COMPLEX METHODOLOGY FOR STUDY OF INTERCITY RAIL TRANSPORT

Svetla Stoilova, Radina Nikolova
Technical University-Sofia, Bulgaria
stoilova@tu-sofia.bg, r.nikolova@tu-sofia.bg

Abstract. In the study a complex methodology for selection a routing of different categories of intercity passenger trains is developed. The big cities located on the rail network are attractive centers for transport service of small towns and rural areas. It is therefore necessary to determine the optimal scheme for interurban transport services that would satisfy both the needs of passengers and the possibilities of transport companies. The methods of linear optimization, Analytic hierarchy process (AHP), Decision Tree and Cost/Benefits have been applied. In the research variant schemes for movement of intercity trains are investigated and the strategies for stochastic variations in passenger flows are examined. The methodology includes four stages. In the first stage the probabilities for stochastic variation of passengers using the AHP method are determined. In the second stage for each scheme of transportation the optimal number of intercity trains is determined by the criterion of minimum direct operating costs and the linear optimization model. The Decision Tree Analysis is applied to determine the best scheme of transport by the criterion of direct operating costs taking into account the stochastic variation of passenger flows. In the third stage the AHP method is applied for determination the weights of the criteria and for selection of the best variant scheme. As the criteria for selecting the best variant scheme of transport the transport satisfaction, average number of train stops, average distance travelled, average speed, reliability, availability of service with direct transport, transport capacity, direct operational costs and comfort are chosen. The best scheme for transportation is determined by using the Decision Tree Analysis. In the fourth stage the method Cost/Benefit is applied for choice of the optimal scheme for intercity trains. The methodology was applied in Bulgarian rail network and was proposed an organization of railway passenger transport.

Keywords: passenger, transport, AHP method, linear optimization, decision tree, cost/benefits.

Introduction

The determination of the optimal scheme for transport of intercity passenger trains is a complex task that has to satisfy the needs of passengers and the capabilities of the railway operator. It is important to take account of the stochastic variations in passenger flows and the changes in the organization of transport related to repair work for rehabilitation of the railway infrastructure. It is necessary to explore different variant schemes for transportation, which should be evaluated by quantitative and qualitative criteria. Suitable methods for examination in this case are the Decision making theory and the Multi-criteria analysis. The Multi-criteria analysis methods allow different alternatives to be evaluated on both quantitative and qualitative indicators.

The AHP approach is one of the more extensively used multi-criteria decision-making methods. In [1] the AHP method is used for optimal decision of the mode of transportation and five factors as the cost, speed, security, punctuality and transportation capacity are compared. The needs of passengers of railway transportation are investigated in [2] by using the AHP method. In [3] the indicators safety, rapidity, time and comfort are applied to analyze the qualitative factors which impact the operation efficiency of the highway passenger transport enterprises. In [4] the possibilities of applying the AHP method are analyzed in making decisions regarding the planning and implementation of the plans in traffic and ensuring qualitative business logistics. The urban mass rail transit network in Ningbo with six preliminary schemes is investigated in [5] applying the AHP model. There are used twenty criteria. In [6] research of passenger transportation quality for train running on the international route Vilnius – Moscow is made with four criterion groups: criteria related to the train elements and the technical state of rails, criteria related to railway trip planning and technology, criteria related to the price of a trip ticket, criteria related to the safety of railway trips. The AHP methodology is used to determine their weights considering the data obtained from the respondents and experts.

This paper aims to propose a complex approach to selection a scheme of transportation for intercity trains by taking into account multiple factors relevant for transport and stochastic variations of passenger flows.

In the reviewed studies the impact of the variation of passenger flows on the choice of the best alternative is not accounted. The costs of transportation are investigated jointly with other criteria and do not make a preliminary optimization by this criterion.

The novel contribution of this paper is, on the one hand, determination of criteria for best organization of intercity trains, and on the other hand, development of a complex methodology for selection of the optimal scheme for transportation of the intercity trains, taking into account the stochastic variation of passenger flows.

Materials and methods

Fig. 1 presents the scheme of complex methodology.

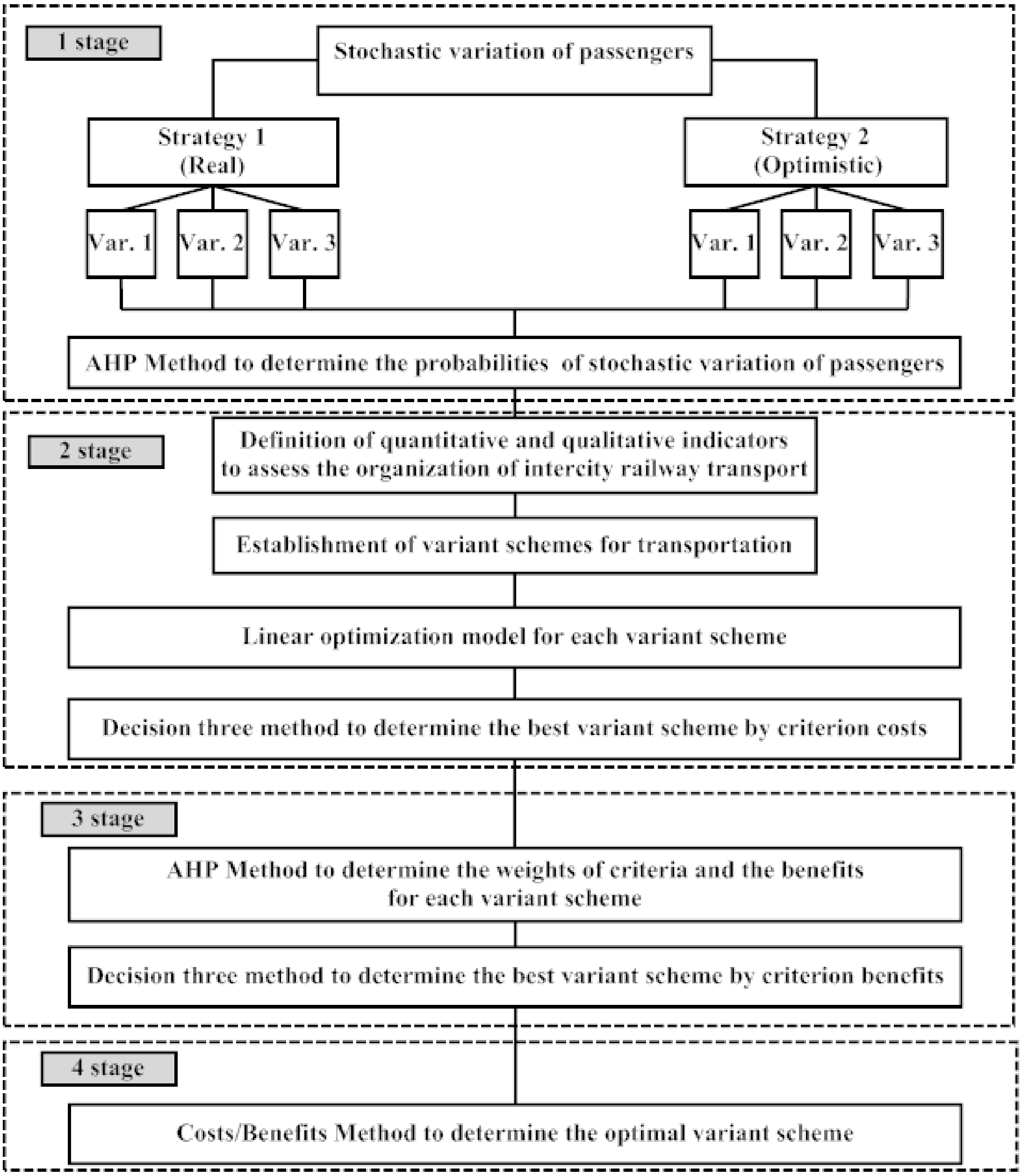

Fig. 1. **Scheme of the complex methodology**

The research includes the following stages:

- **Stage 1:** In the first stage the stochastic variations of passengers flows are determined. In this paper two strategies are investigated – real (strategy 1) and optimistic (strategy 2). In the real strategy the passenger flows are changed by -5 % to 15 % with step of 5 %. In the optimistic strategy the passenger flows are changed by 5 % to 30 %. For each strategy three variants are examined according to the changes in the rail infrastructure: variant 1 – do not carry out repairs on the railway infrastructure; variant 2 – there are reconstructions in the railway infrastructure; variant 3 – the reconstructive activities in the railway infrastructure are completed. The weights of each variant and strategies are determined by the AHP Method using a group of experts, which have given the score by the Saaty’s scale (Table 1). The AHP method is presented in [7].

Table 1

Comparison Scale

Definition	Intensely of importance	Reciprocal values
Equal importance	1	1
Moderate importance of one factor over another	3	1/3
Strong or essential importance	5	1/5
Very strong importance	7	1/7
Extreme importance	9	1/9
Values for intermediate comparison	2,4,6,8	1/2 ; 1/4 ; 1/6; 1/8

- **Stage 2**: In the second stage the best solution by the criterion of minimal operational costs is determined. This stage includes the following steps: determination of the indicatorsto assess the organization of intercity trains; establishment of variant schemes of transportation; the linear optimization model to define the optimal number of trains for each variant scheme by the criterion of minimal operational costs; the decision tree method to determine the solution in the condition of stochastic variations of passenger flows.

In this research the following quantitative and qualitative indicators are applied for choosing the best variant scheme for railway intercity transportation:

K1 – Transport satisfaction. It is the number of trains per day for the variant scheme.

K2 – Average number of train stops. This factor indicates the frequency of service to the settlements for the variant scheme.

K3 – Average distance traveled. This factor indicates the average length of routes for the variant scheme.

K4–Average block speed. It indicates the speed of transport services for the variant scheme.

K5 – Reliability. In the study the reliability is given by the average delay of trains.

K6 – Availability of service with direct transport. The direct transport means direct service by train (without intermediate stops) between large cities (over 100 thousand inhabitants). If the variant scheme offers such service K6 = 1, otherwise K6 = 0.

K7 – Transport capacity. The transport capacity indicates the number of places offered by the variant scheme.

K8 – Comfort. It shows the convenience of the rolling stock while travelling.

In the research schemes of organization of intercity passenger trains according to the train categories and the number of wagons have been examined. Table 2 shows the variant schemes.

Table 2

Variant schemes

Train composition	Train category		
	FT, AFT, DFT	**FT, DFT**	**FT, AFT**
3 wagons	Scheme 1 – A; B	Scheme 4 – A; B	Scheme 7 – A; B
4 wagons	Scheme 2 – A; B	Scheme 5 – A; B	Scheme 8 – A; B
3 and 4 wagons	Scheme 3 – A; B	Scheme 6 – A; B	Scheme 9 – A; B
Note:	Schemes “B” includes trains with electric multiple unit		
	for DFT	for DFT	for AFT

The train categories are: Direct fast trains (DFT), Accelerate fast trains (AFT) and Fast trains (FT).The Direct fast trains are intercity express trains. They are a new category trains in the research.

The Accelerate fast trains are intercity trains. The Fast trains stop at more stations compared to the DFT and AFT. The number of wagons is chosen according to the existing situation of formation of the compositions in Bulgarian rail network. The trains in schemes "A" are composed of wagons. The trains in schemes "B" are composed of wagons and electric multiple units.

To determine the number of trains for each variant scheme the linear optimization model is applied.

For each variant scheme individually the linear optimization model is applied to minimize the total direct operational costs.The objective function is:

$$R_i = \sum_{i_1=1}^{I_1} r_{i_1}^{o,d,FT}.l_{i_1} x_{i_1}^{FT} + \sum_{i_2=I_1+1}^{I_2} r_{i_2}^{o,d,AFT}.l_{i_2} x_{i_2}^{AFT} + \sum_{i_3=I_2+1}^{I_3} r_{i_3}^{o,d,DFT}.l_{i_3} x_{i_3}^{DFT}, \mathrm{BGN} \cdot \mathrm{day}^{-1} \rightarrow \min \tag{1}$$

where $i_1 = 1,...,I_1$ – number of assignments of fast trains;

$i_2 = I_1 + 1,...,I_2$ – number of assignments of accelerate fast trains;

$i_3 = I_2 + 1,...,I_3$ – number of assignments of direct fast trains;

$r_{i_1}^{o,d,FT}$, $r_{i_2}^{o,d,AFT}$, $r_{i_3}^{o,d,DFT}$ – direct operational costs for trains, BGN·km^{-1};

l_{i_1}, l_{i_2}, l_{i_3} – lengths of destination of trains, km;

x_{i_1}, x_{i_2}, – numbers of trains of destinations respectively , , ;

i – number of variant scheme, $i = 1,...,I$.

The objective function (1) defines the optimal plan that provides realization of the necessary passenger transportation with minimal direct operational costs.

The restrictive conditions are:

$$\sum_{i_1=1}^{I_1} L_{i_1 jk}^{FT}.a_{i_1}^{FT}.\alpha_{i1}^{FT}.x_{i_1}^{FT} \geq P_{jk}^{FT}, \tag{2}$$

$$\sum_{i_2=I_1+1}^{I_2} L_{i_2 jk}^{AFT}.a_{i_2}^{AFT}.\alpha_{i2}^{AFT}.x_{i_2}^{AFT} \geq P_{jk}^{AFT}, \tag{3}$$

$$\sum_{i_3=I_2+1}^{I_3} L_{i_3 jk}^{DFT}.a_{i_3}^{DFT}.\alpha_{i3}^{DFT}.x_{i_3}^{DFT} \geq P_{jk}^{DFT}, \tag{4}$$

where $a_{i_1}^{FT}$, $a_{i_2}^{AFT}$, $a_{i_3}^{DFT}$ – number of seats in a train;

$\alpha_{i_1}^{FT}$, $\alpha_{i_2}^{AFT}$, $\alpha_{i_3}^{DFT}$ – coefficients of utilization of seats ;

$j = 1,..., J$ – number of the station where the passenger flows start;

$k = 1,..., K$ – number of the station where the passenger flows finish;

P_{jk}^{FT}, P_{jk}^{AFT}, P_{jk}^{DFT} – passenger flows from station *j* to station *k*, pass. per day;

$L_{i_1 jk}^{FT}$, $L_{i_2 jk}^{AFT}$, $L_{i_3 jk}^{DFT}$ – coefficients that take into account the possibility of a passenger train to serve the assignments of passenger flows respectively P_{jk}^{FT}, P_{jk}^{AFT}, P_{jk}^{DFT};

$L_{i_1 jk}^{FT} = 1$, $L_{i_2 jk}^{AFT} = 1$, $L_{i_3 jk}^{DFT} = 1$, where it is possible;

$L_{i_1 jk}^{FT} = 0$, $L_{i_2 jk}^{AFT} = 0$, $L_{i_3 jk}^{DFT} = 0$, otherwise.

The number of trains must be positive and integer:

$$x_{i_1}^{FT} \geq 0 ; x_{i_2}^{AFT} \geq 0 ; x_{i_3}^{DFT} \geq 0 ; x_{i_1}^{FT} ; x_{i_2}^{AFT} ; x_{i_3}^{DFT} \text{ - integer} \tag{5}$$

The number of trains must not exceed the maximum capacity of the railway line:

$$x_{i_1}^{FT} + x_{i_2}^{AFT} + x_{i_3}^{DFT} < N^{\max} \quad (6)$$

where $N^{\max}$ – maximum capacity of the railway line which is being examined, train·day^{-1}.

To account the stochastic variations in passenger flows the decision tree method is applied. This is a diagrammatic presentation of various alternatives, their possible outcomes with associated probabilities and their possible payoffs, in a decision-making situation, [8]. Each decision tree has two types of nodes: the round nodes correspond to the states and the square nodes that correspond to the decision alternatives. The branches leaving each round node represent the different states while the branches leaving each square node represent the different decision alternatives. At the end of each limb of a tree there are the probabilities and the payoffs. The expected value of a decision alternative is the sum of the weighted payoffs for the decision alternative.The expected value (EV) of the decision alternative a_i is defined as:

$$EV(a_i) = \sum_{v=1}^{V} P(b_v).R_{iv}\,; \quad (7)$$

where a_i – variant scheme (alternative);

b_v – stochastic variation of passenger flows (states);

v – number of stochastic variation of passenger flows, $v = 1,...,V$;

$P(b_v)$ – probability of stochastic variations (defined by AHP Method);

R_{iv} – payoff corresponding to decision alternative a_i and state b_v .

In the research the payoff is presented by direct operating costs or by benefits.

$$\sum_{v=1}^{V} P(b_v) = 1,\ P(b_v) \geq 0, \text{ for all } v = 1,...,V\ . \quad (8)$$

- **Stage 3**: In the third stage the best solution by criterion benefits is determined. This stage includes the following steps: application of the AHP Method to define the weights of the criteria for transportation, prioritization the variant schemes and calculation the scores; the decision three method to determine the best variant scheme taking into account the stochastic variation of passenger flows and the AHP scores.
- **Stage 4**: The final stage includes an optimal variant scheme selection by means of the Cost/Benefit ratio (r_i). The minimal cost/benefit ratio presents the optimal solution.

$$r_i = \frac{c_i}{b_i} \rightarrow \min, \quad (9)$$

where c_i – normalized costs for the variant scheme *i*;

b_i – AHP score for the variant scheme *i*;

The normalized costs present the proportion of direct operational costs for each of the variant schemes.

$$c_i = \frac{R_i}{\sum_{i=1}^{I} R_i}\,. \quad (10)$$

Results and discussion

The complex methodology is applied for the railway line Sofia – Plovdiv – Burgas. This railway direction of the railway network in Bulgaria is characterized by significant passenger flows. The number of stops and the time travel for the investigated categories of trains are shown in Table 3. In Table 3 also the map of Bulgarian railway network and studies route is shown.

Table 3

The number of stops and the time travel for the investigated categories of trains

Train category	Number of stops	
	Sofia-Plovdiv	Sofia- Burgas
DFT	-	2
AFT	4	10
FT	10	24
	Time travel, h	
DFT	2.60	6.45
AFT	2.75	7.08
FT	2.92	7.50
Autobus	2.33	6.16

For this direction the number of international freight trains by the timetable of trains 2015/2016 is 16 pairs; the number of suburban trains is 5 pairs, the passenger trains, which stopped at all stations, are 13 pairs, the number of fast trains from Sofia to Plovdiv is 4 pairs and from Sofia to Burgas – 3 pairs. In the paper the freight trains, suburban trains and passenger trains, which stopped at all stations, are not investigated. The study does not include the high-speed organization of trains. The research includes organization of transportation of intercity trains for two routes in the direction Sofia-Plovdiv-Burgas: Sofia – Plovdiv (156 km) and Sofia – Burgas through Plovdiv (450 km).In this direction 40 % of passengers travel in intercity trains in Bulgarian railway network. The main cities for this direction are Sofia, Plovdiv, Stara Zagora and Burgas. The direct passengers that travel between Sofia and Plovdiv are 36 % of the total passenger flows for the studied direction. It can be seen from Table 3 that the bus transport offers a faster travel. In research transportation with new category direct fast trains is studied. For the route Sofia – Plovdiv these trains do not stop in intermediate stations, for the route Sofia-Burgas these trains stop in two intermediate stations (Plovdiv and Stara Zagora).

The AHP score for the strategies is shown in Table 4 and Table 5.

Table 4

AHP Prioritization matrix for stochastic variations of passenge flows for Strategy 1

Variant	Matrix	-5 %	0 %	5 %	10 %	15 %	Weight
1	-5 %	1	1/2	2	2	2	0.23
	0 %	2	1	2	3	3	0.35
	5 %	1/2	1/2	1	4	4	0.24
	10 %	1/2	1/3	1/4	1	2	0.10
	15 %	1/2	1/3	1/4	1/2	1	0.08
2	-5 %	1	3	5	7	7	0.48
	0 %	1/3	1	5	7	7	0.31
	5 %	1/5	1/5	1	5	5	0.13
	10 %	1/7	1/7	1/5	1	1	0.04
	15 %	1/7	1/7	1/5	1	1	0.04
3	-5 %	1	1/2	1/3	2	2	0.15
	0 %	2	1	1/3	3	3	0.23
	5 %	3	3	1	4	4	0.44
	10 %	1/2	1/3	1/4	1	2	0.10
	15 %	1/2	1/3	1/4	1/2	1	0.08

The weights of the stochastic variation of the passenger flows are used in the decision tree. By applying the linear optimization model presented in formulas from (1) to (6) the number of trains and the operating costs for each variant scheme and for each variation of passenger flows in two strategies are determined.

Table 5

AHP Prioritization matrix for stochastic variations of passenger flows for Strategy 2

Variant	Matrix	5 %	10 %	15 %	20 %	25 %	30 %	Weight
1	5 %	1	2	4	5	5	5	0.31
	10 %	1/2	1	3	4	5	5	0.35
	15 %	1/4	1/3	1	3	3	3	0.14
	20 %	1/5	1/4	1/3	1	3	3	0.09
	25 %	1/5	1/5	1/3	1/3	1	2	0.06
	30 %	1/5	1/5	1/3	1/3	1/2	1	0.05
2	5 %	1	3	5	5	5	5	0.42
	10 %	1/3	1	4	5	5	5	0.27
	15 %	1/5	1/4	1	3	4	4	0.14
	20 %	1/5	1/5	1/3	1	3	3	0.08
	25 %	1/5	1/5	1/4	1/3	1	2	0.05
	30 %	1/5	1/5	1/4	1/3	1/2	1	0.04
3	5 %	1	1/2	1/3	4	5	5	0.20
	10 %	2	1	1/2	5	5	5	0.27
	15 %	3	2	1	4	4	4	0.35
	20 %	1/4	1/5	1/4	1	2	2	0.07
	25 %	1/5	1/5	1/4	1/3	1	2	0.06
	30 %	1/5	1/5	1/4	1/3	1/2	1	0.05

Fig. 2 presents a segment of the decision tree for determination the best variant scheme taking into account the variation of passengers for strategy 1 (var. 1). The decision tree is solved by the Decision Tools Suite software – Precision Tree of Palisade Corporation, [9]. On the right side of the tree the operating costs and stochastic probabilities for each variation of passengers and each variant scheme are shown.

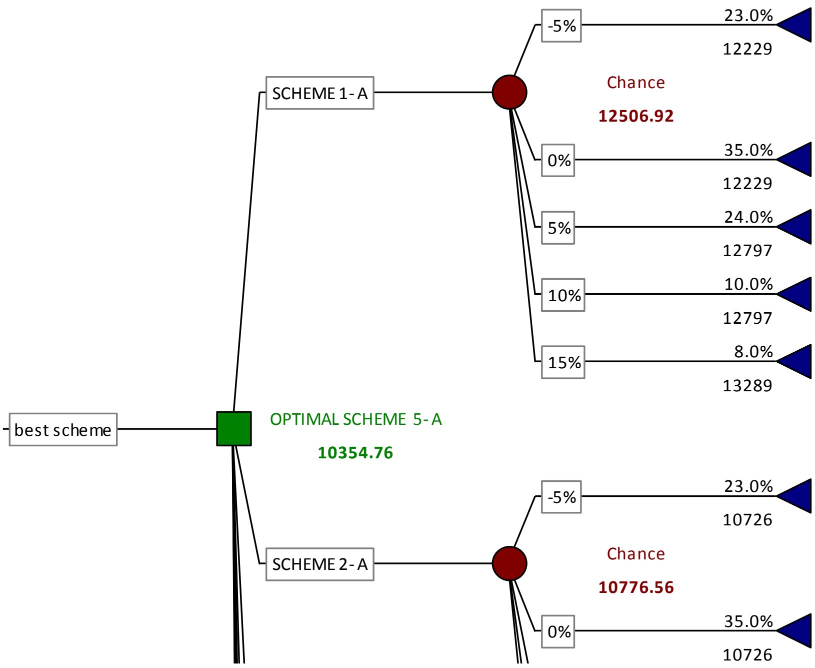

Fig. 2. **Decision tree for costs (example for strategy 1 – var. 1)**

The prioritization of criteria and variant schemes are made by using Super Decision software [10]. Table 6 shows the prioritization matrix and the weights for the criteria. It can be seen that the criterion average speed has the greatest weight. Second in weight is the criterion reliability of transport. The weights to transport satisfaction and availability of direct services have comparable values. The criteria average number of stops and transport capacity also has a similar meaning. The lowest weight has the criterion of average distance.

Table 6

AHP Prioritization matrix and weights of criteria

Prioritization matrix	K1	K2	K3	K4	K5	K6	K7	K8	weight
K1:Transport satisfaction	1	1	5	1	1	1	1	2	0.150
K2:Average number of train stops	1	1	2	1/2	1/2	1/2	1	2	0.104
K3:Average distance travelled	1/5	1/2	1	1/2	1/3	1/5	1/2	1/3	0.046
K4:Average speed	1	2	2	1	2	2	2	3	0.205
K5:Reliability	1	2	3	1/2	1	2	3	2	0.177
K6:Availability of service with direct transport	1	2	5	1/2	1/2	1	1	1	0.129
K7:Transport capacity	1	1	2	1/2	1/3	1	1	1/2	0.091
K8: Comfort	1/2	1/2	3	1/3	1/2	1	2	1	0.098

To prioritize the variant schemes by each of the criteria lingual concepts have been used. They are leveled from excellent, good, above average, average and below average by the level of influence of the strategic criteria. Table 7 presents the prioritization matrix and the importance of the lingual concepts. In Fig. 3 the scores of the variant schemes in Super Decision software are shown. The Super Decision software permits an analysis of inconsistency (Consistency Ratio CR) of the expert scores that allows measuring how consistent the judgments have been relative. In the research the value of CR is satisfied (is smaller 0.1).

Table 7

AHP Prioritization matrix for lingual concepts

Super decisions ratings	Excellent	Good	Above average	Average	Below average	Score
Excellent	1	2	3	4	5	0.42
Good	1/2	1	2	3	4	0.26
Above Average	1/3	1/2	1	2	3	0.16
Average	1/4	1/3	1/2	1	2	0.10
Below Average	1/5	1/4	1/3	1/2	1	0.06

The AHP method has been applied for each stochastic variation of passengers. The score obtained for each variant scheme by the AHP method has been applied to determine the best solution by using the Decision tree method.So, the benefits were obtained. Fig. 4 presents a segment of the decision tree for determination of the best variant scheme taking into account the benefits and the variation of passengers for strategy 1 (var. 1).

Super Decisions Ratings

	Priorities	Totals	K1 0.150546	K2 0.104338	K3 0.046200	K4 0.204556	K5 0.176506	K6 0.128966	K7 0.091264	K8 0.097622
SCHEME 1-B	0.129378	0.698115	EXCELLENT	GOOD	GOOD	GOOD	AVERAGE	EXCELLENT	GOOD	EXCELLENT
SCHEME 2-B	0.145407	0.784607	GOOD	EXCELLENT	GOOD	GOOD	GOOD	EXCELLENT	EXCELLENT	EXCELLENT
SCHEME 3-B	0.127154	0.686115	GOOD	ABOVE AVERAGE	GOOD	GOOD	GOOD	EXCELLENT	GOOD	EXCELLENT
SCHEME 4-B	0.119399	0.644267	EXCELLENT	ABOVE AVERAGE	GOOD	GOOD	AVERAGE	EXCELLENT	GOOD	GOOD
SCHEME 5-B	0.115076	0.620940	ABOVE AVERAGE	ABOVE AVERAGE	GOOD	GOOD	GOOD	EXCELLENT	GOOD	GOOD
SCHEME 6-B	0.121915	0.657843	GOOD	ABOVE AVERAGE	GOOD	GOOD	GOOD	EXCELLENT	GOOD	GOOD
SCHEME 7-B	0.081159	0.437928	EXCELLENT	AVERAGE	GOOD	ABOVE AVERAGE	AVERAGE	BELOW AVERAGE	GOOD	ABOVE AVERAGE
SCHEME 8-B	0.076836	0.414601	ABOVE AVERAGE	AVERAGE	GOOD	ABOVE AVERAGE	GOOD	BELOW AVERAGE	GOOD	ABOVE AVERAGE
SCHEME 9-B	0.083675	0.451503	GOOD	AVERAGE	GOOD	ABOVE AVERAGE	GOOD	BELOW AVERAGE	GOOD	ABOVE AVERAGE

Fig. 3. **Ratings and Priorities in Super – Decision Software (example for schemes “B”)**

The results of the cost/benefits analysis for the schemes “’A” and “B” are shown in Fig. 5 and Fig. 6. The scheme “A” presents the existing rolling stock in Bulgarian Railways. The scheme “B” presents a part of the rolling stock to be by electric multiple units, which are provided in the program for the development of Bulgarian railways.

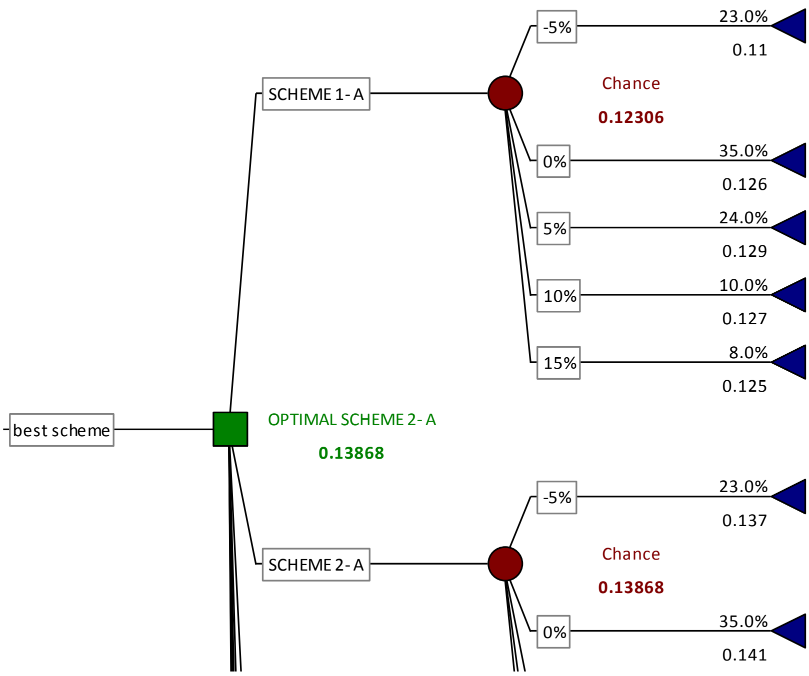

Fig. 4. **Decision tree for benefits (example for strategy 1 – var. 1)**

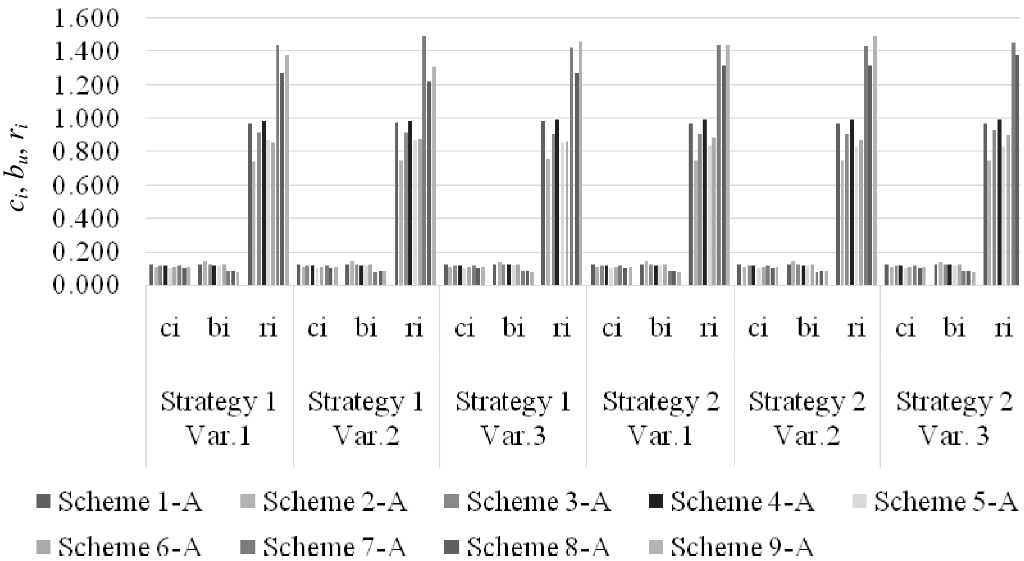

Fig. 5. **Normalized cost, AHP score, cost/benefit ratio for schemes "A"**

The results for both type schemes are analysed separately. The scheme with minimal operational costs for variants 1 and 3 is the scheme 5-A, and for variant 2 is the scheme 8-A for both strategies. For all variants and strategies the best according to the AHP method prioritization is the variant scheme 2-A. This scheme is also optimal by the Cost/Benefits method. The optimal solution is for permanent and for stochastic variation of passengers. The results for the schemes type "B" are similar. The transport service by the scheme 2-A (B) is by three categories of trains: fast trains, accelerate fast trains and direct fast trains.

The results show preserving the existing number of trains when the passenger flows do not change. In the study 1 pair DFT from Sofia to Plovdiv and 2 pairs DFT from Sofia to Burgas are offered. When BDZ purchase new electric multiple units for long distance, it would be appropriate the direct fast trains to be composed by this rolling stock. The proposed organization is characterized by an increased frequency of service, offering direct fast trains and rapid transportation. The offering of new category of trains will reduce the time travel and will improve the competitiveness with bus transport.The complex methodology for selecting the optimal scheme for organization of railway intercity passenger trains can be applied to determine the organization of other categories of passengers trains as suburban trains, as well as a complex organization of all categories of passenger trains on the railway line or railway network.

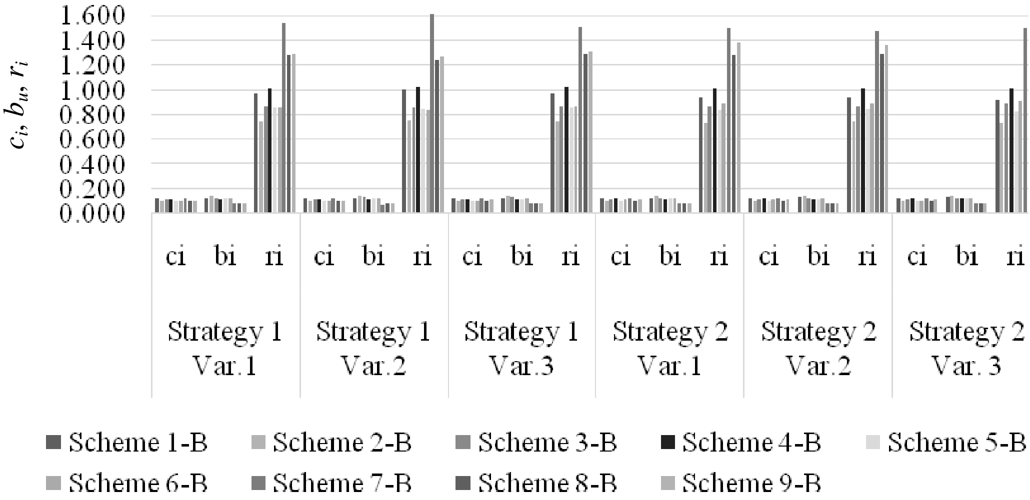

Fig. 6. **Normalized cost, AHP score, cost/benefit ratio for schemes "B"**

Conclusions

1. In this research an original complex methodology has been developed for selection of the optimal scheme of organization of intercity passenger transport taking into account the stochastic variation of passenger flows, which consists of the linear optimization model to minimize the direct operating cost, the method of analytic hierarchy process, the decision tree method and the method of cost/benefit analysis.
2. In the study quantitative and qualitative indicators to assess the variant schemes for railway transport have been proposed. The prioritization of the criteria by using the AHP method shows that the greatest weight have the criteria of average speed (0.205), reliability (0.177) and transport satisfaction (0.150). The AHP method is applied to determine the weights of the stochastic variation of passengers for three variants of infrastructure changes. The stochastic variation of passengers at the completion of the infrastructure changes for real strategy is 5 %, for optimistic strategy it is 15 %. When carried out the infrastructure works for both strategies the passengers decreased by 5 %.
3. By using the Decision tree method the costs and the benefits for variant schemes in the condition of the stochastic variation of passengers are determined. The method of cost/benefit for choosing the optimal scheme for transport has been applied.
4. In the research organization of transportation by a new category of long-distance passenger trains – direct fast trains is examined. The calculations using the given methodology prove the effectiveness of movement of three categories of intercity trains: direct, accelerate and fast trains.
5. The changes in the rail infrastructure and organization of transportation with a new type of rolling stock (electric multiple units) for certain categories of trains have been studied. The results are similar – the proposed scheme of organization is retained, but the number of trains is changed.

Acknowledgement

This research is conducted in relation to the execution of the contract No. 152ПД0040-04" Modeling and analysis of the routing fast and express trains on main railway lines". The research has been funded by the Technical University of Sofia, Bulgaria.

References

1. Xukuo G., Qiong W. Research on the mode of present transportation in China and the analysis of railway transportation. 6th International Conference on Information Management, Innovation Management and Industrial Engineering, 2013, pp. 414-416.

2. Maskeliunaite L., Sivilevicius H., Podvezko V. Research on the quality of passenger transportation by railway. Transport, vol.24, issue 2, 2009, pp. 100-112.
3. Wen H., Lin S. Performance Evaluation of Highway Passenger Transport Enterprises' Operation based on the Model of AHP-DEA. Industrial Engineering and Engineering Management, IEEE 18Th International Conference, Vol. 2, 2011, pp. 811-815.
4. Pogarcic I., Francic M., Davidovic V.Application of AHP method in traffic planning. ISEP 2008.
5. Junneng Y., Ganbin L. Application of AHP Model in Decision of Urban Mass Transit Network Scheme. Management and Service Science. MASS '09. International Conference, 2009, pp. 1-4.
6. Sivilevicius H., Maskeliunaite L. The criteria for identifying the quality of passengers' transportation by railway and their ranking using AHP method, Transport, vol.25, issue.4, 2010, pp. 368-381.
7. Saaty, T.L. Fundamentals of Decision Making and Priority Theory with the Analytic Hierarchy Process. 1-st edition. RWS Publications, 2000. 477 p.
8. McNamee P., Celona J. Decision Analysis for the Professional. USA: SmartOrg, 2008.p.357.
9. The Complete Risk and Decision Analysis Toolkit. [online][22.01.2016] Available at: http://www.palisade.com/decisiontools_suite/
10. Super Decisions: an Introduction. [online][22.01.2016] Available at: http://www.superdecisions.com/super-decisions-an-introduction/