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Comparison of the economic profitability of a conventional freight-dedicated railway corridor and a heavy load freight corridor

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A B S T R A C T

By using mathematical models, this paper will compare the economic profitability of a heavy load freight corridor (30 t per axle) with a conventional freight-dedicated railway corridor 22.5 t per axle). This comparison concerns the construction and operation of a new, single-track of normal gauge, exclusively for freight traffic, and takes into account various demand values of freight volume (10,000-130,000 t daily per direction) and connection length (500km and 1,000 km). Within the framework of this research, the rail infrastructure manager is also the owner of the rolling stock and the operating company. The mathematical model simulates the algorithm "revenues minus expenses" for each of the above railway systems and permits among other things the calculation of the Net Present Value (NPV) of the investment. The results showed that: a) the conventional load corridor can cater for up to approximately 40,000t per day per direction while the heavy freight corridor can carry around three times that volume, b) for daily freight volumes of up to 40,000t, the conventional freight corridor is more profitable c) for loads greater than approximately 25,000t-30,000t, the increase in the connection length results in a marked increase in the economic profitability of both systems since it leads to roughly the doubling of the NPV.

1. Introduction

By using mathematical models, this paper will compare the economic profitability of a heavy load freight corridor with a conventional freight-dedicated railway corridor. This comparison concerns the construction and operation of a new, single-track of normal gauge, exclusively for freight traffic, taking into account various demand values of freight volume and connection length.

The term „heavy load freight corridor" denotes every freight-dedicated railway corridor with an axle load equal to or greater than 25t (25-40t).

The term „conventional freight - dedicated corridor" denotes every freight-dedicated corridor with an axle load of less than 25t (25-20t).

The term „railway corridor" denotes the track that connects two terminal stations and mark the origin and destination of a route.

Two discrete exploitation cases are being considered:

- Hauled electric freight trains of 22.5 t per axle, running at a maximum speed of 100 km/h ,on a new single track of normal gauge and bi-directional traffic operation, dedicated for freight services
- Hauled electric freight trains of 30 t per axle, running at a maximum speed of 80 km/h, on a new single track of normal gauge and bi-directional traffic operation, dedicated for freight services

Within the framework of this research, the rail infrastructure manager is also the owner of the rolling stock and the operating company. Given these facts, the

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term „economic profitability of a new railway corridor" denotes the ability of a single undertaking managing the corridor to generate profit. The financial indicator that has been considered to express the economic profitability of the new railway corridor is the Net Present Value (NPV) of the investment.

In this context, this work:

- records the features of the heavy load freight wagons/trains that differ substantially from those of the conventional load freight wagons/trains and identifies among them the ones that affect directly or indirectly the construction, operation and maintenance of the railway system
- creates a mathematical model that simulates the algorithm "revenues minus expenses" for each of the above railway systems and permit among other things :

✓ the calculation of the cost of the investment necessary for the implementation of the new railway connection, as well as maintenance and operation expenses

✓ the calculation of the revenue generated for the undertaking from the transport of freight

✓ the calculation of the economic profitability of each exploitation scenario

✓ the study of the influence of various design, construction, operational and financial parameters of the railway system on the system's economic profitability

✓ the selection, on the basis of demand for freight volume to be transported via rail on a connection and of connection length, the exploitation scenario that presents the highest economic profitability

2. Description of the problem

The routing of heavy axle - load freight trains on the one hand seems to achieve scale economies as these trains have much higher transport capacity than the conventional axle - load freight trains, while, on the other hand, such an activity increases the construction and maintenance costs of the railway track [1].

The reason for this is that many features of the heavy load freight wagons/trains differ substantially from those of the conventional load freight wagons/trains.

Table 1 presents both the different features of the two railway systems as well as the effects (both positive and negative) that these differences have on the two systems. Furthermore, the design, construction and operation requirements imposed by this are also presented [2].

Table 1: Features of the heavy axle-load freight wagons/trains that differ significantly from those of the conventional axle-load freight trains – Effects and requirements on/for the design, construction, operation and maintenance of the railway system

Wagon/train characteristics that are different in the two railway systems	Conventional axle-load freight trains (Values)	Heavy axle-load freight trains (Values)	Effects/Requirements on/for the railway corridors of heavy axle - load
Running speed	60 km/h - 120 km/h	50 km/h – 100 km/h	Effects : Smaller track capacity, longer travel time Requirements : Smaller curvature radius in the longitudinal and vertical alignment
Axle-load	16 t - 25 t	25 t – 40 t	Effects : Higher track geometry defects deterioration rate, longer train braking distance, higher transported volume of goods Requirements : Steeper gradients in vertical alignment, heavier rails, sleepers of higher mechanical resistance, thicker ballast layer, longer signal spacing, greater traction power requirements, higher maintenance needs, wagons of higher transport capacity
Train weight	1,500 t – 3,000 t	5,000 t – 35,000 t	Effects : Greater braking weight, higher transported volume of goods Requirements : Steeper gradients in vertical alignment, longer signal spacing, greater traction power requirements
Train length	400 m – 800 m	1,000 m – 4,000 m	Effects : Smaller track capacity, higher transported volume of goods Requirements : Longer tracks and platforms in stations
Daily traffic load	10,000 t – 100,000 t	100,000 t – 300,000 t	Effects : Higher track geometry defects deterioration rate, higher transported volume of goods Requirements : Heavier rails, sleepers of higher mechanical resistance, thicker ballast layer, higher maintenance needs
Vehicle clearance gauge	Standard	Widened	Effects : Greater gauge of the rolling stock Requirements : Differentiates depot and station dimensioning, axial distance between tracks, height clearance under structures

Thus, by recognizing the specific problem, this paper will attempt to provide an answer to the following question which is a matter which today concerns many railway companies: "Which is more economically efficient for a railway company? Routing conventional, or heavy axle – load freight trains along a new railway freight corridor?"

The answers, given at times by various researchers, have not been documented in a general, emphatic way, as it is not clarified under which conditions the one exploitation scenario is more economically profitable than the other (e.g. from what demand and onwards, for what length of connection, etc.).

3. Mathematical model, algorithm and basic assumptions

The general architecture of the model is presented in Figure 1. Briefly, the mathematic simulation includes the following steps [3]:

- Calculation of the number and the composition of trains required to satisfy the freight demand
- Calculation of track capacity and track capacity saturation ratio
- Intermediate calculations of different parameters that intervened in the model algorithm like daily traffic load, rolling stock fleet, minimum radius in horizontal alignment, number of required personnel, life cycle of superstructure, number of replacements of the components of the railway system in the duration of its life, goods transported per year (tkm and t) etc.
- Calculation of expenses constituents like cost of feasibility and final studies, cost of required expropriations, construction cost of superstructure, substructure and civil engineering structures, construction cost of railway stations, construction costs of signaling, electrification and telecommunication systems, cost of level crossings, purchase cost for vehicles (wagons, locomotives, etc.), maintenance costs of infrastructure, track installations and rolling stock, replacement costs of the components of the railway system in the duration of its life, cost of energy consumption, cost of personnel salaries, financing cost etc.
- Calculation of revenues constituents like income from freight transportation, residual value of the railway system in the end of its economic life, revenues from lending etc.
- Allocation of each expense and revenue constituent in each year of the economic life of the railway system and calculation of the NPV of the total investment

Presented below are the basic assumptions made for the mathematical simulation and the creation of the model, while Table 2 presents some of the parameters of the model and their reference values.

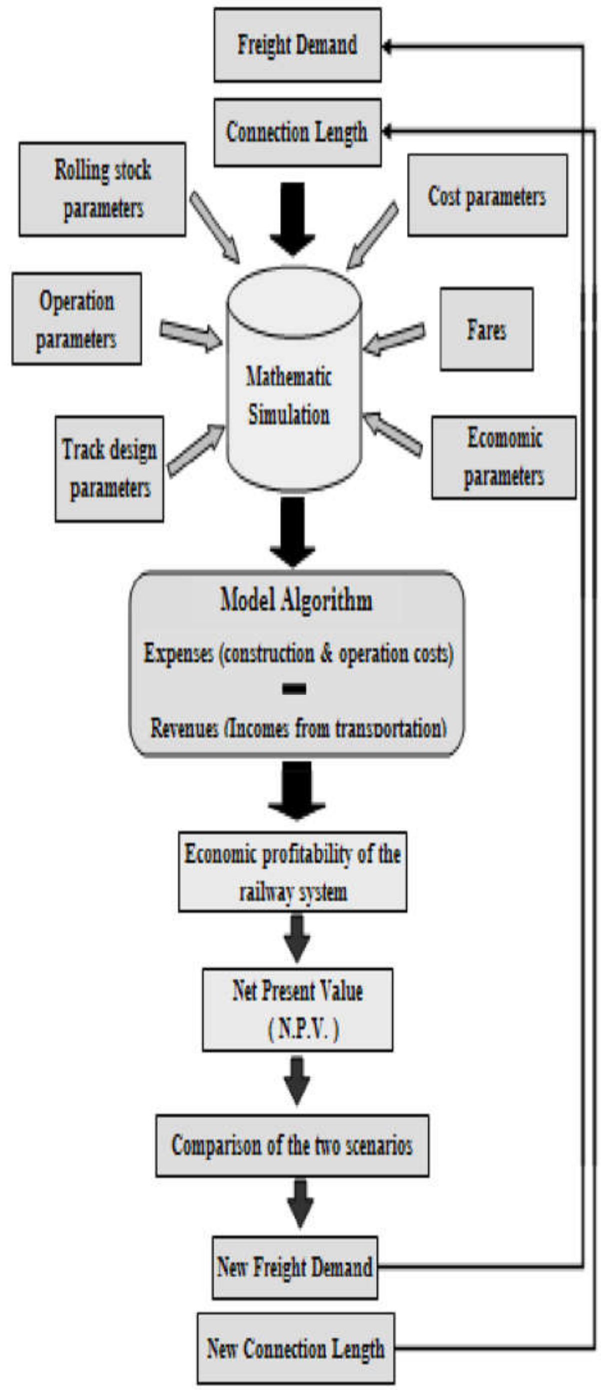

Figure 1: General architecture of the model

Table 2: Basic model input parameters-Reference values

Parameter	Reference values	
	Conventional axle-load trains	Heavy axle-load trains
Length of railway corridor	500 km	500 km
Topography	average difficulty	average difficulty
Track design speed	120 km/h	100 km/h
Maximum running speed	100 km/h	80 km/h
Track design axle - load	22.5 t	30 t
Maximum longitudinal gradient	15‰	10‰
Maximum track cant	150mm	150mm
Minimum curve radii in alignment	600 m	400 m
Maximum permitted residual centrifugal acceleration	1.0 m/s^2	1.0 m/s^2
Type of rails [7]	UIC 60 kg/m, 350 LHT	AREA 136REIH 67.56kg/m, 400UHC
Type of sleepers [8]	B70, 280 kg	HHS32.5, 333 kg
Ballast width	250 mm	300 mm
Distance between sleepers	60 cm	55 cm
Length of railway stations layout	0.750 km	1.200 km
Distances between small railway stations	10 km	10 km
Distances between intermediate freight stations	100 km	100 km
Payload of freight wagons [9]	70 t	95 t
Tare weight of freight wagons [9]	20 t	25t
Power of Traction Unit [10]	6,400 KW	9,600KW
Loading/unloading time per wagon [11,12]	2.5/2.5 min	2.5/2.5 min
Train coupling/de-coupling time per wagon [11]	2.0/2.0 min	2.0/2.0 min
Technical control time per wagon [13]	1.0 min	1.0 min
Maximum length of trains	600 m	1,780m
Construction cost of superstructure	0.425 meuros/km	0.500 meuros/km
Freight fare	0.040 €/tkm	0.040 €/tkm
Percentage of investment funds from loans	50%	50%
Economic life of the railway system	50 years	50 years
Economic life of the infrastructure of track, railway stations, etc	100 years	100 years
Economic life of traction substations	50 years	50 years
Economic life of the catenary, signaling equipment, vehicles etc	25 years	25 years

• The calculation of the track capacity took place using the UIC 405-1R method with the following hypotheses [4,5]:

- ✓ The length of the block section is considered to be 10 km (distance between two successive small stations).
- ✓ The number of routed trains per day cannot exceed the 70% of the track practical capacity. (Maximum track capacity saturation ratio = 70%)

• The minimum regularity of routed trains for both scenarios is 10 trains per direction per day

• Conventional freight trains consist of one or more electric traction units and a maximum of 28 wagons, while freight trains of heavy loads are considered to consist of one or more electric traction units and a maximum of 85 wagons. The length of all vehicles, both power and trailer is 20m.

• The availability percentages of the traction units and wagons are considered to be 90% and 80%, respectively [6].

• Both exploitation scenarios provide a marshalling yard at each end of the connection.

• Maximum occupancy ratio of all wagons is 80%.

4. Comparison of the two exploitation scenarios

In order to answer the question: "Which is more economically efficient for a railway company? Routing conventional, or heavy axle – load freight trains, along a new railway freight corridor?" this paragraph makes a first attempt at determining the limits of demand of freight transportation volume that render, for two lengths of connection (500 km and 1000 km), the one exploitation scenario more economically profitable than the other.

The following steps were methodologically followed:

•Initially, a minimum daily freight load value was taken to be equal to 10,000t per direction for both corridors. It was considered that this demand:

✓ as concerns the conventional network, is served by 10 trains per direction which are composed of a number of power vehicles and a number of wagons (up to 28) which can meet the above requirement. All wagons have a occupancy ratio of 80%.

✓ as concerns the heavy load corridor, is also served by 10 trains per direction which are composed of a number of power vehicles and a number of wagons (up to 85) and can meet the above demands given the same occupancy ratio (80%).

In both exploitation scenarios, a necessary prerequisite is that, in accordance with the UIC method, track capacity saturation ratio should not exceed 70%. Assuming a connection length equal to 500km, the NPV is thus estimated for both systems.

•The value of the daily freight load increased by 100% (20,000t) for both corridors. Thus to meet this demand was taken that:

✓ as concerns the conventional corridor, the number of wagons is initially increased (maximum value of 28 wagons) and thereafter, if demand cannot thus be met, the number of routed trains is increased. The occupancy ratio of the wagons remains stable and the track capacity saturation ratio does not exceed 70% of the practical capacity of the line, in accordance with the UIC method. In each case, the number of traction units required is calculated.

✓ as concerns the heavy load corridor, the number of wagons is initially increased (maximum value of 85 wagons) and thereafter, if demand cannot thus be met, the number of routed trains is increased. The occupancy ratio of the wagons remains stable and the track capacity saturation ratio does not exceed 70% of the practical capacity of the line. In each case, the number of traction units required is calculated.

•assuming the connection length to be equal to 500km, the NPV is thus calculated for both corridors.

•the value of the daily freight load is gradually increased by steps of 10,000t, and the same procedure is repeated.

•After being suitably recorded, the results were compared and evaluated.

Table 3 indicatively presents, for both exploitation scenarios, for a connection length of 1,000km and for the different freight volume values under examination:

✓ the composition of the train (power and trailer vehicles) [14]

✓ the number of daily routes per direction

✓ the saturation ratio of track capacity

✓ the Net Present Value for each of the two scenarios being compared

It is noted that the initials EC (Exceeded Capacity) indicate that the 70% of the practical capacity of the track is exceeded and, for this reason, the financial indicator does not appear. The diagram in Figure 2 shows the change in Net Present Value in relation to freight volume demand for both exploitation scenarios examined for both connection lengths taken. By examining all the combinations of demand and connection length, the following conclusions are reached:

•the conventional freight-dedicated corridor can serve up to around 40,000t daily for each direction, while the heavy freight corridor can cater for roughly three times that volume.

Table3: Application of the model -Results - L= 1,000km

Demand [t/day/direction]	Conventional haul line				Heavy haul line			
	Trains routed /day/ direction	Train composition (power+ trailer vehicles)	Track capacity saturation ratio (Max permitted= 70%)	NPV [meuros]	trains routed /day/ direction	Train composition (power+ trailer vehicles)	Track capacity saturation ratio (Max permitted= 70%)	NPV [meuros]
10,000	10	1+18	29%	-7,205	10	1+ 13	34%	-8,986
20,000	13	2+28	37%	-2,374	10	1+26	34%	-4,398
30,000	19	2+28	54%	1,976	10	1+38	34%	-58
40,000	25	2+28	70%	6,311	10	1+51	34%	4,534
50,000	-	-	EC	-	10	1+63	34%	8,785
60,000	-	-	EC	-	10	2+76	34%	13,233
70,000	-	-	EC	-	11	2+85	38%	19,412
80,000	-	-	EC	-	12	2+85	41%	22,461
90,000	-	-	EC	-	14	2+85	48%	28,433
100,000	-	-	EC	-	15	2+85	52%	31,462
110,000	-	-	EC	-	17	2+85	59%	37,447
120,000	-	-	EC	-	19	2+85	66%	43,525
130,000	-	-	EC	-	20	2+85	69%	46,461

•both systems have a negative Net Present Value for a daily freight for each direction up to approximately 20,000t.

•for daily freights per direction of up to 40,000t which can be served by both systems, conventional load corridors are economically more profitable.

•For heavy load corridors with a daily freight greater than around 30,000t the increase in the connection length results in the significant

•increase in profitability as it means an approximate doubling of the NPV. Similar conclusions also apply for the conventional freights; however, the point where it becomes profitable is at around 25,000t.

The histogram in figure 3 presents, for the two exploitation scenarios examined, for daily freight volumes per direction equal to 30,000t and for connection length L=1,000km, the different costs incurred. The intermediate calculations showed that in the case of the heavy load freight corridor compared with the conventional freight corridor:

- The total construction cost of infrastructure (studies, expropriations, civil engineering works, superstructure substructure, track installations and facilities), is approximately 18.5% greater.
- The superstructure construction cost is 15% greater. (see Table 2)
- The maintenance cost of superstructure is about 52% greater
- The costs are, in contrast, less for maintenance of the rolling stock, energy consumption and personnel.

4. Conclusions

This work identifies the features of the heavy load freight wagons/trains that differ significantly from those of the conventional load freight wagons/trains and compares with the help of mathematical models the economic profitability of the heavy load freight railway corridors with the conventional freight load railway corridors.

The conventional freight load corridor can serve up to 40,000t daily per direction while the heavy load corridor can cater for roughly three-times that freight volume. For daily loads per direction up to 40,000t the conventional freight load corridor is more profitable, while, finally, for loads greater than around 25,000t-30,000t the increase in the connection length results in the significant increase in profitability of both systems as they lead to an approximate doubling in the value of the NPV.

The findings of this paper and particularly the mathematical model created can prove useful to:

- managers of railway infrastructure
- railway operators
- strategic investors (states, investment banks, etc.)
- transportation engineers-researchers and particularly those conducting feasibility studies

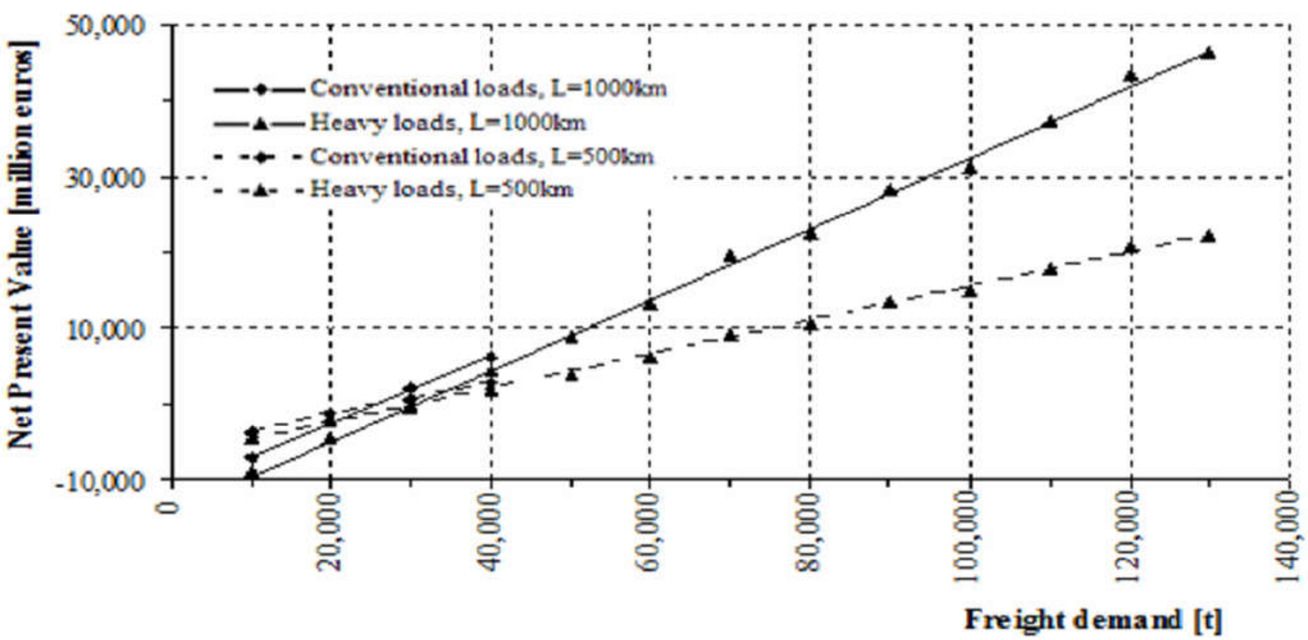

Figure 2: Variation of NPV in relation to the freight demand for a conventional axle-load line and for a line for heavy axle -loads – Length of connection L= 500 km and 1,000km

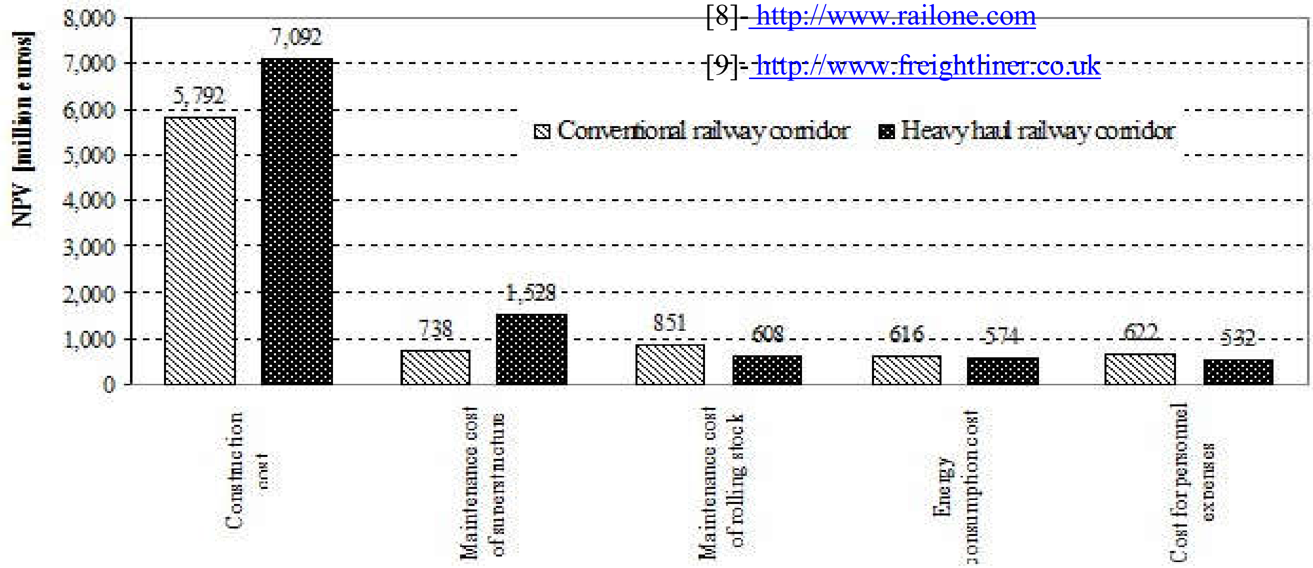

Figure 3: Construction, maintenance and operational costs for conventional and heavy axle-load line – Length of connection L= 1,000 km, Demand for freight = 30,000 t per day per direction

References

[1]- Pyrgidis, C., Christogiannis, E., "The problems **of the presence of passenger and freight trains in the** same track and their impact on the profitability of the railways companies", 9th World Congress on Railway Research, May 22-26, 2011,

Lille, France, Congress proceedings, CD

[2]- Pyrgidis, C., Christogiannis, E., "The problem of the presence of passenger and freight trains on the same track", 4th International Conference TRA (Transport Research Arena) 2012 "Sustainable mobility through innovation", 23-26 April 2012, Athens , Congress proceedings, CD

[3]- Christogiannis, E., „Investigation of the impact of traffic composition on economic profitability of a railway corridor – Fundamental principles and mathematical simulation for the selection of operational scenario of a railway corridor", PhD Thesis (in Greek), Aristotle University of Thessaloniki, Thessaloniki, Greece, 2012

[4]- UIC CODE 405, 1st edition, "Links between railway infrastructure capacity and the quality of operations", Jan 1996

[5]- UIC CODE 405-1R, 1ére édition, " Méthode destinée a déterminer la capacité de lignes", Jan 1979

[6]- Baumgartner, J.P., „Prices and costs in the railway sector", École Polytechnique Fédérale de Lausanne, January 2001

[7]- http://www.voestalpine.com

[8]- http://www.railone.com

[9]- http://www.freightliner.co.uk

[10]- http://www.siemens.com, Siemens Reference List

[11]- Ioannou, P.A., Kosmatopoulos, E.B., Jula, H., Collinge, A., Liu, C.-I., Asef-Vaziri, A., Cargo Handling Technologies Final Report Prepared for Task 1.2.3.2 for the Center for Commercial Deployment of Transportation Technologies, February, 2000.

[12]- http://www.techniplan.net.au

[13]- http://www.averyweigh-tronix.com

[14]- Filipovic Zarko, Elektrische Bahnen, Springer Verlag, 2004