REPORT ON

MODERNIZATION PROJECT OF

IRANIAN STATE RAILWAYS

MARCH 1974

OVERSEAS TECHNICAL COOPERATION AGENCY

JAPAN

Report on Modernization Project of Iranian State Railways

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PREFACE

This survey was executed by the OVERSEAS TECHNICAL COOPERATION AGENCY (OTCA) in accordance with the request made in January, 1974 by the Ministry of Roads, Government of Iran to the Government of Japan through the Japanese Embassy in Tehran for technical cooperation on improvement of the existing railway.

In consideration of the importance and urgency of this matter, the Government of Japan made immediate preparations to organize the survey team consisting of the following technical experts from each field.

The team left Tokyo, Japan on 28th February, 1352 (1974) and arrived at Tehran, Iran on 1st March, 1352 (1974) for the scheduled stay of about three weeks.

Members of the team:

Mr. Fumio KURE	Head of team, Electrification, Japanese National Railways
Mr. Takashi SHIMA	Rolling Stock, Japanese National Railways
Mr. Hideaki ITAKURA	Construction, Japanese National Railways

Mr. Hideto HIDAKA	Operation, Japanese National Railways
Mr. Susumu KAMIYA	Railway Track, Adviser of OTCA
Mr. Yoshio NAKADEGAWA	Signal and Telecommunication, Adviser of OTCA

On 2nd March, a meeting was held in the Minister's room of the Ministry of Roads for the execution of the survey. This meeting was attended by the Minister of Roads and officers concerned of the Ministry of Roads, and the President of the Iranian State Railways (ISR) representing the Iranian side, and Mr. Ohshima, Councellor of the Japanese Embassy and the above members representing the Japanese side.

The following were agreed upon at the meeting:

(1) The objective of the survey will be rehabilitation and renovation of all the existing lines. However, owing to the limitation in available time, the first priority will be given to the Southern Line (Tehran-Khorramshahr-Bandar Shahpour), and the second priority to the North-West Line.

(2) The targets of the improvement will be speed-up, reinforcement of transport capacity and increase

of efficiency by the introduction of automation means. To realize these targets, existing facilities will be improved, and automatic signalling, double tracking and electrification will be effected if necessary.

(3) Necessary information for the survey and all the conveniences for the inspection trip will be offered to the team.

The team made, within the short time available, inspection trips to railway facilities near Tehran, to the Tehran-Khorramshahr-Bandar Shapour Lines and to the Tehran-Djolfa Line.

The team, at the same time, was furnished necessary data and exchanged views with Iranian officers concerned.

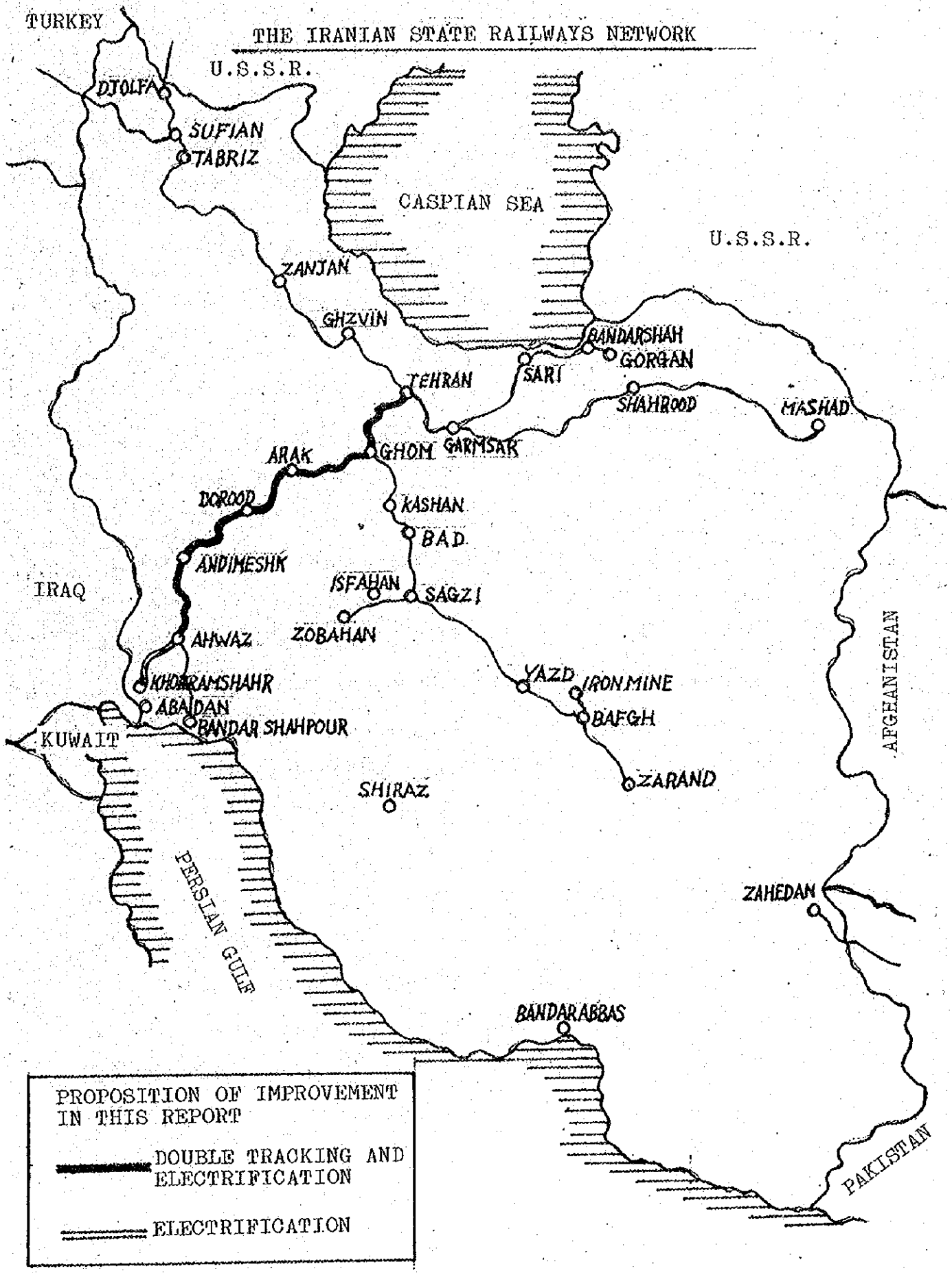
This report has been prepared based on study of the above mentioned survey data, etc.

Thanks to the wise guidance of His Imperial Majesty the Shahanshah Aria Mehr, the economy of Iran has shown remarkable growth and progress in recent years. In consideration of current plans for further development of various industries, including heavy industries, it is the firm opinion of the survey team that drastic improvement of the existing railway is imperative in order to have it assume its role as the main mode of transport and attain further economic development.

In short, this report outlines the measures required for the proper functioning of main lines, taking as an example the Southern Line on which traffic is the heaviest and is growing at a fast pace.

The team wishes to express its gratitude to officers of the Ministry of Roads and ISR for all the positive assistance and friendly cooperation extended to the team members in the execution of this survey.

It is sincerely hoped that this report would be of help to the development of the Iranian State Railways, and further, to the economic development of Iran and improvement of the living standards of her people.


THE IRANIAN STATE RAILWAYS NETWORK
TURKEY
U.S.S.R.
DJOLFA
SUFIAN
TABRIZ
CASPIAN SEA
U.S.S.R.
ZANJAN
GHZVIN
BANDARSHAH
GORGAN
SARI
TEHRAN
SHAHROOD
MASHAD
ARAK
GHOM
GARMSAR
DOROOD
KASHAN
BAD
ANDIMESHK
IRAQ
ISFAHAN
SAGZI
ZOBAHAN
AHWAZ
YAZD
IRONMINE
KHORAMSHAHR
ABADAN
BANDAR SHAHPOUR
BAFGH
KUWAIT
ZARAND
SHIRAZ
AFGHANISTAN
PERSIAN GULF
ZAHEDAN
BANDARABBAS
PAKISTAN
PROPOSITION OF IMPROVEMENT IN THIS REPORT
DOUBLE TRACKING AND ELECTRIFICATION
ELECTRIFICATION

I Role of Iranian State Railways with respect to the economic development of Iran

1 General conditions in Iran

Iran, located in the temperate zone at 25° - 40° N. Lat., with a land area of about 1.65 million km^2 and population of about 31 million, boasts a glorious cultural tradition since the dawn of history.

Under the wise guidance of His Imperial Majesty the Shahanshah Aria Mehr, development plans have been implemented in four stages in the post-world war II years to raise the people's living standards through economic development.

As a result, the economy developed at the rate of 9% - 15% yearly during the last 10 years, and gross national product reached 1,149 billion Rials in 1351 ('72 - '73). Further, in the 5th 5 year development plan commencing in 1352 ('73 - '74), stress is laid on raising living standards, and an annual growth of 15% in gross national product is planned.

It is also noteworthy that in the 5th plan emphasis is placed on the creation of greater social and economic balance among the various regions of the country, and that large-scale heavy industries will begin operation along with the development of

mineral resources.

2 Present situation of Iranian State Railways

The history of ISR is comparatively new. The operation of the main line began with the opening in 1317 (1938) of the Trans-Iranian Railway Line running through Iran longitudinally and extending over 1,400 km. Subsequently, the lines centering around Tehran and those in other areas were gradually constructed and the route length today reaches 4,509 km, all of which are single line.

Cargo transportation by railway reached 6,347,000 tons and 3,627 million ton-km in 1351 ('72), which correspond to 152% and 169% respectively, of the figures 3 years before. This shows the rapid increase of railway freight traffic in line with the recent economic progress.

Passenger transportation, on the other hand, reached 4,096,000 passengers and 2,054 million passenger-km, which are, respectively, 109% and 122% of the figures 3 years before.

Having played a historical role as the "Silk Road" connecting West and the East, the roads in Iran are remarkably developed.

In 1352 ('73), the final year of the 4th develop-

ment plan, asphalt-paved roads extended to 12,500 km.

Land transportation, therefore, mainly depends on road and the share of railway transportation is comparatively small, in freight as well as passenger, in spite of the above-mentioned rapid increase of railway transportation.

3 The role of ISR with respect to economic development

It is more than 100 years since the appearance of the railway as a transportation means. In the early days, the railway was the only modern means of transportation, and in countries where railways were vigorously constructed, the railway network was made to undertake all sorts of land transportation.

In recent years, however, road traffic has developed, and railway transportation turned over a part of its activity to road transportation. Now is the age in which both display their respective merits for economic and social development.

Namely, road motor vehicles have the advantage in the flexibility of "door to door" transportation, while the railway is suitable for transportation of large units of cargo between fixed points, with less personnel and less energy consumption.

The problem today is how to attain the most efficient transportation by making the most of the merits of each mode.

In this case, it is on the trunk lines where there is the demand for long distance mass transportation which is the field where the railway can be most efficiently utilized, and these are the lines now being modernized and reinforced the most in every country.

It is observed that in France, West Germany and Japan the share of the railway in land transportation of freight over distances of more than 400 km is, respectively, 70.5%, 62.2% and 50.2%. It is to be noted that aside from the above figures, the weight of inland water transportation is large in Germany and Japan.

Share of the railway in land transportation of freight over distances of more than 400 km

(million ton-km)

	Rail	Road	Total	Share of Rail	Year
France	34,700	14,500	49,200	70.5%	1969
West Germany	29,700	18,000	47,700	62.2%	1969
Japan	24,900	24,700	49,600	52.2%	1971

Notes: Domestic transport by ship

West Germany : 19,200 million ton-km

Japan : 65,190 million ton-km

In the case of Iran the share of the railway is low, as will be mentioned later in this report, taking as example the Southern Line. This points to the fact that the railway has not yet been given the proper role to play.

The major reason lies in the lack of basic transportation capacity due to the single line, long distance between stations and many gradient sections.

In order to secure mass transportation necessary for the heavy industries to be established in various areas of Iran and to make way for smooth economic

development, it is imperative to take basic measures for the reinforcement and modernization of the railway to enable its full utilization.

4 The direction of railway improvement

The direction of railway improvement for its full utilization is as follows:

(1) To provide the ability for mass and high-speed transportation.

(2) Modernization and automation of every sector and increase of efficiency in labour, energy and installations.

(3) To operate through trains avoiding yard shunting as much as possible for movement of cargo between fixed points in uniform volumes. Further, to improve transportation methods and facilities in order to save time and labour for cargo handling.

(4) To provide the most suitable passenger service, including the method of selling tickets, in accordance with the trend of passenger traffic.

(5) To give proper training to railway staff sufficiently in advance, in implementing modernization measures.

II Improvement of the Southern Trunk Line (Tehran-Khorramshahr, Bandar Shahpour)

1 Present situation of transportation and transportation demand in future

The Southern Line leads, via Ghom and Arak, to Ahwaz, where it branches off into two, of which one leads to Khorramshahr and the other to Bandar Shahpour, and its total route length is 1,044 km. The said line passes through the Iranian Plateau and crosses the Zagros Mountains which is over 2,000 m in altitude, and leads to both ports in the Persian Gulf.

On the way, therefore, there are steep mountains and the track abounds in gradients of 15‰, and there are so many curves, the minimum radius being 220 m. Especially, in the 208 km section between Dorood and Andimeshk descending to the ravine of the Zagros Mountains, there are so many gradients, tunnels and curves, and the difference in elevation between the two points is as much as 1,172 m.

There are 65 stations on the Southern Line and the distance between stations is maximum 23 km and average 17 km, and the usable length of main tracks at stations (hereafter referred to as "effective track length") is 410 m.

Tehran is the capital city of Iran and the center of politics and economy, and its population is more than 10% of total population of Iran. Moreover, Tehran is the center of traffic and is connected to all cities in Iran.

Khorramshahr and Bandar Shahpour can be said to be the only two ports in Iran connected by railways.

In the vicinity of Abadan and Ahwaz, there is the world's largest oil producing area, and large oil refineries are located there. From the viewpoint of transportation, therefore, the importance of the Southern Line connecting both spots is high and the traffic volume on the respective sections has been rapidly increasing these several years, as shown in the following table.

Trend in volume of freight passing over Southern Line

(thousand ton)

Year	1349 (1970)		1350 (1971)		1351 (1972)	
Section	North-bound	South-bound	North-bound	South-bound	North-bound	South-bound
Khorramshahr-Ahwaz	293	246	287	242	207	216
Bandar Shahpour-Ahwaz	323	328	1,202	264	1,087	143
Ahwaz-Ghom	1,321	125	2,470	284	2,746	343
Ghom-Tehran	964	12	1,621	23	1,825	259

Namely, the volume of north-bound traffic between Ahwaz-Ghom in 1351 (1972) reached 2,746 thousand tons which was nearly 50% of the total volume handled by ISR.

According to the MOR's survey executed in October 6 through October 16, 1973, the number of north-bound large-sized trucks with 6 axles or over, excluding oil tank trucks counted at a spot 5 km north of Ahwaz City was 475 per day on the average and the average load was 17.5 tons. However the above survey was made during a special religious period and the economic activities seemed to have been slack on account of it. Therefore, the annual average can be considered to increase by 20%. The average passage of oil tank trucks is, according to the MOR's investigation, about 200 per day, taking annual figures, and the load is 18 tons.

Therefore, the transportation volume by north-bount long distance trucks passing a point north of Ahwaz City on the highway parallel with ISR's Southern Line would be:

$$475 \times 17.5 \times 1.2 \times 365 + 200 \times 18 \times 365 = 4,954$$

thousand tons

Consequently, the total transportation volume by both railways and highways would be 2,746 + 4,954 = 7,700 thousand tons and the share of railways, 35.6% of the above figure. The volume of imported cargo

from the ports of Khorramshahr and Bandar Shahpour can be considered to be 3,560 thousand tons. Moreover, the total volume of exports and imports for all Iran in 1352 (1973) was 9,000 thousand tons (excluding oil). However, MOR indicates that the said volume will make a big increase to 17,000 - 18,000 thousand tons in 1353 (1974), and thenceforth, likely to increase at the annual rate of 15% as per GNP. 70% of the total transportation volume can be considered to be the share of the railway due to the transportation distance of more than 500 km beyond Arak from Ahwaz. Taking account of the above, the transportation volume on the Southern Line (Ahwaz-Arak) can be estimated as shown below.

Estimation of north-bound cargo transportation volume on Southern Line (thousand ton)

Year	1352 (1973)	1353 (1974)	1357 (1978)	1362 , 1983)
Total	7,700	11,680	20,434	41,100
Imported Cargo	3,560	6,922	12,106	24,350
Others	4,140	4,761	8,326	16,747
Railway	2,746 (35.6%)		14,838 (70%)	28,770 (70%)
Highway	4,954 (64.4%)		5,596 (30%)	12,330 (30%)

MOR indicates that the target of transportation volume to be assumed by the Southern Line upon completion of the 5th development plan is 15,000 thousand tons per year, which supports this view.

2 Problems on traffic capacity and countermeasures

(1) Maximum trailing load

a. Present maximum trailing loads are as follows:

Tehran-Andimeshk	1,000 t
Andimeshk-Ahwaz	1,200 t
Ahwaz-Khorramshahr, Bandar Shahpour	1,500 t

b. Double-header of G12 (1,420PS X2) or single GT26 (3,300 PS) can, on 15‰ gradient, haul 1,000 t at most, owing to the restriction of power and strength of couplers.

c. By means of replacing Hook & Screw couplers with automatic couplers, it is possible to haul, on 15‰ gradient, 2,000 t by double-header of GT26 and 3,000 t by triple-header of GT26.

d. Under the following conditions, it becomes possible to haul 1,500 t by single locomotive and 3,000 t by double-header.

d-1 Electrification of the line and adoption of 3,600 kw - 120 t - 6 axle - A.C. electric

locomotive with rectifier.
(Figure 1)

d-2 Adoption of roller bearings on freight cars

e. As the present effective track length at stations is limited within 410 m, the maximum trailing load, as based on this limitation, is about 1,700 t, considering average length of existing freight cars. Therefore, in order to increase the maximum trailing load to beyond 1,700 t, it is necessary to extend the length of passing side tracks, arriving tracks and departure tracks. When undertaking double tracking projects, this should be taken into consideration.

(2) Track capacity

Track capacity is governed by train operation time between two stations. By calculation using an experimental formula, the appropriate track capacity on the section between Tehran and Ahwaz is estimated to be between 35 and 40 trains both ways, a day (Table 1). Therefore, the present number of trains has nearly reached the limit and cannot cope with the great increase of traffic demand in the future.

For wide-scale reinforcement of traffic capacity, fundamentally, early execution of double tracking is most needed. But, for the time being, countermeasures such as increase of maximum trailing load and speed-up of trains should be promptly taken.

The track capacity on double tracks depends upon signal intervals, but for practical purposes, it is possible to increase the capacity up to 120 trains one way.

(3) Track structure

a. The track structure of ISR is considered sufficient for train operation at 80 km/h by existing rolling stock. Furthermore, it may permit a raise up to 100 km/h or more. However, in that case, some parts had better be improved. The items to be improved are as follows:

a-1 Replacement of old type turnout with flexible switch type.

a-2 Re-setting of super-elevation (cant) and extension of transition curve length:
The existing transition curves are generally so short in length that they have to be extended to considerable length (the length shall be at least 400 times of super-

elevation and the change of super-elevation is desired to be 40 mm/sec; thus the length would be as follows,

length $L_{(m)} \geq 7$ x cant $C_{(m)}$ x train speed $V_{(km/h)}$

b. The main points on the track maintenance for the speed-up of the Southern Trunk Line are as follows:

b-1 Replacement of worn rails and other defective materials

b-2 Re-fastening of fish bolts and fastening devices

b-3 Rectification of depression of joint and kinked joint on curved track

b-4 Surfacing and tamping at rail joint

b-5 Lining, especially for curved track (Table 2, Table 3)

(4) Terminal facilities

a. Tehran Station

a-1 The number of existing arrival and departure tracks for freight trains is 10 in total: 4 arrival and departure tracks for both the eastern and the western directions, 2 departure tracks for the eastern direction, and 4 departure tracks for the western

direction which are also used as sorting tracks.

a-2 The number of existing sorting tracks is 10 and their length is about 4.5 km.
4 tracks among them are also used as departure tracks. Besides, there are 10 storage tracks for freight cars, length of about 3.6 km.
As most of them are located quite far from the group of sorting tracks, such storage tracks cannot be used, functionally, as sorting tracks.
The number of freight cars handled is now about 500 cars per day, which can be said to have already reached the limit, in consideration of the factors mentioned in a-2-1 ~ a-2-3.

a-2-1 Since factories, car depot and various equipments for loading and unloading of military goods, etc. are located close to the sorting track group, shunting operation is interrupted when cars go in and out these areas.

a-2-2 Sorting tracks are also used for locomotives waiting to haul main line trains.

a-2-3 A part of the sorting track group is also used as departure tracks. This causes lowering of efficiency of shunting operation.

b. Khorram Ksuhk

In this station, where exclusive oil trains are handled, the placing of tank cars in oil loading tracks and the drawing out of these cars from the tracks are always accompanied by shunting operations.

It is desirable to make improvements to enable train movement to and from the oil loading tracks without any shunting.

3 Improvement from long-range viewpoint

(1) Double tracking

It is necessary to double track between Tehran and Ahwaz to meet the future planned transportation of 15 million tons per year one way.

a. Fundamental consideration for double tracking

a-1 Radius of curves should preferably be more than 400 m for high-speed operation.

a-2 Side tracks shall be provided at some intermediate stations to allow train passing in order to set up a desirable diagram and to ease the control of operation.

a-3 The effective track length at stations shall be corresponding to maximum trailing load of 3,000 tons.

b. Route selection for additional track

Generally, a parallel route to the present track will be added, but the following three alternative routes shall be studied between Dorood and Andimeshk where the topographical condition is bad.

b-1 Addition of parallel track

b-2 Addition of single-line on another route

b-3 Addition of double-line on another route

The "another route" referred above starting from near Dorood and leading to Andimeshk along present national road via the vicinity of West Khoramabad will be studied.

c. For the above 3 ideas, further details shall be studied in view of the following:

	b-1	b-2	b-3	Remarks
1. Difficulty of construction (cost, period)	X	O	Δ	To be further studied
2. Transportation convenience at the intermediate stations	O	X	O	Two lines used separately as north-bound and south-bound in b-2 makes transportation at the intermediate station difficult.

	b-1	b-2	b-3	Remarks
3. Increase of cost and time due to the difference in length of the added track	○	△	X	
4. Possibility of gradient improvement	△	○	○	The merit of improvement in this section cannot be expected, if adjacent section is not improved.
5. Cost in case of preservation of present track	○	○	X	
6. Construction cost for the improvement of effective track length at stations	△	X	○	
7. Possibility of stage by stage operation of additional track	○	X	X	

best ..... ○
worse ..... △
worst X

(2) Selection of motive power

Electric traction requires facilities such as substations and contact-wires which supply electricity to the trains. On the other hand, however, it is possible to use light and powerful motor vehicles. Generally speaking, electric traction has an advantage on the line where traffic volume is large.

As the estimated traffic volume of 15 million tons one way a year on the Southern Line is quite large for railway transport, in general, it seems the traffic volume on the line is in the range where electric traction is advantageous.

a. Planning of electric locomotive

Transportation condition:

Maximum trailing load for freight
3,000 t (double-header)

Balancing speed on 15‰ gradient
46 km/h (full field)

Voltage:	A.C. 50 Hz, 25,000 V
Power:	Continuous rating 3,600 kw, 45 km/h Equipped with regenerative braking system
Weight on driving wheels:	120 t

Comparison with the present diesel locomotive GT 26

	Balancing speed	
	15‰ gradient	10‰ gradient
EL Double-header	46 km/h (full field)	67 km/h (weak field)
DL Tripple-header	36 km/h	50 km/h

In short, on the gradient, double-header of electric locomotive runs faster than the tripple header of diesel locomotive.

b. Ground facilities

As the electric power industry in Iran has been greatly reinforced, there exists along the Southern Line 230 kV power transmission network, from which reception of power is possible. As the voltage of power transmission network is high and the distance between substations is quite far, it is advantageous to adopt auto-transformer feeding system by which voltage drop is comparatively small.

Though total length of tunnels on the Southern Line is 60 km, the clearance between top of

rail and ceiling is 5,800 mm, which is sufficient to accommodate the overhead equipment for electric traction.

c. Merits of electric traction

Railway electrification has, besides what has been stated above, several other merits.

c-1 By adoption of electric multiple-unit trains, speed-up is easily realized. In this case, because of their large acceleration, they are also applicable to transport of commuters in the suburbs of large cities.

c-2 The maintenance cost of electric vehicles is 1/2, or even less, of that of diesel vehicles.

c-3 Even in case of single track electrification, traffic capacity increases by as much as 20 ~ 30% as a result of speed-up.

c-4 Efficient use of energy is possible.
As to powering, there is not much difference between diesel traction and electric traction in terms of energy consumption. However, in case of electric traction, it is possible to save 20 ~ 30% of electric power by adoption of the regenerative braking system on gradient sections.

For generating electricity, water power, natural gas or nuclear power may be put to use.

c-5 As electrification requires much material, such as poles, copper bars, steel bars and fastenings, it is possible to develop domestic industries and to make use of domestic resources.

c-6 It is possible to feed electric power to nearby villages from the electric traction power lines.

(3) Improvement of tracks

a. The track structure should be designed by taking maintenance economy into consideration together with mechanical strength. It is required that the track structure should conform to technical skill and capacity for maintenance, especially for the raise of train speed. Accordingly, it is desirable that the standard of track structure should be re-studied for the increase of traffic volume and for speed-up to 120 km/h or more in the future.

The items to be studied are as follows:

a-1 Adoption of heavier rail of 50 ~60 kg/m and long welded rail

a-2 Use of flexible turnout

a-3 Adoption of prestressed concrete sleeper and double elastic fastening

a-4 Use of crushed stone ballast

a-5 Improvement of radius of curve and transition curve

In order to shorten the operation time for the whole line, in many cases, the raise of restricted train speed on the curved track is more effective than that of maximum speed on the straight line. Therefore, it is advisable to make technical and economic feasibility studies for the applicable curves and to execute the improvement works. As to the radius of curve, in case addition of tracks is newly planned, 400 m or more is desirable.

a-6 Adoption of long welded rail is effective to eliminate the rail joint which is the weakest point of the track, and such rail is indispensable for the high-speed operation. However, generally, it is applicable to the

sections where difference of rail temperature is 70 degree centigrade or less. In case of ISR, the difference of rail temperature might be considerably large, and hence investigation and studies are requested. Strict control of rail temperature is necessary for the laying work and strict restrictions are placed on the maintenance work.

b. As for track maintenance, establishment of a basic system is required and the materialization of following items is advisable.

b-1 Establishment of track inspection standards and their enforcement

b-2 Re-study of the standard of track maintenance and introduction of the means for applying the results of track inspections

b-3 Thorough dissemination of these means to the lowest unit of the organization

b-4 Raise of maintenance technique and widening the education for maintenance gangs

b-5 Improvement of work methods and promotion of use of machinery

(4) Improvement of rolling stock and speed-up

a. The passenger coaches with Minden-Deutz bogies are satisfactory.

b. It is needed for the freight cars to adopt two-axle bogies with roller bearings, and preferably, load compensating device for braking and also quick-responce braking system.

c. By adoption of 6-axle A.C. electric locomotive with rectifier (3,600 kw), in addition to the improvement of track maintenance, it seems possible to shorten the necessary time between Tehran and Khorramshahr as stated below. Calculation is done on the assumption that the maximum train speed is restricted only on the necessary sections between stations and also that the track curvatures will be improved ($R \geq 400$ m) in case of double tracking.

c-1 Freight (3,000 t, double-header), Maximum operation speed 80 km/h

Single track: 21 hours 30 minutes (25 hours at present)

Double track: 16 hours 30 minutes

c-2 Passenger (650 t), Maximum operation speed 100 km/h

Single track: 15 hours (17 hours at present)

Double track: 13 hours 30 minutes

d. If further shortening of time is needed, we recommend the adoption of electric multiple-unit trains.

The necessary time in case of A.C. electric multiple-unit sleeping train (10M3P, 4,800 kw, passenger capacity 535, 600 t) is, by experimental calculation, 11 hours.

Calculation is done on the assumption that the maximum speed is 120 km/h (double track). The improvement of curvatures ($R \geq 400$ m) is also taken into consideration.

Remarks: In case of multiple-unit trains with comparatively light axle load, owing to the less influence upon the track structure than in case of locomotive-hauled trains, it is possible to adopt 120 km/h operation on the same track structure on which 100 km/h operation is maximum allowable speed for the locomotive-hauled trains.

(5) Improvement of Terminal Facilities

a. Tehran Station

The following items are to be considered in connection with reinforcement of yard capacity.

a-1 Extension of the effective track length

The effective length of arrival and departure tracks and draw-out tracks for freight train should meet the future maximum trailing load, assumed to be 3,000 tons.

a-2 Items to be considered for calculating the required number of arrival and departure tracks and sorting tracks

This calculation should be based on the assumption that through trains passing through Tehran Station are to be increased as much as possible.

The number of freight cars to be handled at Tehran Station should be determined after thorough study of transport plan for avoiding duplication of sorting operations in two adjacent yards, including improvement plan of the neighbouring yard like Ghom.

a-3 Fundamental review of track arrangement

It is necessary to review thoroughly the track layout in order to reduce as much as possible the interference of one operation with another in yards.

In view of the present condition of ISR land and the existing facilities at Tehran yard, it will be not easy to improve the track layout in its present location in order to meet the expected transport volume of freight in the future.

a-4 Adoption of humping system to raise the efficiency of train break-up operation

a-5 Automation of yard for labour-saving

b. Exclusive terminals for exclusive train for specific commodities

It is necessary to increase the number of exclusive trains for specific commodities, and to equip the exclusive terminals required for such trains as a means to attain the most efficient transportation to meet the rapid increase of traffic volume in the future.

b-1 Terminal for exclusive train for oil (Khorram Ksuhk Station, etc.)

The undermentioned items are to be studied:

* Increase of maximum trailing load of exclusive train for oil
* Loading of oil in a whole train as it is

b-2 Terminal for exclusive train for marine containers (Bandar Shahpour Station)

It is expected that the handling volume of port goods will increase rapidly as a result of reinforcement of the port of Bandar Shahpour in a large scale and the quick economic development of this country. Therefore, the reinforcement of handling capacity of goods is required at Bandar Shahpour Station.

The following items are to be investigated in order to decide the reinforcement plan:

* Containerization of marine cargo is a worldwide trend. The port goods arriving at or departing from Bandar Shahpour Station would be containerized on a wide scale in the near future. Therefore, the sufficient investigation about the handling equipments for marine container is required, and at the same time, efficient track layout for exclusive train for marine container

should be adopted in the plan.

* In deciding upon track layout, the arrival and departure tracks and the draw-out tracks for the exclusive train for marine container and for common freight trains, and also the sorting tracks should be separately located.

* The effective length of arrival and departure tracks and draw-out tracks should be decided after sufficient investigation about the future maximum trailing load, between Bandar Shahpour and Ahwaz.

(6) Improvement of signal and safety devices, telecommunication devices

a. Adoption of automatic signal

It is necessary to equip and install the automatic signal, automatic train stop, etc. in order to secure the safety of operation to meet the increase of the number of trains as well as the increase of speed due to the completion of double tracking and electrification.

When installing the automatic signal, it is necessary to consider the intervals of trains and visible distance of signal.

b. The necessity of Centralized Traffic Control device in all the lines

It is necessary to adopt CTC device to enable adequate traffic control of trains to meet the increase of transportation volume and speed-up.

c. Reinforcement of telecommunication line

The telecommunication lines shall be improved to meet the increase of information volume in future due to the increase of transportation volume, improvement of service such as the freight car reservation as well as the adoption of CTC (Centralized Traffic Control), CSC (Centralized Substation Control) and so on.

d. Installation of train radio and wayside telephone

In case the distance between stations is long and the transportation volume increases rapidly the facility of train radio or wayside telephone is needed for emergency communication between train and center.

e. Installation of relay interlocking device

For the stations not provided with interlocking device in the railway section south of

Ahwaz, it is necessary to install the relay interlocking device with the increase of train operation in order to secure safety.

f. Improvement of signal and telecommunication equipment in line with the execution of electrification

In line with the A.C. electrification, there is the need to improve signal and telecommunication equipment after careful checking of track circuit selection, induction countermeasure, and insulation coordination.

g. Railroad-highway grade crossing protection

The danger on crossing will be increased due to the increase of number of trains and speed-up after double tracking, therefore it is necessary to automatically detect the approach of train and to give warning.

(7) Effect

a. Single track electrification

Necessary time will be shortened by 10 ~ 20% owing to the speed-up of trains.
Traffic capacity will be increased up to 10 million tons a year, by adoption of 3,000 t

traction of freight trains.

b. Double track electrification

Necessary time will be shortened by 20 ~35%. Traffic capacity will be increased up to 50 million tons a year with 120 trains one way a day.

c. The necessary number of trains to cope with the traffic volume after the completion of the 5th 5 year development plan (15 million tons, one way), will be 28 one way a day, in case of 3,000 t traction of freight trains. Therefore, it is quite possible.

4 Methods and process for execution of improvements

(1) Remedies with present facilities

a. Reinforcement of oil-tanker trains

The conventional Hook & Screw couplers on oil-tank cars should be preferentially replaced with automatic couplers. Using such oil tankers with automatic couplers, special trains exclusively for oil transport are to be prepared with the maximum trailing loads of 2,000 tons each, when loaded. Oil handling facilities in stations should

be improved so that the oil-tanker trains can depart or arrive there immediately without shunting. The oil-tanker trains are to be hauled by the double-header of locomotive on steep sections, and thus the movements of such trains between origins and destinations would look quite similar to those of "pistons" of reciprocating engines.

Since the oil-tankers are comparatively heavy when loaded, the lengths of such trains with even 2,000 tons of trailing loads will be within the effective track lengths at stations.

b. Increase of maximum trailing load

b-1 It is recommendable to concentrate bogie cars with roller bearings to the Southern Line.

b-2 It seems possible to trail 1,700 ~ 1,800 tons by double-header of GT26, considering the effective track length at stations and the average length of freight cars.

c. Improvement of track maintenance

Raising of train speed is possible with the present track structure, provided necessary

maintenance work is performed. At locations where oil type turnouts still remain, restriction of train speed will be necessary till they are renewed.

The improvements urgently required are as follows:

c-1 Replacing of defective track materials

c-2 Re-fastening of fish bolts and fastening devices

c-3 Rectification of depression of joint and kinked joint by using rail bender if necessary.

c-4 Re-alignment of curved track

Introduction of curve lining calculator is recommendable.

c-5 Tamping at the rail joint, surfacing and lining.

c-6 For rectifying track irregularities, the following maintenance target values are tentatively recommended.

Gauge	-4, +8 mm
Cross level	8 mm
Torsion	2 mm/m
Longitudinal level	8 mm/10 m chord
Alignment	6 mm/10 m chord

d. Speed-up

d-1 It is needed to keep the profile of wheel tread as exactly as possible by frequent truing.

d-2 It is needed to keep the bogies in adequate conditions, by controlling such elements as clearances of wearing parts, damping coefficient of shock absorbers, etc., and also by the relevant weight distribution between center pins and side bearers.

d-3 By the above-mentioned measures, it seems possible to increase the present train speed by 10 ~ 20 km/h for both passenger and freight.

d-4 If further increase of speed is required for passenger, we recommend the adoption of diesel hydraulic multiple-unit trains.
By experimental calculation, suppose JNR's limited-express diesel hydraulic multiple-unit train (8DIT, 4,000 PS, passenger capacity 572, 400 t) is put to use, the necessary time between Tehran and Khorramshahr will be 14 hours.

d-5 It is quite inefficient to restrict the train speed within a certain level throughout two adjacent stations. Therefore, we recommend

the introduction of ground marks only on certain sections where the restriction of speed is needed.

(2) Execution of consulting contract, etc.

a. Double tracking (Tehran-Ahwaz)

Decision upon construction standards and comparison of different routes for calculation of construction costs. Especially, attention should be paid to the section between Dorood and Andimeshk.

a-1 Gradient

The reduction of gradient is undoubtedly desirable, but it would have little effect unless the improvement be applied on the overall lines. It should also be taken into consideration that the longer routing would cause disadvantage in terms of operation time and maintenance cost.

a-2 Improvement of curves

Should be improved to be preferably over 400 m in radius.

a-3 Rail line layout in station compound

Should be decided in accordance with the maximum trailing load of 3,000 tons.

b. Electrification, adoption of CTC (Tehran-Ahwaz-Khorramshahr)

A.C. 25 kV, 50 Hz

Fundamental planning should be established for the economical comparison between electric and diesel operation.

b-1 Motor vehicle

Decision upon main features, etc.

b-2 Transportation planning

Decision upon train operation planning and rolling stock untilization planning

b-3 Location of substations, power transmission line, feeding system

* Calculation of voltage drop in feeding system
* Calculation of substation load capacities
* Calculation of voltage variation and unbalance in power source

b-4 Decision upon overhead line structure, its range and facility standard

b-5 Decision upon CTC facility standard and interlocking in station compound

b-6 Decision upon location of signals, facility standard of track circuit

b-7 Decision upon ATC facility standard

b-8 Decision upon telecommunication facility standard, telecommunication system

b-9 Decision upon facility scale for rolling stock inspection and maintenance

c. Terminal facilities

c-1 Establishment of fundamental planning for terminal facilities in accordance with the through oil-tanker transport and container transport

* Decision upon rail line layout and the specification of load handling facilities

c-2 Establishment of improvement planning of Tehran freight yard (including automation), with necessary effective track length, shunting capacity and departing and arriving tracks in accordance with the forecast future traffic volume on the Southern Line

* Decision upon rail line layout, specification of signal and safety devices and automation facilities

d. Track

It is needed to study the most suitable track structure and maintenance system in preparation for the future increase of traffic

volume and speed-up. To expedite these, it would be effective to organize a project team in ISR and if necessary, to have cooperation of consultants as to the track construction and also to invite specialists as to maintenance system.

The contents of the needed study are as follows:

* Parts of track structure
  Rail and its accessories, Fastening device and sleeper, Ballast and roadbed, Long welded-rail
* Shape of the line
  Curve, Super-elevation, Transition curve
* Several standards for track maintenance

(3) Construction process and schedule

a. Double tracking (Tehran-Ahwaz, 816 km)
It takes at least six months for investigation and design before the start of construction. It is the construction of tunnels which affects the construction period. The longest tunnel on the present line is 2.5 km and it seems that the longer tunnels would be necessary on the proposed new route.

The excavation capacity for tunnel is, in average, 100 m/month and though it is possible to start digging from both ends, the road construction to the pit-mouths brings about another problem.
It is estimated that the necessary construction period will be 4 ~5 years, if there are no special difficulties and also fund and construction capacity are sufficiently provided.

b. Electrification and CTC (Tehran-Khorramshar, 936 km)
It takes at least six months for investigation and design before the start of construction, eight months for preparation of materials after the contract.
As for the electrification and CTC, as it is necessary to instruct and train enginemen, CTC operators and the electric facility maintenance gangs, it would be needed to divide the line into 2 ~ 3 sections and to start electric operation accordingly.
It would take about three years to start operation on the first section, about four years to complete the whole line.

c. Construction process and reinforcement of traffic capacity

The method to adjust the construction process for the immediate reinforcement of traffic capacity is as follows:

c-1 Improvement of couplers on freight cars

c-2 Elongation of the effective track length at stations

c-3 Electrification of the section between Arak and Andimeshk

c-4 Speedy construction work for the addition of track between Arak and Andimeshk and its partial accomplishment together with the electrification

By means of the above stated method, it is possible to quadruple the present traffic capacity (10 ~12 million tons).

III Improvement of other lines

As the facilities and rolling stock on the other lines of ISR are, more or less, in similar condition as on the Southern Line, the improvement measures stated on the chapter II are applicable on other lines. However, such measures should be properly selected in accordance with each traffic volume.

2 Especially, the Survey Team's comments upon the North-West Line (Tehran-Tabriz-Djolfa) are as follows:

(1) Tehran-Tabriz 751 km

* Maximum gradient 15‰
* Average distance between stations 15.6 km

As the facilities are nearly equal to those on the Southern Line, the track capacity seems to be about forty trains a day. However, the present number of trains are fourteen except on the section near Tehran.

It is possible to increase train speed, provided that the measures stated on II-4-(1)-c are adopted as to track maintenance and that the measures stated on II-4-(1)-d are applied as to the improvement of operation planning.

(2)	Tabriz-Djolfa	134 km
	Maximum gradient	28‰
	Average distance between stations	15 km

On this line are several continuous steep gradients. Electrification of this line has been planned and its preliminary work has now begun.

With adoption of 6-axle A.C. electric locomotives and improvement of the couplers on freight cars, there are possibilities of 1,500 t traction by means of the double-header of the locomotive, which would contribute much to the reinforcement of traffic capacity.

3 Future planning in Tehran area

There are important problems for ISR in Tehran and in the suburbs, such as freight marshalling yard, freight handling facilities and the short-cut lines.

In case the double tracking is adopted on this area, it seems there are possibilities for ISR to bear a part of transport of commuters.

Therefore, it is urgently needed to establish an overall future planning, taking every individual planning into consideration, such as road construction planning, housing program, rapid transit planning and ISR's improvement planning.

FIGURE 1

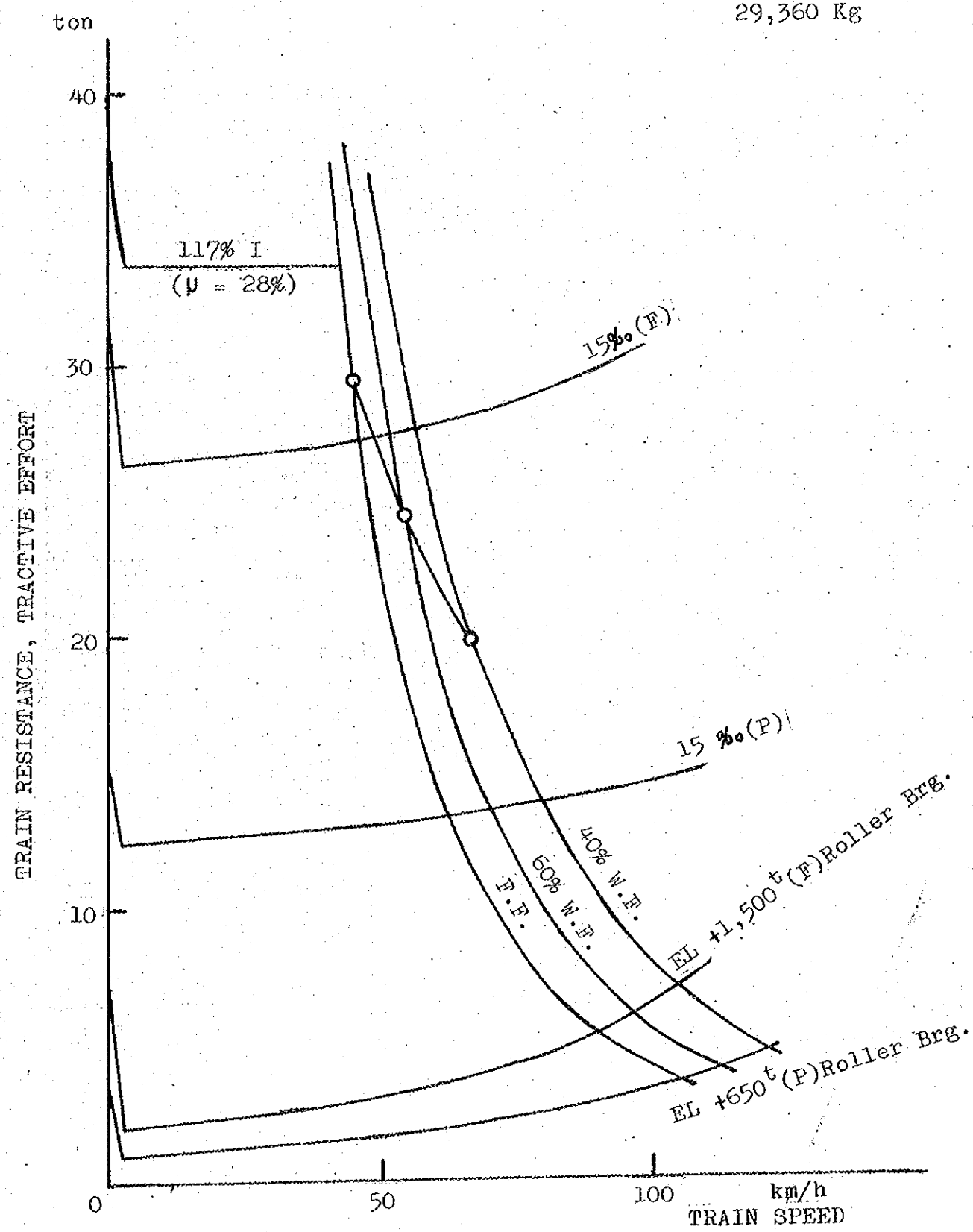

6-AXLE 120t A.C. LOCOMOTIVE
CONTINUOUS RATING 3,600 KW
45 km/h
29,360 Kg
ton
40
30
20
10
0
117% I
(μ = 28%)
15‰(F)
15 ‰(P)
40% W.E.
60% W.E.
F.E.
EL +1,500t(F)Roller Brg.
EL +650t(P)Roller Brg.
50
100
km/h
TRAIN SPEED
TRAIN RESISTANCE, TRACTIVE EFFORT

Table 1 Track capacity, section by section

section	distance (km)	number of trains	track capacity		maximum trailing load
			mean	minimum	
Tehran Ghom	180	30	43	30	1,000 t
Ghom Arak	140	28	39	34	
Arak Dorood	147	34	38	33	
Dorood Andimeshk	208	34	38	30	
Andimeshk Ahwaz	141	30	40	30	1,200 t
Ahwaz Khorramshahr	121	6	30	29	1,500 t
Ahwaz Bandar Shahpour	107	10	40	31	1,500 t

* Calculation formula

$$N = \frac{1,440}{t - c} \times f$$

N : track capacity (number of trains/day)

t : mean operation time between two stations

c : signal handling time

f : coefficient of track utilization

Table 2 Existing Track Structure in Southern Trunk Line

Rail	Type U33 (46.3$^{kg/m}$) One unit length 12.5^{m} x 4 = 50^{m} (12.5^{m} in some sections)
Sleeper	Steel sleeper, concrete sleeper RS type and Wooden sleeper, using 21 sleepers/12.5^{m} = 1,700 sleepers/1^{km}
Fastening devices	For Steel sleeper Gauge block, Clip, Screw spike For Concrete sleeper Support plate, Spring clip, Rubber pad, Screw spike For Wooden sleeper Tie plate, 3 Screw spikes for 1 unit (1 spike for outside of rail, 2 spikes for inside of rail)
Ballast	Crushed stone (Screened gravel in some sections) Thickness 250^{mm}～ 350^{mm}
Rail joint	Fish plate with 4 or 6 joint bolts
Turnout	46.3$^{kg/m}$ rail Turnout number 1 : 9
	Radius of lead curve 190^{m} or 300^{m} Flexible switch (hinged switch in some sections)

Table 3 Alignment

<table>
<tr><td>Min. radius</td><td colspan="2">220 m</td></tr>
<tr><td>Cant</td><td colspan="2">Theoretical formula:
$h\ (m) = 0.011 \frac{V^2 (km/h)}{R\ (m)}$
Practical formula:
$h\ (m) = \frac{V\ (km/h)}{2R\ (m)}$
Max. value of actual cant : 140^{mm}</td></tr>
<tr><td rowspan="9">Transition curve</td><td colspan="2">Cubic parabola</td></tr>
<tr><td>Radius of curve (m)</td><td>Length (m)</td></tr>
<tr><td>220 ~ 440</td><td>60</td></tr>
<tr><td>500</td><td>53</td></tr>
<tr><td>600</td><td>44.17</td></tr>
<tr><td>800</td><td>33.13</td></tr>
<tr><td>1,000</td><td>26.50</td></tr>
<tr><td>1,200</td><td>22.08</td></tr>
<tr><td>1,500</td><td>17.67</td></tr>
<tr><td>2,000</td><td>13.25</td></tr>
<tr><td>Length of straight line between reversed curves</td><td colspan="2">30^m or more</td></tr>
<tr><td>Max. gradient</td><td colspan="2">15 / 1,000</td></tr>
<tr><td>Radius of vertical curve</td><td colspan="2">$2,000^m$, $5,000^m$</td></tr>
</table>