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DETERMINING THE PRIME COST OF RAILWAY TRANSPORTATION AND IDENTIFYING VARIABLE COMPONENTS

2023

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Note: *This study presents a definition of a shipping cost calculation model , which is based on template numbers which should be replaced with actual data. The model requires more work and remaining articles should be divided according to the parameters. This paper represents the description of the conducted work and developed principles.*

1. ABSTRACT

This paper set out to provide transportation planners and policymakers with a systematic process through which to estimate costs representative of the area and service in question and to ease their analysis and decision-making procedures. Although the methodology presented herein is not meant to replace the in-depth and detailed feasibility studies or professional railroad planning activities, it can be used as an intermediate tool to allow planners to more easily perform railroad analysis and planning activities, prior to contracting out feasibility studies. Finally, should this research be further developed, it ought to address other categories of railway services, such as intercity and high-speed trains.

2. INTRODUCTION

As Georgia undertakes a process of approximating its legislation with that of the EU, as envisaged by the EU-Georgia Association Agreement, railway transport reform in 2023 is expected to establish a European model for the Georgian railway network. In compliance with the EU Directives, Georgian Railway is divided into three strategic business units (SBUs): the Infrastructure SBU; the Passenger SBU; and the Freight SBU.

Regarding infrastructure, two prominent Western models are first introduced here: the US model and the European model. The former entails the privatization of infrastructure, along with operations. Meanwhile, the European model applies a different approach, whereby the state maintains ownership of infrastructure, but operations (e.g. freight shipments and passenger carriage) may be acquired by private companies. The European model is more suitable for Georgia's context for two main reasons. First, selling railway assets to private actors may increase geopolitical risks depending on the origin and intentions of the given actors. Second, attracting new players to the market such as operators and cargo forwarders, rather than selling assets, is a more prudent means of revitalizing the Middle Corridor. To summarize, Georgia should keep the ownership of its railway assets but attract investments from new market players by providing equal access to its railway infrastructure.

The corresponding reform is being implemented in various phases, with the equal admission to railway infrastructure component covered under the EU Directive 2012/34. The Directive envisages the introduction of new companies to the market and the introduction of a new rolling stock of electric locomotives. The European model gives space for substantial opportunities in renewing and upgrading the railway infrastructure and services. Other EU directives also stipulate the licensing and certification of introduced operators, which will increase the quality of the Georgian railway network services. To highlight the need for such reforms, some of the electric locomotives in Georgia's present rolling stock were manufactured around 60 years ago.

When it comes to determining the costs of shipment by rail, there are two prominent pricing methodologies used in the world. The first is based on a principle whereby the seller (railway) sets the price based on the existing market demand. The second approach is based on the average prime cost, and adding a certain profit margin as necessary for development. In the first stage of designing a suitable model for the Georgian network, variable and fixed costs were identified by specific line items, following interviews with representatives of the relevant SBUs.

Ultimately, according to the component of free access to European rail infrastructure (directive 2012/34), the main goal of the present research is to identify the variable components that determine the prime cost of shipment.

3. LITERATURE REVIEW

There are various methodologies available for describing cost structures. In this section, a number of categorizations found in the existing literature are presented. Many of these show similarities with one another, while in many cases differences are discovered in terminology rather than in definitions. The purpose of this overview is to help the reader understand the different terminologies used according to various specific contexts.[1] For instance, common costs refer to a type of indirect cost that arises when an activity is shared or undertaken voluntarily by two or more parties. To illustrate this point, in some cases the producer chooses to conduct certain activities with one or more other actors, normally because it is economically advantageous to do so. Indeed, the producer may achieve positive scale or synergy effects as a result. Meanwhile, joint costs emerge when activities must be shared in the course of delivering a product, meaning that the producer has no choice whether or not to share these costs. At the same time, it is important to distinguish between direct and indirect costs. The latter category is usually divided into joint and common costs.[2]

Allocation of joint costs is considered to be more problematic, examples of which are given in a 2005 study: "Work research indicated, that the costs of the upward and downward movement are the same (the only difference between a full and an empty train is the ticket printing trivial expense). However, a train only runs for the benefit of pas-

1 https://www.kth.se/polopoly_fs/1.87038.1550157057!/Menu/article/attachment/09_09-002 PHD_report.pdf

2 Comp. e.g.: ANIANDER, BLOMGREN, ENGWALL (1998)

sengers, therefore, according to the causal principle, this group should bear almost the entire cost, and the way back should be considered as a by-product and must incur marginal cost. However, should this principle stop in the evening? That is, when passengers are returning, and those going to the theater are moving in the opposite direction? The latter will use the train and therefore share its operation expenses, which will reduce the costs of passengers returning home."[3]

The Baumol-Willig rule[4] states that allocated costs should be no greater than the stand-alone cost and no less than the incremental cost. Otherwise, joint production would not continue and the economic benefits would be lost; the same effect would be apparent if the allocated costs were to exceed the revenue from a particular product.

Using Ramsey pricing, indirect costs should be allocated to products in inverse proportion to their price elasticity, or as he expresses it in common parlance: "Load the costs onto those who have little choice but to pay."[5]

A common characteristic of railway systems is that many resources are indivisible or – within certain limits – fixed. Indeed, a high proportion of costs is therefore fixed and independent of transport volume. In addition, the marginal costs for rail traffic can be calculated using different time horizons. For example, the cost of adding one ton of freight when loading a wagon will differ from investing in new rolling stock (which may require more than a year for realization). To clarify, the cost of adding one ton of freight – where the transport capacity of the wagon has not already been reached – is close to zero. Meanwhile, adding a wagon, which is already in operation, to an already scheduled train can be done within a time horizon of a few days. Here, the marginal costs would relate to energy, infrastructure, and maintenance. Pertinently, the regulatory costing model of the Canadian Transportation Agency (CTA) distinguishes between specific and unit costs. Both are variable costs, as seen from the figure below, which shows the cost categorization used in this model.[6]

The differences between specific and unit costs are explained as follows: "Specific costs are those costs which can be directly attributed to the traffic or service for which costs are to be determined (for example, crew wages)."9 According to the CTA model (see chapter 2.3.7), specific costs are those meeting the following criteria:

- the costs are 100% variable;
- the expense is directly related to the traffic movement or service for which costs are being determined;
- the collection of expense data permits the cost to be identified as attributable to specific segments of the rail operation

3 OXERA (2005), p.7

4 ERGAS, H., RALPH, E.: Pricing Network Interconnection: Is the Baumol-Willig rule the right answer?, 1996

5 KAPLAN (2001)

6 CTA - CANADIAN TRANSPORTATION AGENCY (2006)

Unit costs are defined as follows by costs, which are common to all railway traffic and services. A unit cost represents a mathematical relationship between two variables: railway expenses (dependent variables) and levels of output (independent variables). System-wide unit costs are used to assign common costs to services. Unit costs are developed through one of the two techniques. If the common cost is deemed to be 100% variable with the system workload statistics to be used for cost allocation, the unit cost is developed from the direct relationship between expenses and workloads. This is called direct analysis. If the common cost is deemed to be less than 100% variable with the associated workload statistic or is dependent on two or more workload statistics, regression analysis (simple or multiple) is normally used. Furthermore, a geographical cross-section of costing data input is required in order to ensure that costs are truly representative of the railway system in total. Meanwhile, regression analysis is the most widely used tool in estimating the fixed and variable costs and distinguishing the causal effects of different workloads on grouped expenses (cost complexes).[7]

A model can be seen as a simplified depiction of a more or less complex phenomenon in reality. According to Hicks, a cost model (or economic model, as he puts it) can be used to understand the cost behavior of a company in the real world. Depending on the type of business, the model may take on different forms. Indeed, a model suitable for one kind of business, or even one company, may be totally inappropriate for another.[8]

Activity-Based Cost (ABC) model is stated as a highly accurate methodology focusing on indirect costs, tracing rather than allocating each expense category to the particular cost object (which is in line with the bottom-up approach, see below). Moreover, the ABC model makes "indirect" expenses "direct." In addition, when comparing between the TCA and ABC models, it goes as far as to state that the former "is unable to calculate the 'true' cost of a product."[9]

7 Aniander, Blomgren, Engwall, et al. (1998)

8 Hicks, S.T. (1999)

9 Roztocki, N. (1998), p.24

4. RESEARCH METHODOLOGY

In our research, variable costs were identified as wear and tear, traction electricity, and traction for fuel, materials, repairs, and the leasing of rolling stock. The remaining costs are handled as fixed costs since they are not affected by a change in the volume of shipment. Below, the determination of variable costs and the methodology for their distribution among sections in the proposed model (according to a specific carriage) are presented.

For each specific shipment, only the volume of the cargo is known. The type of cargo, the number of wagons required and the direction of shipment are determined in advance. All parameters have been decided so that the prime cost of shipment can be determined based on the input data.

4.1. TRACTION ELECTRICITY

Traction electricity is the volume of power that an electric locomotive consumes during the shipment of freight. Therefore, the higher the weight of the train and the intensity of movement (which, in turn, depends on the volume of cargo), the higher the electricity cost for traction. Therefore, we can say that this cost is variable and directly proportional to any changes to the volume of cargo.

In the model, the corresponding electricity cost for traction is allocated to all sections of the railway network. Information and data about consumed kW/hours for traction by section is gathered at the Power Supply Department at Georgian Railway, where, based on the substations' data, electricity (kW) consumed for traction is distributed across sections and electricity cost is derived for a given section by applying the relevant rate.

The calculation starts by listing sections, indicating the distances each of them cover. Next, alongside every section, the actual kW/hour consumption is inserted over the selected period (tentatively X year) and the corresponding cost is outlined in GEL. Next, the average rate per kW/hour is derived. Since electricity cost is dependent on the weight and intensity of movement of a train, gross ton-km (cargo weight + wagon weight) *distance of shipment) is the driving parameter for this cost. Respectively, the net ton-km carried on a relevant section during the selected period and its respective gross ton-km is indicated. The total gross ton-km is thus provided, with empty movement gross ton-km also added to the data. In order to derive the gross ton-km for a specific shipment, ton-km net is calculated according to the distance covered by the section and the weight of the cargo, after which the ton-km net is converted to gross ton-km by means of a statistical factor. Meanwhile, electricity consumption for total gross ton-km is calculated statistically in kW/hours for each section separately.

The factor of this cost is used to convert the gross ton-km for a specific shipment into electricity consumption (kW/hours). Next, the estimated electricity cost is applied and the consumed electricity for the shipment in monetary form is calculated. To do so, first the sections involved in the shipment should be determined, and relevant calculations should be performed for a specific shipment - weight gross ton-km and ton- net km of the rolling stock, respective consumption in kW/hours, and cost in GEL.

It should be noted that another factor taken into account in the calculation of expenditure is the intensity of movement on a specific section.

Since the intensity of movement on a specific section needs to be factored in to establish the cost of a specific shipment for the company, the shipment is divided into two parts: net weight of the rolling stock; and gross weight of the rolling stock. For every shipment, net weight is calculated only once, while gross weight is dependent on the type of route. If the shipment is conveyed to a point from which the wagons will return without any load, the costs arising from the movement of empty wagons should be attributed to the original shipment that necessitated the return of empty wagons. From a statistical perspective, if after unloading the cargo delivered to a specific section, the emptied wagons are loaded with other cargo on a return trip, the cost of the return of gross weight of the rolling stock is not added to the original shipment. In the third (extreme) case, for statistical purposes, if, on a specific section, wagons always move in an empty condition (due to the specificity of the shipment streams), yet the client requests the loading of wagons in the same direction, this shipment incurs only additional net cargo shipments, and the gross weight of the rolling stock should not be included in the attribution and/or calculation of costs.

4.2. LEASING OF ROLLING STOCK

This cost is variable since every additional ton reduces the availability of railway wagons, thereby increasing the likelihood of having to use foreign wagons.

This cost component in the model is distributed among sections for a specific shipment, for which first sections and the relevant distances covered are provided and listed. For every section, the average speed of the rolling stock is known, and based on that, the average time taken to pass a section is roughly calculated. To ensure equal conditions for shippers with respect to accruing this cost to their shipments, the share of wagon-days for wagons with a foreign code as part of total shipments is determined.

To do so, the type of wagon, the number of days in the year, the average time spent in a railway yard during the period, and the utilization rate of wagons owned by Georgian Railway during the period were all used. Based on the gathered information, the wagon-days for wagons utilized by Georgian Railway for shipment are calculated. Next, statistical information and data is gathered on wagon-days for foreign wagons used in the shipment. Accordingly, the shares of domestic and foreign wagons are calculated. Next, the relevant cost of wagon-days for foreign wagons is derived, based on which the average charge for one wagon-day for a specific type of wagon is also determined. By multiplying the charge for one foreign wagon-day by the share factor, we derive the cost to be accrued for one wagon-day on average per shipment.

In addition, the type of wagon for the shipment is indicated, as well as whether a specific section is passed in the shipment. Thereafter, costs are attributed to the involved sections according to requested wagons and by means of the factor explained in the description of the electricity part.

4.3. MATERIALS

The cost of materials is handled separately for each department, since the intensity of required repairs of assets is dependent on various parameters.

Signaling, Centralization and Interlocking Department (SCB) materials cost

The main SCB assets are Arrow electric drive, crossing gates, traffic lights, cables, impedance transformers, relay equipment, and control equipment. For the first two assets, the volume of the wear and tear of materials depends on the frequency of their operation; which in turn rests on the number of trains to pass over the given section in the relevant period. The frequency of train movements is interlinked with the volume of cargo.

Meanwhile, sections and their relevant lengths are provided and listed. Since the variable of SCB materials consumption depends on the number of trains to have passed the relevant section, train-km determines how costs are allocated to sections accordingly. These data are not recorded by section and therefore a factor of total gross ton-km and total train km are applied. Using this factor, the gross ton-km of each section is converted to train-km for the given section. Since for each specific shipment it is unknown how many train km will be realized (i.e. it is possible that each train may combine various shipments), in order to attribute the cost of materials to a specific shipment by means of the train-km and carriage-km ratio derived for each section, we can calculate on average the number of trains and kilometers for a specific wagon" or "the train-km rate for a specific wagon. Moreover, it is calculated whether a specific section is involved in the given shipment. Subsequently, we calculate the train-km of existing wagons for the specific section. Based on SCB information and data, the cost of materials consumed for Arrow electric drive and crossing gates on relevant sections is calculated. Following on, the materials expenditure per train-km is calculated for each section and, based on this, the cost of variable materials arising from the shipment is calculated. Crucially, the calculations also take into account the intensity factor described above.

4.4. CONSUMPTION AND COST OF TRACK MATERIALS

The cost of track materials is divided into several types. The interviews showed that these types were established depending on the intensity of the carriage of cargo, which would affect the gross ton-km. Hence, our goal is to calculate variable costs per unit of gross ton-km and develop a mechanism for the conversion of a specific shipment to gross ton-km.

The model for track materials cost provides various types of information, with sections and their distances provided and listed. In addition, total gross ton-km during the selected period on relevant sections is provided (including empty wagons mileage), net ton-km, and ton-kilometer gross (without empty mileage). At the next stage, the factor used to convert ton-km net into the relevant gross ton-km is derived.

Furthermore, the calculation presents the cost of track materials" at relevant sections, after which the cost of variable track materials per ton-km is calculated. Moreover, it is indicated whether a specific section is involved in the shipment, according to which the passed ton-km net is calculated in accordance with the ordered shipment. In the calculations, ton-km of the rolling stock of the relevant shipment is calculated using the given factor and the net ton-km. Based on these data, the cost of variable track materials for a shipment is calculated. It should be noted that for the cost calculations, the intensity index of loaded movement on a section is used, which is described in the paragraphs above.

5. RESEARCH RESULTS AND INTERPRETATION

Example: a shipment of oil with the following details:

- Tons: 60
- Type of wagon: tank car
- Number of wagons: 1
- Wagon ownership: inventory (Georgian Railway)
- Route: Gardabani - Poti

The following is to be calculated:

- Variable cost of shipment
- Attributed fixed costs

4.1. IDENTIFICATION OF VARIABLE COSTS AND THEIR ATTRIBUTION TO TRANSACTIONS

Variable costs in the railway business:

- Electricity for traction – gross ton-km
- Fuel for traction – tons processed in a station
- The cost of leasing foreign wagons – duration of shipment
- Materials and repair – gross ton-km
- Operational data
- Relevant variable cost of for operational gross ton-km

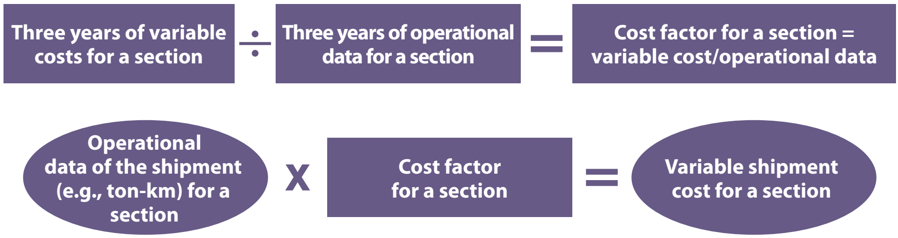
CALCULATION OF OPERATIONAL DATA

Carriage ton-km gross = (**Weight of the freight** + **Number of wagons * weight**) x **Distance of carriage**

Carriage foreign wagon days = (**Section length/average speed** + **Average delay time at a station**) x **The average share of foreign wagons as part of total shipment**

*Hence, shipment ton-km gross = (60 t + 23 t * 1 carriage) * 364 km = 30,212 ton-km gross. Shipment foreign carriage-days = (364 km / 33.8 km/hr / 24 + 0.15 days * 7 stations) * 56% = 0.82 days.*

SIMPLIFIED SCHEME - CALCULATION OF VARIABLE COSTS



The table presents the attribution of fixed costs for operational data, including the following:

- Determining the type of fixed costs for each service;
- Distribution of common and joint costs;
- Distribution of infrastructure costs for freight and passenger services pro rata to gross ton-km; and
- Distribution of administrative costs by the earning power of transactions.

FIXED COSTS BASE

	Direct fixed costs				Joint fixed costs	Common costs
Fixed costs base	**Shipment**	**Station service**	**Passenger carriage**	**Rolling stock lease**	**Infrastructure**	**Administration**
Salaries	41733	20380	15935	–	41131	10679
Depreciation	28532	5462	7630	6637	47610	1132
Electricity (traction)	–	–	–	–	–	–
Electricity (utility)	–	–	–	–	–	2551
Materials	8989	–	1566	–	6608	189
Fuel (traction)	–	–	–	–	–	–
Fuel (utility and other)	–	–	–	–	–	1835
Fuel (lubricants)	868	–	161	–	129	1
Property and land tax	2328	362	1096	597	7521	9854
Repair	8029	201	940	–	268	222
Materials and repair (total)	2624	201	2506	–	2791	411
Security	–	–	–	–	–	7504
Other operational costs	–	–	–	–	–	17754
Wagons lease costs	–	–	–	–	–	–
Spacecom	4874	807	–	4177	–	–
Services total	80959	27212	27329	11410	99182	51721
Infrastructure component	91352		7830			
Administration component	38725	6483	1884	4629		
Total	211036	33694	37043	16039		

ATTRIBUTION OF FIXED COSTS TO OPERATIONAL DATA

	Shipment	Station service	Passenger carriage	Rolling stock lease
Driving data Unit of data	10,722,214	22,627,500	3,261,745	857,538
cost per unit	19,68	1,5	21,4	18,7
	Ton-km gross	St. carr. tons	Passenger	External wagon-days

* The allocation of derived fixed cost per unit to a shipment according to its operational data

Total operational data of a shipment (e.g., ton-km) **x** **Fixed costs per unit of data E** **=** **Fixed cost of the entire shipment**

Example: Oil Shipment

- Total variable cost – GEL 2.1 ton
- Attributed fixed costs per ton – GEL 12.0
- Total cost – GEL 14.1
- Rate per ton – GEL 21.4 (Kazakhstani oil)

6. CONCLUSIONS

As a result of distribution, on average, for statistical purposes, in 2011, 2012 and 2013, per shipped ton of cargo:

- Variable costs – GEL 2.1
- Fixed costs – GEL 10.8
- Average revenue – GEL 18.8.

The presented model enables the estimation of the cost of a specific shipment and entails the following parameters:

- Shipped tons;
- Shipment route;
- The number and type of wagons used for shipment;
- Ownership of the wagon(s) and
- GEL/CHF exchange rate.

OTHER RESULTS OF THE RESEARCH

Station service per ton of cargo:

- Variable costs – GEL 0.5
- Fixed costs – GEL 1.5
- Average revenue – GEL 3.4

Foreign wagon lease rate per carriage-day of revenue:

- Variable costs – GEL 4.5
- Fixed costs – GEL 18.7
- Average revenue – GEL 28.3

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