit, that means the train has passed through the section.





#### 3.2.3.4) Station close-in time

The time between a train pulling out of a station and the next train entering referred to as close-in, is the main constraining factor on rail transit lines.

This time is primarily a function of the train control system, train length, approach speed and vehicle performance. Close-in time, when added to the dwell time and an operating margin, determines the minimum possible headway achievable without regular schedule adherence impacts, referred to as the non-interference headway.

When interference occurs, trains may be held at approaches to stations and interlockings. This requires the train to start from stop and so increases the closein time, or time to traverse and clear an interlocking, reducing the throughput. With throughput decreased and headways becoming erratic, the number of passengers accumulated at a specific station will increase and so increase the dwell time.

The capacity consumption of a railway line can be calculated using the timetable compression method for given infrastructure characteristics, rolling stock characteristics and timetable pattern.

This compression method is based on a deterministic microscopic calculation of conflict-free train paths with minimum headway times using blocking time theory This approach is also adopted as the standard method for assessing capacity. consumption by the International Union of Railways, which also gives empirically derived guidelines on the total required buffer time in a timetable pattern to be stable for delays.

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## 4) Traffic capacity analysis of rail system

Traffic analysis in railway systems <sup>[9]</sup>, depending on the level of design in which it is carried out, with different degrees of investigation.

Analytical tools differ primarily because of the different level of detail required to develop the analysis process.

Dynamic simulation methods, actually reproduce exercise in all aspects of infrastructure, technologies, rolling stock and traffic management, allowing thorough analysis of the operation of the system, but require a high level of basic information.

Synthetic methods based on topological and functional considerations require the characterization of the infrastructure, technologies and rolling stock limited to the essential elements needed to define the operation of the plant.

The low level of detail of initial inputs, the reliability in detecting plant criticality, make synthetic methods of extremely tools, from the very beginnings of the design process, make quick comparisons between alternative design hypotheses.



Figure 8:Synthetic traffic capacity methods

# 4.1) Dynamic method of simulation

To dynamically reproduce of rail system, each element must be carefully "modelled" and therefore requires a high degree of detail.

The principle scheme of the various simulation methods can be summarized briefly through a series of standard steps, where it is possible to observe the functional links between the activities:

- INDIVIDUATION AND CONFIGURATION STUDY AREA
- CONSTRUCTION OF REFERENCE SERVICE TIME
- CALIBRATION OF THE MODEL
- ITERATING SIMULATION PROCESS



Figure9: block diagram of the simulation process

## 4.2) Synthetic method

Develop a synthetic method of station design and verification railways, through which capacity of the station to be operated, can be expressed of service quality, in analogy with the ways of operating typical of modern engineering transportation.

The method is a contribution techniques and railway infrastructure optimization ,that supports decision making in the transport infrastructure sector, and in particular, the design of new plants or the adaptation of existing plants.

The synthetic method, applied to railway engineering, allows one a synthetic representation of the operation railway station, when known distribution of train arrivals over a reference timetable.

The assessment of the potential of station facilities can be carried out by using synthetic methods, having the particular need of a limited number of incoming information and providing, using appropriate indexes, judgments about the response of the plant to the solicitation of traffic in the observation period selected.

the methodology is articulated into next four phases:

- ACQUIRING THE TOPOLOGY OF THE DESIRABLE PLAN FROM SCHEMATIC PLANS
- MATHEMATICAL REPRESENTATION BY MATRICIAL STRUCTURES.
- DEFINITION AND CALCULATION OF PARAMETERS, DESCRIBING
   THE FUNCTION OF THE PLAN
- CONDITION OF VERIFICATION SYSTEM

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## 4.2.1) Compatibility matrix<sup>[10]</sup>

Direct comparison between the various movements is made possible by the definition of the itineraries matrix ,in each line and each column correspond to defined itinerary: each element (i; j) of the matrix identifies the comparison between a pair of itineraries ,whose compatibility or incompatibility, are represented by conventionally defined symbols.

The ones most frequently used to represent predictable cases in relation to topological incompatibilities, which are represented in the following figure:

"C" to indicate compatible itineraries

- "A" for comparing itineraries with oneself
- "X" for the comparison of intersecting itineraries
- "Z" for the comparison of two converging routes
- "S" for the comparison of two divergent itineraries
- "U" for comparison of frontal impact routes
- "D" to compare itineraries places one in continues of the other



Figure10: Simple crossing station layout

	1 ae	2 ag	3 ai	4 fb	5 cg	6 ci	7 hb	8 hd	9 Ib	10 Ld
1 ae	а	S	S	С	С	С	С	С	С	С
2 ag		а	S	×	Z	Z	С	С	С	С
3 ai			а	×	×	Z	×	×	С	С
4 fb				а	С	С	Z	С	Z	С
5 cg					а	S	×	С	×	С
6 cí						а	×	×	×	С
7 hb							а	S	Z	×
8 hd								а	×	Z
9 Ib									а	S
10 ld										а

table 4: Compatibility matrix for a line junction

The operating characteristics of a station plant can be summarized by the use of three numerical quantities with a definite physical meaning:

- average number of circulations
- average occupancy time
- total delay

## 4.2.2) Average number

indicated with i and j a generic pair of itineraries, the average number of possible circulations ñ within the node can be expressed by following relation:

$$\overline{n} = \frac{N^2}{\sum_{inc} n_i n_j}$$

where N =  $\Sigma$ ni =  $\Sigma$ nj represents the total number of circulations, or movement, occurring in the plant.

In fact, an appropriate matrix on whose rows and columns is the number of trains using the various itineraries in the reference period.

Physically represents the average number of circulations that can be carried out at the same time without any interference.

It is understood how it provides an immediate indicator of the possibility of traffic in relation to the topology structure of the node.

#### 4.2.3) Average occupation time

The determination of the average time occupation requires the introduction and clarification of the difference between occupancy and interdictions. the first of these consists of four stages, decision, training, journey and release, and takes place when two trains are in the condition of using the same type of itinerary (ie. when there is an incompatibility of type " A"). From that moment when itinerary coming used, the other incompatible itineraries cannot be formed, so the time when they are subject to this condition is referred to interdiction time.

Interdiction and occupation times are generally different and particularly sensitive to the presence of central apparatus that can achieve a type release progressive of the various itineraries, and the presence of distancing system in line that gives the possibility of sending more trains. Once these times are calculated based on system data, a matrix can be constructed that is referred to as a "matrix of times".

The rows and columns that appear in it correspond to the various itineraries, the generic element (i, j) contains the occupancy or intermission time that routing routes run against those on the columns. 'In particular, on the main diagonal are the occupation times, while the other boxes contain the interdictions. Clarifying this aspect in the average occupation time can be provided by the expression:

$$\bar{t} = \frac{\sum_{inc} n_i n_j t_{ij}}{\sum_{inc} n_i n_j}$$

which in fact represents a weighted average of the times overwhelmed with incompatible circulations.

## 4.2.4) Delay

Delay represents the total delay that the circulation takes during the reference period within the plant. In the case of constant arrivals, each pair of incompatible routes (ij) may give rise to delay, equal to:

$$\widetilde{R}_{ij} = \frac{n_i n_j t_{ij}^2}{2 \cdot T}$$

By further introducing a matrix whose elements consist of the delays generated between the pairs of incompatible itineraries may give the following expression the delay:

$$\widetilde{R} = \frac{\sum_{inc-AS} n_i n_j t_{ij}^2}{2 \cdot T}$$

In which you will be careful not to extend the sum of the "A" and "S" incompatibilities since there can be no delayed phenomena due to the fact that two trains cannot be physically present on the same itinerary.

#### 4.2.5) Condition of verification

It can be assumed that a plant works in an efficient condition if the following equation of time congruity is observed:

## T≥B+R

Where: T represents the unit of time taken as a reference (e.g. 20 hours).

B the total occupancy time of the plant.

$$B = \frac{N}{\tilde{n}} * t$$

R the amount of time removed from delays to actual circulation due to the simultaneity of ñ express trains.

It is, however, interesting to compare the total time of regular occupation B with the reference interval T as shown below

Technical literature provides a limit. experimentally obtained at peak time, on the use of plant (B) equal to 65% of T exceeded which would result in the regular circulation with consequent perturbative phenomena (accumulated delays) for the whole day, value of reference is around 35-40%.

It is therefore an easy-to-use methodology that offers a fairly realistic assessment of the operation of the plant, even with a level of design not too pushed (feasibility, preliminary) where quick evaluations are to be made hypotheses between different project. The level of information required to characterize the model is definitely reduced and not very detailed, especially with regard to signalling and station equipment. The detriment of this method is the rapid growth of matrix operations and size of implant is increased. Graphic layout of the plant (schematic plan / functional layout) with attribution of functions

- . Assignment of starting and ending itineraries
- . Stationary assignment
- . Travel direction assignment
- . Definition of functional links

. Define the configuration of the system as a following possible constructive intervention

RESEARCH AND AUTOMATIC INDIVIDUALIZATION OF ALL STATION PLANTS BASED ON THE ATTRIBUTED FUNCTIONS OF THE PLAN

AUTOMATIC ANALYSIS TOPOLOGY AND EXTRACTION OF INCOMPATIBILITY MATRIX

.Extends all plant

.Partialized (in complex plant)

.Extends to different plant configurations (to take into account any interventions within the plant)

FILLING THE TIMES MATRIX THROUGH DIFFERENT STRATEGIES OF POPULATION



.UTILIZZATION COEFFICIENTS OF SYSTEM

Figure 11: Automatic analysis procedure by synthetic methods

## 4.3) Synthetic method for analyse capacity (IF-CAP)

IF-CAP is a software developed by ITALFERR S.P.A. COMPANY in collaboration with departments of transportation and hydraulic, SAPIENZA university in order to increasing the capacity of circulation railway network.

The need for developing comparative analyses, in the context of the design of new plant and existing infrastructural enhancement facilities, prior to proceeding with the preliminary and definitive design, found in the synthetic methods valid instruments for the studies of the circulation capacity, requiring the developing automatic application procedures to minimize the computational burden in the presence of complex nodes.

In the design process, attention is mainly focused on the functional aspects and the effectiveness of the proposed interventions, in order to address the most inexpensively the reduced available economic resources.

The procedure allows you to:

modelling, by simple graphical operations, a complex in-railway operation; reproduce the system configuration by defining its functional aspects through a graphics platform;

Identify all the itineraries present in the plant and analyse the topology of the plant;

Automatically compile the incompatibility matrix of complex installations (1000 x 1000 itineraries), having the possibility to vary, partially or reduce the study area at any time with extreme simplicity;

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Manage different plant configurations as a result of functional macro steps of exercise; this is a very common case in railway practice that occurs every time you intervene in existing installations;

Automatically compile the matrix of occupancy and interdiction times by adopting different filling strategies.

The procedure consists of three modules:

- archive module;
- project module;
- calculation module.

# 4.3.1) Archive module

the archive module (Figure12) allows you to create multiple studies for each single plant to evaluate different configurations or different uses of the same plant.

In following picture is shown the new file(Tehran station)in archive module .

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Fig 12: archive module

# 4.3.2) Project module

The project module (Figure13) implemented on a CAD platform, allows to reproduce systematically the layout of the plant by using a dedicated configuration menu.

All the elements of the schematic plan (auxiliary lines, stationing, armaments, starting / ending shields etc.) are reproduced through appropriate graphic symbols is associated to which the peculiar information of the element.

In following picture is illustrated the Tehran station project module.



Fig 13: project module of Tehran station.

You can also assign a range of 5 conventional colours to the various graphic elements.

The module computing processes of the information introduced with the project module and allows the user to extend the study to the entire plant by detecting automatically all possible routes, including part of it, through a precise selection of origin / destination.

During this operation, however it is possible:

- include / exclude from route calculation or plant parts;
- assign traffic volumes for each origin / destination
- view all the itineraries at any time

In order to evaluate ,if itinerary selected are corresponds to that actually used in real circulation; it should be noted that the procedure for each origin destination proposes selected, it's possible for all alternatives path.

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10-III_A	7	0	1	6	0	0	NO	NO	Colore	0
10-IV_A	7	0	2	5	0	0	NO	NO	Colore	0
10-III_A	6	0	4	2	0	0	NO	NO	Colore	0
10-IV_A	6	0	5	1	0	0	NO	NO	Colore	0
10-III_A	9	0	2	7	0	0	NO	NO	Colore	0
10-IV_A	9	0	3	6	0	0	NO	NO	Colore	0
10-III_A	8	0	5	3	0	0	NO	NO	Colore	0
10-IV_A	8	0	6	2	0	0	NO	NO	Colore	0
5-XVII_A	6	0	4	2	0	0	NO	NO	Colore	0
5-4_A	6	0	5	1	0	0	NO	NO	Colore	0
5-XVI_A	5	0	3	2	0	0	NO	NO	Colore	0
5-XIV_A	5	0	2	3	0	0	NO	NO	Colore	0
5-XV_A	5	0	3	2	0	0	NO	NO	Colore	0
5-XIII_A	3	0	1	2	0	0	NO	NO	Colore	0
5-3_A	1	0	0	1	0	0	NO	NO	Colore	0
XVII-XIII_A	4	0	4	0	0	0	NO	NO	Colore	0
XVII-XIV_A	3	0	2	1	0	0	NO	NO	Colore	0
XVII-XV_A	2	0	1	1	0	0	NO	NO	Colore	0
XVII-XVI_A	1	0	0	1	0	0	NO	NO	Colore	0
2-VI_A	6	0	3	3	0	0	NO	NO	Colore	0
2-V_A	6	0	2	4	0	0	NO	NO	Colore	0
2-III_A	7	0	3	4	0	0	NO	NO	Colore	0
2-IV_A	6	0	4	2	0	0	NO	NO	Colore	0
2-VIII_A	5	1	1	2	1	0	NO	NO	Colore	0
2-XI_A	6	1	3	1	1	0	NO	NO	Colore	0
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zioni										

Figure 14: example of itineraries selection.

## 4.3.3) Calculation module

When the operation module of the plant has been completed, it is possible to complete and review the volume traffic operations and assign the occupancy times of all routes.

The matrix of times procedure can be compiled through:

- The fixed time of Automatic attribution of all itineraries interdiction.
- The time proportional of automatic attribution of the incompatibility type.
- The specific time of manual attribution for each single incompatibility.

The procedure allows to manage installations with a maximum number of itineraries (1000), therefore it is able to analyze even the largest existing railway systems relatively with little times calculation.

The ability to build a shared archive allows you to reuse through similar duplicate functions, similar systems already studied by other users, thus minimizing the modeling time of the study object. Choosing to use a CAD platform has made the use of the procedure extremely easy and quick, greatly reducing the time of analysis. moreover, the possibility of analyzing, through appropriate function, configurations corresponding to interruptions for works within the plants, allowed to evaluate any critical circulation.

The speed performance of the plant verification allowed to use:

- In evaluating interventions on existing plants by immediately assessing the good functional choices by comparison between existing situation and possible project configurations;
- In evaluation of new plants on existing lines or new lines across the various design alternatives;
- For the construction of a shared archive allowing analysis from different point of view, plant, topology and circulation capacity.

# 5) Intervention and Improvement of existing lines

## 5.1) Step 1: Actual capacity analyses

Improving existing lines, as well as providing the best performance for the entire system, has the advantage of costing much less than the new lines; and is much less impactful for the territory crossed, and because the works require smaller and simpler yards (often only updates of railroad technology) and because residents are already accustomed to the presence of the infrastructure. Expanding the band occupied by a railroad involves a much lower consumption of land than a new line, and does not require cutting the viability and geometry of farmland and farmland in the area crossed.



Figutr15:project model of Tehran station

Thanks to IF cap application, after analysing and entering the existing data of the current station circulation Tehran showed us the low values of the regular and total coefficients of the station, and after having seen the coefficients it was intervened to decrease the rails to stand for more space to train in high-speed trains for the future.

There is one important circumstance to have mentioned, for choose the lower value of utilization coefficient we need to more and more time proof the distribution of train on the tracks (position of trains on the tracks) for take the best value.

It also is important before the verified the application, eliminate the tracks which take more time for passage of trains , so we considered these for each step in order to more capacity of station.

After finished the data loading phase is possible calculate the synthetic indexes with the limit values.in the table5, are reported the input and output.

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23	Coefficien	t calculate	F	Exceeding stop point	1	1	Nu	mber of compa ieraries (clas	atible se C)	2030				
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Table5: the synthetic result of actual capacity of Tehran station

# 5.2) Step 2: intervention to elicit finite tracks

According to the IF Cap application and the regular and total utilization coefficients, it is possible to reach the highest values up to equal 0.45, so we have intervened to elicit finite tracks to arrive at desirable coefficients.

In following It was illustrated in Figure 16 The new Tehran station with 5 main tracks and same number of previous traffic.



## Figutr16:intervention of project model of Tehran station with 5 tracks

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			compatibility table / % occupancy time			Total circulation number (N)			206	
			Туре	Description	*	Ave	Average number of circulation compatible (N avg)		2.264	
			С	Compatible	0	Av	Average occupation time (tmedio)		218.671	
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			s	Divergence	0.8		B+R <sub>p</sub>		21,621.369	
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Coefficient calculate		F	Exceeding stop point	1	Nu	Imber of companies (class	atible se C)	960		

Table6: the synthetic result of new station with 5 tracks and same trains number

The excel analyses related to IF-Cap software in figure above show us low number of coefficient of utilization with just 5 tracks and same number of trains, this make sense the station of Tehran has capacity of train more than 206<sup>[11]</sup>, daily train just with 5 tracks.

## 5.3) Step 3: Passenger flow forecast

Passenger flow forecast is of essential importance to the organization of railway transportation and is one of the most important basics for the decision-making on transportation pattern and train operation planning.

Passenger flow of railway features the periodic variations in a short time and complex nonlinear fluctuation because of existence of many influencing factors. In this part, we consider the study of chain's company (CREC)<sup>[12]</sup>, for forecasting the one part of rail transportation between two main cities (Tehran and Esfahan) they already working on this project and by using the data analyses by CREC company and considering the percentage increasing passenger flow for all rail line connected to Tehran station.

Passenger flow forecast adopts the research results in Traffic Study and Ridership Forecast Reports. Such report forecasts that the ridership in the future is divided according to the service categories at the Initial Term of project (2020), Medium Term (2035) and Long Term (2050).

Operation plan in this year is shown in following table:

Deserves	- O-min	Initial terms	Medium	Long terms					
Pasenger	s Service	(2020)	terms (2035)	(2050)					
O/D	Service	Number of Train /day							
Tehran-Esfahan	Daily Non stop	10	11	12					
	Daily Multi stop	6	8	9					
Tehran-Quom	Daily Multi stop	7	10	11					
Tehran-Quazvin	Daily Multi stop	9	11	12					
Tehran-Tabriz	Daily Multi stop	8	10	11					
Tehran-Mashad	Daily Multi stop	46	55	60					
Tehran-Shiraz	Daily Multi stop	9	11	12					
Tehran-Ahvaz	Daily Multi stop	8	9	10					
тс	т	103	125	137					

Table7: Passenger Train Operation Plan for each OD

## 5.4) Step 4: Updating the tracks for demand grows

Passenger numbers are increasing and demands and expectations are changing, the train station is changing and offers a host of potential developments for passengers. Ensuring that large numbers of travellers can move freely and efficiently to, through and from a station, is essential for maintaining the overall transport system's operational efficiency.

In over cases after forecasting passengers growth in future, in2050 the passenger trains growth is about 33% and we need to update the over platforms Interfered, in this step we designated more 5 tracks against increasing the capacity of circulation and number of trains.

In following figures illustrated the new station.



Figutr17: intervention of project model of Tehran station with 10 tracks

Now after updating the tracks for demand grows and new design of station we need to calculate the capacity of new platform and new data by IF-cap application.

In the following picture showed the capacity of station(number of trains) Significantly increased and the number of train from 206 increased to **353**.

This new tracks capacity is more than forecasting for future growth demand till 2050, because the number of trains forecasting is **274** trans daily.

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		z	Confluence	1		Occ inter	upation time f rference (F	for R <sub>o</sub> )	4,053.390	1
		s	Divergence	8.0			B+R <sub>p</sub>		31,796.982	1
		U	Frontal collision	1		Regular coefficient of occupation (Cree)		of a)	0.3952	
		D	prosecution	1		Total coefficient of occupation (Ctot)			0.4529	
Co	efficient calculate	F	Exceeding stop point	1		Nun	nber of comparent	atible se C)	1682	

Table8: the synthetic result of new station with 10 tracks

## 5.5) Step 5: High-speed rail (HSR)

In following pictures' illustrated the new design of Tehran trains station with the additional tracks (red lines) for high speed trains.

By adding capacity to the railway network, high-speed rail can divert a large share of passenger rail service to new, dedicated tracks, thus freeing up capacity on the conventional rail network for freight and other intercity and commuter rail services.



Figutr18: intervention of project model of Tehran station with 10 tracks+5 tracks for HSR

After design the new tracks, we need to calculate the capacity of new Tehran station with high speed lines by IF-CAP software for reach the amount of enhancement of station and numbers of daily trains.

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5			cor	npatibility ta upancy time	ble/%		Total circulation numl	533		
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9			с	Compatible	0		Average occupation t	time	218,206	
11			A	Coincidenc	1		Summation of delay	s	17.422,408	
13			x	Intersection	0,8		Regular occupation til (B)	me	27.883,317	
15			z	Confluence	1		Occupation time for interference (R	or (a)	4.176,940	
17	Calcolo	con t %	s	Divergence	0,8		B+R <sub>p</sub>		32.060,257	
19	Calcolo	con t assegnato	U	Frontal	1		Regular coefficient	t of	0,3972	
21	Matrix tim	es calculate	D	prosecution	1		Total coefficient of occupation (Ctot)		0,4567	
23	Coefficie	nt calculate	F	Exceeding stop point	1		Number of compatil	ble C)	2494	

Table9: the synthetic result of new station with 15 tracks

According to the value obtained by software, the station capacity, significantly increased and the number of trains increased from 353 to 533.

So by adding just 5 tracks we have possibility to 180 more number of daily trains.

A matter of great importance is the total number of new tracks station is the same number of present Tehran station.

just with Improving existing lines, as well as providing the best performance for the entire system, has the advantage of increasing capacity of station with minimum cost and time.

## 5.6) Step 6: Effect of using technology and signalling

The technology and how it affects the overall efficiency of the rail network in Tehran.

The purpose of the application is to enhance the capacity of the network by specifically increasing the number of trains. Ensuring efficiency in this system would mean using less time between divergence and intersection of trains. Another feature of the technology is a more enhanced signally system which improves on safety of train passage. Increasing the number of trains has would mean more traffic and thus necessitates a more effective way of signalling. In the application the utility coefficient is proportional to the number of trains in the network.

The technology developed seeks to reduce the utility coefficient and thus create capacity for more trains to be utilised in the network.

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Table10: the synthetic result without using technology

In the above figure calculated with IF-CAP software without considering the technology, it shows us how influence the technology in capacity of station.

The number of trains are reduced from 533 to 478, this value is about 10.3 % decreasing the capacity of station.

Developing innovative technologies, technology such as signalling and communication and other IT tools can do much to help modernise railways.

ERTMS is a prime example, based as it is on two main new pieces of technology: the European Train Control System, the signalling and control-command component, and GSM-R, the radio system for communicating between track and train.

In analysis capacity in all steps we consider to having technology in Tehran station but in reality there is not equipped to new technology and signalling, so because of that in following table are illustrated the different usage of technology in each step how effect on capacity of Tehran station.



Table11: decreasing capacity of station without using technology

#### 6) Conclusion

Maximize the use of existing infrastructure by ensuring sufficient reliability of the service is an important challenge for increase the competitiveness of rail transport towards the other modes of transport.

The existing lines improved, as well as providing the best performance for the entire system, has the advantage of costing much less than the new lines; and is much less impactful for the territory crossed, and because the works require smaller and simpler yards (often only updates of railroad technology) and because residents are already accustomed to the presence of the infrastructure. Expanding the band occupied by a railroad involves a much lower consumption of land than a new line, and does not require cutting the viability and geometry of farmland and farmland in the area crossed.

IF-Cap application applied in this thesis in order to minimize the computational burden in presence of complex nodes.

The purpose of the application is to enhance the capacity of the network by specifically increasing the number of trains.

There is a definite need for transportation systems that meet the needs of increased population sizes and forecasting demand grows in future is the key factor considered for efficiency of Tehran station for long time.

This paper showed us the using technologies significantly influence in traffic capacity of Tehran station, ensuring efficiency in this system would mean using less time between divergence and intersection of trains.

Because there is a solution will refer to time periods of application and different needs of investment, depending on the characteristics of innovation, technologies and different proposed methods.

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