Formulation of Train Delay Reduction Strategies with the Origin of Fleet in Tehran Subway system Railway Company Using AHP and SWOT Models

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***Abstract*—**One of the most basic advantages and frugalities resulting from the existence of subway system, is increase in the transportation speed, reduction of the dawdling of passengers and help in formation of social order by providing people with the possibility of exact planning; thus, having proper strategies for protection and improvement of this advantage in Railway Company is a priority.

The objective of this article is to investigate and identify delay factors with the origin of fleet and to determine weaknesses, strengths, opportunities and threats present in this area for formulation of proper strategies for reduction of delays. In this regard, after identifying the effective factors and determining the weaknesses, strengths, opportunities and threats present IFE and EFE matrixes were constituted and proper strategies based on SWOT matrix were determined.

According to the results of this article after an opinion poll from experts of operations and railroad transportation of the Railway Company, 11 factors were identified as strengths, 3 factors as weaknesses, 4 factors as opportunities and 4 factors as threats.

According to the results of AHP analysis regarding the delays in this company, the most important strength is training and proper training planning for training train drivers, the most important weakness is the antiquity of the fleets, the most important opportunity is the expertise of the repair and maintenance constructor and the most important threat is passenger's culture on using subway system. In order to select the best strategy the QSPM technique has been used. Based on this analysis, the highest priority strategy was obtained the identification of the trend of technology changes in building different trains in the world for optimal purchase.

***Keywords*—**Fleets, railroad transportation, strategy, train steering, delays.

I. Introduction

ACCORDING to the population increase in Tehran and due to traffic problems, air pollution, high depreciation of vehicles, fairly high cost of using them, waste of time using of subway system in Tehran is essential. One of the main advantages and frugalities of the existence of the subway system is providing more speed of transportation, reduction of wasting of passengers time and help for forming social order through the exact planning possibility for people, in the way that the average of subway system speed is 36 km/h while this speed for the bus and taxi is respectively 6 to 15 and 8 to 30 kilometers per hour.

At present, the fleets used in Tehran subway system are classified into many groups. The trains which entered for transporting in the beginning of operation are known as DC trains which work with an electricity of 750 volts. After a while, transferring of their technology to the country, manufacturing of spare parts and assembly of them are taken place in our country. Thus, the same generation of trains is divided into two sections of Chinese and Iranian DC trains. With the development of technology and possibility of making newer trains which are famous as AC trains, a newer generation of these trains entered the cycle of operation which with the passage of time also were added to the Tehran Subway system fleets in the generations of 100, 300 and 500 series in building which has been used with up-to-date technology.

The biggest advantage of the Subway system lies is possibility of providing the train schedule according to the passengers which can coordinate their other personal work in advance. Therefore, the train schedule in subway system is so important. On the other hand, the defection of equipments and fleets is inevitable and this problem created many problems for the subway system company and its passengers.

According to the reports about delays in Railway Company, the identified factors were divided in 11 sections which included the highest amount of delays. These factors include course line and structure, station structure, fleets, electricity, institutions, control and symptoms, communication, passenger and other human factors, unexpected cases, strategic, traffic management. According to the available statistics the highest reasons of delay have been defection fleets in 2012. It should be noted that the main delay factors with the origin of fleets also contain: traction, brake, the door wagon, compressed air system, computer equipments, wheel gearbox and equipment outage, which according to the statistics in line 2, which has the highest variety and oldest fleets, there is the highest delay and in line 4 which has the least variety and newest fleets is seen the least delay.

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Thus, the goal of this article is to investigate and identify the delay factors with the origin of fleets and to determine the weaknesses, strengths, opportunities and threats to determine suitable strategies for reduction of delays to create improvement. In this regard, after identifying the effective factors and determining the weaknesses, strengths, opportunities and threats, the IFE and EFE matrixes were constituted and the appropriate strategies were determined based on SWOT matrix. The QSPM matrix has been used for ranking the formulated strategies.

II. Research Method and Methodology

The main goal of doing this study is the formulation of proper strategies for the delay reduction of the movement of trains in the Railway Company. Thus, in terms Of objective this article is considered an applied research. Moreover, base on nature and method, this is a descriptive-survey study based on library study and also field methods such as questionnaire distribution.

The multi-factorial decision-making models and AHP model have been used to identify the relations and determine the weight of the present study factors. The SWOT technique and QSPM techniques to determine the strategy and ranking them have been used respectively. For analyzing the obtained data from statistical software of Excel and Super decision software have been used to solve the multi-factorial technique problems and the hierarchical analytic process.

The statistical population of this study is the experts of command center, operations and transportation of Railway Company which for identifying the effective delay factors and to provide the primary list, in the first phase during the interview with experts was designed 25 questionnaires.

In the second phase, for the multi-factorial decision-making topics has been used the snowball sampling. One of the common approaches in consecutive sampling is snowball sampling. This type of sampling is a non-probability method which has a random selection state as well. This method when is appropriate that members of a group or society could not be easily determined. In this method, the researcher first identifies persons and after receiving data from them asks them to introduce other person or persons (Babie, 2002). This method is also used to identify experts in especial field (Makni&MacCyb, 2008). In this study the hierarchical analytic process has been used for ranking main standards and selection of the optimal option. Sa'ati (2002) believes that 10 experts are adequate for studies based on paired comparison. As a result, 10 professional experts have been used as the sample in the study to weigh the standards. The executive research algorithm is presented in figure 1.

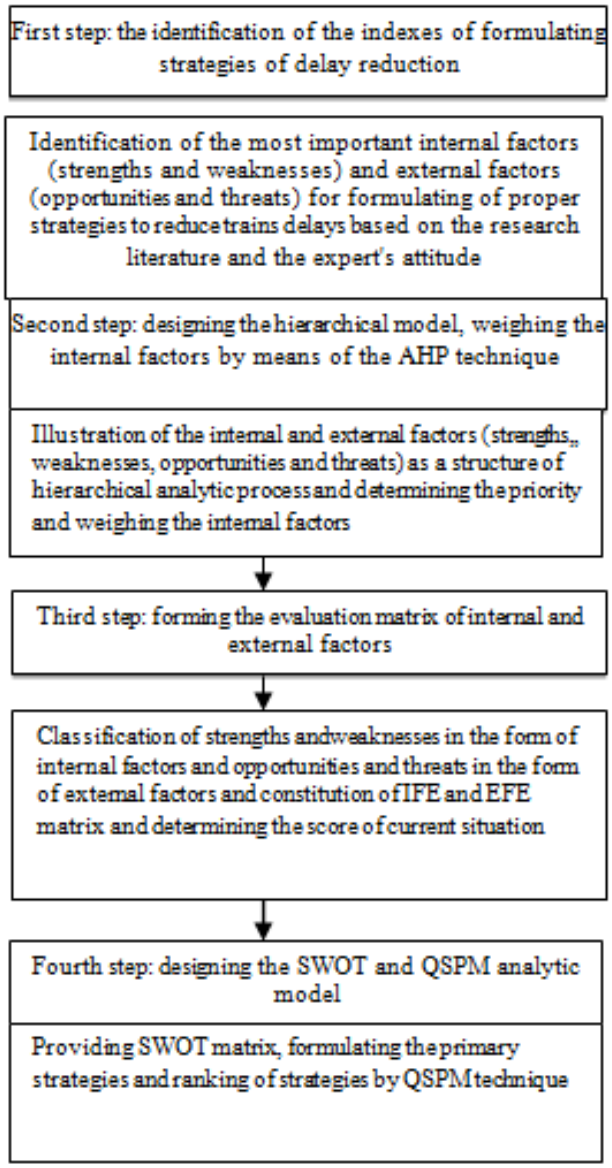

Fig. 1: the Research Executive Algorithm

To investigate the validity of the questionnaire has been used by Content validitymethod. In way that the questionnaire has been given to a number of experts and professionals in this field and they were asked for comments regarding the questions and evaluation of hypotheses and they all approved of the questionnaire.

In the questionnaire of the experts which is based on the paired comparison of all elements with one another, the possibility of not considering a variable is zero. Therefore, as all standards have been considered in this test and the designer is unable to adopt a certain orientation in designing the questions, then the questionnaires are valid based on the paired comparison by ownself (Qodsipour, 2004).

To investigate the reliability of the Likert spectrum questionnaire has been used the Cronbach's alpha coefficient. The obtained Cronbach's alpha of experts' questionnaire was calculated 0/82. As Cronbach's alpha coefficient was calculated more than 0/65, the reliability of the questionnaire was evaluated as optimal.

The reliability of the AHP experts' questionnaire was also compatible with the calculation of the index. On the one hand, as the questionnaire is based on the hierarchical analytic analysis and it's Saati's scale type. On the other hand, for investigating the questionnaire has been used an inconsistent index. These indexes state that if the degree of inconsistency of the paired comparisons exceeds 0/1, the comparisons should be re-considered. As in the questionnaire all the factors of the model have been considered and compared with one another, so all relevant probabilities will be eliminate by not considering a variable. On the other hand, as the questionnaire compares and evaluates all the factors in pairs, the most possible questions is asked with an optimal structure and all factors are considered in this test and the designer is unable to have a specific orientation in designing the questions, there will be no need to assess reliability (Mehrgan, 2004: 170).

III. Research Results

3.1 Identification of internal and external factors

To identify the internal and external factors, first with a review of the research literature in this study and interview with expert professionals in the area of the command center and operations, a primary list of effective factors in train delays was identified. The most important internal and external factors into two groups of strengths, weaknesses, opportunities and threats have been used the questionnaire with the Likert spectrum to classify. The questionnaires were completed during the interview by 25 experts of command center and railway transportation operations.

3.2 identification of the final list of weaknesses, strengths, opportunities and threats

The mean of the strengths, weaknesses and threats was obtained and each factor which has a mean upper than 3 in the list of internal factors was known as strength and each one which was lower than 3 was identified as weakness. In the list of external factors also each factor that had a mean above 3 in the list of external factors was identified as opportunity and each one that was lower than 3 was identified as threat. The summary of the results has been presented in table 1.

3-2- classification of internal and external factors and their illustration as the structure of the hierarchical analysis process (AHP)

After identifying internal and external effective factors in delays and classifying them based on the Likert spectrum into four groups of weaknesses, strengths, opportunities and threats was constituted the decision tree (hierarchical diagram) to determine the weight of factors and indexes. The hierarchical diagram is presented in the figure 2.

TABLE I
FINAL LIST OF INTERNAL AND EXTERNAL FACTORS

Environmental opportunities	**Expertise of repair and maintenance constructor**	**3.98**	O1
	The primary contracts of train purchase according to the line topology	**3.73**	O2
	The relationship of railway transportation industry with university	**3.92**	O3
	Technology transference in building external parts	**3.31**	O4
Environmental threats	**Coldness and warmth**	**2.56**	T1
	External sanctions	**2.67**	T2
	After sale services of imported components	**2.17**	T3
	Culture of passengers in using the subway system	**2.73**	T4

Internal and external factors	Sub-factors	mean	symbol
strengths	Training	4.21	S1
	Degree of accurate governance of trains	3.90	S2
	Optimal governance of trains	3.83	S3
	Fault diagnosis and troubleshooting time	4.10	S4
	Organizational structure	3.02	S5
	Studying the trend of delays in the past	3.08	S6
	Planning for provision of spare parts according to the life expectancy	3.56	S7
	The job satisfaction of the operating personnel	3.85	S8
	Participation of the repair and maintenance personnel	3.65	S9
	Evaluating the technical comments of experts and technicians of repair and governance	3.52	S10
	Ability for experience and governance skill	4.19	S11
weaknesses	The number of different models of fleets	2.90	W1
	Multiplicity of the governance type due to different models of fleets	2.98	W2
	Oldness of fleets	2.71	W3

The table and the eigenvector have also been illustrated as W1. To do hierarchical analysis first the internal and external factors are compared based on the goal in pairs. For this purpose the experts have been used in groups. It should be noted that as only one comparison has taken place, there is no need to calculate the rate of inconsistence and the conducted comparisons could be trusted. Then by means of the geometric mean technique (G) and the normalization of the

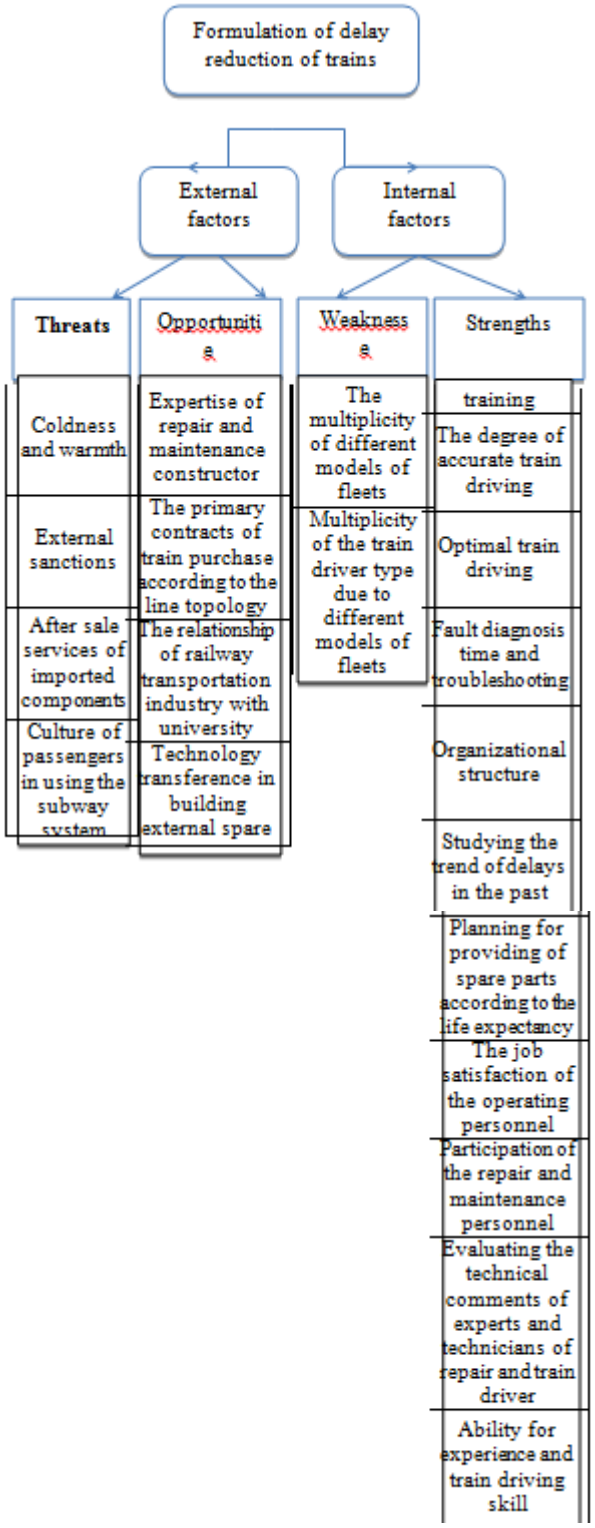

Fig. 2 The hierarchical diagram is presented

Measures obtained, the eigenvector has been calculated as W. To do the related calculations has been used super decision Software. The conducted calculations are presented in table 2. W numbers show the weight of main factors in relation to one another based on which internal factors have a higher importance compared with other factors.

3-4- comparing and determining the weight of sub-factors of internal and external factors

Among internal and external factors, factors have been selected as strengths, weaknesses, opportunities and threats. To compare the 22 factors the paired comparison is needed which has been undertaken from the perspective of 10 experts. The paired comparison matrix has been presented with the collection of the view of experts by the geometric mean method in the table. Also, the consistency rate of the done comparisons is smaller than 0/1 so conducted comparisons could be trusted.

3-5- the final weight of standards of internal and external factors by AHP technique

After calculating the weight of the elements of each cluster, the final priority of the indexes of the matrix of SWOT could be calculated. The weight of the comparison of the internal and external factors (W1) multiple the weight related to the elements relevant to them (W2), helped to obtain the final weight of opportunities, threats, strengths and weaknesses. The final weight of opportunities, threats, strengths and weaknesses are multiplied in the weight of related elements to each cluster and in the end the final priority of each index is calculated. The result of calculation was conducted and the related weights to the indexes of the matrix of questions are presented in table 2:

3-6- forming the evaluation matrix of internal and external factors.

To provide the evaluation matrix of internal factors (IFE) first the strengths and then the weaknesses are listed and each factor is allocated a weight coefficient between zero (insignificant) and one (highly significant). In this condition, the sum of the weight coefficients allocated must be equal to one. This weight will be calculated by means of AHP technique.

Each of these factors is given the grades 1 to 4 based on the present condition. Grade 1 expresses a basic weakness, grade 2 little weakness, and grade 3 expresses strength and 4 very high strength of the factor (Moharramnezhad, 2012).

-To determine the final grade of each factor, the coefficient of each factor is multiplied in its grade.

- We calculate the sum of the final grades of each factor so that the final grade of the subject under study is determined.

If their mean is lower than 2/5, that is to say the research subject is weak in terms of internal factors and if the mean grade is more than 2/5, the research subject has strength (Moharramnezhad, 2012).

To provide the matrix of the external factor evaluation, the same measures were taken

TABLE II
FINAL WEIGHT OF OPPORTUNITIES, THREATS, STRENGTHS AND WEAKNESSES

rank	final weight	primary weight	symbol	Sub-factors	Indicators in standard	Weight of Indicators	Indicators	Weight of main factors	main factors
7	0.1	0.1	S1	Training	0.35	0.6	strengths	0.58	internal
12	0	0.1	S2	The degree of accurate train driving					
9	0	0.1	S3	Optimal train driving					
10	0	0.1	S4	Fault diagnosis time and troubleshooting					
13	0	0.1	S5	Organizational structure					
16	0	0.1	S6	Studying the trend of delays in the past					
17	0	0.1	S7	Planning for provision of parts according to the life expectancy					
19	0	0.1	S8	The job satisfaction of the operating personnel					
18	0	0.1	S9	Participation of the repair and maintenance personnel					
20	0	0.1	S10	Evaluating the technical comments of experts and technicians of repair and train driver					
21	0	0.1	S11	Ability for experience and train driving skill					
14	0	0.2	W1	The number of different models	0.23	0.4	weaknesses		
				of fleets					
15	0	0.1	W2	Multiplicity of the drivers type					
				due to different models					
				of fleets					
1	0.2	0.7	W3	Oldness of fleets					
2	0.1	0.4	O1	Expertise of repair and maintenance	0.23	0.5	opportunities	0.42	external
				Constructor					
4	0.1	0.2	O2	The primary contracts					
				of train purchase					
				according to the					
				line topology					
11	0	0.2	O3	The relationship of railway					
				transportation industry					
				with university					
8	0	0.2	O4	Technology					
				transference in building					
				external parts					
22	0	0.1	T1	Coldness and warmth	0.19	0.5	threats		
3	0.1	0.3	T2	External sanctions					
5	0.1	0.3	T3	After sale services of					
				imported components					
6	0.1	0.3	T4	Culture of passengers in using					
				the subway system					

TABLE III
IFE MATRIX

Weighted score	Advantage of the present state	weight	Sub-factors	internal factors
0.341	4	0.0852	training	strengths
0.260	4	0.0651	The degree of accurate train driving	
0.216	3	0.0719	Optimal train driving	
0.204	3	0.0680	Fault diagnosis time and troubleshooting	
0.255	4	0.0637	Organizational structure	
0.169	3	0.0564	Studying the trend of delays in the past	
0.134	3	0.0445	Planning for provision of parts according to the life expectancy	
0.124	3	0.0412	The job satisfaction of the operating personnel	
0.133	3	0.0444	Participation of the repair and maintenance personnel	
0.150	4	0.0376	Evaluating the technical comments of experts and technicians of repair and train driver	
0.121	4	0.0304	Ability for experience and train driver skill	
0.060	1	0.0596	The multiplicity of different models of fleets	weaknesses
0.115	2	0.0574	Multiplicity of the train driver type due to different models of fleets	
0.275	1	0.2746	Oldness of fleets	
	2.55	1.0000		

TABLE IV
EFE MATRIX

Weighted advantage	Advantage of the present state	Weight	Sub-factors	External factors
0.588	3	0.1960	Expertise of repair and maintenance constructor	opportunities
0.401	3	0.1336	The primary contracts of train purchase according to the line topology	
0.280	3	0.0932	The relationship of railway transportation industry with university	
0.352	3	0.1174	Technology transference in building external parts	
0.087	2	0.0436	Coldness and warmth	threats
0.157	1	0.1567	External sanctions	
0.130	1	0.1297	After sale services of imported components	
0.260	2	0.1298	Culture of passengers in using the subway system	
2.254		1.0000		

3-7- designing the SWOT analytic model

For the simultaneous analysis of internal and external factors matrix is used the internal and external. This matrix is deployed for determining the situation of industry or organization or a subject and for its constitution grades of internal factor evaluation matrix and external factor evaluation matrix must be placed in its vertical and horizontal dimensions so that the position of industry or organization in market is

determined and proper strategies could be determined for that. This matrix is compatible with SWOT matrix and can determine proper strategies for the organization.

The SWOT analysis method analyzes each of the factors of strengths, weaknesses, opportunities and threats which have been identified in the previous stage in a systematic way and reflects the strategies proportionate to the situation. In SWOT model after listing each of the factors of strengths, weaknesses, opportunities and threats which have been identified in the previous stage and writing them in their related cells based on the order of weighted advantage, the considered strategies are obtained of the intersection of each of them. Thus, this matrix always leads to the four group of strategies of ST, WT, WO, and SO. The results of the conducted analysis and the obtained strategies are shown in table 5.

3-8- Evaluation and Ranking of Strategies by means of QSPM

One of the methods and techniques of evaluation is the monitoring and supervision to study the strategy of using quantitative strategic planning matrix or QSPM. In this method it is determined which selected strategic options are possible and in fact ranks these strategies. The ranking of the strategies is depicted in table 5:

TABLE V

LIST OF THE FINAL STRATEGIES ALONG WITH RANKING

rank	Total advantage in QSPM	Strategy	Symbol of strategy
15	2.004	development of training programs in integration between operating personnel and constructor	SO1
14	2.149	increase of using the comments of the constructor for improvement of the trend of diagnosis time of fault and troubleshooting	SO2
6	2.687	outsourcing of some activities to specialized constructors	SO3
7	2.611	development of relationship between university area and operations and railway; repair and maintenance	SO4

IV. DISCUSSION AND CONCLUSION

Based on the results of this article after an opinion poll from experts in the field of operations and Railway Company, 11 factors were identified as strengths, 3 factors as weaknesses, 4 factors as opportunities and 4 factors as threats.

According to the results obtained from AHP analysis in this company concerning the delays, the most important strength is training and planning for suitable training to train the leaders, the most important weakness is the oldness of fleets and the most important opportunity the expertise of the repair and maintenance constructor and the most important threat the culture of passengers in using the subway system.

To select the best strategy was used the QSPM technique. Based on this analysis, the highest priority strategy was resulted to be identifying the trend of technology changes in building different trains in the world for the optimal purchase. By investigating the current state of this strategy in the company it was determined that at present limited number of companies are operating in the country in the area of building, transference of technology and assembly of rail equipments. According to the results of this study the necessary efforts and plans must be conducted in such a way that the localization of this science is made possible in the country; thus, the following suggestions in this area could be offered:

- Dispatch of professors, university students and technical experts for training and transmission of science into the country
- Help to universities for attraction and localization
- Definition of university projects in identifying and resolving the present problems
- Financial support in implementing scientific projects proportionate with the country's prospect
- Purchase of trains with up-to-date technology from industrial countries when the transmission of science is also possible
- Purchase of required trains according to the defined perspective of the lines and of one technology model
- Planning and Knowledge in identifying the faults and problems of purchased trains in the guarantee period for provision of high consumption consumable parts
- Purchase management, demand, warehouse based on the net comprehensive systems
- Considering facilities for the internal constructor to encourage their entry into this area of science and technology

Regarding what was said it could be concluded that the most significant factor in reduction of delays with the origin of fleets is the health of fleets; therefore, all operating and repair and maintenance of fleets' units must do their best to conduct maintenance operations exactly, accurately and on time so that the least failure takes place in the path for trains.

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