OPEN ACCESS

International
Journal
Of Modern Engineering Research (IJMER)

Estimate Capital and Operating Costs for Railway Transportation in the Arab Republic of Egypt

H. S. Riad[1], H. N. Zohny[2], W. M. Ibrahim[2], M. N. E. M. Younes[3]

[1]*Associate professor of railway engineering, Public Works Department, Faculty of Engineering, Ain Shams University, Cairo, Egypt*

[2]*Assistant professor of railway engineering, Public Works Department, Faculty of Engineering, Ain Shams University, Cairo, Egypt*

[3]*Demonstrator of railway engineering, Public Works Department, Faculty of Engineering, Ain Shams University, Cairo, Egypt*

ABSTRACT*: It is necessary to estimate accurately transportation costs (capital and operational) for Egyptian National Railway (ENR) when developing transport tariffs in order to calculate the necessary subsidy to decrease the gap between revenues and actual expenses. To realize this goal, three models proposed to estimate the operating costs for ENR for long distances passenger, short distances passenger and freight transport services, taken into consideration the inflation rate in prices. These models must be compatible with the actual operating which reflects the average rates for both performance and consumption and they are also simple and easy to be applied based on financial and economical concepts. They are represented in operating units (passenger. kilometers) for passenger trains or (ton. kilometers) for freight ones.*

Keywords*: Operating costs, Egyptian National Railway, Operating units, Freight transport, Capital cost.*

I. INTRODUCTION

Besides its technical and infrastructural features, performance and environmental impact, the convenience of a given transportation technology must not leave out the correct assessment of its costs. The present paper applies on Egyptian National Railway (ENR) which is a public sector company owned by the Egyptian government and is considered as the second railway network in the world.ENR is the largest economic institutions in the field of transportation services in Egypt as it has a total network of 4900 km (single and double tracks) where the signal system is either electrical (15%) or mechanical (85%), and consists of more than 705 stations , 885 bridges and tunnels and more than 3500 passenger cars **[1]**.

Average annual Passenger volume was about 155 million passengers (about 0.43 million passengers / day) while freight volume was about 4 million tons during a period from 2008/2009 to 2013/2014. **[1]**

Due to this importance, it is necessary to estimate the operating costs of this important service to arrive at some pricing policies can reduce the required subsidy. The present paper proposes three models to estimate the operating costs for long distances passenger, short distances passenger and freight transport. So it is important to analysis the types of transportation in railway to study the different costs.

II. TRANSPORTATION TYPES IN RAILWAY

Transportation types in railway divided into passenger and freight transport

2.1 Passenger Transport

ENR classified the passenger transport as shown in table (1) according to trip distance as follows:

- Short distances passenger (Trip distance < 100 km.hr)
- Long distances passenger (Trip distance > 100 km.hr)

Table 1: Passenger traffic fluctuation from 2008/09 to 2013/14

	Long distances passenger		Short distances passenger	
Fiscal year \ Item	Passenger.km (millions)	Average trip distance (km)	Passenger.km (millions)	Average trip distance (km)
2008/2009	12125	277	13648	55
2009/10	14251	341	13846	67
2010/11	14706	349	12660	69

2011/12	16165	340	12643	70
2012/13	16158	343	12704	96
2013/14	7996	325	8220	63

2.2 Freight Transport

Transportation for freight is carried out by two methods:

a. Unit trains they carry just one product from the origin to the destination and represent about 85% of the total freight trains number.

The following types of product that used this type of train:

-Petroleum - Cooke coal.

- Iron Ore - Wheat.

b. Mixed trains they carry different types of products in one trip and represent about 15% of the total freight trains number.

Table (2) gives the annual tons and ton.km for freight service

Table (2): Freight traffic fluctuation from 2008/09 to 2013/14

Item / Fiscal year	Ton (millions)	Ton.km (millions)	Average transport distance (km)
2008/2009	5	1592.1	318.42
2009/10	5.8	1889.3	325.74
2010/11	6.2	1965.4	317
2011/12	4.1	1431.9	349.24
2012/13	3.3	1163.1	352.45
2013/14	3.9	1341.6	344

III. COSTS DEFINITIONS

Costs can be divided into different divisions:

- Variable and fixed costs.
- Direct and indirect costs.
- Specific and common costs

Variable and Fixed Costs:

Variable costs are those where the cost of the function is dependent on the volume of activity, these costs include costs such as **[2]:**

- Fuel consumption.
- Maintenance of units.

Fixed costs are those that do not directly change with service levels in the short and medium term, these costs include costs such as:

- Administrative costs
- Rents - lighting, water and telephone
- Depreciation
- Basic insurance

Direct and Indirect Costs:

Direct costs can be defined as costs which strongly dependent on operations **[3]**

Indirect costs can be defined as costs which cannot be accurately attributed to specific cost objects

Specific and Common costs:

Specific costs are costs that related directly to a certain service (passenger or freight), For example:

- Costs of construction of tracks and signals when the line is used for one service
- Costs of rolling stocks
- wages for drivers

Common costs are costs that common between passenger and freight, For example

- costs of construction of tracks and signals when the line is used for passenger and freight service

It is Difficult to separate the costs of each service in the common costs.

IV. COST COMPONENTS

Costs elements can be divided into:

- Capital costs.
- Operating and Maintenance costs.

4.1 Capital Costs

Capital costs are defined as the one-time costs to construct the railway, including the guide way (ballast, track), stations, structures, engineering/design, and administrative costs, for example:

- Construction of tracks, stations, yards and signals
- Construction of workshops, administrative building and maintenance equipment
- Rolling stock (locomotives, cars and brake vans)
- Additional costs (Clubs, hospitals…).

The capital cost $\mathbf{C_{CAP}}$ can be estimated as the sum of the following costs **[2]**:

$C_{CAP} = C_{CON} + C_{RO} + C_{ST}$

$C_{\mathbf{CON}} = C_{STUD}+C_{LAND}+C_{BUILD}+C_{TRACK}+C_{ELEC}+C_{SIGN}$

Where the components are:

C_{CON} for construction;
C_{RO} for rolling stock;
C_{ST} for the station and equipment;
C_{STUD} for studies (feasibility study, preliminary study);
C_{LAND} for land and rights;
C_{BUILD} for main building works;
C_{TRACK} for the track age;
C_{ELEC} for the electric traction equipment;
C_{SIGN} for the signaling systems.

The average construction cost for new railway widely ranges between 1.5M€ and 70 M€ per kilometer of line. It depends not only on the technology but mainly on the relief of the landscape. If there are a lot of hills and mountains, then there will be more tunnels and bridges to be built **[2]**

4.2 Operating and Maintenance Costs

Operating and Maintenance Costs (O&M) defined as the ongoing annual costs to operate and maintain [4]. O & M costs consist of the ongoing costs associated with operating, maintaining, and managing the transit system. These costs typically include:

- Railway tracks maintenance
- Operating costs of trains, stations and yards
- Parts and materials
- Equipment maintenance
- Administrative costs including labor, supplies, building operations, communications, etc.)
- Insurance

Operating cost model can be written as follows: **[2]**

$Cope = C_{TRACTION} + C_{DEPRECIATION} + C_{MAINTENANCE} + C_{SALARY} + C_{ACCESS}$

ENR was re-organized along strategic business in 2008/2009 in such a way the cost items were distributed on the six sectors: **[5]**

- Long- distance Passenger Services.
- Short- distance Passenger Services.
- Freight transport.
- Administrative Expenditures
- Shared services
- Infrastructure

Three of them considered as direct costs while the other three considered as indirect as follow:

- Direct costs : short distances – long distances – freight transport
- Indirect costs: administrative expenditures – shared - infrastructure service

Since 2008/2009, according to the Unified Accounting System (UAS) the operating costs elements divided into four groups. **[1]**

- Group (1) : raw material- petroleum materials- spare parts & maintenance - electricity and water – writing tools
- Group (2) : wages
- Group (3) : expenses
- Group (5) : burdens and losses

Note: Group (4) will not be taken into consideration in costs, as it represents revenue and profits

V. PROPOSED METHODOLOGY TO CALCULATE OPERATING COSTS

A methodology was proposed to estimate the actual operating costs for long distances passenger, short distances passenger and freight transport.

The following suggested six steps are applied on this methodology during period from (2008/2009) to (2013/2014).

Step (1): Calculate the values of inflation coefficients considering the inflation in year (2008/ 2009) = 1 as a base year.

Step (2): Modify the actual operating cost elements for the six sectors related to the base year (2008/2009).

Step (3): Distribute the indirect costs among long, short distances passenger and freight transport

Step (4): Calculate the total modified costs for each direct services

Step (5): Propose mathematical models to estimate operating costs for each service with the prices of base year and using operating units.

Step (6): Propose model to estimate special inflation rate for each service and group as a function of general number inflation to get the actual costs at any year.

Applying the proposed methodology in ENR, we can obtain the mathematical models to estimate the ENR costs as follows:

Step 1: Calculating the Values of Inflation Coefficients

Inflation coefficients calculated related to year (2008/2009) as a base year for general number, materials and wages as shown in table (3)

Note: Inflation coefficients for any item = Inflation rate at any year / Inflation rate at base year (2008/2009)

Table (3): Inflation coefficients related to base year from 2009 to 2014

Item \ Year	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14
General number (G)	1.00	1.13	1.29	1.32	1.37	1.40
Paper and its products	1.00	1.02	1.05	1.10	1.12	1.13
Petroleum products	1.00	1.02	1.07	1.10	1.11	1.12
Transport means	1.00	1.01	1.03	1.06	1.06	1.07
Machines and equipment	1.00	1.01	1.02	1.02	1.08	1.10
Raw materials	1.00	1.05	1.31	1.35	1.43	1.46
Wages*	1.00	1.14	1.62	2.23	2.65	2.78

*Average wages of worker in year for ENR

Step 2: Modifying the Actual Costs for the Six Sectors

Modify the actual operating costs elements related to base year 2008/2009, in order to become in the prices of base year for the last six years using the inflation coefficients in prices during this period.

Firstly, choose for every cost the inflation coefficients in prices of materials elements which compatible with it. Secondly, calculating the modified costs of all items for six sectors from (2008-2009) to (2013-2014)

Note: Modified costs = actual cost / inflation coefficients compatible with cost elements.

Step 3: Distributing the Indirect Costs

ENR distributed its actual cost among six sectors, three of them considered as direct costs: (long, short distances passenger and freight transport)

The three others considered as indirect costs: (shared costs, infrastructure and administrative)

The indirect costs will distribute among long, short distances passenger and freight transport using operation units firstly, calculate the total modified costs for indirect costs as the sum of cost elements for the three indirect costs.

Secondly, choose every cost elements and what compatible with the operating unit.

Thirdly, distribute the total modified costs for indirect costs in the long, short distances passenger and freight transport using selected operating units as follow:

1. Obtaining the selected operating units for both passenger and freight (train.km, car.km, ton (load+ empty).km).
2. Calculating the total operating unit for both passenger and freight as shown.
3. Calculating the share ratio of each service from the total operating unit.

Finally, calculating the share of long distances passenger, short distances passenger, freight transport from total modified costs.

Note: Share ratio of any service from operating units = operating units for this service / total operating units for all services

Step 4: Calculating the Total Modified Costs

Calculate the total modified costs for each direct service as follow:

Total modified cost for each direct service = modified cost from direct cost + share for service from indirect modified costs

Step 5: Proposing Mathematical Models

Derive equations for each service linking costs as function of:

- Pass.km for long and short distances passenger
- Ton.km for freight transport

Firstly, Costs elements will be divided to variable and fixed and then apply this classification on the three services.

Secondly for variable costs which depend on the operating units mathematical models for them were proposed using regression analysis and for fixed costs that were independent on the volume of traffic will be calculated as the average of costs from 2008-09 to 2013-14, then they were considered as model constant.

Finally, the proposed models obtained for the three services for each cost groups as shown in table 4, 5 and 6

- **Results:**

Table (4): Proposed costs model for long distances passenger

Service / Group	Long distances passenger
Group (1)	$C_1 = 0.0027*PL^2 - 65.291*PL + 652920$ ($R^2=0.6888$)
	$C_{11} = 0.701 * PL$
Group (2)	$C_2 = 34.705* PL$
Group (3)	$C_3=36.386 *PL$
Group (5)	$C_5=4.607 * PL$
Total cost equation	$C_t = 0.0027*PL^2 + 11.108*PL + 652920$ where: PL- no of (pass. Km) for long distances in millions, C – costs in thousand L.E

Table (5): Proposed costs model for short distances passenger

Service / Group	Short distances passenger
Group (1)	$C_1=.0023*PS^2 - 51.112*PS + 426341$ ($R^2=0.6638$)
	$C_{11}=0.705 * PS$
Group (2)	$C_2=30.86 * PS$
Group (3)	$C_3=26.78 * PS$
Group (5)	$C_5=4.59 * PS$

Total cost equation	C_t=.0023*PS^2 +11.823*PS + 426341 where: PS - no of (pass. Km) for short distances in millions, C – costs in thousand L.E

Table (6): Proposed costs model for freight transport

Service / Group	Freight transport
Group (1)	C_1= 0.0071*F^2 - 3.9136*F + 29250 (R^2=0.828)
	C_{11}= 2.794 * F
Group (2)	C_2= 83.487 * F
Group (3)	C_3= 123.458 * F
Group (5)	C_5= 7.609 * F
Total cost equation	C_t = 0.0071*F^2 + 213.434*F + 29250 where: F - no of (Ton. Km) for freight transport in millions, C-costs in thousand L.E

Step 6: Proposing models to Estimate Special Inflation Rate

Proposed models to estimate the special inflation rate as function of the general inflation number to get the costs model become in favor of the use at any fiscal year taking into account inflation in the year of the study as follow:

- Calculate the subtotal of each group for the actual and modified costs for the three services (long, short distances passenger and freight transport).
- Get special inflation number in prices for any year and group of costs by dividing the actual costs for this group on the modified costs.
- Link the special and general inflation number coefficient using mathematical equations for the three services and each group as shown in table (7),(8) and (9)

Note: Special inflation number coefficient = Actual cost / Modified cost.

- **Results:**

Table (7): Proposed model to estimate the special inflation rate for long distances passenger

Service / Group	Long distances passenger
Group (1)	SC_1 = 0.2913*GC + 0.6945 (R^2=0.8841)
Group (2)	SC_2 = 3.893*GC – 3.0879 (R^2=0.881)
Group (3)	SC_3 = 0.6085*GC + 0.3712 (R^2=0.9044)
Group (5)	SC_5 = GC (R^2=1)
Total cost equation	SC_t = 1.653*GC – 0.7215 (R^2=0.9208) where: SC(special inflation rate) , GC(general inflation number coefficient = G/147.4)

Table (8): Proposed model to estimate the special inflation rate for short distances passenger

Service / Group	Short distances passenger
Group (1)	SC_1 = 0.2785*GC + 0.7066 (R^2=0.8445)
Group (2)	SC_2 = 3.9646*GC – 3.164 (R^2=0.8782)
Group (3)	SC_3 = 0.7079*GC + 0.2692 (R^2=0.9556)
Group (5)	SC_5 = GC (R^2=1)
Total cost equation	SC_t = 1.949*GC – 1.0343 (R^2=0.9035) where: SC(special inflation rate) , GC(general inflation number coefficient = G/147.4)

Table (9): Proposed model to estimate the special inflation rate for freight transport

Service / Group	Freight transport
Group (1)	SC_1 = 0.28*GC + 0.704 (R^2=0.7968)
Group (2)	SC_2 = 4.0868*GC – 3.2983 (R^2=0.8668)
Group (3)	SC_3 = 0.3935*GC + 0.5965 (R^2=0.9398)
Group (5)	SC_5 = GC (R^2=1)

Total cost equation	$SC_t = 1.6488*GC - 0.7293$ $(R^2=0.8772)$ where: SC(special inflation rate) , GC(general inflation number coefficient = G/147.4)

VI. Applications and Conclusions

Applying the present proposed methodology to predict the ENR operating costs using the previous models for costs and special inflation number for the next period from (2014/2015) to (2019/2020) as shown in table (10), (11) and (12)

Table (10) Estimated Modified and actual operating cost for long distances passenger service during period from 2014/2015 to 2019/2020

	Long distances passenger		
Item / Fiscal year	Modified cost (thousand L.E)	Special inflation coefficient	Actual cost (thousand L.E)
2014/2015	1801778	1.81	3252633
2015/16	1916186	1.94	3709231
2016/17	2035972	2.07	4206803
2017/18	2161136	2.20	4747455
2018/19	2291679	2.33	5333291
2019/20	2427600	2.46	5966419

Table (11) Estimated Modified and actual operating cost for short distances passenger service during period from 2014/2015 to 2019/2020

	Short distances passenger		
Item / Fiscal year	Modified cost (thousand L.E)	Special inflation coefficient	Actual cost (thousand L.E)
2014/2015	951583	1.94	1850728
2015/16	970521	2.10	2036895
2016/17	999152	2.25	2250724
2017/18	1038171	2.41	2498363
2018/19	1088498	2.56	2786964
2019/20	1151282	2.71	3124861

Table (12) Estimated Modified and actual operating cost for freight transport service during period from 2014/2015 to 2019/2020

	Freight transport		
Item / Fiscal year	Modified cost (thousand L.E)	Special inflation coefficient	Actual cost (thousand L.E)
2014/2015	669610	1.79	1199281
2015/16	7169`80	1.92	1377452
2016/17	764845	2.05	1568970
2017/18	813205	2.18	1774028
2018/19	862060	2.31	1992821
2019/20	911409	2.44	2225540

The following figure (1) shows the average percentage costs for groups of cost from total costs

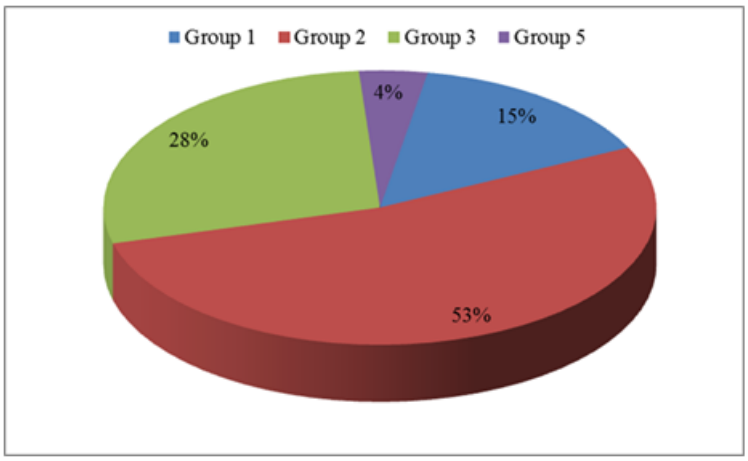

Figure 1: Average percentage value for groups of cost.

Fixed costs represent about 85% of total operating costs, while variable costs represent 15% of the operating costs. Wages of worker and employee represent about 53% of the total costs.

This paper is meant to provide transportation planners and policy makers with a formal process for estimating costs that are representative of the area and service in question, for analysis and decision, making purposes.it can be used as an intermediate tool to allow planners to more easily perform planning activities own, before to contracting out feasibility studies.

Further development on this research will be addressed to other categories of railway services, such as metro and high-speed trains.

REFERENCES

[1]. Egyptian National Railway (ENR), 2014 "Annual Report & Final Account".
[2]. Domenico Gattuso & Antonio Restuccia, 2013" A Tool for Railway Transport Cost Evaluation".
[3]. Oskar Froidh, 2006"Modelling Operational Costs of a Future High-Speed Train ".
[4]. Technical Memorandum No. 7b, September 2009"Operating Cost Evaluation".
[5]. Mints – Misr National Transport Study, March 2012"The Comprehensive Study On The Master Plan For Nationwide Transport System In The Arab Republic Of Egypt ,Final Report Technical, Report 2, Railway Sector ".
[6]. Central Agency for Public Mobilization and Statistics (Capmas).