BDZ TECHNICAL ASPECTS

CHAPTER 8 TRAIN OPERATIONAL PLAN

8.1. GLANCE ON ACTUAL TRAIN OPERATION

8.1.1. Analysis of Train Operation Condition

The technical aspects of BDZ transport, etc., are analyzed and explained on following ways as far as possible.

- **Relation between traffic demand and train km**
- **Analysis of train operation diagram**
- **Simulation of train running performance**

  By considering railway track curvature, by switch and by gradient

  By improving actual facilities and rolling stock

  In case of future high speed train

8.1.2. Freight Transport

(1) Freight train km by traffic demand in the past 10 years

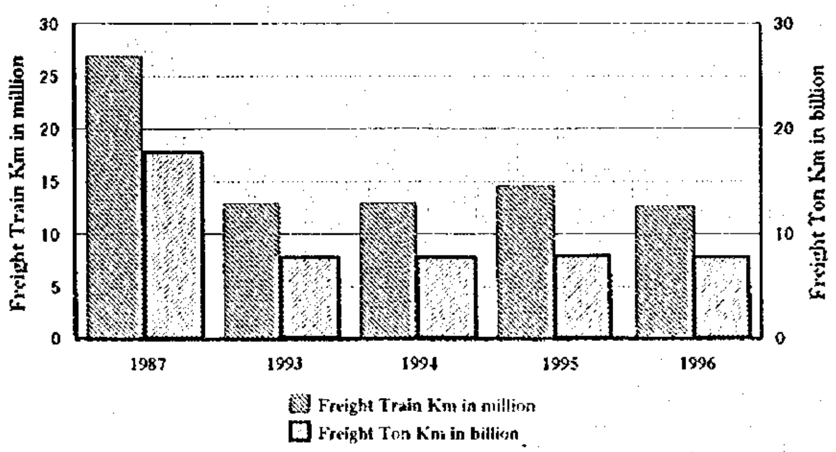


Fig.8.1.2- 1 Transition of freight train km and freight ton km

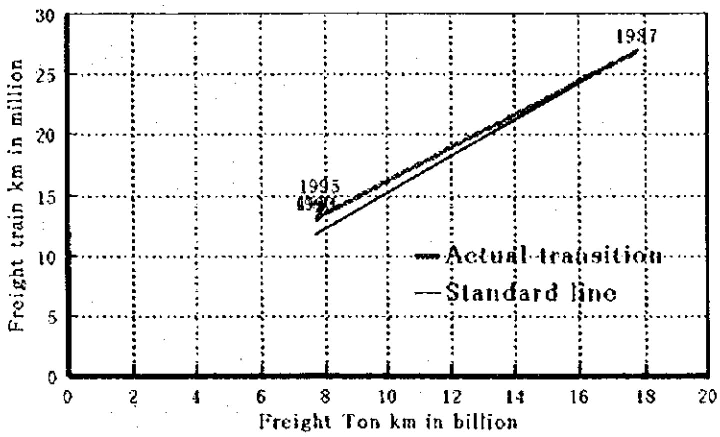


Fig.8.1.2- 2 The Relation between Freight train Km and Freight ton Km

The freight ton km and freight train km are varied in small area and the values of 1993 ~ 1996 are expressed in the nearly same place in the above figure 8.1.2-2, because of the big difference from the value of 1987. The precise data of them are indicated in the table 8.3.1-1.

The freight trains of BDZ are operated according to the scheduled train diagram by the request of customers. The freight train km is proportionally decreasing according to the freight traffic demand in 10 years. The fulfillment of the traction capacity of each freight train is aimed at eagerly in the past 10 years for the economy of train operation.

The capital cost of the track, personnel and rolling stock is not decreased by rapid changing of traffic demand and by decrease of train km.

By utilizing this period of demand decreasing, direct train operation service without stopping at intermediate stations can be realized with relatively small cost by way of abolishing pushing locomotive at mountainous sections, etc. The train km will be raised up to some extent, but the burden of customers will be lessened for preparing enough cargo to satisfy the standard for operating freight trains. The new traffic demand will be born by decreasing the transport cost and by raising up the convenience of customers.

(2) Necessity of shortening the freight delivery time

The travel speed of freight trains is required to be 60 km/h and more in the freight transport market. Actual freight train speed remains 30 ~ 39 km/h.

The train diagram shows that the intermediate stopping time for coupling - discoupling freight wagons is relatively plenty and it causes the decrease of train travel speed, the difficulty of announcement of arriving time to customers and the delay of modernization of freight information system.

The traditional transportation system depending on the train composition work in the marshalling yards and on the couple - discouple of freight cars at intermediate stations, is being changed to the direct access block train system gradually. This endeavor is considered to be effective for increasing competitiveness to the road transport organs in the days of highway transportation.

(3) Necessity of concentration of loading and unloading stations

Too many short distance freight trains are planned in the area of major terminal stations. They are not competitive with road vehicles and are creating bottle-neck for the planning necessary trains.
Freight trains are decreasing the average speed by stopping at many intermediate stations. By co-operating with trucks, railway can increase the rapid delivery service and economize the transportation cost.

(4) The train km operated and diagrammed

The ratio of freight trains km operated per diagrammed trains is supposed to be approximately 52 %.
For the convenience of smooth operation of freight trains by the request of customers, some uncertain freight trains are prepared, in advance, in the train operation diagram.
The freight train km is summed up and the scheduled freight train km show the two times of difference. This indicates that the capacity of transporting freight goods by actual train diagram is enough for the future demand increase.

8.1.3 Passenger Transport

(1) Problem of passenger transport

A breakthrough is sought for the BDZ passenger service. Problems are abundant; small curvatures, steep gradient, safety system, riding comfort, passenger information system, tariff, travel time etc. The most vital factor of them is considered to be the low speed of the present intercity train service. As indicated by the multiple regression analysis, a considerable transfer of traffic from road to rail mode can be expected by speeding up of trains.
It is advised that some experimental intercity high-speed services should be realized on selected sections. This will accelerate speed up program on the other lines from the actual results, which will support the capital investment by proving the real increase of income.

(2) Transition of intercity train speed

Although train speed up is necessary for surviving in the market of intercity transport, the passenger train speed has been kept at the same level in past 10 years and is decreased on some line at some period. In these years, the improvement endeavor is slightly admitted but the degree is not enough for recovering the traffic demand in the day of rapid construction of high way network.

Following data of express trains are gathered from the train timetables published by BDZ.

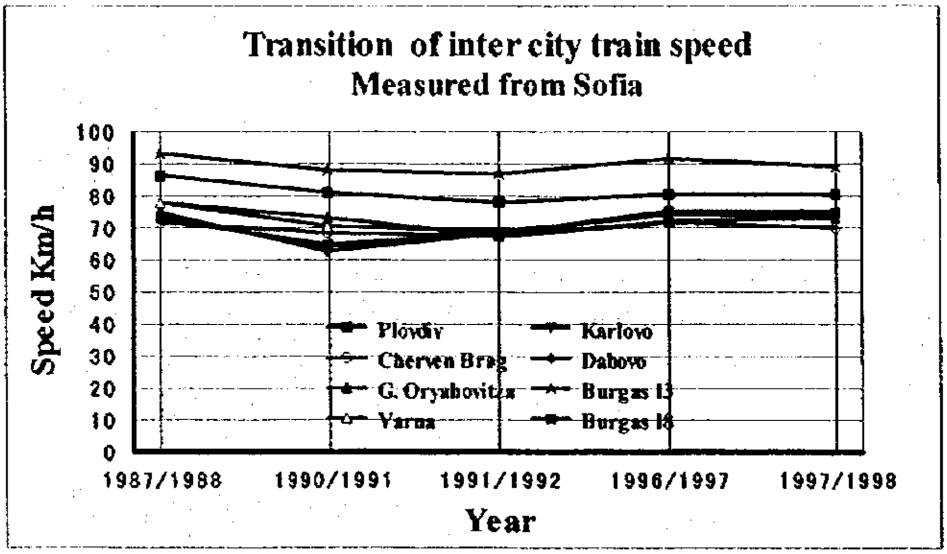


Fig.8.1.3- 1Transition of intercity train speed of each important section

The names of stations in the Fig.8.1.3-1 express the terminal station of the train that started from Sofia. The train speed is calculated by the distance between terminal station and Sofia and by the travel time of the train until to the terminal station.

(3) Traffic Demand and Passenger Train Km in the past 10 years

The transportation capacity of passenger trains in terms of train km can not be controlled by the traffic demand directly. In the period of retreat, some decrease of efficiency can not be avoided. The decrease of formation, number of coaches of a train, is executed which moderates the decrease of cost benefit performance. In the case of passenger transportation, the positive endeavor of increasing passenger demand is the most important way for improving the management.

Passenger train km of BDZ is well controlled in these days for the cost saving, as shown in the following figures.

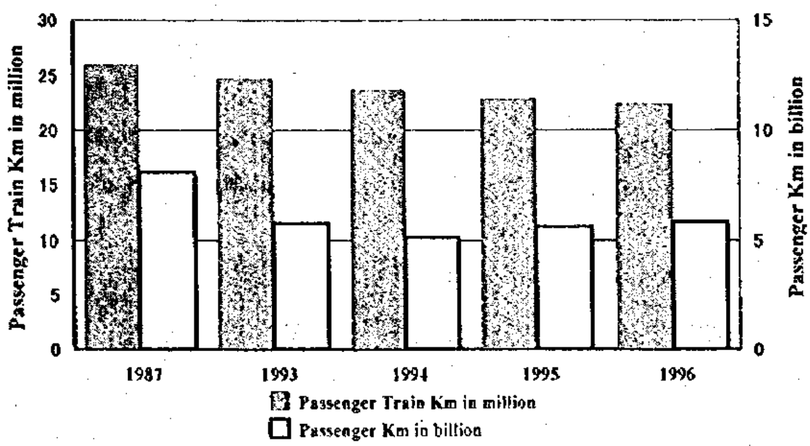


Fig.8.1.3- 2 Transition of Passenger km and Passenger train km

Although the passenger volume had been decreased until 1994, the passenger traffic data show the inclination of recovery since 1995. The passenger train km is controlled to suppress the excess train km in these years for approaching the reasonable zone.

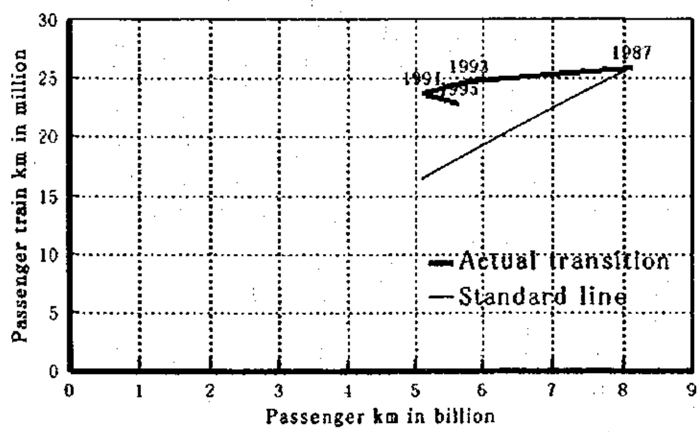


Fig.8.1.3- 3 The Relation between Passenger train Km and Passenger Km

The regulation of passenger train km by traffic demand is not so easy when compared to the freight service. The standard line is indicated for the case that passenger train km is proportional to passenger km.

The trace of the control of passenger train km is shown in the above figure. The nowadays' endeavor of BDZ for reducing operation cost should be appreciated.

The future passenger train planning should be done in the field of superiority of railway by considering the cost performance and competitiveness with road, because the reduction of passenger trains is very difficult when they are once operated.

(4) Rate of passenger trains operated

The ratio of passenger trains km operated per diagrammed trains km is supposed to be approximately 70 %, although the ratio will be varied by the transportation market circumstances.
The difference is produced from the fact that there are many seasonal trains and international trains in the train time-table which are not operated every day.
The most of trains are operated by a set of pair trains of two directions and the train km is summed up for one direction. The train km of both directions is estimated by multiplying 2 to the summed up data of one direction.

(5) Intercity passenger transport

The actual limiting speed of express trains is too strict and is causing slow travel speed as for competing with the highway network under construction. The limiting factors of speed are curves, switches, signals, gradient of track, bridges, strength of track, etc.. Improvement measures on total main lines are being analyzed for finding the appropriate way of increasing travel speed and maximum speed in this master plan study as far as possible.
Each trunk line were analyzed and some features of trunk lines are shown in the item 8.2.

(6) Suburban transport

The electrified network of urban transportation inside Sofia City is well organized and the frequency service is also superior to that of the railway urban service. Generally speaking, the mass transportation system in big cities in Bulgaria is prepared fairly well by trolley bus, by tram-car, etc.
The urban and suburban traffic lines of BDZ are the bottle neck sections of important trunk lines that should be used for intercity passenger trains and for long distance freight trains.
It is recommendable that BDZ might keep the same service level for urban transport by considering the strategy of future train diagram; more freight trains, increase of train speed and frequency increase of intercity trains, etc.

8.2 FEATURES OF MAIN LINES

The track figure of curves and gradient will give fatal effect to speed limit and to running characteristics of rolling stocks.
The improvement degree of speed and travel time by each method will give fundamental influence to the policy making. The train-run curves are calculated by selecting some examples. For understanding the simulation works of train running curves, the track figures and train running speed limits etc. are explained at first.

8.2.1 Features of No. 1 Line

(1) Track figure and speed limit

The main part of this line is the section between Sofia and Plovdiv that is double tracked and electrified. The electrification of the international route of No.1 line is being undertaken on two single-track sections which connect to Yugoslavia and to Turkey.
By the electric traction, the travel hour and hauling capacity will be improved to increase the competitiveness in the international transportation market. Although the process of these projects is subjected to the political situation of adjacent countries, the track capacity and the train operation service should be improved on these international use sections.
The highest track level is about 740 m at Dragoman station. The gradient is continuos down warded to Sofia and to Dimitrovgrad Yuz

See Appendix A-1 Figure of the track gradient between Sofia and Kalotina
See Appendix A-2 Curves between Sofia and Kalotina
See Appendix A-3 Curves and speed limit of ordinary and pendulum type train between Sofia and Kalotina

The track section between Sofia and Plovdiv is abundant of up and down gradient and with many sharp and small curves because of the existence of mountain range between Sofia andSeptemvri.

See Appendix A-4 Figure of the track gradient between Sofia and Plovdiv
See Appendix A-5 Curves between Sofia and Plovdiv
See Appendix A-6 Curves and speed limit of ordinary and pendulum type train between Sofia and Plovdiv

(2) Bar chart of trains programmed

The figures of train operation in the bar chart are the basis for the calculation of train Km on each line. In this item, the train operation condition of main lines will be introduced for knowing the actual situation of BDZ transport by using the bar chart diagram of trains.

1) Freight train

Many freight trains from branch lines flow in No.1 line section of Kalotina – Sofia to carry freight goods from the mines and factories on branch lines.

See Appendix B-1: Bar Chart of Freight Trains of Kalotina - Sofia

On the section between Iskar and Sofia, the freight trains of No.3 lines are flowing into the freight Yard on this section.
For the utilization of track capacity of No.1 line, the freight train operation system should be modified to avoid the operation of such freight trains only for using that marshalling yard on the above section between Iskar and Sofia.
The traffic demand between Sofia and Plovdiv will be increased fundamentally in future.

See Appendix B-2: Bar Chart of Freight Trains of Sofia - Plovdiv

Most of freight trains are terminated at Svilengrad and at Plovdiv freight stations. The international freight trains are relatively few and they are not operated directly to Sofia, Yugoslavia and to Turkey.

See Appendix B-3: Bar Chart of Freight Trains of Plovdiv – Svilengrad

2) Passenger train

The international trains from Dimitrovgrad Yuz to Sofia and the passenger trains from Kalotina Zapad of boundary station, passenger trains from Kalotina and from Dragoman are running on the section between **Sofia and Kalotina.**
These passenger trains will be increased by expanding living places in the suburban area of Sofia and by increasing international traffic. Although the section between Volyak and Sofia is double-tracked, the density of passenger trains and freight trains will be raised up and still this section will become a bottleneck. The actual number of passenger trains are relatively few but it will be augmented by considering the importance of international transportation and the possibility of enlarging the Sofia City Urban Area to these surrounding zones.

See Appendix C-1: Bar Chart of Passenger Trains between Sofia and Kalotina

More express, rapid and international trains will be operated on this line section between **Sofia and Plovdiv,** according to the development of these two cities and the increase of international transport.
Passenger trains are densely operated between Sofia and Plovdiv. The intercity fast trains of Express and Rapid are approximately two times to the local passenger trains that stop at most of stations. Some local passenger trains are operated up to Iftiman or to Septemvri by considering the need.
This line section is the most important for the passenger train operation in BDZ and for the social activity of Sofia and Plovdiv. The new signal system and new train control system, etc., are equipped on this double track and electrified section.

See Appendix C-2: Bar Chart of Passenger Trains between Sofia and Plovdiv

The section between **Plovdiv and Svilengrad** is single tracked and non electrified.
International trains are operated but relatively few on this section in spite of the importance of connecting Yugoslavia, Bulgaria and Turkey and of connecting Rumania, Bulgaria and Turkey.
Actual train operation service is not enough and it is inconvenient for the international passengers who travel between Sofia and Turkey, etc.
Most of the trains on this section are operated from Plovdiv and some trains are from Dimitrovgrad.
In future, the demand of operating trains on this line will be increased for the operation of international trains to and from Yugoslavia and Turkey, and for the intercity domestic trains which connect Sofia and Plovdiv.
It is possible to absorb the future traffic demand on this double track section by some improvement projects.

See Appendix C-3: Bar Chart of Passenger Trains between Plovdiv and Svilengrad

By considering the importance of the traffic among adjacent countries, this section will be electrified and the track capacity of this single track section shall be raised up by shortening the train travel time among stations.
This track capacity on the single track section will come to its limit soon and the traffic demand increase on the single track sections should be absorbed by partial double tracking or eliminating the ineffective trains or constructing different level crossing at intermediate

terminal stations, etc.

(3) Train diagram

1) Freight train diagram

Freight Train Diagram on No.1 line
Distance from Sofia

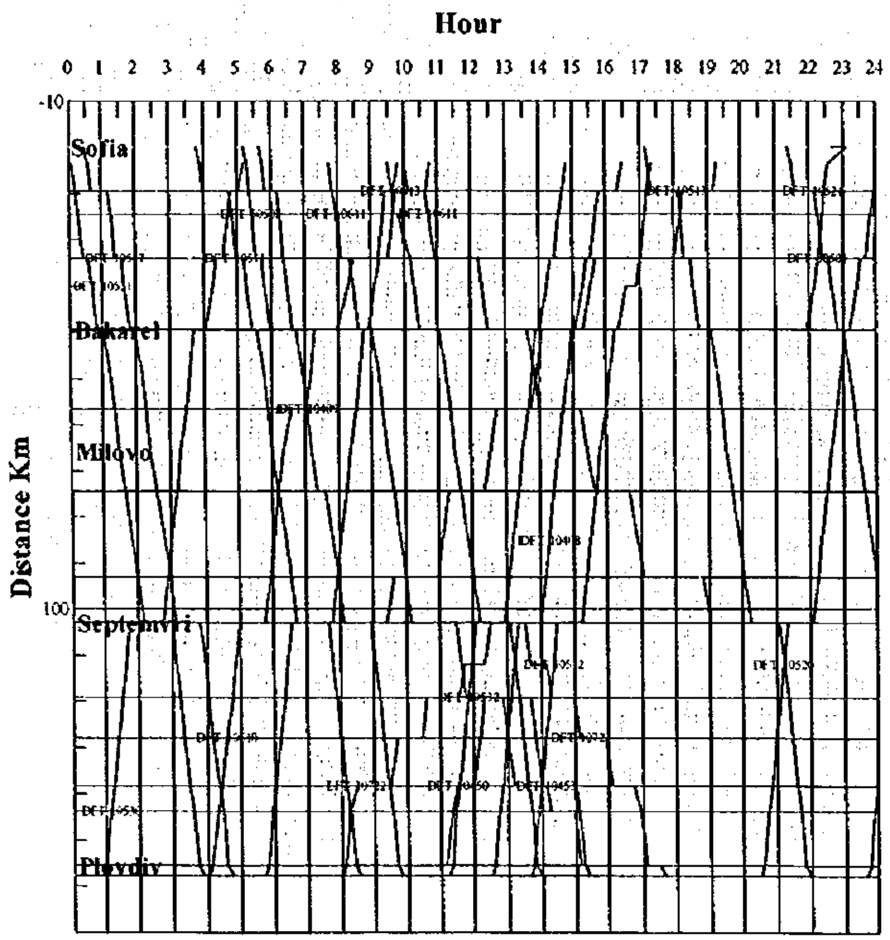


Fig.8.2.1- 1 Freight Train Diagram between Sofia and Plovdiv

The freight trains are running almost 24 hours among many passenger trains. Most of trains are operated between Sofia and Plovdiv but some freight trains are operated up to Septemvri from Sofia and from Plovdiv. The stopping time at intermediate stations operation is remarkably plenty in day-time. For increasing the freight trains between Sofia and Plovdiv, the fundamental improvement measures will become necessary because of the too steep gradient of the mountainous section and of the difference of travel speed among freight and fast passenger trains. The improvement of brake system of freight trains will become an

important action for raising up the freight train speed.
Fundamental improvement project, such as creating new tunnel line with big radius of curves and with moderate gradient,, will become necessary in future not only for freight trains but also for passenger trains.

2) Passenger train diagram

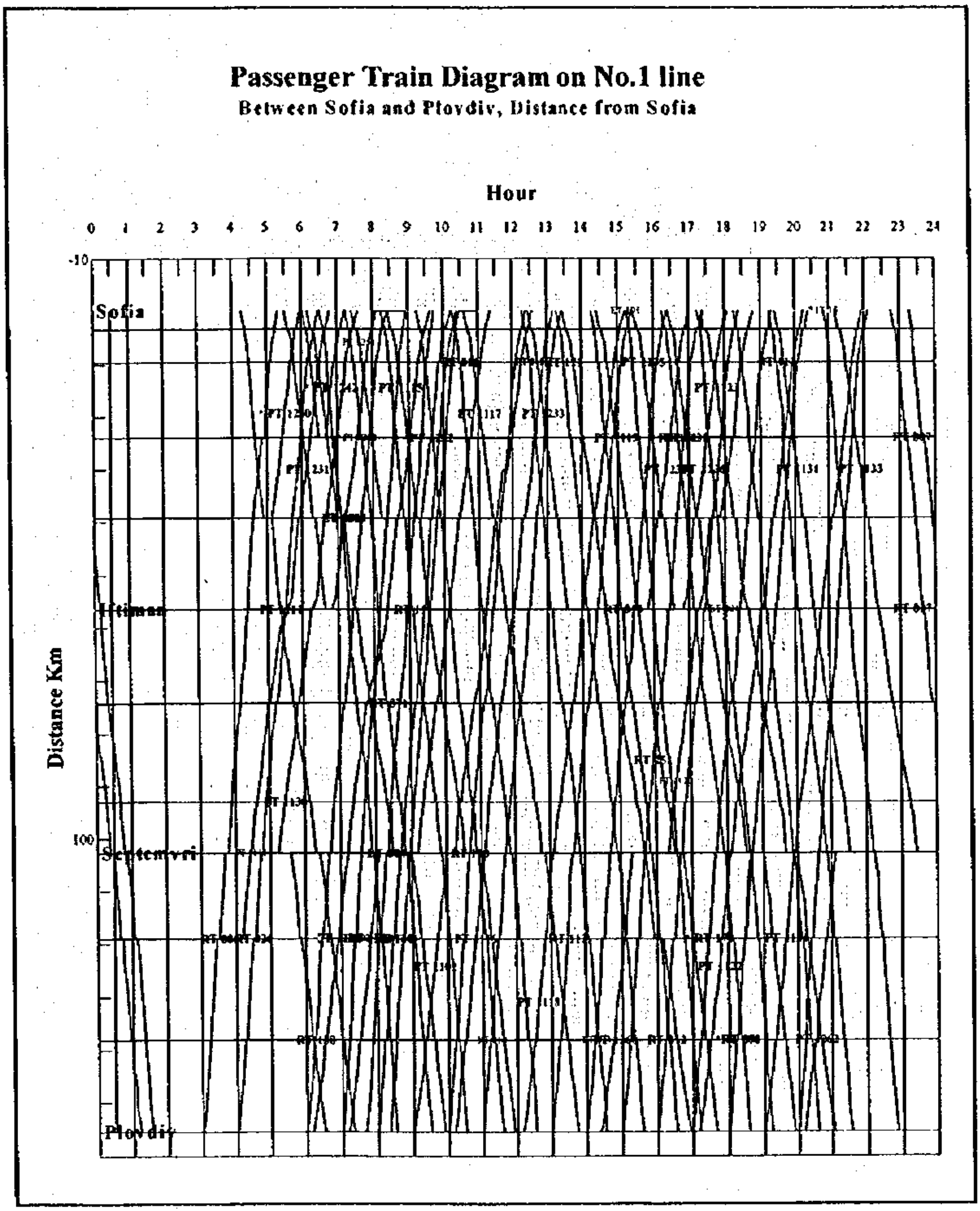


Fig.8.2.1- 2 Passenger Train Diagram between Sofia and Plovdiv

The passenger trains are running regularly between Sofia and Plovdiv. The time difference among fast trains and local passenger trains which stop at most stations is relatively little. The travel speed of fast trains can be increased by utilizing the passing facilities at intermediate stations and by improving switch speed limits at intermediate stations more effectively.

(4) Train Speed of No.1 line

1) Average Speed of Freight Train

As shown in the table 8.2.1-1, the average travel speed of the freight trains on the No.1 line with steep gradients is low and is calculated as approximately 27 – 31 Km/h. By any means, the freight train speed should be elevated as far as possible for the competition and for the parallel running among passenger trains.

Table 8.2.1- 1 Average Speed of Freight trains

Train hour of line 1 =	54.42	Hour
Train Km of line 1 =	1,463.00	Km
Average train speed =	26.89	Km/h

	Train Hour	Train Km	Speed
	Hour	Km	Km/h
Sofia - Provdiv	54.42	1,463.00	26.89
Provdiv - Sofia	49.85	1,546.90	31.03

2) Average Speed of Passenger Train

Table 8.2.1- 2 Average Speed of Passenger Train

Train hour of line 1 =	203.55	Hour
Train Km of line 1 =	11,201.30	Km
Average train speed =	55.03	Km/h

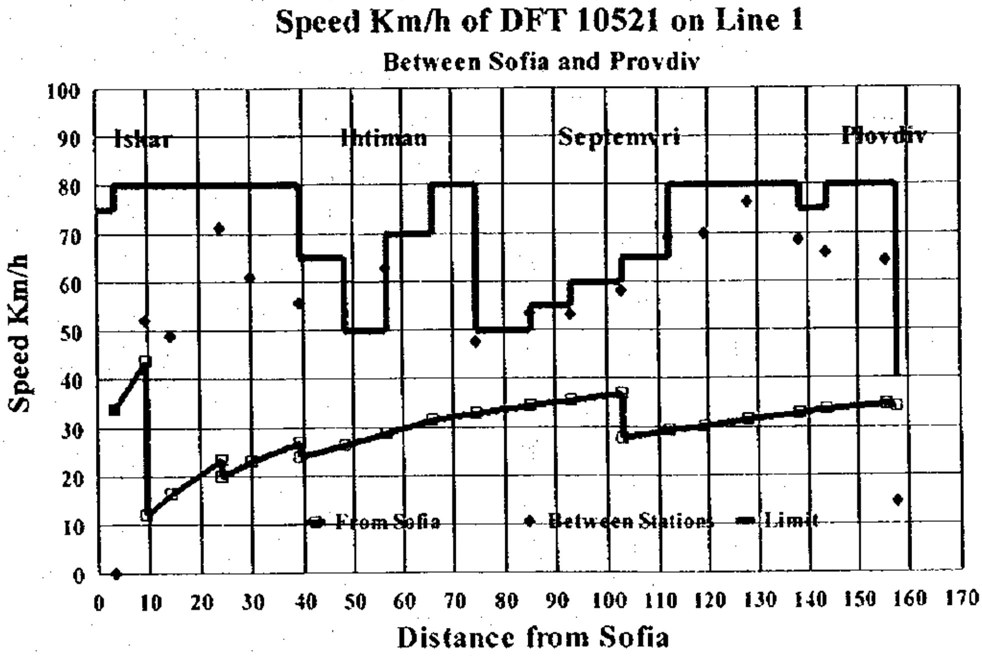
	Train Hour	Train Km	Speed
	Hour	Km	Km/h
Sofia - Plovdiv 1	33.83	1,939.60	57.33
Sofia - Plovdiv 2	39.38	2,283.70	57.99
Plovdiv - Svilengrad	25.90	1,314.30	50.75
Svilengrad - Plovdiv	25.88	1,271.70	49.13
Plovdiv - Sofia 1	27.17	1,433.00	52.75
Plovdiv - Sofia 2	27.52	1,552.00	56.40
Plovdiv - Sofia 3	23.87	1,407.00	58.95

As shown in the table 8.2.1-2, the average travel speed of the passenger trains on the No.1 line is calculated as 55.03 Km/h.
The speed of intercity passenger train will be elevated, because the speed up is necessary for the competition with road. The way and the rate of possible speed up will be shown in the item 8.3.3 of long term plan.

3) Speed and Speed Limit of Typical Trains

Freight Train

On average, the freight train runs at 27 – 31 Km/h between Sofia and Plovdiv.
The direct access typical freight trains with new brake system can run up to 70 — 75 Km/h.
The running procedure of following figures of DFT 10521 and DFT 10531 show that rapid freight trains are running at average speed of 55 – 60 Km/h with stopping at some intermediate stations.



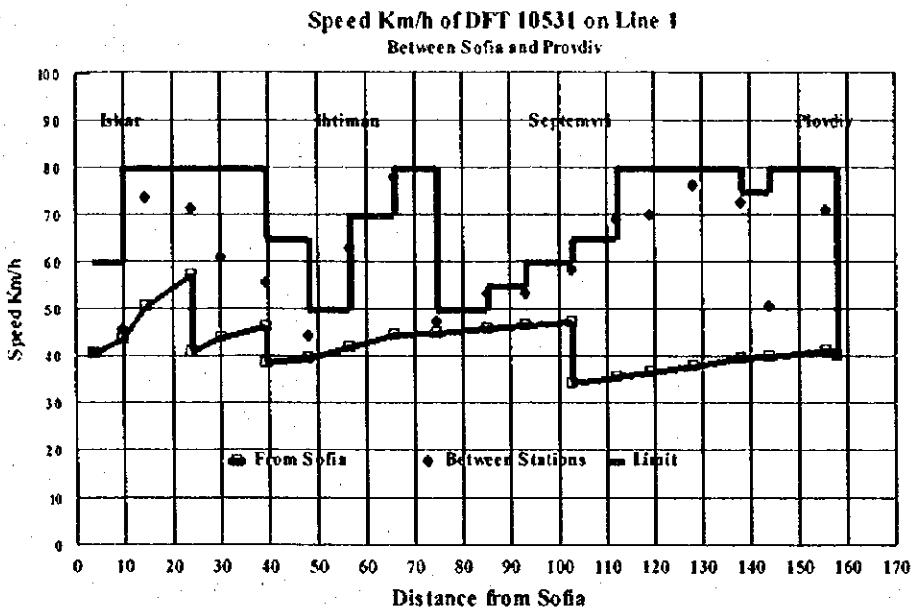


Fig. 8.2.1- 1 Actual Speed and Speed Limit of Freight Train DFT 10521 and DFT10531

Passenger Train

On average, the passenger train is running at 55.03 Km/h between Sofia and Plovdiv.
The fast passenger trains can run up to 125 Km/h.
The running procedure of following figure shows that express train 801 runs at average speed of 77 Km/h between Sofia and Plovdiv.

Train Speed on line No. 1

In case of Express Train 801

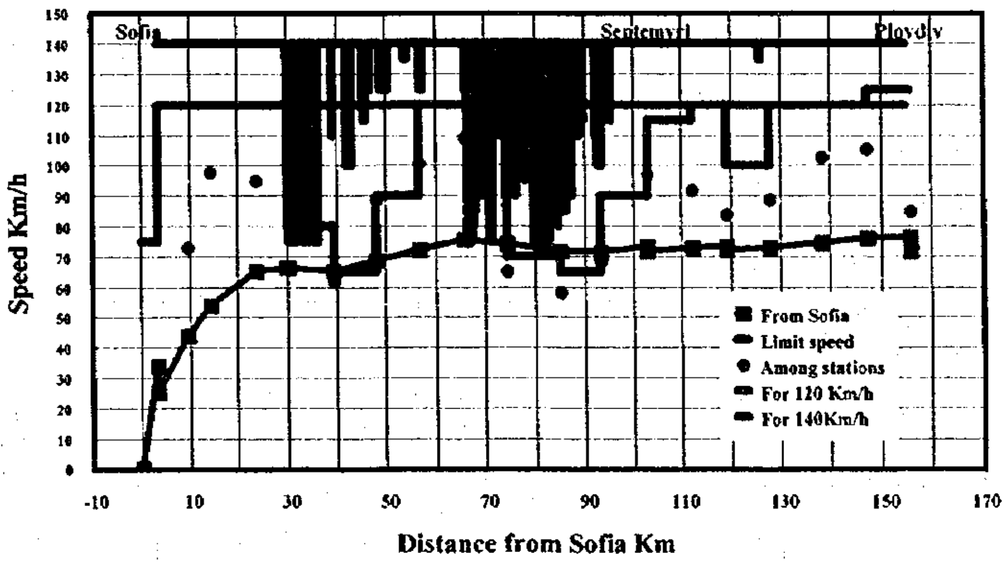


Fig. 8.2.1- 2 Actual Speed and Speed Limit of Express Train No. 801 between Sofia and Plovdiv

The speed limit which is caused by the curves at 66 – 83 Km from Sofia is too strict and it shall be improved to be R 400 m and more, because that the curves are giving a remarkable influence on the average travel speed of the fast trains of line No.1. In future, when it become necessary to operate high speed trains with speed of 200 Km/h and more, the sections of 30 – 50 Km and 65 – 95 Km might be replaced by new track line with the standard curvature of 2000 – 2500 m. .

(5) Speed limit by future trains of No.1 line

For the evaluation of train speed up projects, precise analysis will be done on the section between Sofia and Plovdiv by simulating train running performance.
For the simulation of running curve of future trains, it is necessary to know correct information about the track condition: speed limit by curves, by gradient of route, by switch , by type of rolling stock, etc.

1) Route information on the section between Sofia and Iftiman

The sharp and small curves, the speed limit of ordinary type trains and the speed limit of

pendulum type trains are shown by sectional wise in the figures of appendix A1 – A6.
On the section of Sofia - Iftiman, there exist many sharp and small curves with the radius of 300 m between 30 and 36 Km. Radius of 300 m gives speed limit of 75 Km/h to ordinary type trains and 90 Km/h to pendulum type trains by considering safety, comfort of passengers, allowance of track maintenance and for car maintenance, etc.
These curves are existing in the mountainous sites where the gradient of up and down are also very steep. Its cost to improve the curvature and steep gradients which give restriction to train speed is very expensive. It's better to utilize this section to its speed limit by setting the allowable super-elevation to track and by keeping the good track condition, although some places should be improved.
The section between 36 and 43 Km has relatively short curves of R 500 m and R 600 m. If these curves be improved to R 700 m, the ordinary type train speed will be raised to 120 Km/h on the section of 37-66 km. The possible maximum speed of pendulum train on this section will be raised up from 120 Km/h to 140 Km/h.
For raising the limiting speed on the down gradient section, the braking capacity also should be studied carefully. Fundamental improvement will be realized at the time of introducing new rolling stock for replacing the old ones.
This steep gradient section will be improved by way of creating new tunnel line in case of fundamental renovation of train operation in distant future.

2) Route information on the section between Iftiman and Septemvri

On the section of Iftiman – Septemvri, there exist many sharp and small curves with the radius of 300 m between 66 and 72 Km and between 79 and 83 Km.
The curvature of R 300 m gives speed limit of 75 Km/h to ordinary type trains and 90 Km/h to pendulum type trains as mentioned above. Some curves on the section of 81 – 82 Km are a little less than R 300 m but, by keeping good track condition and by setting enough super-elevation, trains can be operated at 75 Km/h constantly.
Anyhow, this section is also in the mountainous sites and gradient of up and down is very steep. Its cost to improve the curvature and the steep gradient, which give restriction to train speed, is very expensive. For a while, it's better to utilize this track figure to its speed limit by setting the allowable super-elevation to track and by keeping the good track condition.
The section between 66 and 88 Km has other curves of R 400 m and R 600 m.
For the sake of drivers' control, the ordinary type train speed on above section will be limited to 90 Km/h after passing 75 Km/h speed limit section. The possible maximum speed of pendulum train on this section will be 95 and 110 Km/h relatively on the section mentioned above. If the R 500 m curve between 93 and 94 Km be improved, ordinary train maximum speed will be 110 Km/h and the pendulum type train speed will be 140 Km/h. After passing

the mountainous sites, trains can run to its maximum speed.
This steep gradient section will be improved by way of creating new tunnel line in case of fundamental renovation of train operation in future.

3) Route information on the section between Septemvri and Plovdiv

On the section of Septemvri – Plovdiv, there exists one curve of 900 m radius at 126 Km with short length.
This relatively flat section with good track alignment can be used for the super high speed train operation in future, without big remodeling work by combining new tunnel line on the mountainous sites.

8.2.2 Features of No. 2 Line

(1) Line figure and speed limit

The total section between Sofia and Varna is double tracked and electrified. On the section between Sofia and Mezdra, there is a famous mountainous site but the gradient of the section between Sofia and Cherven Brag is uniformly designed. The track route of Dragoman – Sofia (No.1 line) and Sofia– Cherven Brag (NO.2 line) has many sharp and small curves but the gradients of these sections are well designed to be moderate and is convenient for hauling of downward heavy freight trains.

See Appendix D-1: Figure of track gradient between Sofia and Cherven Brag
See Appendix D-2: Figure of track gradient between Cherven Brag and G. Oryahovitza
See Appendix D-3: Curves between Sofia and Cherven Brag

The curves, the speed limit of ordinary type train and the speed limit of pendulum type train by curves are shown in sectional wise in the Appendix D-3 ~ D-7.
On the section of Sofia -- Mezdra, there exist many sharp and small curves with the radius of 300 m between 14 and 77 Km. Radius of 300 m gives speed limit of 75 Km/h to ordinary type trains and 90 Km/h to pendulum type trains by considering safety, comfort of passengers, allowance of track maintenance and for car maintenance, etc.

See Appendix D-4: Speed limit in case of ordinary type train between Sofia and Cherven Brag

This sharp and small curved sections are in the mountainous sites but the gradient of up and down are well designed and moderate between Sofia and Cherven Brag, when compared to No.1 line between Sofia and Septemvri. Its cost to improve the curvature and steep gradient which will give restriction to train speed is very expensive. It's better to utilize this section to its speed limit by setting the allowable super-elevation to track, by keeping the good track condition and by increasing the braking capacity.
The curves at 33 and 52 Km are relatively short curves of R 200 m and a little more. The two curves should be passed by way of local limitation by indicating speed restriction boards.
After passing these mountainous sites, the track figure of curves becomes very smooth and the ordinary type train can run to maximum speed of 120 Km/h and the pendulum type train can run at maximum speed of 160 Km/h.
The curves at 150, 190 – 200, 280 – 290, 330 – 350, 435 – 440, 455 – 465 and 510 – 540 Km

are existing at big terminal stations or in Varna City area.
The track figure of curves is very smooth and the ordinary type train can run to maximum speed of 120 Km/h and the pendulum type train can run at maximum speed of 160 Km/h by restricting speed at stations above mentioned.

See Appendix D-5: Speed limit in case of Ordinary type train between Cherven Brag and Varna

See Appendix D-6: Speed limit in case of pendulum type train between Sofia and Cherven Brag

See Appendix D-7: Speed limit in case of Pendulum type train between Cherven Brag and Varna

(2) Bar chart of train programmed

1) Freight Train

On the section of Sofia – Mezdra – G. Oryahovitza, freight trains between Sofia and Mezdra and trains between Assen and G. Oryahovitza are mainly scheduled. The trains which will carry the international freight goods from Ruse and from Varna are relatively few.
No. 2 line is mainly used for sectional transport of medium distance, although this line is running through the most important country regions.

See Appendix E-1: Bar chart of freight train of Sofia – Mezdra – Gorna Oryahovitza of No.2 line

On the section of G. Oryahovitza – Shumen – Sindel – Varna, main freight trains between Gorna Oryahovitza and Varna and many local trains between Han Krim and Kaspichan are scheduled. The trains which carry the international freight goods from Ruse and from Varna are relatively few. Freight carried by local freight trains might be more suitable for road transport modes.
The plenty number of freight trains in Sindel area are scheduled to be related to No.8 line and to Varna.

See Appendix E-2: Bar chart of freight train of Gorna Oryahovitza - Varna of No.2 line

2) Passenger Train

The main purpose of this No.2 line is admitted as for the intercity service of Sofia – Mezdra – Vidin on No.7 line, Sofia - G. Oryahovitza – Ruse and Sofia – Varna.

A plenty number of fast and international trains are operated on the section between Sofia and Varna. On the section of Sofia – Lakatonik – Mezdra, express, rapid and local trains are operated and some of them are for No.7 line.

The No.2 line is one of the most important lines for the train operation in BDZ and for the social activity by connecting Sofia, Cherven Brag, G. Oryahovitza, Ruse, Varna, etc. The signal system and train control system, etc., are not sufficient for higher speed and for increase of number of trains and the safety system should be modernized.

See Appendix E-3: Bar chart of Passenger trains of Sofia – Cherven Brag of No.2 line

Passenger trains that stop at most of stations are operated between Cherven Brag and G. Oryahovitza. Many intercity trains of Express and Rapid are operated densely aiming at Varna and at Ruse. Some rapid trains are operated between Cherven Brag and Pleven. They are operated from Sofia, Mezdra and Plovdiv because Cherven Brag, Pleven and G. Oryahovitza are important cities in Burgaria.

See Appendix E-4: Bar chart of Passenger trains of Cherven Brag– G. Oryahovitza of No.2 line

See Appendix E-5: Bar chart of Passenger trains of G. Oryahovitza – Varna of No.2 line

This line section is used for intercity and for commuter service.

Local passenger trains are operated on this section; to connect Gorna Oryahovitza, Shumen, Kaspichan, Sindel and Varna area. Some local trains are operated between Shumen and Kaspichan.

On the suburban of Varna, some local passenger trains are operated.

Most of the fast trains on this section are operated from Sofia. One rapid train comes from Plovdiv via No. 4 line. Express and Rapid trains are running in parallel by decreasing travel speed of express trains. The express trains should run to its maximum by considering the competition with road transportation.

(3) Track Capacity

No.2 line is double tracked and electrified. Although this line is one of the most important trunk lines of BDZ, the railway line route is unfavorable to road network.

The track capacity of this line is relatively low because of the signal system, the level crossing

train operation at intermediate stations and of the track occupation of trains at terminal stations, etc.
In future, the demand of operating trains on this line will be increased on the international trains to and from Rumania via Ruse and on the fast trains between Sofia and Varna.
It is possible to absorb the future demand on the double track section by some improvement project to solve the above mentioned problems.
From the view point of commercial strategy, the competitiveness of No.2 line between Sofia and Varna or between Ruse and Varna should be investigated fundamentally and utilized. Many local trains might be admitted to be converted to road transport for saving the track capacity of bottle neck section between Shumen and Varna.

(4) Train diagram

1) Freight train

The freight train diagram on the section between Sofia and Cherven Brag are shown in the figure 8.2.2-1.
The freight trains are not so many as shown in the bar chart diagram and in the train operation diagram.
In future, the traffic demand of operating trains on this line will be increased for the international trains to and from Ruse and Varna and for the intercity trains which connects Sofia and Varna.
It might be possible to absorb the future demand on this double track line by some improvement measures by considering actual train operation. The freight trains on this section are not so many. Anyhow, the track capacity is enough.
The energy favored track section between Dragoman – Sofia – Cherven Brag should be utilized strategically. The road condition in these areas is not so good specially in winter season, although highway is under construction. One locomotive can haul heavy freight train with keeping same speed by using few energy on these famous mountainous sites like the cases in foreign countries.

Freight Train Diagram on No.2 line

Distance from Sofia

Hour

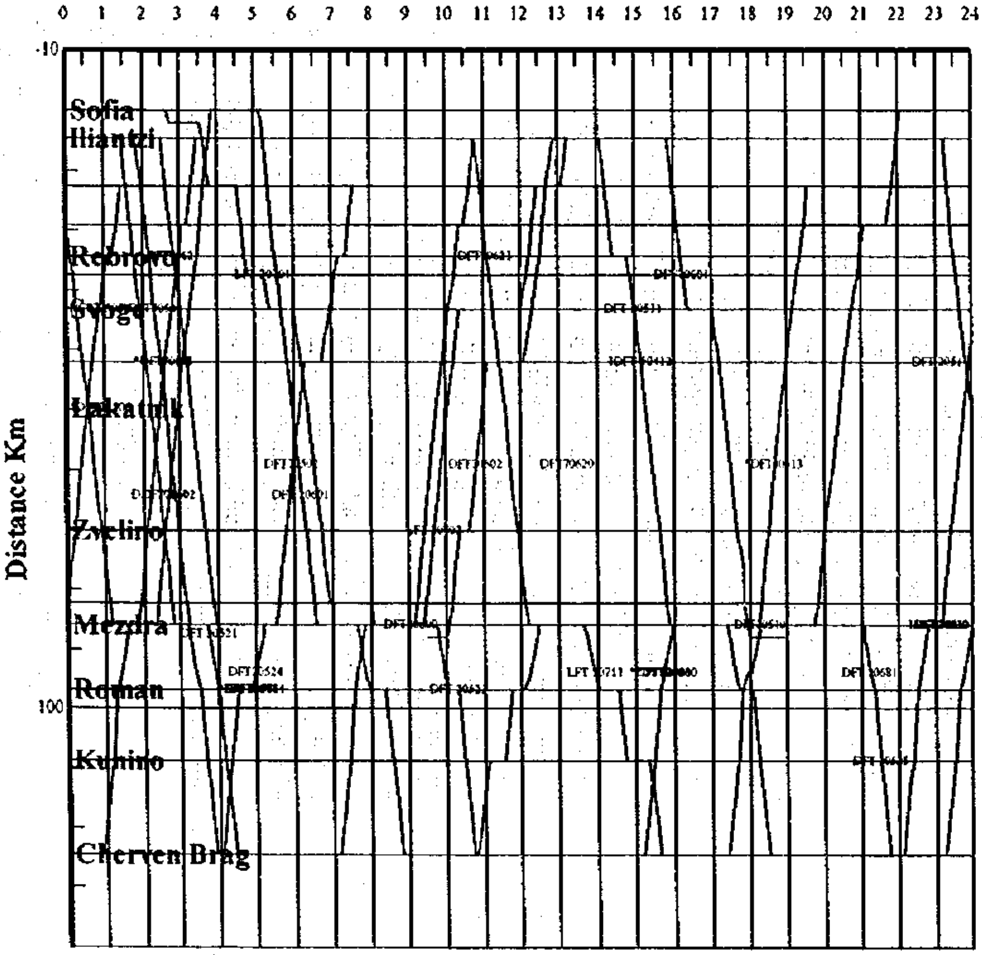


Fig.8.2.2- 1 Freight Train Diagram of No.2 line between Sofia and Cherben Brag

2) Passenger train

The passenger trains are running regularly between Sofia and Varna. The number of fast trains on this line are relatively few, because of the inferior passenger share of railway. The railway route of No.2 line is not favorable when compared to road network. No.2 railway line is connecting to Goma Oryahovitza but road network is constructed to combine Sofia and Varna by shorter route.

The difference of network between road and railway gives a fundamental effect on the traffic share by travel time.

The difference of travel time among express, rapid and local passenger trains is relatively little.

If the running speed of faster trains is increased by utilizing the passing facilities at intermediate stations, then the railway passengers will be increased effectively. The shortening of travel time of fast trains is possible with small cost.

(5) Train Speed of No.2 Line

1) Average Speed of Freight Train

Table 8.2.2- 1 Average Speed of Freight trains

Train hour of line 2 =	416.68	Hour
Train Km of line 2 =	13,217.40	Km
Average train speed =	31.72	Km/h

	Train Hour	Train Km	Speed
	Hour	Km	Km/h
Sofia - Cherven Brag	41.03	1,275.70	31.09
Cherven Brag - G. Oryahovitza	90.68	2,464.80	27.18
G. Oryahovitza - Kaspichan	43.12	1,691.00	39.22
Kaspichan - Varna	24.60	859.90	34.96
Varna - Kaspichan	26.23	1,002.30	38.21
Kaspichan - G. Oryahovitza	51.70	1,866.70	36.11
G. Oryahovitza - Cherven Brag	88.65	2,432.90	27.44
Cherven Brag - Sofia	50.67	1,624.10	32.05

As shown in the table 8.2.2-1, the average travel speed of the freight trains on the No.2 line is low. The average travel speed is calculated as of 27 – 38 Km/h by sectional and directional wise. Generally speaking, the freight train speed aiming at Sofia is admitted more rapid than the trains aiming at Varna inspite of the up gradient.

2) Average Speed of Passenger Train

As shown in the table 8.2.2-2, the average travel speed of the passenger trains on No.2 line is calculated as 58.34 Km/h.

The average passenger train speed between Sofia and Cherven Brag is relatively low and 50 -- 57 Km/h because of the strict limitation by curves in the mountainous site.

The fastest section is 66 -- 68 Km/h, measured between Cherven Brag and G. Oryahovitza. The average passenger train speed between Gorna Oryahovitza and Varna is decreased to 59 – 61 Km/h ridiculously inspite of the favorable track figure.

Table 8.2.2- 2 Average Speed of Passenger Train of No.2 Line

Train hour of line 200 =	363.45	Hour
Train Km of line 200 =	21,203.40	Km
Average train speed =	58.34	Km/h

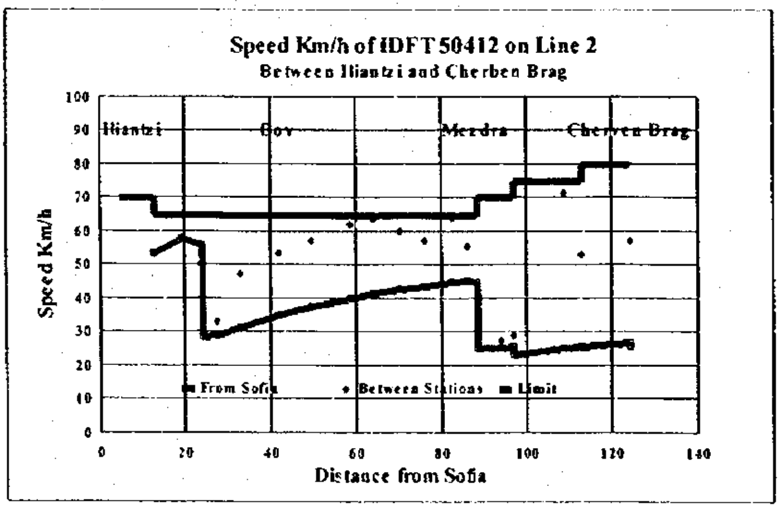
	Train Hour Hour	Train Km Km	Speed Km/h
Sofia - Cherven Brag 1	27.58	1,388.80	50.35
Sofia - Cherven Brag 2	28.95	1,657.10	57.24
Sofia - Cherven Brag 3	23.03	1,239.80	53.83
Cherven Brag - Gorna Oryahovitzua	40.97	2,770.50	67.63
Gorna Oryahovitzua - Varna 1	33.75	2,050.90	60.77
Gorna Oryahovitzua - Varna 2	23.73	1,423.90	60.00
Varna - Gorna Oryahovitzua 1	34.52	2,058.20	59.63
Varna - Gorna Oryahovitzua 2	24.18	1,428.90	59.09
G. Oryahovitzua - Cherven Brag	44.15	2,923.80	66.22
Cherven Brag - Sofia 1	29.70	1,474.50	49.65
Cherven Brag - Sofia 2	29.60	1,495.20	50.51
Cherven Brag - Sofia 3	23.28	1,291.80	55.48

The intercity fast train speed on this line can also be elevated. The speed up is necessary for the competition with road. The way and the possible speed up rate will be shown more precisely in the following.

3) Speed and Speed Limit of Typical Train

Freight Train

On average, the freight train runs at 31.72 Km/h between Iliantzui and Cherven Brag.



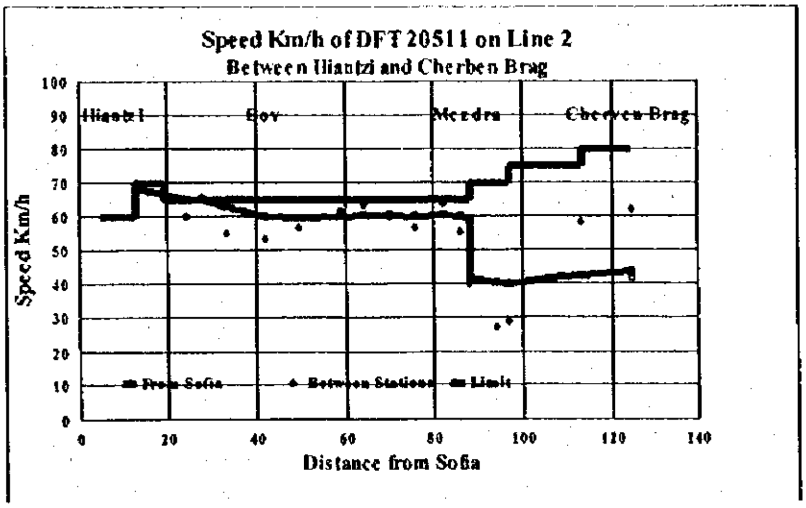


Fig.8.2.2- 2 Actual Speed and Speed Limit of Freight Train No. IDFT 50412 and DFT 20511 between Iliantzui and Cherven Brag

Speed limits of trains are indicated in the train time table for driver as speed limit. Running speed between two stopping stations and the average travel speed from Sofia and to the intermediate stopping stations are calculated from the data of actual train time table.

The direct access freight trains can run up to 65 — 70 Km/h between Sofia and Cherven Brag stations.

The running procedure of DFT 50412 and DFT 20511 shows that rapid freight trains are running at average speed of 27 – 45 Km/h by way of stopping at intermediate stations or not.

The difference between two DFT trains is caused by the way of stopping at intermediate stations. The two trains' running speeds between stations are relatively similar but the travel speeds of the two trains are quite different.

The above figure shows that the travel time of total freight trains on No.2 line can be reduced to half by change of operation diagram. This will give the possibility to increase the operation efficiency of locomotives and to shorten the delivery time of freight goods completely by system change. That fear of decreasing the utilization efficiency of locomotives by block train system will be gone out by increase of rotation efficiency.

The gradient of No.2 line is moderate and it is appropriate for freight train operation and the non stop freight train can continue same speed and can haul the more wagons compared to No.1 line. This No.2 line figure is more suitable to freight train operation than to passenger train operation. The direct operation method will enlarge the chance of freight trains by parallel running to the passenger trains in day time.

Passenger Train

On average, the passenger train runs at 58.34 Km/h between Sofia and Varna.

The fast trains between Sofia and Cherven Brag are running approximately at 50 – 60 Km/h.

The running procedure of following figure shows that the express train 201 runs at average speed of 70 Km/h. The average speed of the express train on this section is relatively low because of the speed limit between 11 – 88 Km.

The speed limit which exists by the curve at 32 Km and at 52 Km from Sofia shall be improved to R 300 m and more, because that curves are giving a remarkable influence on the average travel speed on the express of line No.2.

In long future, when it become necessary to operate high speed trains with speed of 200 Km/h and more, the section of 10 – 95 Km might be replaced by new track line with the standard curvature of 2000 – 2500 m.

The running procedure of the express train 201 shows that the average running speed between Sofia and Mezdra can be raised up to 75 Km/h by small improvement project.

The passenger trains between Cherven Brag and G. Oryahovitza are running approximately at 66 – 67 Km/h.

The running procedure of Fig.8.2.2-4 shows that the express train 201 runs at average speed of 73 Km/h between Cherven Brag and G. Oryahovitza. The average speed of the express train on this section is relatively low because of the stopping chance at intermediate stations are many.

The speed limitations are existing at big stations where most fast trains are stopped. The speed limitation 100 Km/h that exists between 190 and 281 Km can be improved by some countermeasures.

The train speed can be improved strategically by reducing stopping chances.

The running procedure of the express train 201 shows that the average running speed between Cherven Brag and G. Oryahovitza can be raised to 90 Km/h and more by small improvement project.

In the figures, the speed limit of trains are indicated in the train time table for drivers and other speed limits in case of 120, 140 km/h that are calculated by curves theoretically are explained for understanding general concepts. Other speed limits of switches, the strength of facilities and down gradient are not indicated here.

But the chapter 8.3 of long future projects estimated only for knowing the effect of each case and their approximate amount of investment, the other speed limits above mentioned are considered as far as possible.

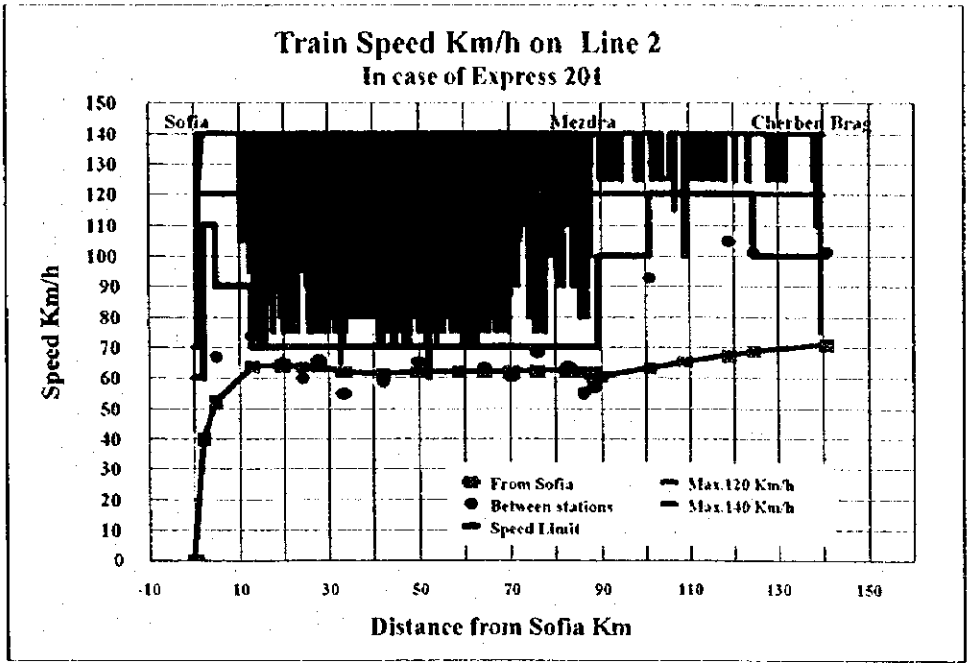


Fig.8.2.2- 3 Actual Speed and Speed Limit of Express Train No. 201 between Sofia and Cherven Brag

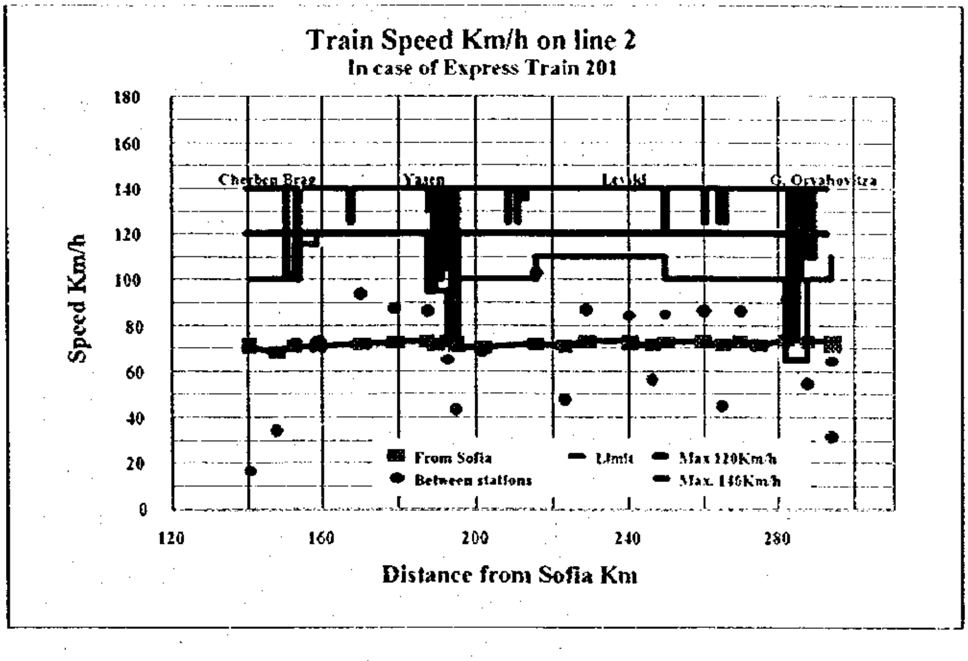


Fig.8.2.2- 4 Actual Speed and Speed Limit of Express Train No. 201 between Cherven Brag and G. Oryahovitza

8.2.3 Features of No. 3 Line

The most part of the sections between Sofia and Zimnitza are single tracked but all sections of this line are electrified.

(1) Train Operation

1) Freight Train of No. 3 Line

This No.3 line is used mainly for direct operation between Sofia and ports areas.
The main trains carry the goods between Sofia area and ports; Varna and Burgas.
Some trains on No. 3 line are operated between Karlovo and Dimnitza and between Karlovo and Dimnitza.

See Appendix F-1: Bar Chart of Freight Train between Sofia and Dabovo

See Appendix F-2: Bar Chart of freight trains between Dabovo and Varna

2) Passenger Train of No. 3 Line

The passenger trains from Sofia to Karlovo are operated by two routes; one route is via Ilientzui and the other route is via No.1 line of Sofia – Kazichane – Stolnik. Passenger trains are operated on the section of Karlovo – Tulovo – Dabovo.

See Appendix F-3: Bar Chart of Passenger trains of Sofia - Dabovo

See Appendix F-4: Bar Chart of Passenger trains of Dabovo–Karnobat–Varna

Several Rapid trains are operated between Sofia and Burgas by connecting intermediate junction stations on No.3 line.
These rapid trains will be increased by the increase of the relation between Sofia and two international ports of Burgas and Varna.
Many passenger trains are operated between Dabovo and Karnobat and between Karnobat and Varna. Passenger trains are operated to connect of the junction stations of Dabovo, Zimnitza, Karnobat, Sindel and Varna.

(2) Track Capacity

The track capacity between Stolnik and Karlovo is used approximately 50 %. It is sufficient for future increase of traffic demand. No.3 line has the role to absorb the overflowed trains from No.1 and No.2 lines.
According to the traffic demand of other two trunk lines and the strategy of train system, a partial double tracking project will become necessary for increasing the capacity and decreasing the waiting chances of trains on No.3 line in future.

(3) Train Diagram

1) Freight Train Diagram

The main purpose of this line is to connect Sofia and two international ports of Black Sea. In spite of the role of this line, freight trains on the single tracked No.3 line are stopped many times at intermediate stations, because of the couple and disconnection of wagons and of waiting the opposite direction trains.
The former work at intermediate stations should be decreased as far as possible.
The latter work caused by single track line might be solved by creating some partial double tracking sections.
How to decrease the stop chance is important for increasing the efficiency and the competitiveness of train operation.
There is a wide vacant time zone, called "window", where no trains are planned. This window is necessary for the track maintenance work in day-time. The No.3 line is single tracked and the waiting chance will be increased by number of trains on No. 3 line, if the chance of operating trains from No.1 line or on No.2 line to No.3 line is augmented in future.

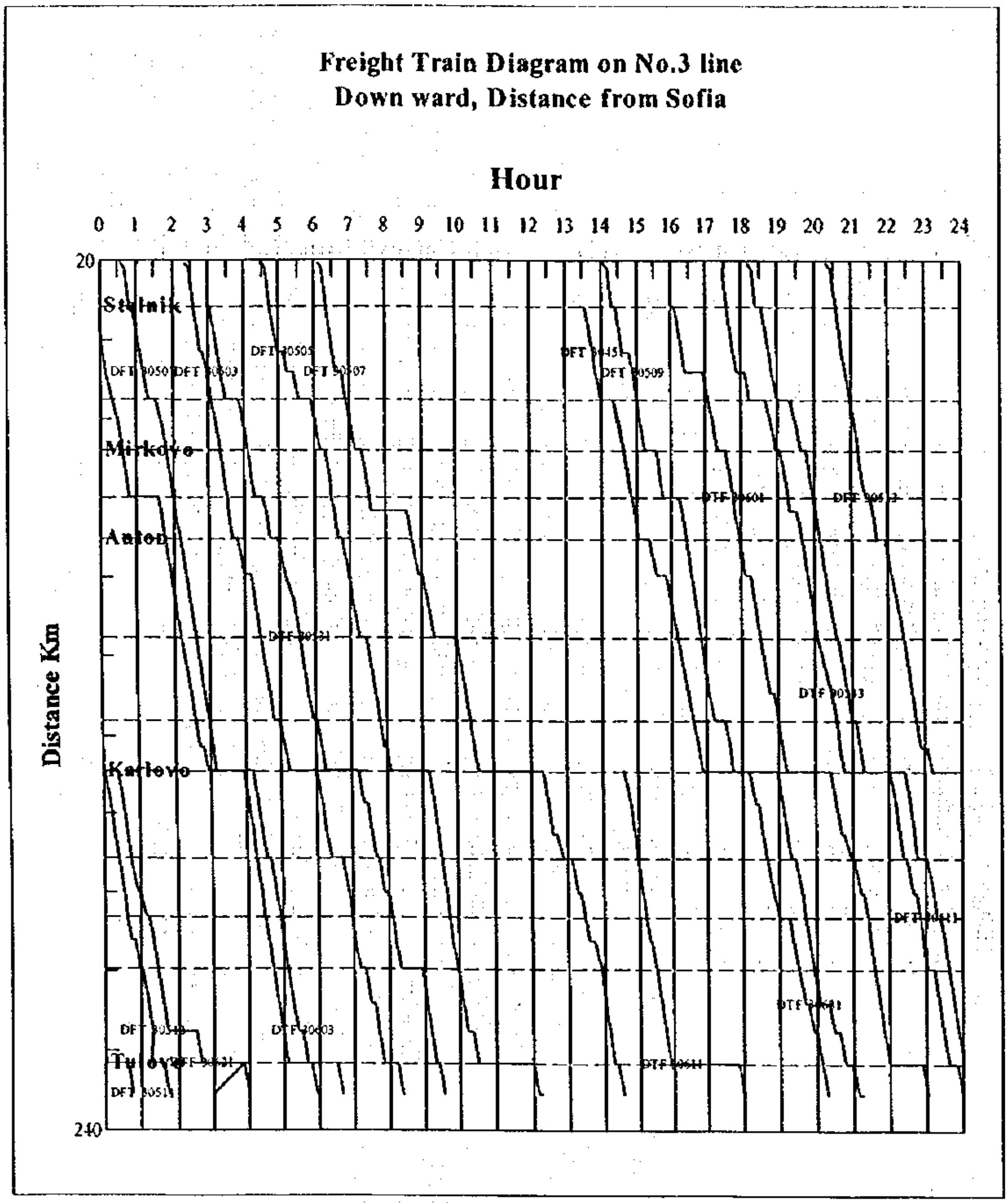


Fig. 8.2.3- 1 Freight Train Diagram

(4) Train Speed

1) Average Speed of Freight Train

As shown in the following table, the average travel speed of the freight trains on the No.3 line is low and the average speed is calculated as of 33.22 Km/h.

The freight train speed should be elevated as far as possible for the competition with road.

Table 8.2.3- 1 Average Speed of Freight Trains of line No.3

Train hour of line 3 =	359.68	Hour
Train Km of line 3 =	11,948.40	Km
Average train speed =	33.22	Km/h

	Train Hour	Train Km	Speed
	Hour	Km	Km/h
Sofia - Davovo	110.02	3,149.70	28.63
Davovo - Karnobat	72.85	2,215.20	30.41
Karnobat - Davovo	62.80	2,468.00	39.30
Davovo - Sofia	114.02	4,115.50	36.10

2) Average Speed of Passenger Train

As shown in the following table, the average travel speed of the passenger trains on the No.3 line is calculated as 53.79 Km/h.

Table 8.2.3- 2 Average Speed of Passenger Trains of No. 3 Line

Train hour of line 3 =	197.50	Hour
Train Km of line 3 =	10,623.50	Km
Aveerage speed =	53.79	Km/h

Train Hour	Train Km	Speed	
Hour	Km	Km/h	Note
25.18	1,321.80	52.49	Sofia - Dabovo 1
24.30	1,200.60	49.41	Sofia - Dabovo 2
25.03	1,384.30	55.30	Dabovo - Varna 1
18.23	1,099.70	60.31	Dabovo - Varna 2
20.77	1,188.40	57.23	Varna - Dabovo 1
19.57	1,021.80	52.22	Varna - Dabovo 2
24.55	1,277.90	52.05	Dabovo - Sofia 1
19.93	1,064.50	53.40	Dabovo - Sofia 2
19.93	1,064.50	53.40	Dabovo - Sofia 2

The average passenger train speed between Sofia and Dabovo is relatively low and 50 – 53.5 Km/h because of the curves and of the single track .

The average passenger train speed between Dabovo and Varna is 52 – 60 Km/h.

The intercity passenger train speed on this line can also be elevated and the speed-up is necessary for the competition with road; the way and the rate of possible speed-up will be shown more precisely in the following.

(5) Speed Limit of Typical Train

1) Freight Train

On average, the freight train runs at 29.51 Km/h between Iliantzui and Karnobat. Speed of freight trains is restricted by curves and steep gradient on the section of ups and downs in mountainous site. The freight train speed is restricted by the brake performance on the down gradient sections for the sake of safety.

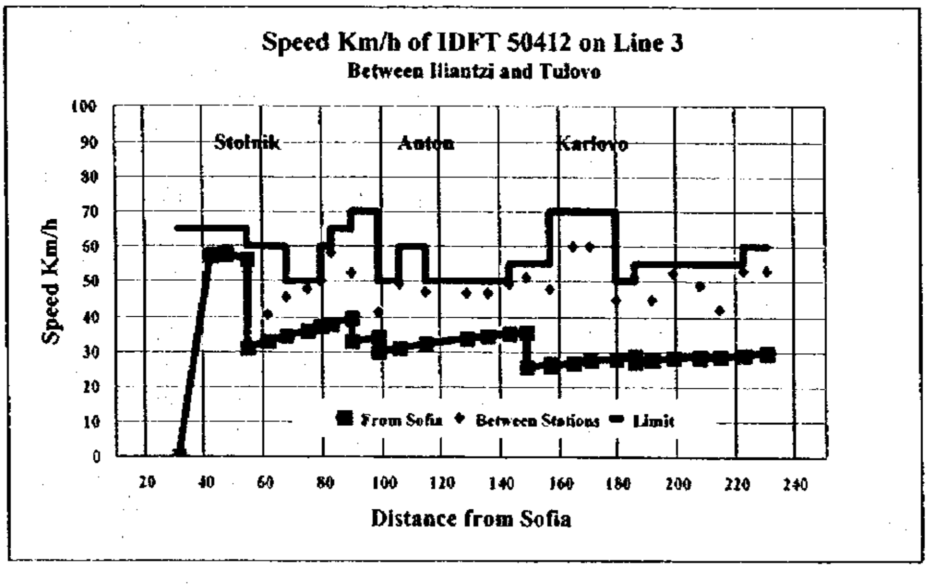
The direct access typical freight trains can run easily at 60 – 65 Km/h between stations, when the brake system is improved.

The running procedure of following figures of IDFT 50412 and DFT 30501 shows that rapid freight trains are running at average speed of 30 – 40 Km/h by stopping at intermediate stations. The difference of speed between two DFT trains is caused by the chance of stopping at intermediate stations.

The two trains' running speeds between stations are relatively similar but the travel speeds of the two trains are different. This shows the deliberate selection of stopping station is very important task for the usage efficiency of rolling stock and drivers.

The figure shows that the travel time of total freight trains on No.3 line can be reduced by 30 – 40 % by changing the operation system. This will give the possibility to increase the operation efficiency of locomotives and to shorten the delivery time of freight goods. The fear of decreasing the utilization efficiency of locomotives by block train system will be gone out by increase of rotation efficiency.

The direct operation method will enlarge the chance of freight trains' parallel running to the passenger trains in day time.



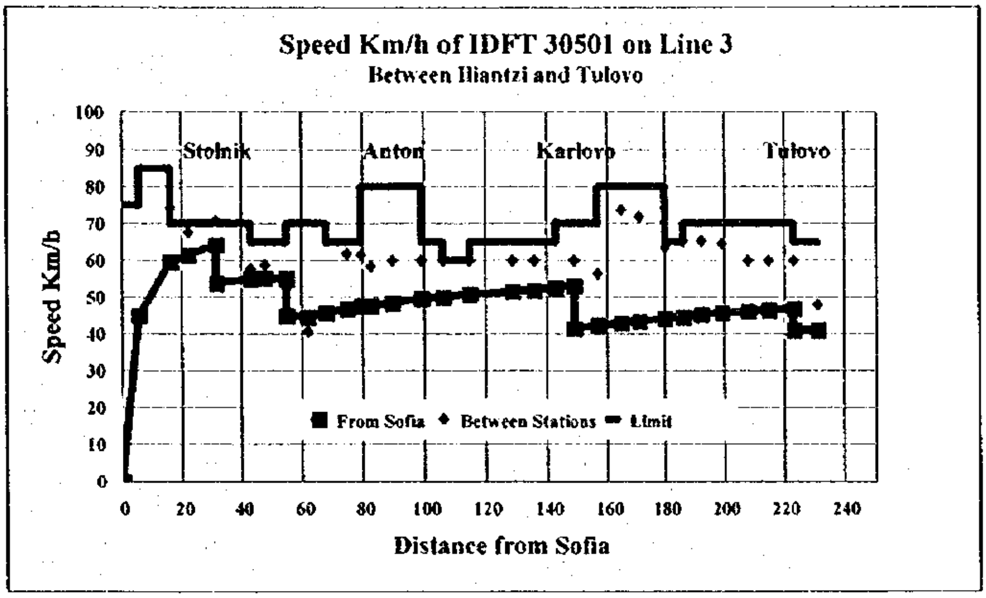


Fig.8.2.3- 2 Actual Speed and Speed Limit of Freight Trains of IDFT 50412 and IDFT 30501 between Sofia and Dabovo

2) Passenger Train

On average, the passenger train runs at 53.79 Km/h between Sofia and Varna.

The passenger trains between Sofia and Dabovo are running approximately at 52 – 58 Km/h. The passenger trains between Dabovo and Varna are running at 52 – 60 Km/h.

The express passenger trains can run up to 120 Km/h but the speed limit on the section between Sofia Stolnik and Dabovo is 75 – 100 Km/h.

The running procedure of figure shows that the express train 321 runs at average speed of 62 Km/h. The average speed of the express train on this section is relatively low because the speed limit between 35 and 55 Km is 70 Km/h and 80 – 90 Km/h on the section of 55 – 185 Km.

The lowest speed limit by curves at 46 – 49 Km from Sofia is 70 Km/h but the speed limits on the section between 54 – 132 Km are relatively similar of 100 Km/h except the curve at 64 Km. The gradients between Stolnik and Karlovo are steep and the speed limit are given mainly for the safety of braking on down gradient section.

The curves and the steep down gradient are giving a remarkable influence on the average travel speed on the express train of line No.3. In future, when it become necessary to increase track capacity by double tracking project, the new track line should be constructed by tunnel with more moderate gradient and with larger curves.

The running procedure of the express train 321 shows that the average running speed of fast trains between Sofia and Karlovo can be raised up from 62 to 75 Km/h and more by the degree of decreasing stopping stations.

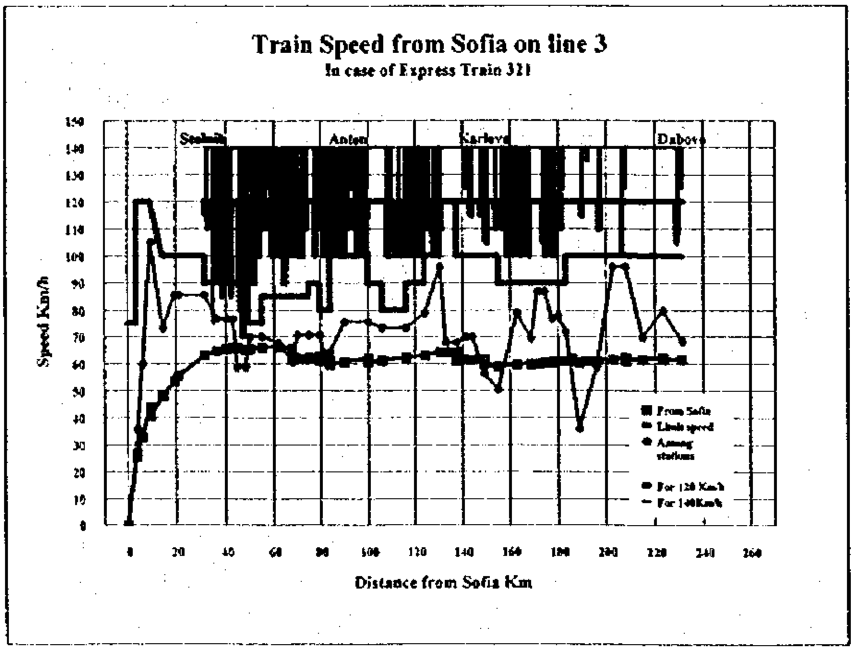
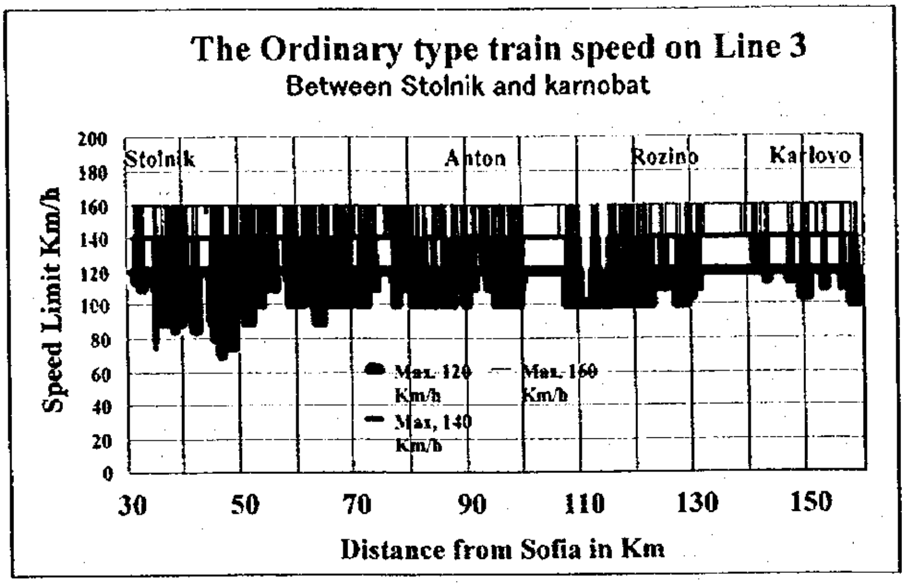


Fig.8.2.3- 3 Actual Speed and Speed Limit of Express Train No. 321 between Stolnik and Dabovo

(6) Speed limit by ordinary type train and by pendulum type train

The curves, the speed limit of ordinary type train and the speed limit of pendulum type train by curves are shown in sectional wise in the following figures.
On the section of Stolnik – Karlovo, there exist many uniform small curves with the radius of 500 m between 54 and 130 Km. Many curves with radius of 300 m are existing at 47 – 50 Km.
Latter speed limit might give speed limit of 75 Km/h to ordinary type trains and 90 Km/h to pendulum type trains. Former section's speed limit might give 100 Km/h to ordinary type trains and 120 Km/h to pendulum type trains. By considering safety, braking capacity should be guaranteed for increasing speed of fast trains.
The improvement degree will be decided from the running characteristic of rolling stock too.
The curves at 33 and 52 Km are relatively short curves of R 200 m and a little more. The above two curve points should be passed by way of local limitation by indicating speed restriction boards.



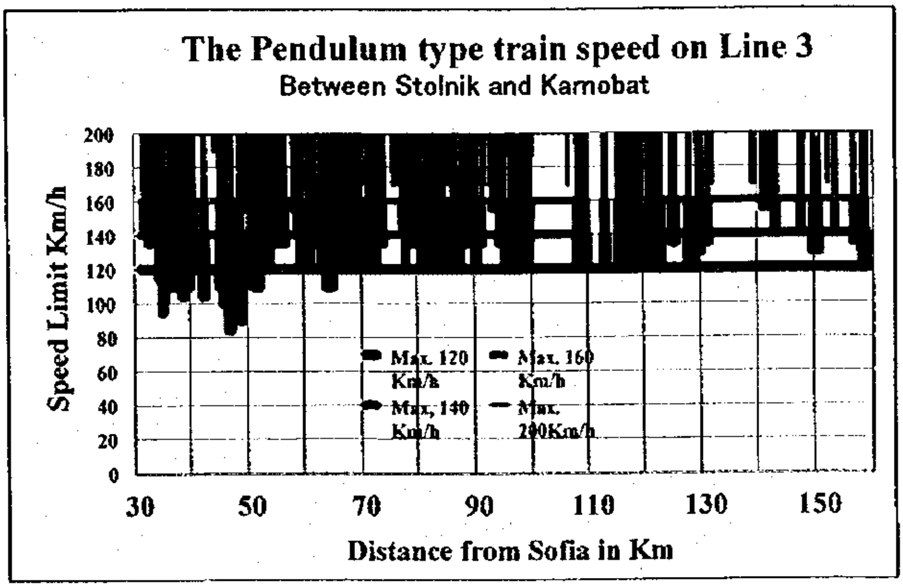


Fig.8.2.3-4 Speed limit in case of ordinary type train and of pendulum type train between Stolnik and Karlovo

After passing these mountainous sites, the track figure of curves becomes relatively smooth and the ordinary type train can run up to maximum speed of 120 – 130 Km/h and the pendulum type train can run up to maximum speed of 150 - 160 Km/h.

Limiting speed on this section between Karlovo and Dabovo are shown in the figure.

8.2.4 Features of Other Main lines

(1) No .5 Line

Most of this line is single track, but this line is conceived important for suburban transport of Sofia city and for international transport. The section of No. 5 line that connects Greece and Macedonia is being electrified rapidly.
The parallel road of this No.5 railway route is congested by many trucks.

1) Train Operation of line No.5

- **Bar chart of freight train diagrammed**

On the section of Sofia – Dupnitza – Kulata, short distance freight trains between Gorna Bana and Pernik and trains among Pernik, K. Petrov and Kulata are scheduled. But actual trains carrying international freight goods from and to Greek are not so many.

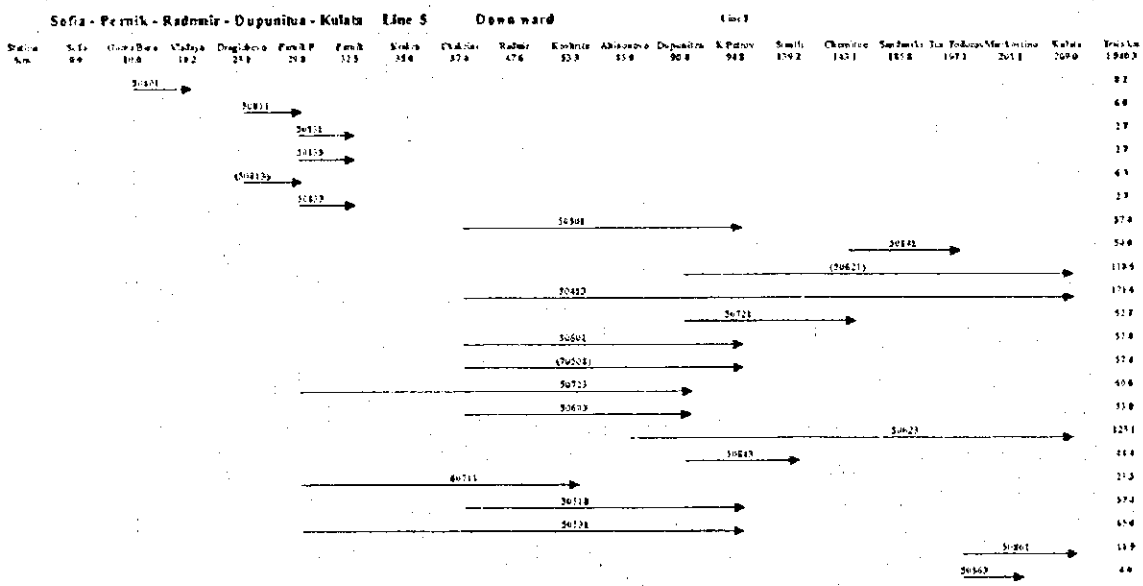


Fig.8.2.4- 1 Bar chart of freight train of No. 5 Line

No. 5 line is mainly used for short and medium distance, although this line is admitted as one of the most important international lines.

- **Bar chart of Passenger Train**

The passenger trains are mainly operated from Sofia to Pernik and to Dupnitza and some passenger trains are scheduled from Dupnitza to Kulata.
The rapid trains are runnning from Sofia to Sandanski, famous hot spring resort place, and to Kulata, the boundary station to Greek. The electrification of this line is proceeding rapidly and Diesel hauled trains are being replaced by multiple unit electric cars and by trains hauled by electric locomotives.

These rapid trains will be increased by the improvement of the relation among Burgaria,Greek and Makedonia in parallel with the improvement of train speed and service, including smooth treatment at boundary station, etc.

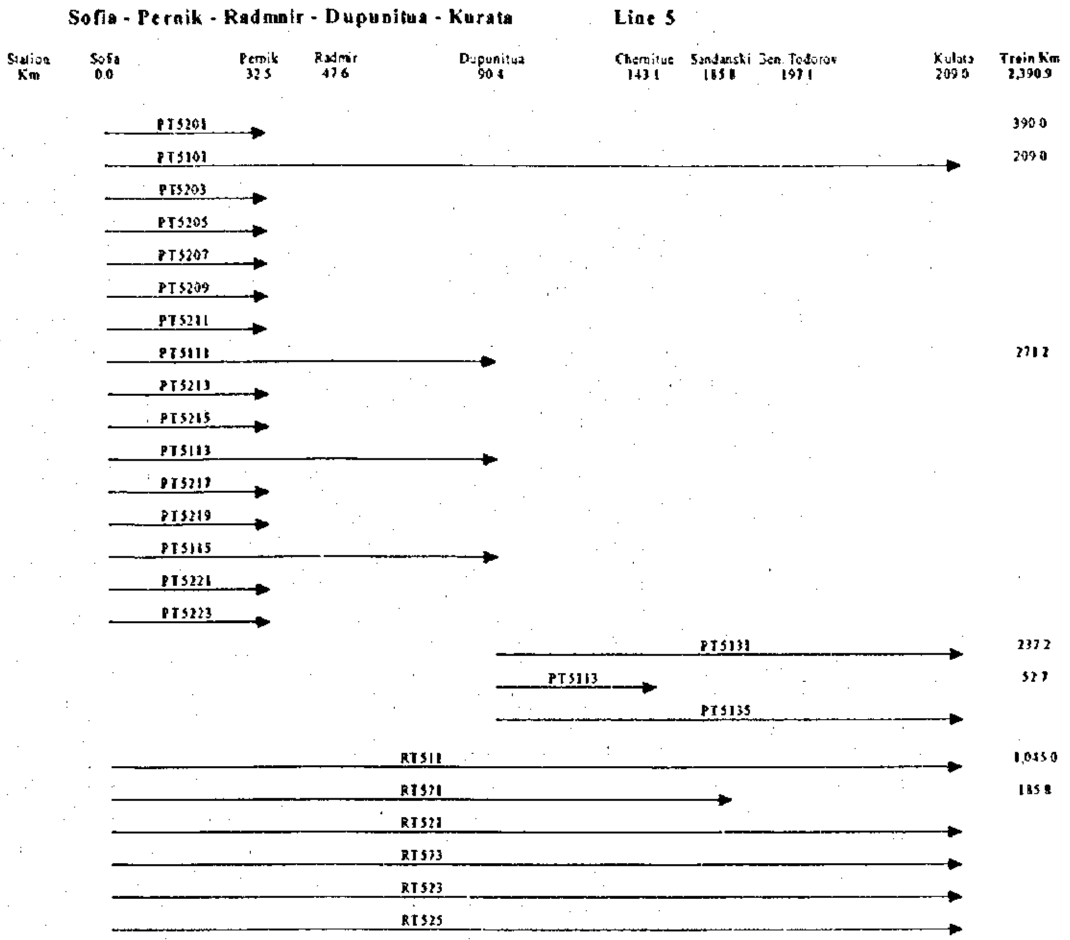


Fig.8.2.4- 2 Bar chart of passenger trains of No. 5 Line

2) Train Diagram of No. 5 Line

Passenger Train Diagram

Regularly local passenger trains are running between Sofia and Pernik. Some trains are operated among Pernik, Dupnitza and Kulata.
The number of passenger trains are relatively few. On this line, there are famous sight seeing place, hot spring of Sandanski and Kulata boundary station. In line with the future demand procedure, more aggressive measures will become necessary for promoting the project between Bulgaria and Greece.

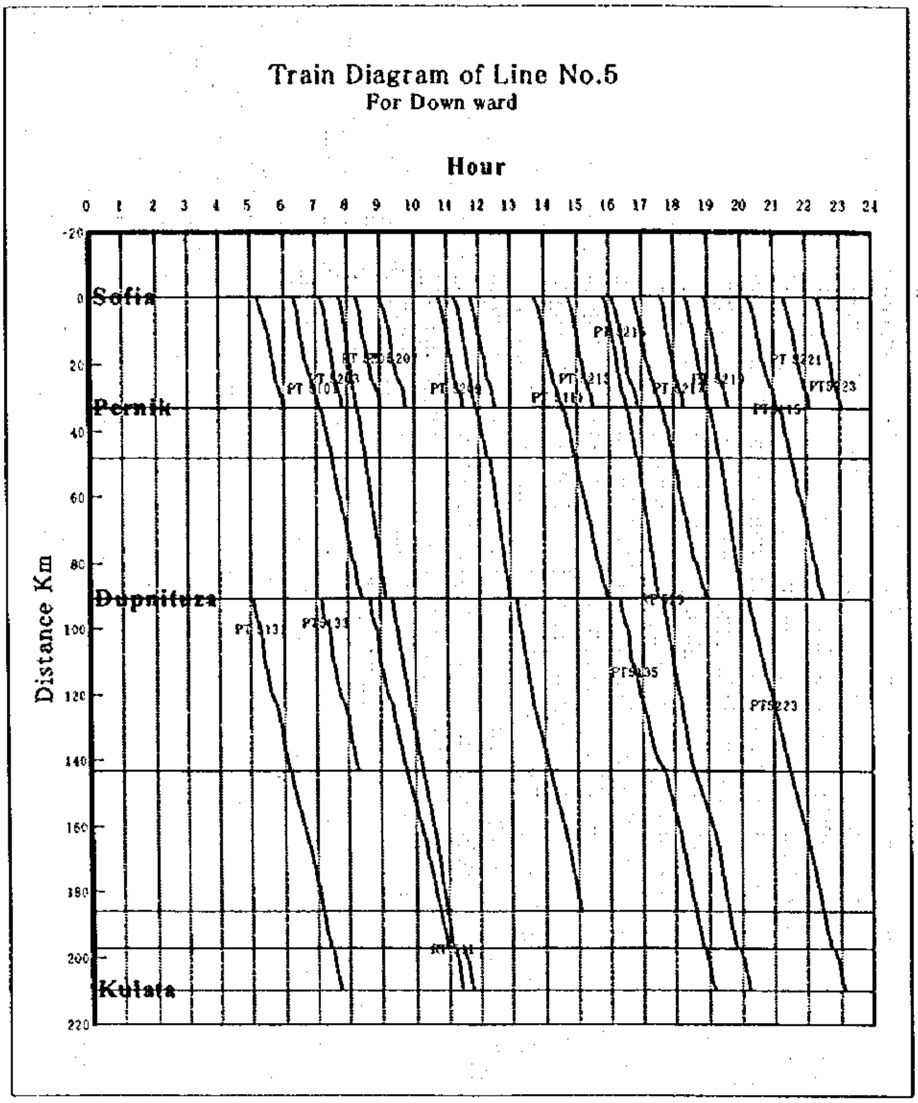


Fig.8.2.4- 3 Train Diagram of Passenger Train of No.5 Line

3) Train Speed

- **Average Speed of Passenger Train**

As shown in the following table, the average travel speed of the passenger trains on the No.5 line is calculated as 42.57 Km/h.
The passenger train speeds between Sofia and Kulata are relatively low of 40 – 45 Km/h because of the strict limitation by curves in the mountainous site.
The intercity passenger train speed on this line can also be elevated and the speed up is necessary for the competition with road; the way and the possible speed up rate should be studied accordingly.

Table 8.2.4- 1 Average Speed of Passenger Train of No.5 Line

Train hour of line 500 =	99.02 Hour
Train Km of line 500 =	4,215.00 Km
Average train speed =	42.57 Km/h

Train Hour	Train Km	Speed	
Hour	Km	Km/h	Note
30.13	1,338	44.40	Sofia - Kulata 1
29.87	1,195	40.01	Sofia - Kulata 2
15.13	676	44.67	Kulata - Sofia 1
23.88	1,006	42.12	Kulata - Sofia 2

The No.5 line is single tracked and the travel speed is strictly limited by small curves. The train speed is insufficient to compete with the road vehicles which run on parallel road of the railway line.

(2) No. 8 Line

This line is electrified and partially double tracked which forms the main trunk line combined with No. 1 line among Sofia, Burgas and Varna.
The problem of No.8 line is the scarce of the track capacity for connecting No.1, No.3 and No.4 trunk lines with Burgas and Varna too.
The future prospect of this line section is considered to be the most brilliant one. Fundamentally the bottle neck of line capacity should be solved by double tracking, but the transference of railway local freight to road should be planned at the same time for saving the capacity.

1) Train Operation of No. 8 Line

- **Bar chart of train diagrammed**

Freight Train

On this No.8 line section, freight trains from two trunk lines of No.1 and No.3 and freight trains from many branch lines are flowing in to carry freight goods from almost all of the regions in Burgaria.
The freight trains between Plovdiv and Burgas, the freight trains between Mihailovo and Stara Zagora, freight trains between Stara Zagora and Karnobat and the freight trains among Karnobat, Durzba and Burgas are densely operated on this No.8 line.
There are many short distance freight trains which cause the bottle neck of No.8 line for increasing long distance international and domestic freight trains.
The improvement measures might be the reform of train scheduling and the double tracking of bottle neck section.
The local freight movement shall be transferred to road transport and the cooperation between railway and road might be desired already.

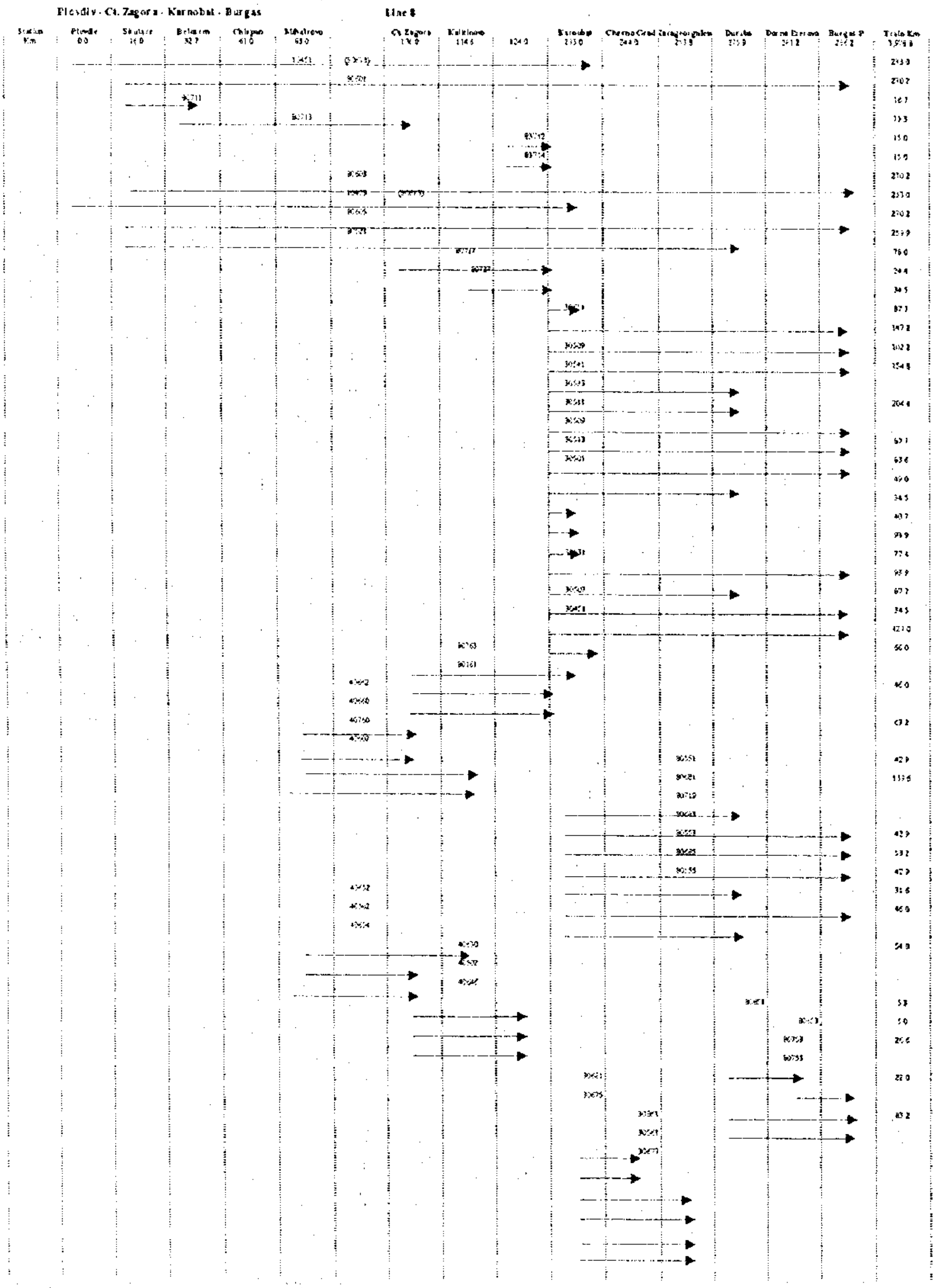


Fig.8.2.4- 4 Bar chart of Freight Train of No. 8 Line

Passenger Train

The local passenger trains are operated among Plovdiv, Stara Zagora and Zimnitza and among Zimnitza, Karnobat and Burgas.
Several fast trains are operated among Plovdiv, Stara Zagora, Karnobat and Burgas.
These fast trains will be increased by enlarging the importance of international port Burgas.

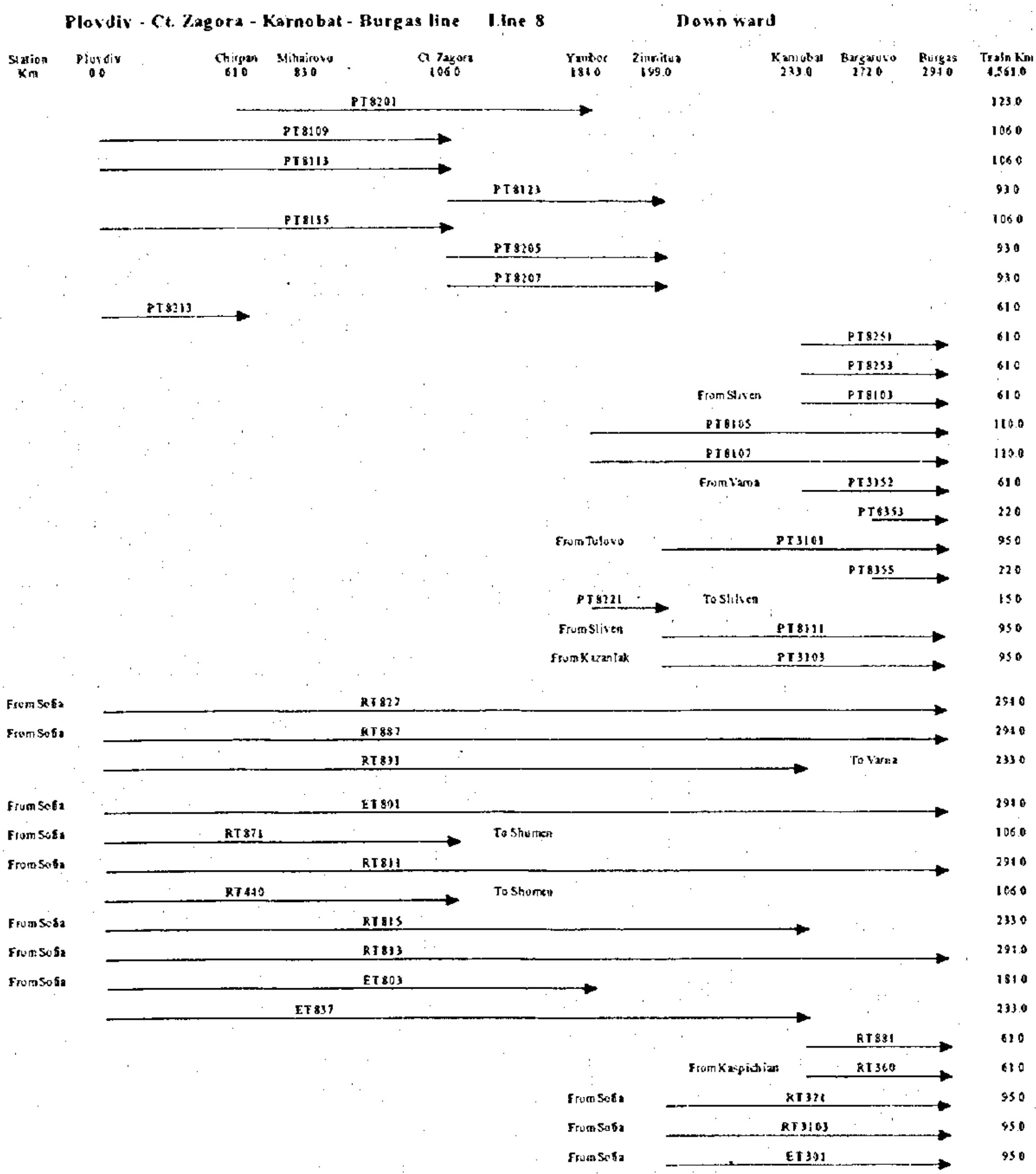


Fig.8.2.4-5 Bar chart of Passenger trains of No. 8 Line

2) Track Capacity

One example of track capacity line 8 is shown in the figure 8.2.4-6, the track capacity of all main lines should be studied and then the transportation improvement plan on total network will be clarified according to its necessity.
The actual situation of severe competition with road and with other foreign routes necessitates preparation of more flexible train operation diagram which enables rapid train operation than the study of how many train can be operated. Trains are operated to 81 % of its capacity limit on the track section between Stara Zagora and Noba Zagora. This section will become bottle neck and should be double-tracked for efficient train operation in future.

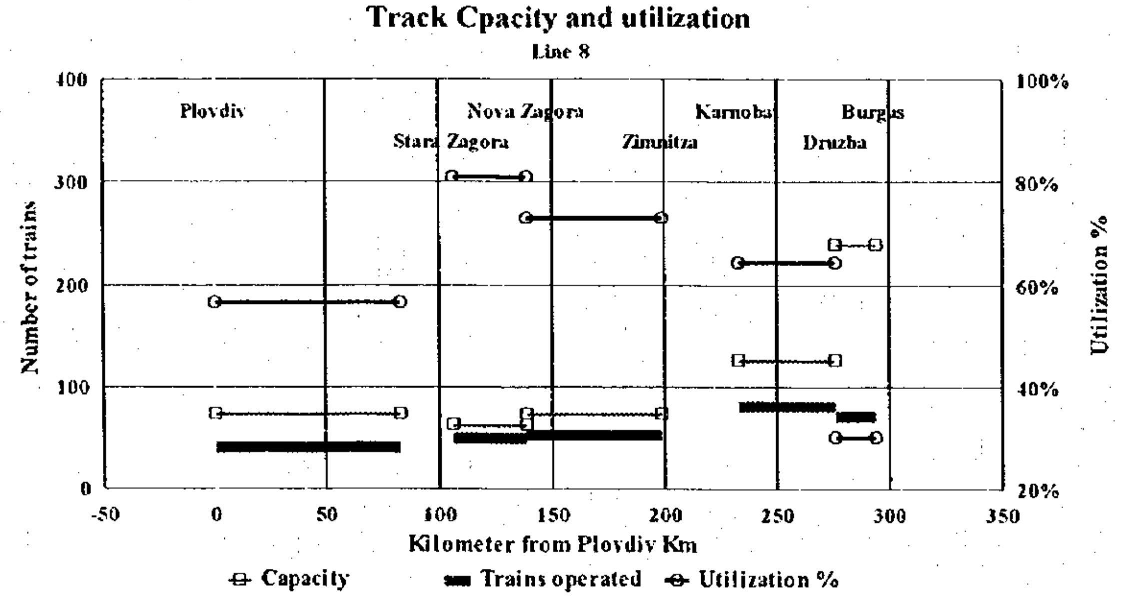


Fig.8.2.4-6 The track capacity of No.8 line

The section between Plovdiv and Burgas is the most important traffic line for surviving railway transport. The trains, which run through the track lines of No.1, No.3 and No. 4, will use this single track section between Stara Zagora and Ziminitza. The highway improvement projects on this area are being proceeded and the quality of railway service is required to be modernized as soon as possible for the coming day of severe competition. The traffic volume estimation shows the rise and sink in short period on this section.
The track capacity on single track section is very high but the train number is relatively few. This means how difficult it is to operate trains on this section. If this single track section is improved, the track capacity can be raised up and can serve well to the economy of BDZ and Burgaria for a long period.

8.3. LONG TERM TRAIN OPERATION PLAN

Way of long term train plan is shown in the following flow chart.

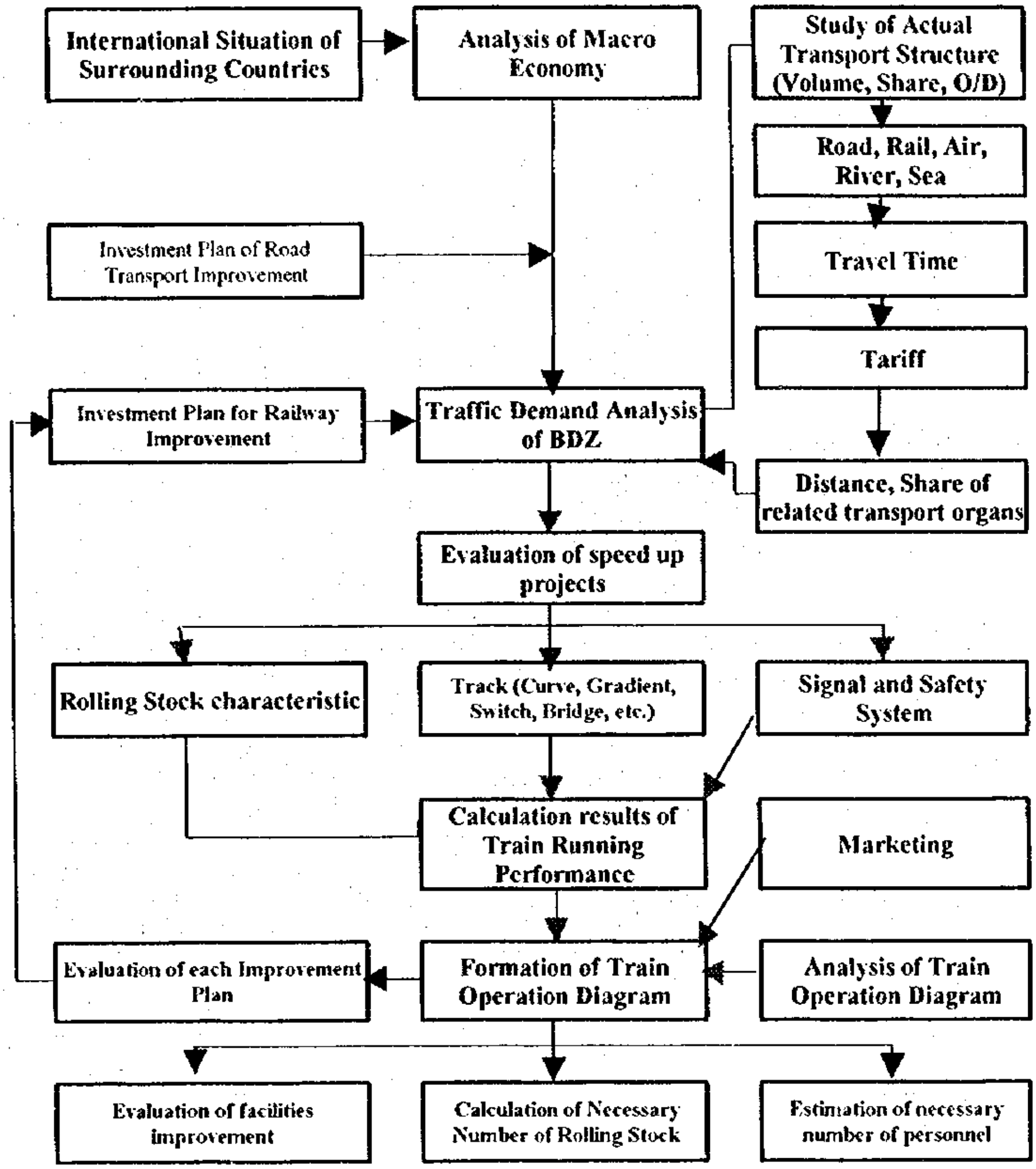


Fig.8.3- 1 Work flow chart of preparing the future train operation plan

8.3.1 Traffic Demand and Train km

Table8.3.1- 1 Freight ton km, passenger km and train km

	Train Km				Passenger	Freight	Traffic Unit
Year	Passenger	Freight	Others	Total	billion pkm	billion ntkm	TU
1987	26.00	27.00	11.00	64.00	8.100	17.80	25.90
1993	24.70	13.00	9.90	47.60	5.800	7.70	13.50
1994	23.70	13.00	10.30	47.00	5.100	7.80	12.90
1995	22.90	14.50	10.20	47.60	5.658	7.85	13.51
1996	22.40	12.70	9.90	45.00	5.850	7.74	13.59
1997	23.13	13.77	9.80	46.70	6.040	7.63	13.67
1998	23.49	13.57	9.80	46.86	6.230	7.52	13.75
2005	25.260	12.219	9.800	47.28	7.236	6.536	13.772
2010	23.893	16.598	9.800	50.29	5.670	9.196	14.866
2015	23.893	17.147	9.800	50.84	5.670	9.500	15.170
2020	23.452	14.223	9.800	47.48	5.238	7.600	12.838

Note: Train Km in past time is based on the data of BDZ through Strategic Department and EBRD (1998)
Train Km in future is estimated by the work of JICA team.
Traffic volume is based on the data JICA team (1995,2005,2010,2015,2020)and BDZ (RRP)

Future train km is calculated in accordance with the transition of traffic demand estimated by JICA. The future traffic demand used here is based on the traffic increase ratio of JICA estimation and the past time traffic demand values are based on the official data shown in the edition of BDZ.

The figures of train km are calculated by the past time characteristics indicated in the former item and by considering the change of operation system.

The results of estimation of train km are shown in the above table.

The further detail explanation will be done for freight trains and for passenger trains in the following.

(1) Freight transport

Freight Train Km

The freight train km is precisely proportional to the traffic demand in the past 10 years, as shown in the fig.8.1.2-2.

The adoption of direct block train system will gradually increase freight train running km according to its degree, although the total efficiency will be rather increased for the sake of improved rotation by travel speed. .

The trend of transition of freight train km is shown in the above table and in the following figures.

The train km level in future is supposed to be a little higher than that of the past 10 years.

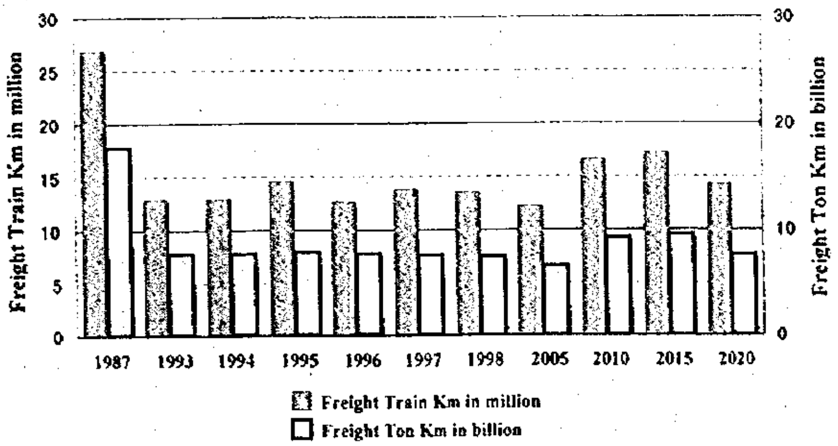


Fig.8.3.1- 1 Freight train km in past time and in future

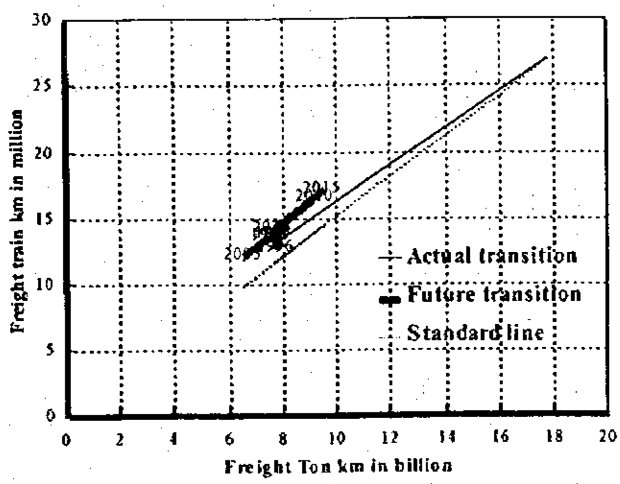


Fig.8.3.1- 2 The relation between freight ton km and train km

The data of years are duplicated for some years because of the little difference of the ton km and train km concerned. The precise data of each year are indicated in the table 8.3.1-1.
The freight train km in 2000 – 2020 will vary within the range of 12 - 18 million km that will be influenced by tariff policy and by the improving measures.

(2) The passenger transport

1) Train km

The passenger train km may vary within the range between 22.5 and 25.5 million km according to the tariff policy, to the system changing and to the highway construction, etc.

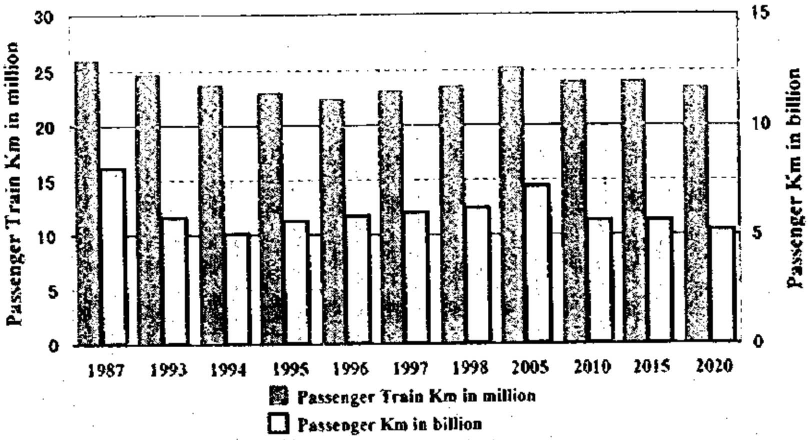


Fig.8.3.1- 3 Passenger train km in past time and in future

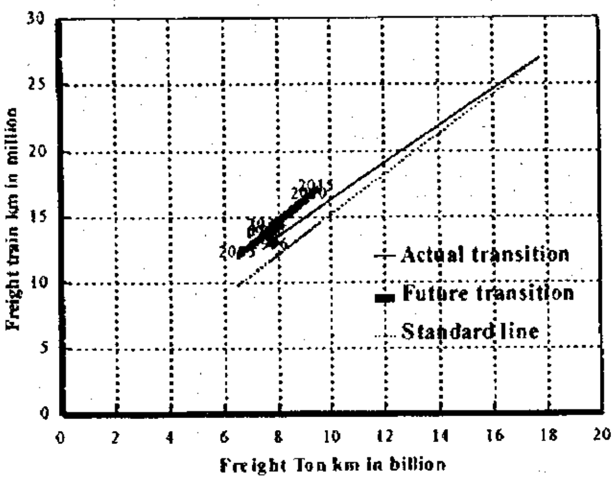


Fig.8.3.1- 4 The relation between passenger km and train km

The passenger train km has a characteristic of remaining the past time service as shown in the figure of former item because of the difficulty of adjusting the train numbers by the rapid demand changing.

The future passenger train km will be adjusted with some time delay and with some adjustment of number of coaches of each train, etc. When the traffic demand decreases for long period, the train km will be decreased to half level of the demand changing as shown in the past time experience of BDZ.

2) Passenger train running curve in near future

The passenger train **with maximum speed 130 km/h and with limit speed of improved switch 130 km/h** might be the most provable target in near future. The running curve of a express train with 10 coaches hauled by locomotive E44 is simulated on the section **between Sofia and Plovdiv.** The result of the simulation is shown in the following figures.

The train operation time is calculated by seconds, but in the figure the passing time at each station is shown by minutes for easy understanding's sake.

The train operation time is calculated by seconds, but in the figure the passing time at each station is shown by minutes for easy understanding's sake.

When starting Sofia station, the train driver will check the brake performance at low speed area. This previous act to check the safety mechanism is important and the limiting speed is assigned to be 25 km/h in future train planning too.

Train speed is limited by curvature, down gradient and switch. In this example calculation, the switch limit might be elevated to 130 km/h by improving project.

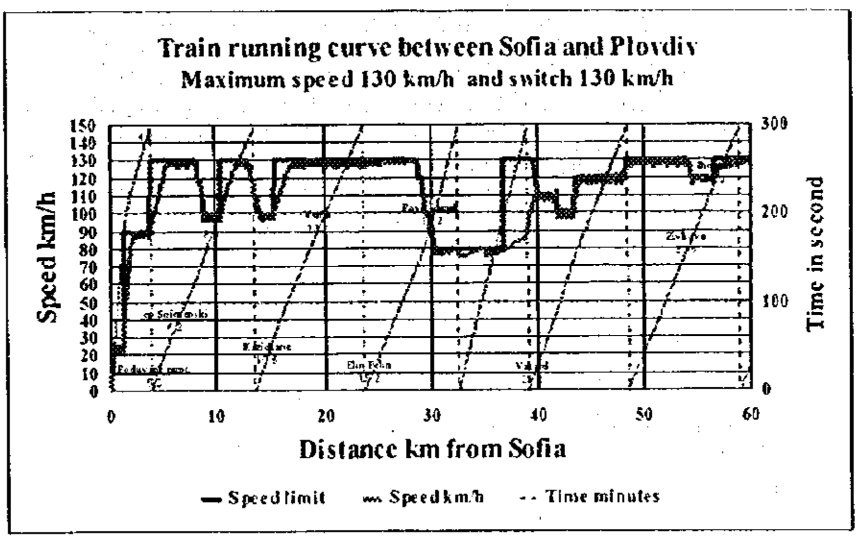
The train speed control is simulated as follows:

Time delay is 2 seconds.

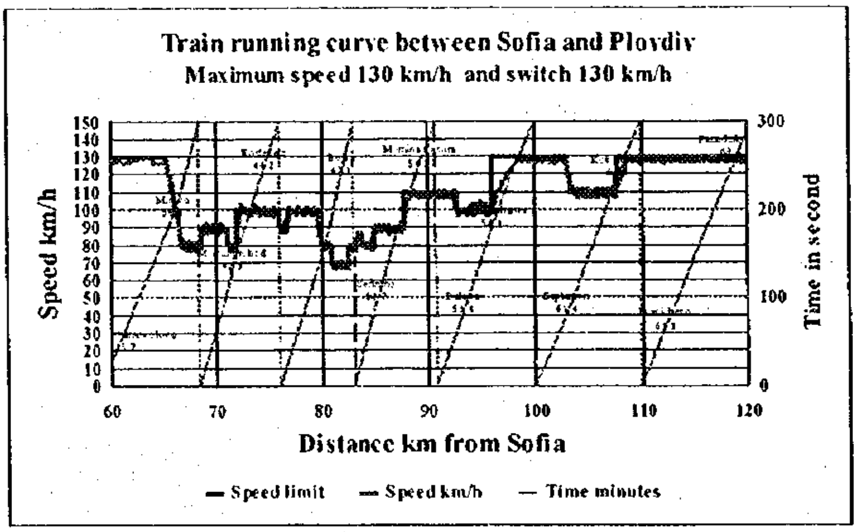
Speed control is done by automatic control.

The train speed is indicated on Y-axis and the time passing is shown on the 2Y-axis. The time passing procedure is expressed by every 300 seconds to show the transition of time passing precisely by speed changing..

Between 0 and 60 km section



Between 60 and 120 km section



Between 120 and 160 km section

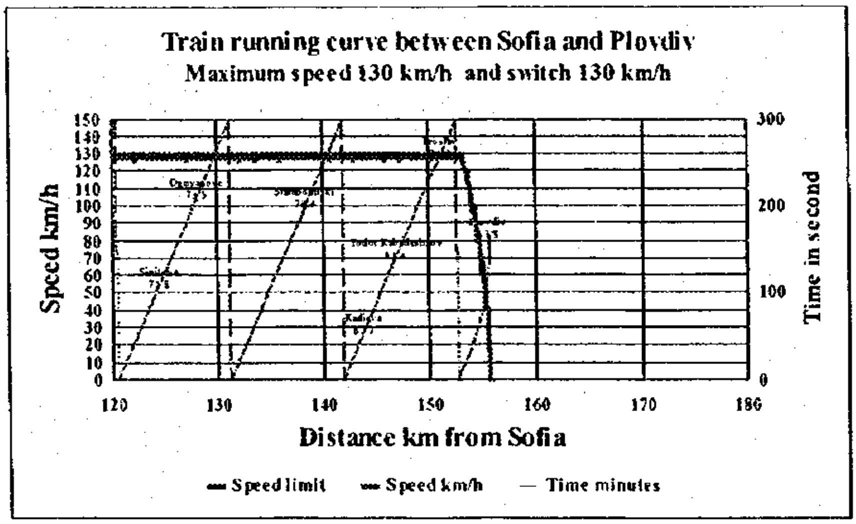


Fig.8.3.1- 5The running curve of a express train with 10 coaches hauled by locomotive E44

The way of indication is quite same in the other simulation of future train running curves which will be shown latter.

As mentioned before, the scheduled travel time is calculated by adding 5 % allowance to the simulated travel time for the track maintenance, for train driving and for train diagram formation.

The running curve is simulated for the case of non-stop operation.

The other cases of 1 stop and 2 stop are calculated by adding the loss time of braking, stop time and acceleration.

8.3.2. Future Train Operation Plan

(1) Freight train km

Future freight train km of each line is estimated for the project evaluation and for knowing the necessity of capital investment by the result of demand forecast and by the data for the estimation of train km.
The data in the Table 8.3.2-1 are summed up from the freight train diagram 1996/1997.

Table 8.3.2- 1 Freight train km by line 1996/1997

No. of line	Section	Train km up	Train km Up & Down	Line km
Total		**33,360.00**	**66,720.00**	**4,081.30**
100	Kalotina - Sofia	809.2	1,618.4	70.1
101	Sofia - Plovdiv	1654.8	3,309.6	158.5
102	Plovdiv - Svilengrad	1449.3	2,898.6	164.3
112	Bolshevik - Aldomirovtzui	54.8	109.6	13.7
113	Bolshevik - Aldomirovtzui	10.8	21.6	10.8
115	Bakarel - Chukrovo	53.2	106.4	26.6
116	Septemvri - Dobrinishte	38.6	77.2	38.6
117	Varvara - Pazardzik	0	0.0	16.3
118	Stamboliiski - Peshtera	28.2	56.4	28.2
119	Asenovgrad - Krumovo	10	20.0	10.0
200-201	Sofia - G.Oryahovitza	3857.2	7714.4	294.0
202	G. Oryahovitza - Varna	3287.1	6574.2	246.4
221	Cherven Brag - Oryahovo	88.2	176.4	102.4
222	Cherven Brag - Zlatna Panega	67.2	134.4	33.6
223	Yasen - D. Mitropoliya - Cherkvitza	56.8	113.6	43.0
224-225	Troyan - Levski - Sviskovo	437.4	874.8	130.4
226	Preslav - Han Krum	6.9	13.8	6.9
227	Shumen - Smyadovo - Komunari	125.6	251.2	50.4
228	Kaspichan - Noba Pazar		0	5.0
229	Debnar - Dovritch - General Korevo	712.7	1425.4	117.5
242	Oresh - Belene	25	50	12.5
300	Sofia - Dabovo	4,217.5	8,435.0	320.3
301	Karnobat - Komunari - Sindel - Barna Feriboot	1287.1	2,574.2	129.3
331	Musachevo - Yana - Obedinena - Kremikovtzi	110.1	220.2	13.3
333	Kazichane - Musachevo - Stolnik	135.3	270.6	135.3
334	Yunak - Staro Oryahovo	24.7	49.4	24.7
400	Ruse - Stara Zagora	2440.7	4881.4	257.4
401	Mihailovo - Podokova	637.1	1274.2	135.2
441	G. Oryahovo - Elena	43.6	87.2	43.6
442	Gabrovo - Tzareva Livada	51.6	103.2	17.2
500	Sofia - Pernik - Radmnir - Dupunitua - Kulata	809.2	1618.4	210
551	Dupnitza - Golyamo Selo - Bobovdol	1654.8	3309.6	19
552	Petriz - General Todorov	1449.3	2898.6	10
556	Boryak - Pernik	356.9	713.8	48
600	Radmir - Gyushevo	155.7	311.4	54
700	Mezdra - Ruska Bala - Boichinovtui - Vidin	725.6	1451.2	181
771	Boitzinovtui - Berkovitza	51.7	103.4	36
772	Brusarizi - Lom	92.7	185.4	22
800	Plovdiv - Ct. Zagora - Karnobat - Burgas	3978.8	7957.6	286.2
800	Plovdiv - Trahia - Skutatare	129.0	258	16.2
881	Fililovo - Panagyurishte	0.0	0	77
882	Fililovo - Karlovo	71.1	142.2	71.1
882 1	Dolna Mahala - Hisara	15.4	30.8	15.4
883	Nova Zagora - Simeonograd	540.5	1081	61.5
884	Yambor - Elhovo	43.1	86.2	43.1
886	Pomorie - Vradimir Parkiv	49.6	99.2	24.8
900	Ruse - Camuil - Kaspchan	1,363.1	2726.2	137.5
991	Samir - Todorovo - Silistra	152.8	305.6	113.0

Note: Km means the line length concerned.

Table 8.3.2- 2 Future freight train km on major lines
In million train km

	1995	2005	2010	2020
100	0.3517	0.2964	0.4027	0.3449
101	0.7193	0.6062	0.8234	0.7054
102	0.6299	0.5309	0.7212	0.6178
201	1.6765	1.4129	1.9194	1.6442
202	1.4287	1.2041	1.6357	1.4012
300	1.8331	1.5449	2.0986	1.7977
301	0.5594	0.4715	0.6405	0.5486
400	1.0609	0.8940	1.2145	1.0404
401	0.2769	0.2334	0.3170	0.2716
500	0.3517	0.2964	0.4027	0.3449
700	0.3154	0.2658	0.3611	0.3093
800	1.7294	1.4575	1.9799	1.6960
Sub Total	10.9331	9.2139	12.5165	10.7219
Total	14.5000	12.2192	16.5979	14.2227
Rate sub/total	75.40%	75.41%	75.41%	75.39%

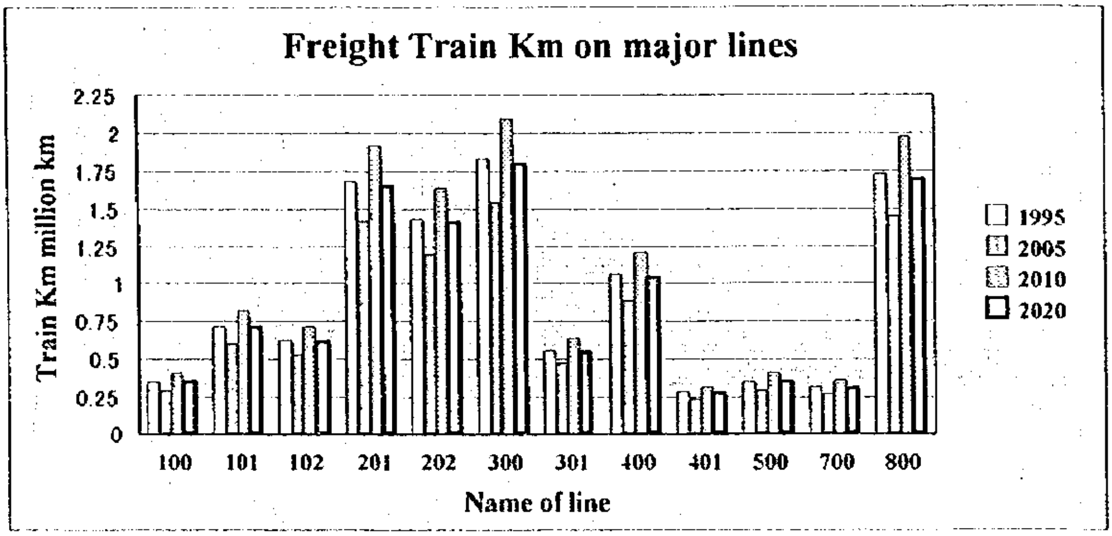


Fig.8.3.2- 1 Transition of the freight train km of each major line

As for freight train km, No. 201, No. 202, No. 300 and No. 800 lines are the first class lines. The second line is No.400. The third lines are No. 101, No. 102 and No.301. The other lines are at the same level.
The line section of No. 800 is electrified and partially single tracked. Because of the importance of No. 800, the bottle necked single track section should be doubled as soon as possible for the coming severe competition days.
Burgas and Varna coast line areas are heavily industrialized and are famous for the sight seeing place. The No. 8 line connects the No. 1 line and No.3 line to the coast. There are operated many passenger trains and freight trains by competing road traffic.

(2) Passenger train

The data in the Table 8.3.2-3 are summed up from the passenger train diagram 1996/1997.

Table 8.3.2- 3 Passenger train km by lines 1996/1997

Total Passenger km up & down / year = 32,124.3 1000 km / year
Total Passenger km up & down / day = 88,011.8 km / day

Line number	Section	Train km down	Up & Down	*Km
Total		**44,005.90**	**88,011.80**	**4,284.00**
100	Kalotina - Sofia	704.0	1,408.0	54
101	Sofia - Setembri - Plovdiv	4,181.0	8,362.0	156
102	Plovdiv - Dimitrovgrad - Svilengrad	1,128.0	2,256.0	143
112	Borshebik - Aldmirovtzi	84.0	168.0	14
113	Sofia - Banka	342.0	684.0	19
115	Chikrovo - Vakarel	65.0	130.0	13
116	Setembri - Dobarinishte	676.0	1,352.0	141
118	Provdiv - Peshtera	138.0	276.0	46
119	Provdiv - Asenovgrad	306.0	612.0	18
200	Sofia _ Mezdra _ Cherben Brag	4,388.0	8,776.0	141.0
201	Cherben Brag - Goma Orahobitza	2,968.0	5,936.0	153.0
202	Goma O. - Krim - Sinder - Varna	2,855.0	5,710.0	249.0
221	Cherven Brag -Bala Slatina -Oryahovo	451.0	902.0	104.0
222	Cherben Brag - Zlata Panega	102.0	204	34.0
223	Pleven - Cherkvitza	150.0	300	50.0
224	Levski - Svishtov	336.0	672	48.0
242	Belene - Svishtov	48.0	96	24.0
225	Levski - Troyan	345.0	690	83.0
226	Han Krim _ Preslav	16.0	32	8.0
227	Shumen _ Komnari	300.0	600	50.0
228	Kaspichan - Novi Pazar	45.0	90	5.0
229	Varna - Razdelna- Kardam	496.0	992	131.0
300	Sofia - Kazichene - Stolnik - Karlobo - Tulobo- Dabovo	2,670.0	5,340.0	231.0
301	Dabovo - Zimnitua - Karnobat - Komunari - Sindel - Varna	2,731.0	5,462.0	283.0
331	Sofia - Iliantzi - Stolnik	238.0	476.0	34.0
333	Sofia - Podyane - Kremikovtzi	68.0	136.0	34.0
334	Sindel- Staro Orahovo	56.0	112.0	28.0
400	Ruse - Goma O. - Tsuareva - Dabovo	2,306.0	4,612.0	223
401	Dabovo - Ct. Zagora - Dimitorovgrad - Momtuirgrad - Podkova	1,335.0	2,670.0	211
441	Goma Oryahovitza- Elena	44.0	88.0	44
442	Gabrovo- Tzareva Livada	153.0	306.0	17
500	Sofia - Pemik - Radomir - Dupunitua - Kulata	2,390.9	4,781.8	209
551	Dupnitza - Bobov Dol	152.0	304.0	19
552	Gen Todorov - Petrich	110.0	220.0	10
556	Sofia - Bolyak - Pemik	209.0	418.0	56
600	Sofia - Pemik - Radmir Kyostendil	730.0	1,460.0	136
700	Mezdra - Ruska Bala - Vidin	2,205.0	4,410.0	181
771	Boichinovtzui - Berkovitza	432.0	864.0	36
772	Brusartzi - Lom	286.0	572.0	22
No 800	Plovdiv - Ct. Zagora - Kamobat - Burgas	5,012.0	10,024.0	223
801	Plovdiv - Panagyorishte	308.0	616.0	77
802	Plovdiv - D. Mahala - Karlovo	623.0	1,246.0	67
803	Nova Zagora - Simeonovgrad	63.0	126.0	61
804	Yambor - Elhovo	172.0	344.0	43
805	(Plovdiv -)Dolna Mahala - Hisar	196.0	392.0	16
900	Ruse - Samir - Sindel - Varna	1,026.0	2,052.0	226
991	Samuil - Silistra	366.0	732.0	113

Note: Line km is partially duplicated as for the convenience of train time table use.
Note: line 116 = line116+line117

Future passenger train km of each line is estimated for the project evaluation and for knowing the necessity of capital investment by the result of demand forecast and by the data for the estimation of train km.

Table 8.3.2- 4 Future passenger train km on major lines

In million train km

	1995	2005	2010	2020
100	0.366	0.366	0.367	0.367
101	2.176	2.257	2.082	2.107
102	0.587	0.578	0.579	0.579
201	1.545	1.543	1.539	1.572
202	1.486	1.467	1.474	1.446
300	1.389	1.398	1.428	1.409
301	1.421	1.446	1.482	1.447
400	1.200	1.197	1.258	1.224
401	0.695	0.690	0.696	0.705
500	1.244	1.244	1.249	1.256
700	1.147	1.146	1.141	1.146
800	2.608	2.625	2.623	2.632

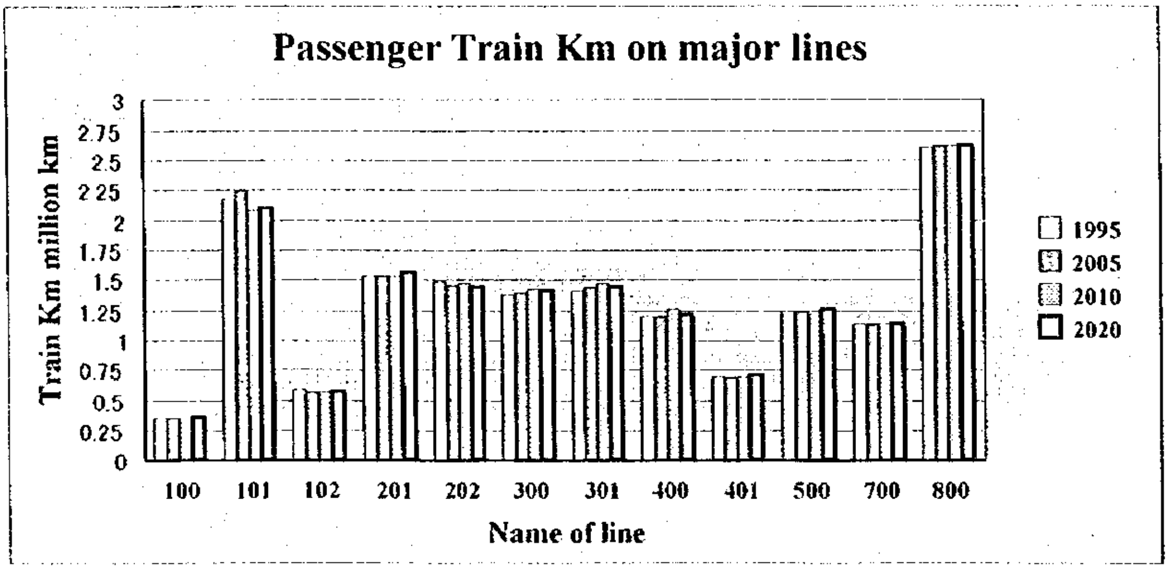
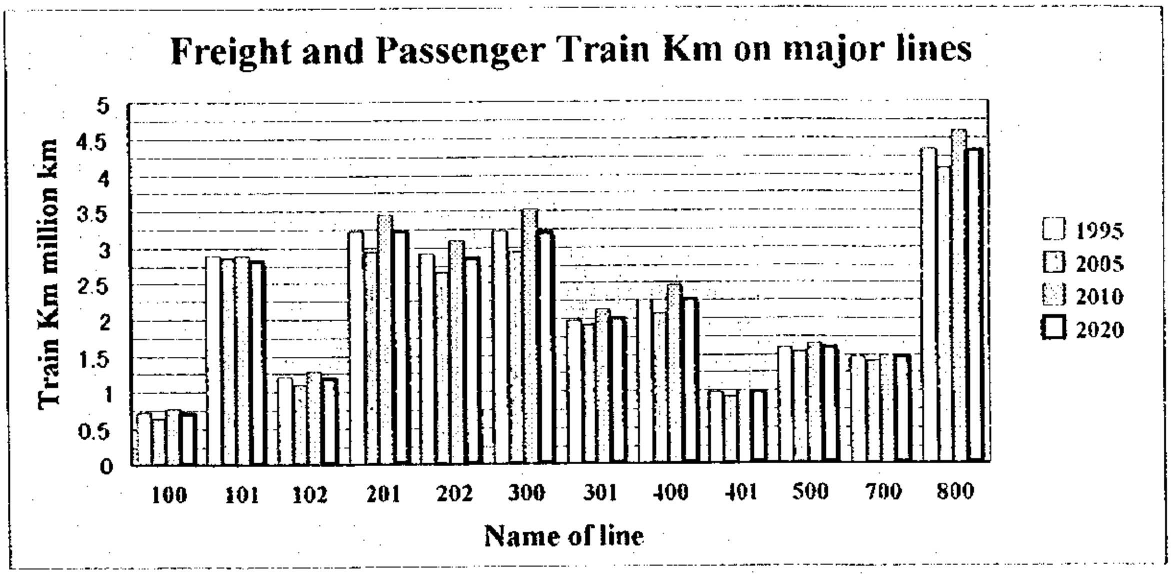


Fig.8.3.2- 2 Transition of the passenger train km of each major line

(3) Freight and passenger train

Table 8.3.2- 5 Future Freight and passenger train km on major lines in million train km

	1995	2005	2010	2020
100	0.718	0.663	0.769	0.712
101	2.895	2.864	2.906	2.812
102	1.217	1.108	1.300	1.197
201	3.221	2.956	3.458	3.217
202	2.914	2.671	3.109	2.847
300	3.223	2.943	3.527	3.207
301	1.981	1.917	2.122	1.996
400	2.261	2.091	2.472	2.264
401	0.972	0.924	1.013	0.977
500	1.596	1.541	1.651	1.601
700	1.463	1.412	1.502	1.455
800	4.338	4.083	4.603	4.328
Sub Total	26.7975	25.1719	28.4333	26.6119
Total	37.400	37.479	40.491	37.675
Rate sub/total	71.65%	67.16%	70.22%	70.64%



Note: The train km is explained in million km per year.

Fig.8.3.2- 3 Transition of freight and passenger train km of each major line

The roll of No.8 line is one of the most important railway lines. As mentioned before, this partial single tracked line is coming to its capacity. The seasonal trains can not be realized without prolonging the travel time. The train capacity increase should be realized by double tracking project as soon as possible.

8.3.3. Train-run Curve of Future Project

By using the No.1 line section between Sofia and Plovdiv, train-run curves are simulated for understanding the effect of each project and future running time.
The running curve of 130 km/h when improved switch limiting speed in near future is already shown in former item. In this item, the high-speed train-run curve by the projects of the long term or after the year of 2020 are shown for realizing the capability of BDZ for the next Century.

(1) Pendulum train of maximum speed 160 km/h

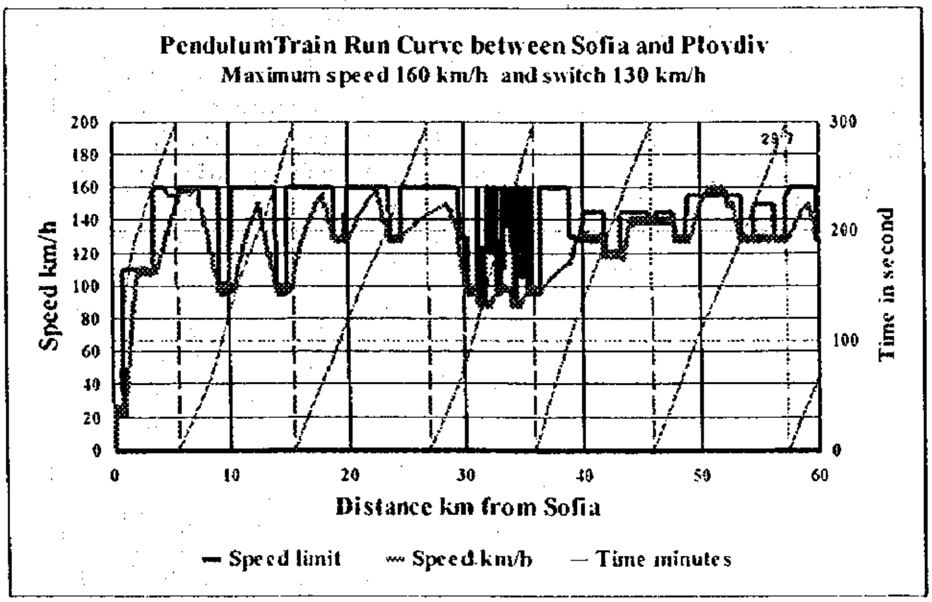
Two run curves of pendulum train are simulated:

- **Pendulum train of maximum speed 160 km/h with speed limit 130 km/h at switch of stations**
- **Pendulum train of maximum speed 160 km/h with speed limit 160 km/h at switch of stations**

In the figure of train-run curve, the time procedure is indicated by seconds, which is returning by every 5 minutes, but the simulation results of the run time is converted to minutes for easy understanding.
The limiting speed by curves, down gradient and switch limit at stations is indicated for case of the most severe speed.

1) Pendulum train of maximum speed 160 km/h with switch 130 km/h

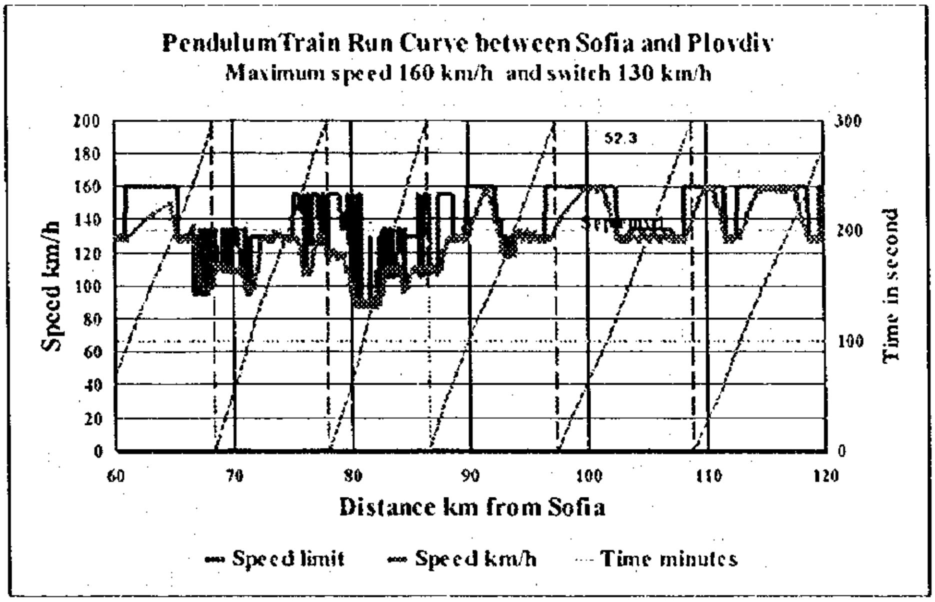
Section between Sofia and 60 km



Special limitation at station is giving fatal problem on running performance for 160 km/h pendulum train operation. Generally speaking, the limiting speed caused by stations is unfavorable effect for train operation.
In this case, switch speed limit is supposed to be 130 km/h but the switch limit speed should be

improved to be 160 km/h as shown in the next run curve of pendulum train.

Section between 60 km and 120 km



Section between 60 km and 120 km

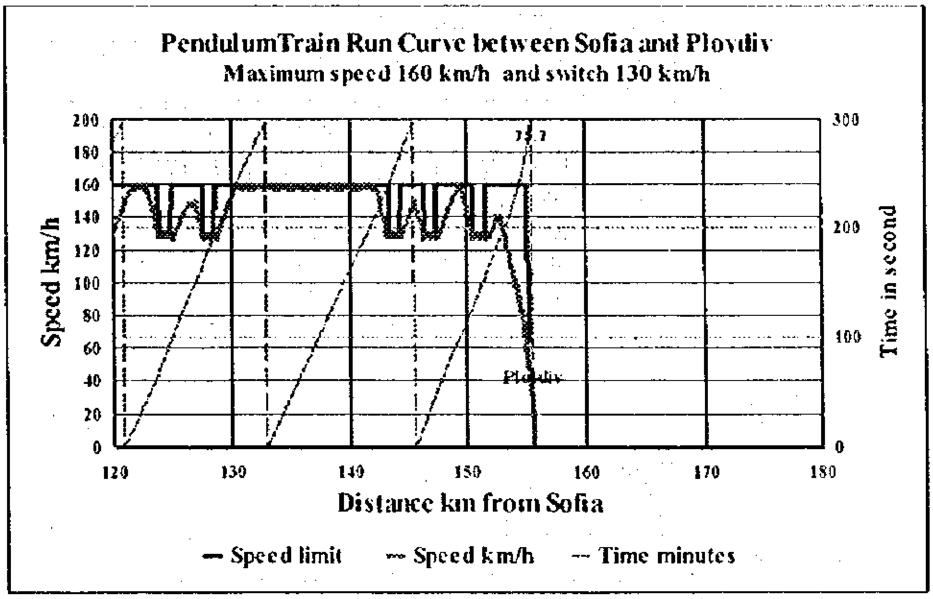


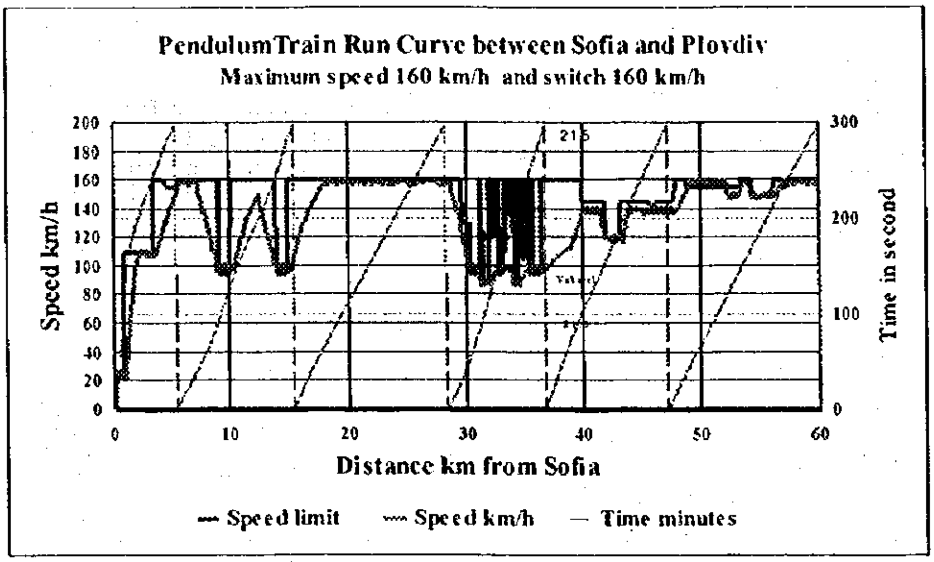
Fig.8.3.3- 1 Run curve of pendulum train of 160 km/h and 130 km/h speed limit on switch

The project of 160 km/h pendulum train operation should be realized by introducing 160 high-speed turnouts at entrance and departure main tracks.
Other big problem is the special speed restriction at 9-10 km and at 14-15 km sections. They are existing at special reasons of related stations. These two speed reduction sections are a remarkable effect on running performance of pendulum trains and of other speed up project.

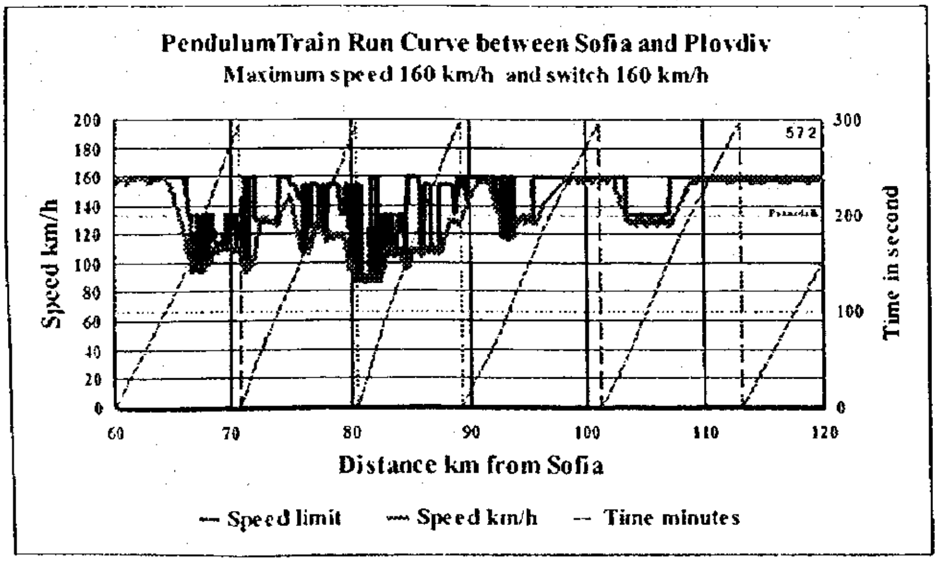
2) **Pendulum train of maximum speed 160 km/h with switch 160 km/h**

Special speed limits at two sections of 9-10 km and of 14-15 km are mainly caused by actual special restriction of station areas, as mentioned before.
These two sections should be improved until to "without speed limitation", because the track curves are relatively good in these line sections.
1 minute reduction of travel time will produce approximately the 1.5 % income increase and the capital and operational cost will remarkably be improved by increasing the number of these trains in future until to 1 %.

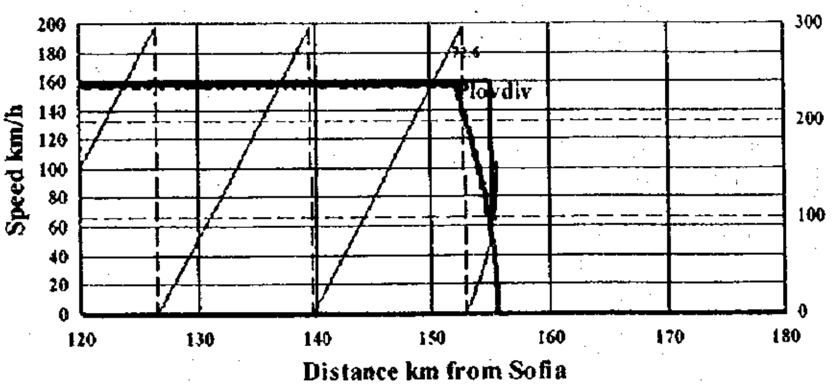
Section between Sofia and 60 km



Section between 60 km and 120 km



Section between 120 km and Plovdiv



Calculated speed =	128.5	Km/h
Scheduled train speed=	134.9	Km/h
Calculated time =	72.6	= 1 hr 13 min.
Scheduled travel time =	76.2	= 1 hr 16 min.

Fig.8.3.3- 2 Run curve of pendulum train of 160 km/h and 160 km/h speed limit on switch

The speed limitation by switch is supposed to be 160 km/h but other speed limit is remained same to the case of 130 km/h actual operation. The removing effect of switch limit is good not only for running time but also for comfortable running of train, for saving energy and for maintenance cost of braking apparatus, etc.

The two speed limits at about 10 km and 15 km should be improved at the time of 160 km/h operation.

Other limiting speed is caused by the steep gradient but this problem can be solved by brake capacity improvement. In this simulation, the down gradient speed limit is designed by considering the actual train capability.

(2) Super high-speed train of maximum speed 300 km/h

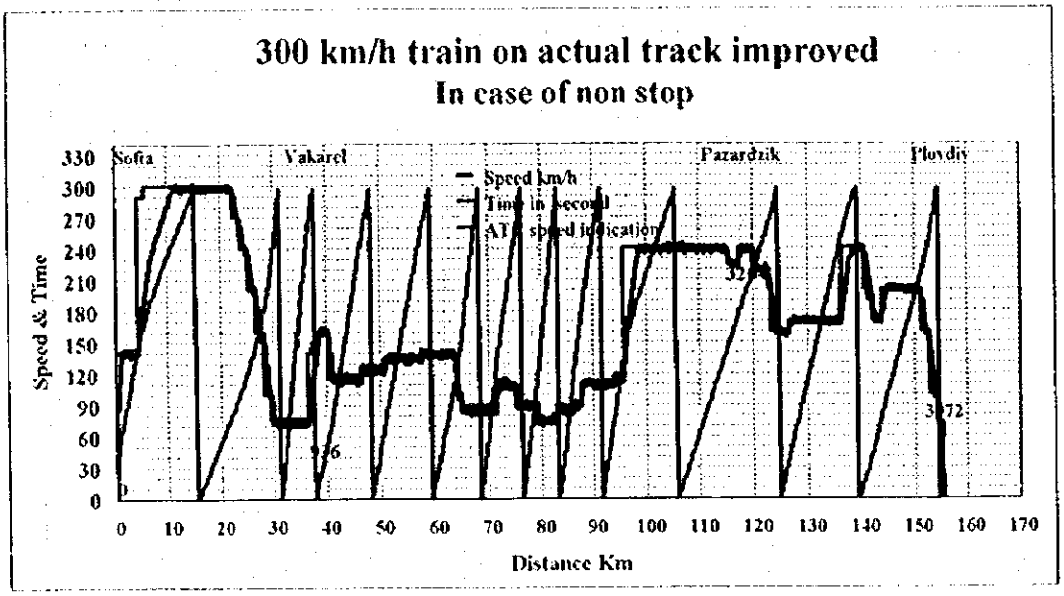
1) On actual track improved

In case of super high-speed train, the speed limit is being shown by ATC control system as shown in the running curve figures of super high-speed trains.

The running performance of 300 km/h train on the actual track are simulated for two cases of non stop and 1 stop case at Pazardzik station to know approximately the loss time of stopping high-speed train.

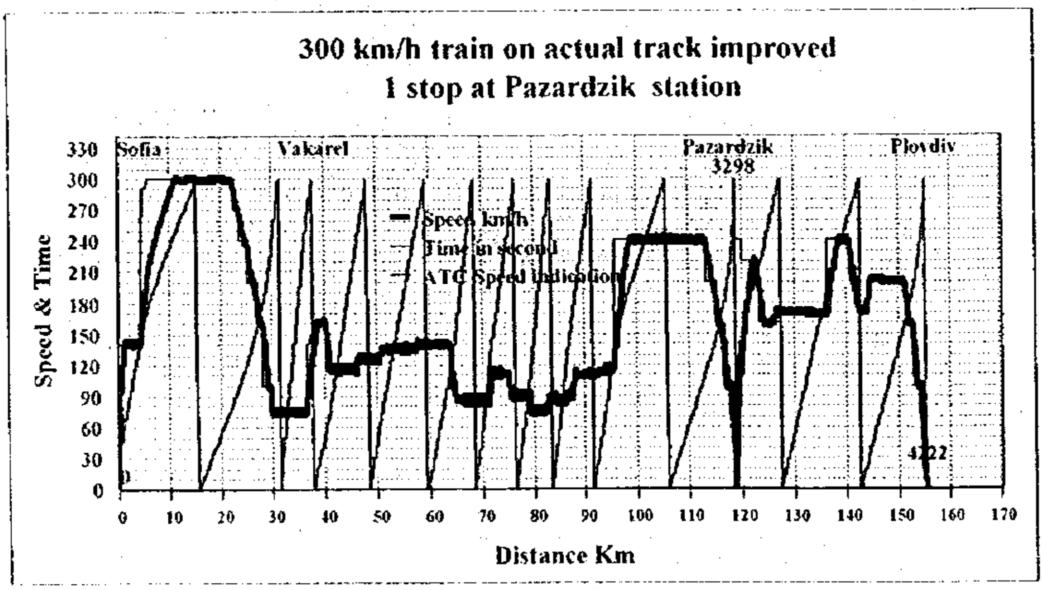
The loss time will be aroused by the deceleration of a train, by stopping at station and by the speed difference at the acceleration to non stop train running.

The loss time will be varied by the condition of running performance of train at near by station related and by the signal indication of each case.



Calculated run time = 66.2 Minutes
Schedule travel time = 69.5 Minutes
Average speed = 134.2 Km/h

Fig.8.3.3- 3 Run curve of non stop super high-speed train 300 km/h on actual track with partial improvement between Sofia and Plovdiv



Calculated run time = 70.37 Minutes
Schedule travel time = 73.89 Minutes
Average speed = 126.27 Km/h

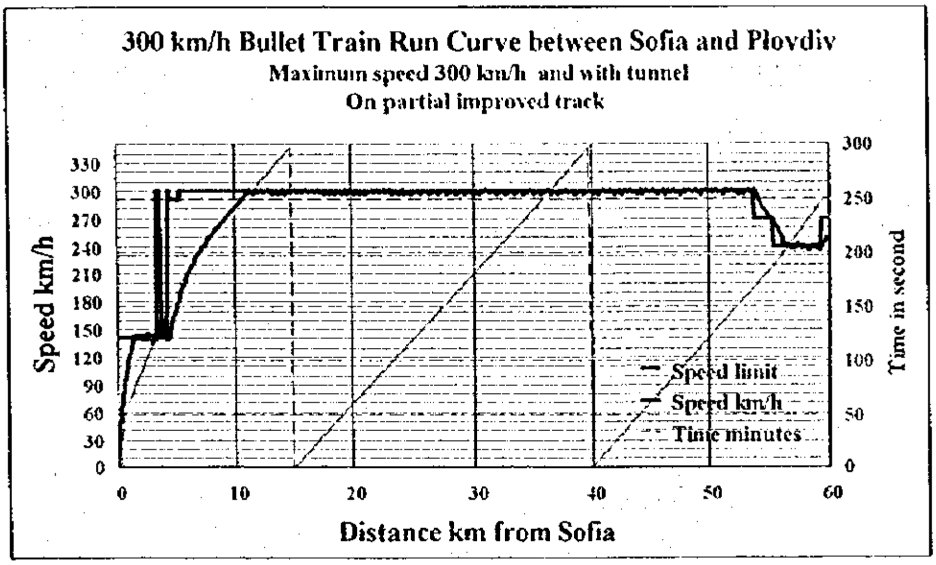
Fig.8.3.3- 4 Run curve of super high-speed train 300 km/h in case of 1 stop on actual track with partial improvement between Sofia and Plovdiv

In this master plan stage, it's not necessary to know precisely the each loss time at a unknown station. Here is indicated one example of the time loss of high-speed train for assuming

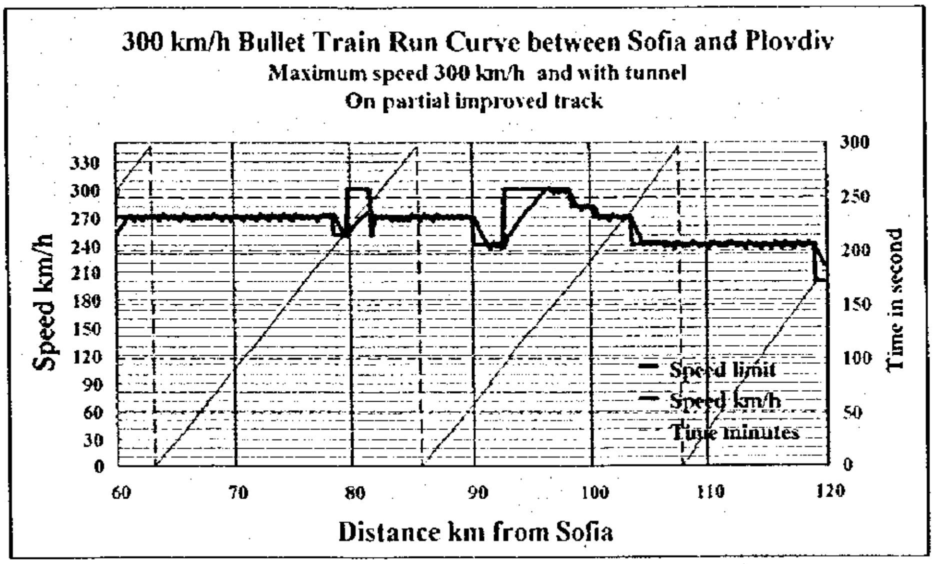
approximately the dimension of the loss time of each stop.
In this case, the loss time of 1 stop is assumed as 4.5 minutes by stop time 90 seconds at intermediate station.
This loss time becomes bigger in the case of higher speed at the braking points.

2) On partial new track line

Section between Sofia and 60km



Section between 60 km and 120 km



Section between 120 km and Plovdiv

The condition of running simulation is that the section between Sofia and Septemvri is completely improved by new tunnel line and the section between Septemvri and Plovdiv is partially improved on few short curved sections. These special places can be recognized in the annex figure of the

former item.
The tunnel section has two points with curve speed limit for considering the track design. On the section between Septemvri and Plovdiv, some limiting curves require decreasing speed of super high-speed train.

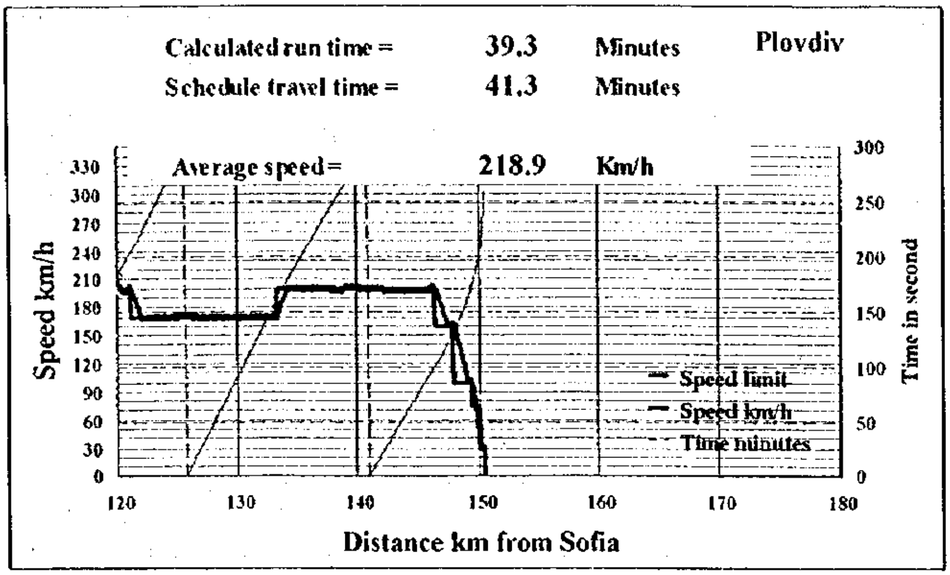


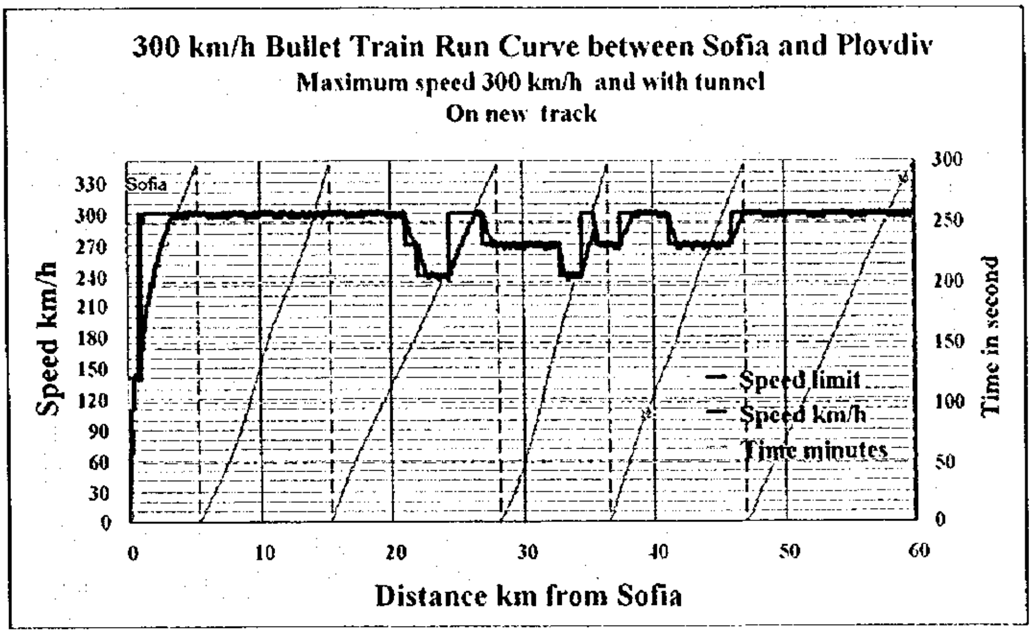
Fig.8.3.3- 5 Run curve of super high-speed train of 300 km/h on partial improved with new tunnel line between Sofia and Plovdiv

The super high-speed train has a characteristic of actual 300 km/h trains. By this partial new track, 300 km/h train will connect Sofia and Plovdiv by 42 minutes.

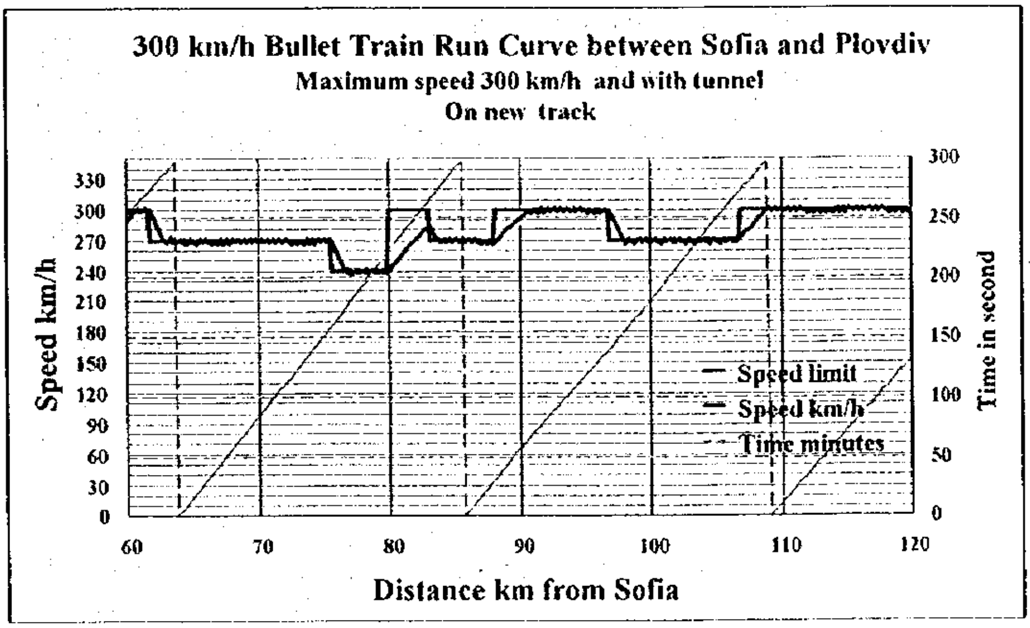
3) On the complete new line between Sofia and Plovdiv

The following bullet train is running on the complete new line between Sofia and Plovdiv. Track figure is designed by considering the topography of the related area.
The track resistance is calculated by curves, gradient and by tunnel or open condition. The train running characteristics is supposed to be the most advanced one.
By the speed up project, the train number will be increased and the speed difference of various trains will need the complete new double track line for super high-speed trains in the day of connecting western Europe and Asia by BDZ.
On the completely new line track line in parallel with actual track, 300 km/h train will run in 37 minutes between Sofia and Plovdiv.
In the chapter 7, the economical effects are already explained in the table.

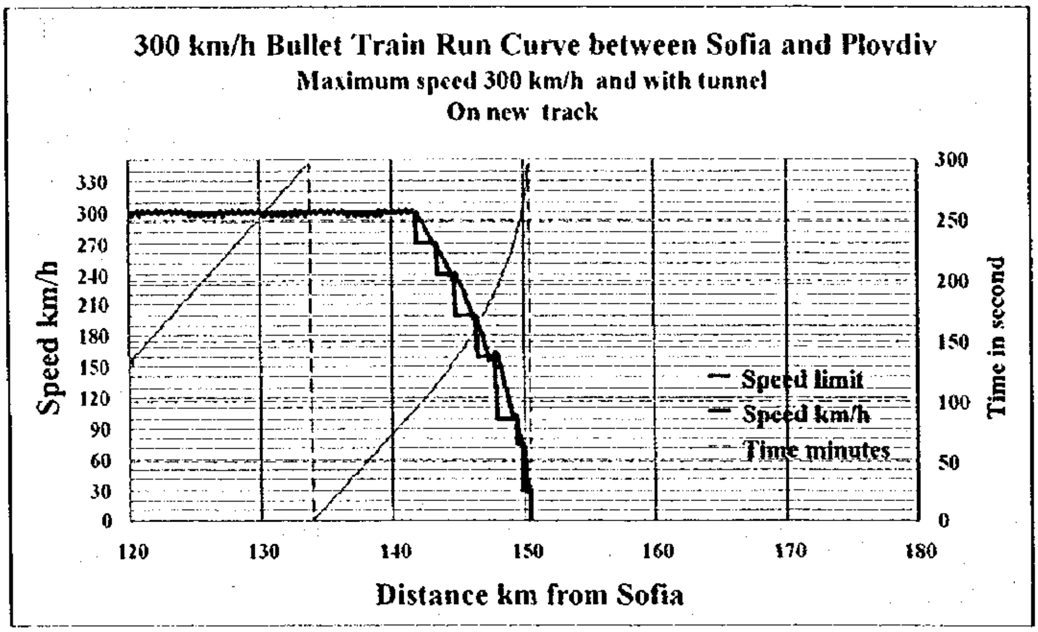
Section between Sofia and 60km



Section between 60 km and 120 km



Section between 120 km and Plovdiv



Calculated run time =	35.3	Minutes
Schedule travel time =	37.0	Minutes
Average speed=	244	Km/h

Fig.8.3.3- 6 Run curve of super high-speed train of 300 km/h on new line with tunnel between Sofia and Plovdiv

8.3.4. Simulation of Running Time of Future Speed-up Plans and Their Effect

By selecting the most important section between Sofia and Plovdiv, the effect of improving measures on travel time and their effect are calculated.

(1) Shortening of travel time

Base Case is the travel time of the actual express train noted in the published time table of BDZ. For the convenience sake, the simulated cases are classified in the following;
The contents of each improving project are as follows:

- **Case A**: The express train on improved track with maximum speed 130 km/h and switch limiting speed 100 km/h at stations.
- **Case B**: The express train on improved track with maximum speed 130 km/h and with switch limiting speed 130 km/h at stations.
- **Case C**: The pendulum type express train on improved track with maximum speed 130 km/h and switch limiting speed 130 km/h at stations.
- **Case D**: The pendulum type express train on improved track with maximum speed 160 km/h and switch limiting speed 130 km/h at stations.
- **Case E**: The pendulum type express train on improved track with maximum speed 160 km/h and switch limiting speed 160 km/h at stations.
- **Case F**: The super high speed express train with maximum speed 300 km/h on actual track
- **Case G**: The super high speed express train on new tunnel track with maximum speed 300 km/h and on partial improved track between Septemvri and Plovdiv.
- **Case H**: The super high speed express train on new track with maximum speed 300 km/h between Sofia and Plovdiv.

The results of simulation of train running time of each case are explained in the items of 8.3.2 and 8.3.3.

Table 8.3.4- 1 Travel Time by new express

	Improvement measure		Speed km h		Non stop	Non stop	1 stop	2 stop
Project name	Coach	Track	Maximum speed	Switch limiting speed	Calculated travel time	*Travel time on diagram	*Reduction rate of time	*Reduction rate of time
Actual	Normal		130-120	100			1(1hr57min.)	1(2 hr 0 min)
Case A	Normal	Improved	130	100	1 hour 39 min	**1 hour 44 min**	0.915	0.917
Case B	Normal	*Partial	130	130	1 hour 28 min	**1 hour 32 min**	0.812	0.817
Case C	Pendulum	*Partial	130	130	1 hour 24 min	**1 hour 28 min**	0.778	0.783
Case D	Pendulum	*Partial	160	130	1 hour 16 min	**1 hour 20 min**	0.718	0.733
Case E	Pendulum	*Partial	160	160	1 hour 13 min	**1 hour 16 min**	0.684	0.700
Case F	Bullet light weight coach	*Partial	300	300	1 hour 6 min	**1 hour 10 min**	0.632	0.658
Case G	Bullet light weight coach	Sofia-Septemvr	300	300	0 hour 39 min	**0 hour 41 min**	0.402	0.442
Case H	Bullet light weight coach	All	300	300	0 hour 36 min	**0 hour 37 min**	0.368	0.408

Note: Travel time on train diagram is calculated by adding 5% to simulated running time.
Note: Stopping time at intermediate station by project is assumed to be 1 minute 30 seconds.

Non stop train's running curves are precisely simulated for each case. For the cases of 1 stop operation, some examples are calculated and the loss time of one stop is measured approximately and added to the cases of 1stop or 2 stops, because the loss time might be different according to the running performance at each stopping station near by.

The estimation of the relation among the tariff, speed-up and the traffic volume is important work for deciding actual investment plan.

Table 8.3.4- 2Share of Road by the Railway Access Convenience Group

From	To Group C	To Group B	To Group A	Km	Group C	Group B	Group A
Sofia	Montana			109	0.24		
Sofia	Plovdiv			156	0.36		
Sofia		Trojan		167		0.98	
Sofia	Pleven			176	0.22		
Sofia	Vidin			211	0.44		
Sofia		Gabrovo		226		0.98	
Sofia		Haskovo		234		0.94	
Sofia	Stara Zagora			234	0.56		
Sofia	G. Oryahovitza			235	0.42		
Sofia	Dimitrograd			244	0.38		
Sofia	Velko Tarnovo			247	0.41		
Sofia		Kardzali		259		0.95	
Sofia			Sliven	279			0.29
Sofia	Dopovo			286	0.5		
Sofia			Jambol	300			0.21
Sofia	Svilengrad			303	0.78		
Sofia	Rousse			324	0.78		
Sofia	Aitos			361	0.68		
Sofia	Razgrad			370	0.91		
Sofia			Shumen	386			0.53
Sofia			Burgas	392			0.33
Sofia	Silistra			446	0.84		
Sofia			Varna	470			0.36
Sofia			Dobrich	512			0.63

Note 1: Railway accessibility to each station from Sofia is estimated from the difference of distance between road and railway and from the share.
Note 2: The above data are based on the survey of BDZ.
Note 3: Cities of Group A, Group B, Group C are classified by railway service degree.

Tariff and speed are two main independent factors to influence the selection of transport modes by passengers. The endeavor of speed-up of trains in many countries are resulted to recover railway passenger volume intercity areas. The increase ratio of speed-up or shortening the travel time is approximately equal to the increase rate of passenger volume by the actual experience. The passenger volume increase will become 1 – 2 times to speed-up rate by a mathematics model.
The multiple regression analysis is applied to the data of distance, speed and tariff of BDZ and road.
The acquired formulas by regression analysis are shown in the following formula;

$S_{road} = -\mathbf{0.61130966} \times P_{road/rail} - \mathbf{0.88016712} \times T_{road/rail} + \mathbf{1.989338369}$

$S_{rail} = +\mathbf{0.61130966} \times P_{road/rail} + \mathbf{0.88016712} \times T_{road/rail} - \mathbf{0.989338369}$

$(S_{road} + S_{rail} = 1)$

where:

Sroad: Share of road vehicle passengers
Srail: Share of railway passengers
Proad/rail: Price rate of Road by Rail = Proad/Prail
Troad/rail: Travel time rate of Road by Rail = Troad/Trail

The standard error of share of road and rail = 0.174535748
The standard error of tariff rate of road / rail = 0.154629849
The standard error of time rate of road / rail = 0.354996473

(3) Share Recovery by Speed-up Project

For general understanding sake's, the averaged values are used in this master plan stage, although it is possible to calculate the share changing on each line.
The changing the travel time and the share recovery are calculated by using the No.1 line train run simulation results and by the formula gained by multiple regression analysis.

Δ Share rail = 0.88016712 x Troad1/Ttrain1 x (Ttrain1/ Ttrain2 – 1)

Ttrain1 : Actual travel time of express train
Ttrain2 : Improved travel time of express train by project

Table 8.3.4- 3 Share increase by speed-up projects of Sofia-Plovdiv

	Improvement	Improvement	Improvement	Speed	Speed	1 stop	1 stop	1 stop
Project name	Coach	Track	Signal	Maximum	At switch	Railway speed up rate %	*Railway share	*Railway share up rate
Actual	Conventional		Conventional	130-120	100	1.00	0.65	100.00%
Case A	Conventional	Improved	Conventional	130	100	1.08	0.70	108.23%
Case B	Conventional	*Partial	Conventional	130	130	1.22	0.78	120.38%
Case C	Pendulum	*Partial	ATC	130	130	1.27	0.81	125.15%
Case D	Pendulum	*Partial	ATC	160	130	1.39	0.87	134.58%
Case E	Pendulum	*Partial	ATC	160	160	1.46	0.91	140.71%
Case F	Bullet - light weight coach	*Partial	ATC	300	300	1.52	0.98	151.14%
Case G	Bullet - light weight coach	Sofia-Septemvri	ATC	300	300	2.39	1.00	153.85%
Case H	Bullet - light weight coach	Renovated	ATC	300	300	2.60	1.00	153.85%

The above comparison is done for the cases of 1 stop and 2 stops, because of the lack of examples of non stop trains in train time table of BDZ.
Share increase can be calculated by using the averaged value but the procedure of calculation is not difficult to be applied for each city pair section. In the above table, the transition for the important section between Sofia and Plovdiv is indicated for showing the effect of speed-up.

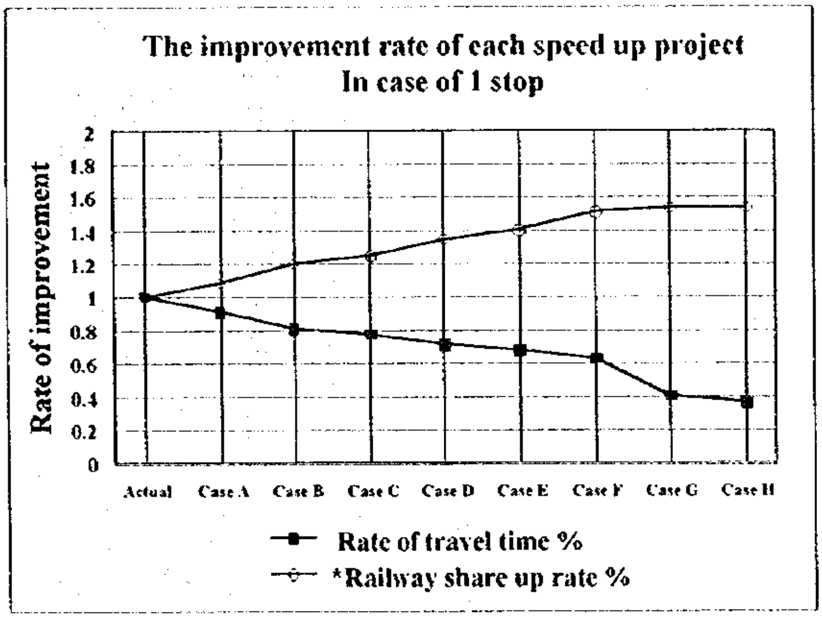


Fig.8.3.4- 1 Effect of each speed-up case

The share increase by railway speed-up might be saturated at the case G of 300 km/h Super High Speed Train on partial new track line between Sofia and Septemvri

Generally speaking, share model can be applied in the sphere of little improvement for judgment of the effect on the management. For evaluation in case of further increase of speed-up rate, **"gravity mode, etc."** should be applied for knowing their effects on the benefit, because, in such zones, total traffic demand itself will be augmented eminently.

The effect of speed-up should not be judged only from the share increase but also from the efficiency increase of rolling stock and operational personnel. To the rate of speed-up, the cost of one train will be decreased and the increase of trains can be done by relatively suppressed number of train sets.

By practical experience, the traffic volume will be increased 2 – 3 times than actual situation in case of super high speed project.

On the period of complete innovation of railway service, the half effect will be absorbed by special tariff that will save the augmentation cost for increasing the train speed and the other half should be delivered to passengers that will cause the increase of passenger volume itself.

Anyhow, effort will be rewarded as benefit to railway and it will dedicate to the development of Bulgaria at the same time.

8.4 Others

8.4.1 Way of train diagram formation in BDZ

The train operation diagram is being formed by the calculation of travel time among stations, based on the train type, stopping stations, maximum speed among stations, traction locomotives, etc. Finally the operation of trains is explained on train time-table and on printed train diagrams that are prepared manually for each line. The preparation method of the train time-table is very nice and the field organs are using them for daily train operation work.
The change of transportation situation for railway service is so rapid that the manual working method can not pursuit the market changing sufficiently. The speedy work that is required for the reflection of technical improvement of railway should be achieved by computerized train planning system. The introduction of computer system for train operation planning becomes more and more important for the survival of railway.
The computerized total train operation planning system is being completed in RRI of BDZ. Their technical level is high and if computer with enough capacity be supplied, they can prepare the computerized train operation planning system by themselves in short period.
The train operation planning system is generally based on UIC regulation.
The competition in these days is forcing the utilization of the allowance included in the regulation for facilities of track, rolling stock running gear, comfort, etc. By measuring precisely the running performance of modern trains, train speed can be increased by relatively small cost.
The computerized train planning system will also support the evaluation work of each railway project for increasing speed and augmentation of competitiveness, etc.

8.4.2 Train operation safety system

(1) Safety control system and regulation

Safety is the most important service of transportation business.
The consciousness on the importance of safety is highly kept in all field of BDZ organization.
Highways are being constructed and its network is spreading rapidly in Bulgaria.

(2) Training and behavior of operation control

The important operational staffs, engine drivers, station masters, etc., are trained well in the military railway school and their behavior on train operation is good, but still it's necessary to improve the safety system for higher speed operation and for preventing the time loss of train operation.

(3) Countermeasures for prevention of accidents

The competition with road is becoming severe for railway management and this requires the higher speed, more various types of trains that will cause the increasing chance of passing-by treatment at intermediate stations, quick response for preparing necessary trains, etc.
The increasing speed is aimed eagerly by BDZ for increasing the competitiveness but the supporting safety system is not sufficient, although human treatment is well organized as seen the training, daily operation control of drivers at depot and on operation, etc.
The train operation system with ATC is introduced on the section between Sofia and Plovdiv.

The signals on main lines are mainly equipped with color light system but they are not equipped with automatic signal circuits on many sections.
The modernization of safety facilities of train control should be accelerated for increasing the competitiveness of train operation quality by considering the future strategy of each line.

(4) Accident data

The classification of accidents in BDZ is unlike with other countries and detail comparison on each type of accident is not so easy.
The following data in UIC 1982 report and the data BDZ 1995 are refitted for aiming equal comparison as far as possible.

1) General comparison

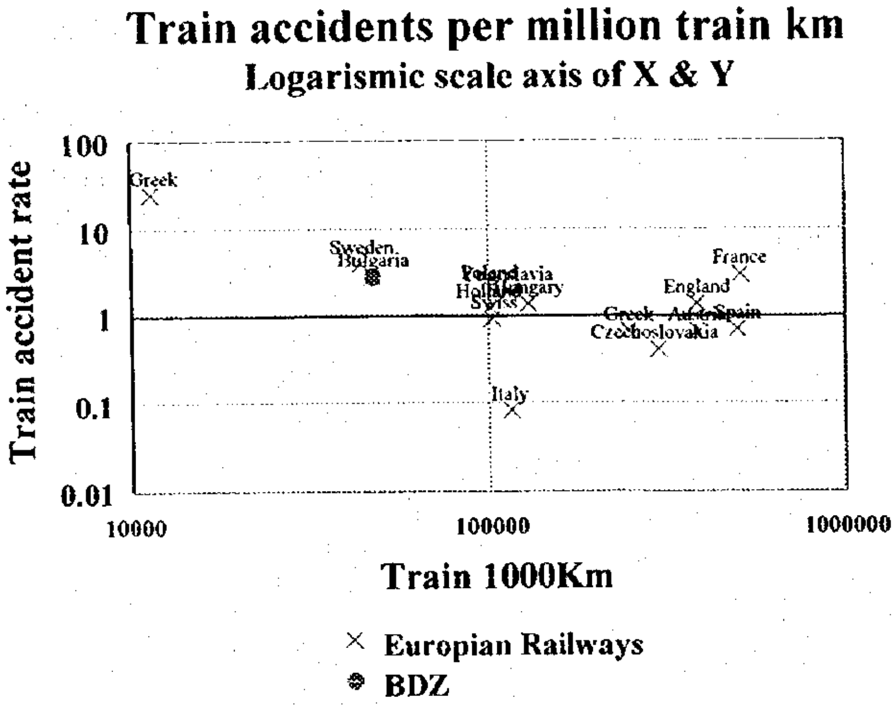


Fig. 4.1- 1 Train accidents per 1 million train km in European Railways

Although the precise analysis is not possible because of the difference of classification of rain accidents, the number of train accidents of BDZ is showing a little higher value in European countries as shown in the Fig.4.1-1.
The BDZ data of train accidents are including the incidents of shunting operation inside stations. The rate of train accidents caused by shunting operation is recognized higher than the accidents in other European countries.
The incidents inside stations of BDZ are caused by the aged facilities and these are giving the disturbance of train operation, as shown in the following analysis, whereas the operation discipline on main lines is maintained well.
The training and regulations for extraordinary cases are well prepared in field organs of locomotive shed of stations etc. and they are saving fatal accidents at the extraordinary tempo caused by imperfection of safety system.

Train accident's rate of BDZ is calculated by using the number of train accidents 137, including train accidents on main line and on the area of inner part of stations.

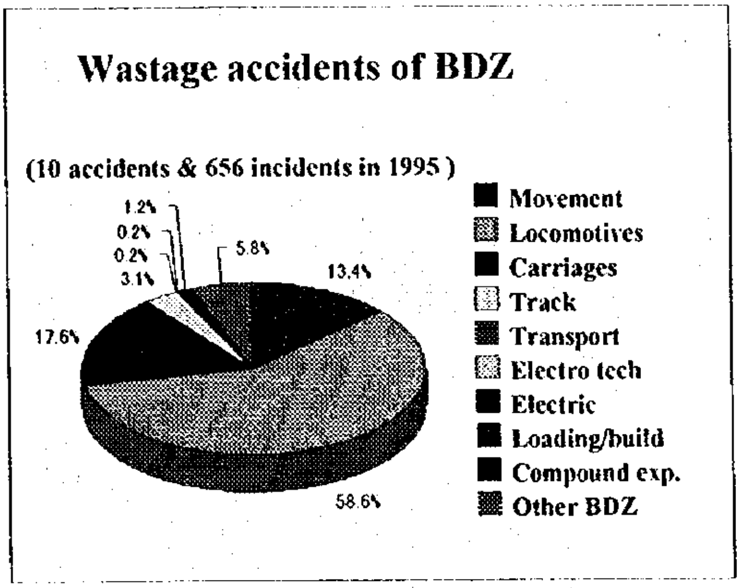


Fig. 4.1- 2 Wastage accidents of BDZ

According to the classification of BDZ, the Number of accidents of BDZ on main line was 10 in 1995. The number of wastage accidents in 1995, which caused some influences to operation, was counted 656. For clarifying the sectional proportion of accidents, the 656 wastage accidents are selected here. The major factors of failures are rolling stock, locomotives and carriages, and the operational movement section.

2) Accidents of train operation

The data are prepared by assuming from the official data of BDZ. These data of internal area of stations are elevating up the rate of train accidents of BDZ. When we see the rate of train accidents on main track line in other European countries, we can say that the rate of train accidents on main track lines is relatively low in case of BDZ.
Out of 137 train accidents, including level crossing accidents, 88 accidents are caused by operating stuffs.
The number of derailment by shunting operation might be 78 out of 88 operation errors in stations.
The second accidents are of cutting switches that were caused by mistake of route ascertainment by relative personnel. These accidents will induce train derailments, because many serious secondary train accidents were reported in other railways.

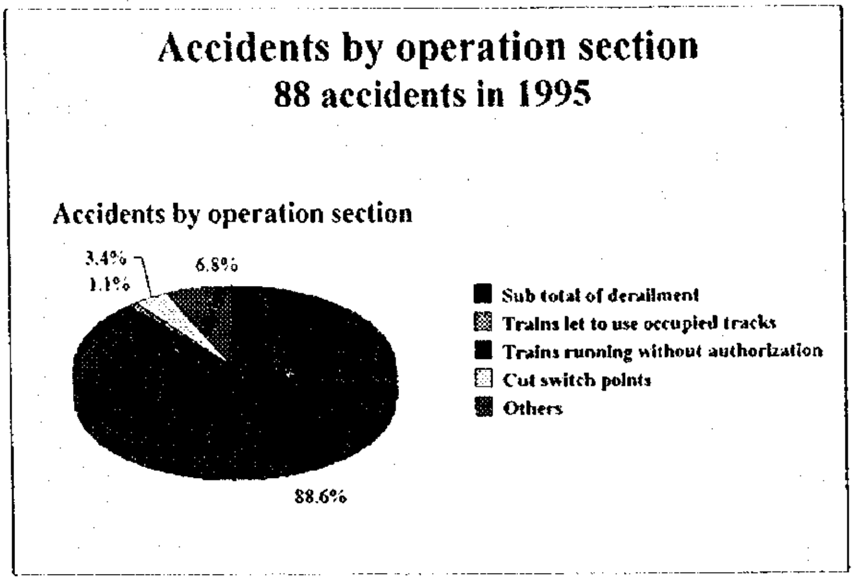


Fig. 4.1- 3 Accidents caused by operation section

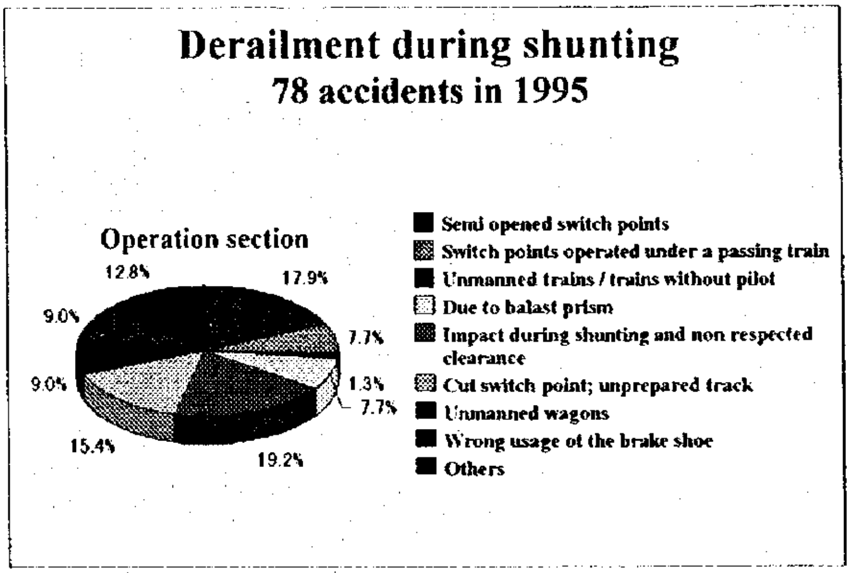


Fig. 4.1- 4 Derailments caused by shunting operation

3) Accidents by locomotive or driver

The education, health check, indication of provisory speed limit, training of engine drivers etc. are completely executed and the moral of operational stuff is kept also in good condition.

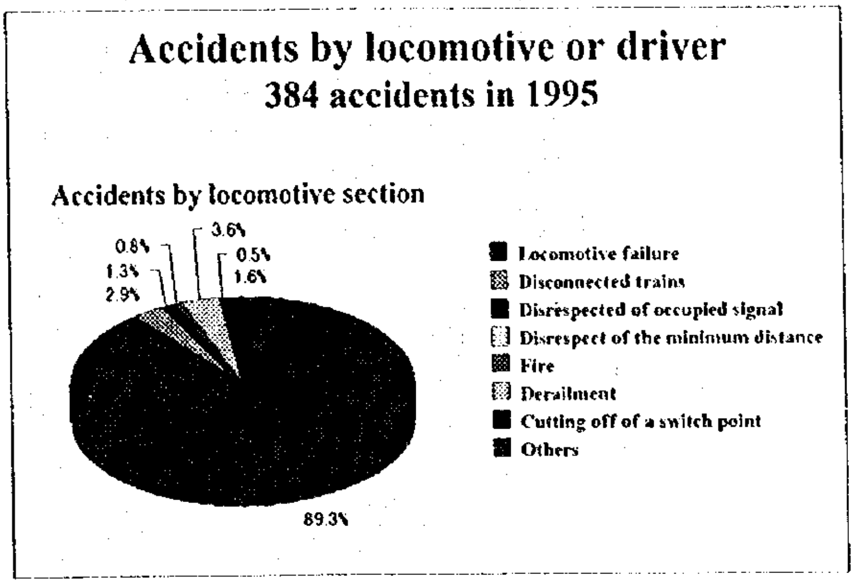


Fig. 4.1- 5 Accidents by locomotives' or drivers' section

The major errors of this section are caused by the failure of locomotives by age or by maintenance condition. The accidents of disconnection and derailment should be marked, that are admitted in this section and carriage section.

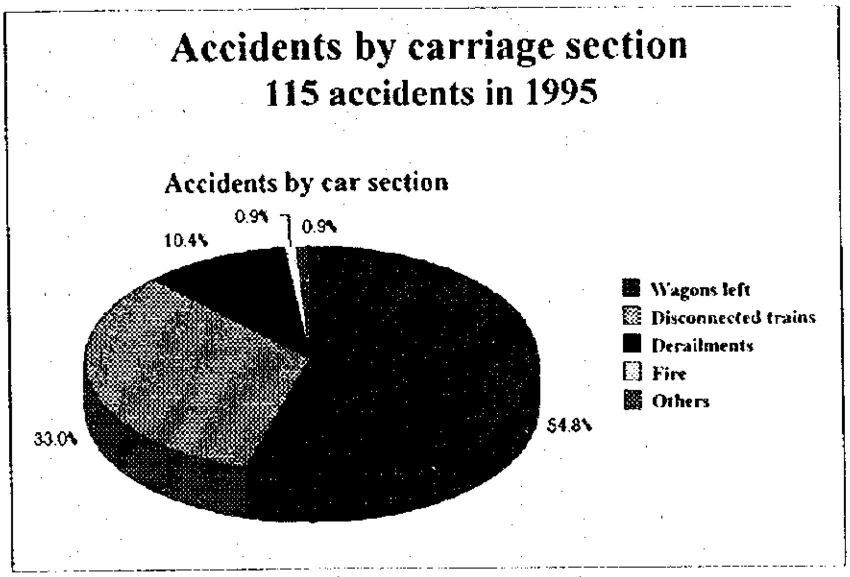


Fig. 4.1- 6 Accidents by carriage section

Disconnection of cars is serious, which will cause the train collision on main line, and still they are counted so many in BDZ. These dangerous accidents to cause train collision should be completely wiped out.