# AN ACCOUNT-ORIENTED APPROACH FOR THE MARGINAL COST BASED PRICE CALCULATION IN THE CASE OF THE HUNGARIAN STATE RAILWAYS

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## 1. INTRODUCTION

In the competition for technological, economical and social efficiency the professionals and researchers of each scientific fields are working on the escalation of new results, in order to improve welfare in the society. The transport economist – having an interdisciplinary research field – are no exception of this: they have the simultaneous task of providing economical and social welfare, of providing efficiency and equity and of providing technological optimum for transport processes. This first chapter underlines the importance and consequence of the research activities within the transport economics.
A characteristic topic of the mentioned theme is to configure the cost calculation system and pricing method of the transportation companies, including railway companies: in this case the researcher can not avoid the basic technical processes that are described by financial ones, and have special attributes, constraints and barriers [Tán99]. At the same time, attention has to be paid to the instructions of the economic theory, in order to help the railway company to contribute to the increase of social welfare. One of the currently consorting optimisation theories in economics is the neo-classical doctrine with its marginal costs and marginal revenues.
The neo-classical school was founded by Walras, and by his mathematical model that describes the usage of marginal costs and marginal revenues [Wal87]. First application of this was evolved at the beginning of the 20th century with the welfare theories of Marshal [Mar16] and Pigou [Pig24], later with the overwork of this by Hotelling [Hot38]. As a result of their work, a new, prospective challenge was revealed before theorists and practitioners of the economics: the mathematical equations that were resulted from the research don't only provide the profit-maximum of the company, but, at the same time they show the way to the optimal capital-allocation and efficiency among companies for the society.
The marginal cost theory passed more "scientific cycles" since its appearance at the beginning of the 20th century [Rot01a]. Its history was not a linear development, the "periodical" adjective is more appropriate, since, in certain time intervals the theory started to decline. After its appearance the theory was very popular thank to the mathematical optimum, regarding company and asset efficiency. The neo-classical economists (like Walras, Marshal and Hotelling) dedicated special attention to the elaboration of the mathematical equations and their application.

The marginal cost theory was born on the basis of production industry (machinery, textile, toys, etc.), its adaptation in the service sector started later, and in the transportation even later. Application within the transport industry is delayed with one time period compared to the one in the production industry. After completing the theory, scientists started to elaborate on the constraints and barriers, and as a result of the numerous disadvantages, the theory started to get over. When it appeared in the transport sector, its popularity within the production industry was again appreciating. This might has been the real reason for the trials within the transport industry. Scientists queried its equity issues and applicability. But its advantages did not let scientists to come by the theory without consideration when having the task of economic optimisation. This is well reflected by the fact that in the recommendations of the Commission of the European Union the theory of marginal cost based pricing become more and more stressed. One of the most broadly discussed topics of the announced research framework programmes is the examination and valuation of the marginal cost theory. In the work and recommendations of the DG TREN the Commission's opinion seems to be reflected: more examination of methods are needed that can help to utilise better the society's scarce resources, let it be about tolls for using transport infrastructure [Far00], about analysis and monetarisation of external effects of transport activities, profitability of transport companies, utilisation of transport assets from social point of view, or about optimal capital, made available for transport companies.

As a result of all this, the Commission reframed the possibilities of marginal cost pricing in the 1995 Green Paper and in the 1998 White Paper [Ecm98], and recommended its usage for the transport sector, allowing exceptions only in special cases. Since in the following years the applicability of the scheme was widely discussed, the attitude of the Commission changed: under some circumstances, only the limited usage of the rule is desired. Now, as a result of earlier research, the better cost coverage solutions make the marginal cost equation more accurate.

This paper – after disclosing the theoretical background of the marginal cost pricing rules – searches for solutions of applicability using the example of European railway companies, and in particular the Hungarian State Railways. During the negotiation, usually the economical viewpoint will be the first, while the practical applicability is continuously paid attention to. This latter is a strong aim, since the developed model need to be beneficial for the railway company, a non-usable theoretical innovation is without any value.

## 2. THE NEO-CLASSICAL MARGINAL COST THEORY

In order to understand the constraints, barriers and development possibilities of the „pure" marginal cost theory a short overview of the early results at this field is necessary. Therefore, this chapter examines the mathematical background of the most important corner-stone of the neo-classical welfare theory.

When thinking about the optimal production quantity (provided transport performance) of a certain company, the mathematical formulas assume that the company has the aim to maximise its total profit. This total profit is the difference between the total revenue (TR) and the total cost (TC):

$Tp(q)=TR(q)-TC(q)=P(q) \cdot q-TC(q).$ (1)

The primary condition to reach the maximum of the profit (1) is, that the marginal profit becomes zero, i.e. more production does not mean more profit for the railway company (in case it is possible, the company simple can increase output and increase its earnings, and the maximum is not reached yet).

$$\frac{dTp}{dq} = Tp'(q) = \frac{dTR(q)}{dq} - \frac{dTC(q)}{dq} = 0 \quad (2)$$

If the (2) function is simple re-arranged the following equation is received as a result:

$$\frac{dTR(q)}{dq} = \frac{dTC(q)}{dq}. \quad (3)$$

As the total revenue derived by the volume is equal to the marginal revenue, and the total cost derived by the volume is equal to the marginal cost, the (3) equation can be formulated as follows:

$MR(q)=MC(q).$ (4)

The secondary condition for reaching the maximum profit in the equation point is that here the marginal profit becomes negative (if it does not turn to the negative range, the function only ensweeps the x axis and starts to increase again). This condition can be fulfilled by producing the second derivative of the (1) total profit function. If the TC function that reaches the x-axis has a negative slope, the marginal profit becomes negative with the increasing output. This is reflected by the (5) equation:

$$\frac{d^2Tp}{dq^2} < 0. \quad (5)$$

If the (1) function of the total profit is split into its two components, and the derivation is carried out on them separately, we reach the desired relation between the marginal cost and marginal revenue functions:

$\frac{dMR(q)}{dq} - \frac{dMC(q)}{dq} < 0$, and therefore (6)

$$\frac{dMR(q)}{dq} < \frac{dMC(q)}{dq}. \quad (7)$$

This latter condition (7) means, that the profit is only maximal, if the marginal cost has a more positive slope than the marginal revenue function (MR), i.e. it crosses the MR function from bottom.

The two ambivalent structures of the neo-classical marginal cost theory are the monopoly and the perfect competition. The figure 1. explains the meaning of the meaning of the (4) and (7) equations within the model of monopoly.

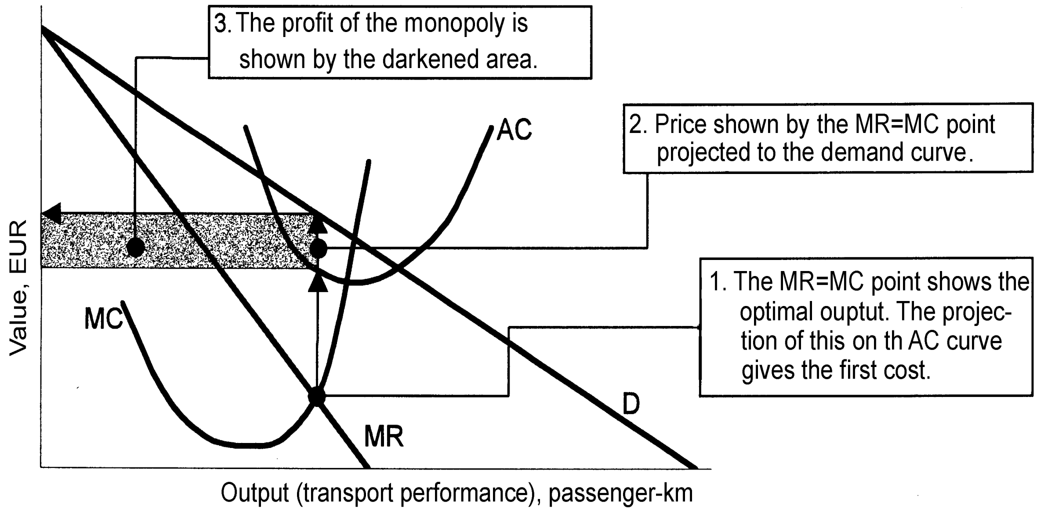


*Fig.1.: Price setting in case of monopoly*

In case of monopoly the price is determined by the MR=MC equation, but only indirectly: the projection of the MR=MC point on the demand curve shows the appropriate market price. Cost recovery and the earnings depend on the position of cost curves compared to the demand curve and the provided equilibrium within the relevant production interval. This means that with an accurately chosen price structure the monopoly can gain positive economic profit in long term as well.
In case of perfect competition, the (4) equation above has to be completed with two further factors: the marginal cost is equal to the price and the actual demand, beside the marginal revenue, too. The company meets in this case a horizontal and linear demand curve (D).

$$MR=MC=P=D. \quad (8)$$

The company can not influence market prices, it only accepts them and works together with other market actors. The marginal cost curve is equal to the supply function of the company. Positive or negative profit is only earned in a short term, when the company uses or suffers from the deficiency of the market.
The “benefits” and usage possibilities of the classical marginal cost theory can be summarised as follows. The main gains source from two different viewpoints:
1. In case of profit-earning of the company, the marginal cost theory is an output-regulation.
– If MC<MR, increase output, because the additionally provided performance unit drives more benefit than cost.

– If MC>MR, decrease output, because the additional performance units make more loss than earnings (if the company produces a unit less, the cost is singing faster than the income).

2. In case of considering the available assets for the company the theory is a capacity-regulation.

– If MC<MR, the available capacity is too big, for this capital other market actor would provide better profit.
– If MC>MR, the capacity is not enough (more asset is needed), because the company can not meet the requirements of the market, the desired output level is economically only accessible with more used capital.

In case of transport companies the No. 2. regulatory-effect of the marginal cost theory is of higher importance.

A seen in this chapter, the marginal cost theory gives different suggestions for the company, depending on the market environment. But, in all cases, the social and private optimum of production can only be reached, when the output and asset rule is connected to the marginal cost conditions.

However, the above described optimum can be reached only under strongly proper circumstances. A whole scientific area has been developed to analyse the practical fulfilment of the constraints and barriers of the neo-classical welfare theory. These researches show that the required market environment is very rare, and practically there are some important difficulties that stiffen the everyday usage of the marginal cost theory.

## 3. DRAWBACKS OF THE NEO-CLASSICAL MARGINAL COST THEORY AND THE DRIVING EXPEDIENCES FOR THE ELABORATION OF THE MARGINAL COST MODEL

With theoretical and practical considerations it is easy to recover some serious disadvantages of the marginal cost theory that make the usage very awkward. This chapter examines some of the barriers and explains the need for the elaboration of a compound pricing scheme.

The literature of the theme provides some reflections within this field [Böt77], [But93], [Hut60], [Lös63], [Thi64]. These constraints can be summarised as follows:

– The restrictive constraints of the theory are not valid for the real market environment (irrational consumers, not only profit maximisation at the company, irrational working power owners, non-coherent behaviour of the government, more regulatory measures apart from prices, instability in the economy, more co-ordination mechanisms apart from the market one, non consistent customer preference orders, high transaction costs, not only competitive input markets, etc).
– Because of the wide range economies of scale, average costs are over marginal costs and the full cost recovery is not accessible, loss can be obtained in the business processes of the company.
– If the congestion cost are indicated in the prices – in order to finance the infrastructure –, it causes very heavy cost alternation process, and this is undesired.
– If the marginal cost pricing scheme remains in its original form, in case of the railway companies company deficit arises (as described above, because of the high average costs). Without modifying the scheme, only

the state budget balance-help is possible, but this causes some abusive effects: high transaction costs, lack of development initiatives, need for directed tax-usage from the tax-payers, bad information flow between the sectors).

- According to some opinions, the marginal costs does not allow to fulfil the equity constraints, because one has to pay all costs that he causes, not only the incremental costs.
- The transport performance at the railways is not a perfectly divisible good, therefore when calculating the marginal costs, high price differences can arise.
- The "legitimated" state influence in the management of the company can imply market-strange instructions for the company.
- The stability of the scheme is weak, and is strongly depending on the fulfilment of the restriction constraints.
- The introduction has a strong resource-need, and possibly causes a heavy re-structuralisation within the economy (if implemented at more branches of the economy).
- Because of the company deficit, no capital is accumulated for further developments, and the development initiative can start an independent life from the company.
- A strict application of the marginal cost theory limits the changes in the price policy, and all discounts and/or markups.
- The pricing of technological slow-motion – e.g. running empty cars backwards – is circuitous and strongly debated.
- There is a strong difference between the marginal costs of similar, but technologically different tasks (direct journey vs. changing 2 times at stations).

As these factors were discovered, it become clear, that the "original" marginal cost theory can not be applied within the railway transportation sector. At the same time, the current cost calculation method of the Hungarian State Railways (HSR) meets some important requirements, and keeps the calculation on a stable way within the company. But it does not fulfil some other needs that is emerged by the demand for optimal usage of the society's scarce resources. Therefore, it seemed to be necessary to provide some further suggestions that can help the company to fit its business processes better to the needs of the market that are better represented in the marginal cost theory. These suggestions could be elaborated within a new cost calculation model, as the best. When planning the new model, the following requirements seemed to be the most important:

- to make possible to represent the economical methodology within the company;
- to utilise and to practice the domestic and international research results, that can help the company to achieve better efficiency;
- to eliminate the drawbacks of the current cost calculation system, and to give solutions for the difficulties without giving up the available features;
- to be usable in the everyday-life of the company, not only to give theoretical assumptions;
- to eliminate all serious drawbacks that could inhibit its practical usage.

It was evident already at the beginning of the research work that the marginal cost theory (and social optimum) can solve many of the current problems. At the same time, it has some serious drawbacks that its “pure” – i.e. definition-like – usage is not possible for a railway company.
According to preliminary efforts, if we can adopt some elements from the marginal cost theory, but do not insist on the classic definition, a special business model could be elaborated that considerably improves the efficiency of the business processes and serves the better utilisation of the current assets. These thoughts were the initial ones when starting the elaboration of the account based marginal cost model. This model is introduced in the following chapters both regarding the theoretical and the practical issues.

## 4. THEORETICAL BACKGROUND FOR THE ACCOUNT-ORIENTED MARGINAL COST MODEL

### 4.1 Cost Components of the Model

Since the account-oriented marginal cost model is a composite calculation scheme constructed with using the elements of the marginal cost theory, the internal controlling system of the company and the accounting processes, the data acquisition of the model can only partly depend on the neo-classical theory. Therefore, the guide of the marginal cost theory is used when:
defining the ground performance indexes and their statistical indexes;
defining the performance units;
defining cost drivers;
allocating costs to cost drivers;
structuring the cost drivers;
processing cost data trends;
evaluation and examination of cost data.
However, the account oriented marginal cost model gives up the usage of the marginal cost theory when:
processing market prices;
defining the necessary cost coverage ratio;
deciding about certain capacity-management questions.
For the requirements of the data collection (mentioned above), a new data-structure had to be worked out. This data structure provides the cost information in cost-records. The structure of the cost-record is shown by fig. 2.

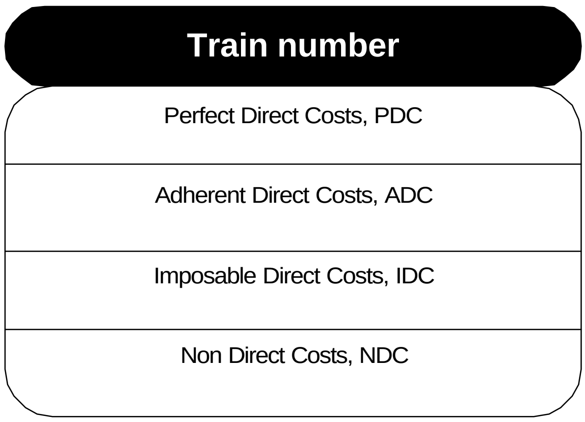


*Fig. 2. The structure of the cost record*

The elements of the PDC components are those, that can be addressed without any mathematical operation (like the fuel consumption of a certain shipment). ADC elements include those costs, that can be easily addressed to a certain train number with a simple division of time or distance (like the wage of the train driver: division by time among different trains). IDC elements are those, that can be allocated to a train number based on the ground ADC data (like the wage of the boss of the train drivers). NDC elements are rather administrative costs, and management costs, that can not be directly allocated to a train number. These are broken up to train numbers according to performance indexes.

From these cost records functions are built for each activity of the railway company according to the following equations (9), that formalise the relation between the cost components and the performance of the railway company:

$PDC_1=fp_1(q_1)+fp_2(q_1)+\ldots+fp_n(q_1);$
$PDC_2=fp_1(q_2)+fp_2(q_2)+\ldots+fp_n(q_2);$
:
$PDC_m=fp_1(q_m)+fp_2(q_m)+\ldots+fp_n(q_m);$
:
$ADC_1=fa_1(q_1)+fa_2(q_1)+\ldots+fa_q(q_1);$
$ADC_2=fa_1(q_2)+fa_2(q_2)+\ldots+fa_q(q_2);$
:
$ADC_m=fa_1(q_m)+fa_2(q_m)+\ldots+fa_q(q_m);$
:
$IDC_1=fi_1(q_1)+fi_2(q_1)+\ldots+fi_r(q_1);$
$IDC_2=fi_1(q_2)+fi_2(q_2)+\ldots+fi_r(q_2);$
:
$IDC_m=fi_1(q_m)+fi_2(q_m)+\ldots+fi_r(q_m);$
:
$NDC_1=fn_1(q_1)+fn_2(q_1)+\ldots+fn_s(q_1);$
$NDC_2=fn_1(q_2)+fn_2(q_2)+\ldots+fn_s(q_2);$
:
$NDC_m=fn_1(q_m)+fn_2(q_m)+\ldots+fn_s(q_m);$ where (9)

1…m: number of railway activities (like IC service, container transport, etc.),
1…n: number of perfectly direct cost (PDC) components,
1…q: number of adherent direct cost (ADC) components,
1…r: number of imposable direct cost (IDC) components,
1…s: number of non-direct cost (NDC) components,
$fp_i$: function of PDC elements;
$fa_i$: function of ADC elements;
$fi_i$: function of IDC elements;
$fn_i$: function of NDC elements;

Previous studies [Ron03] show that the above mentioned cost components are not available at the same time, because there is a one-month gap in the collection of the cost components. Therefore, the cost record can only be summarised with using the net present value method:

$$CRec=PV_4(PDC)+PV_4(ADC)+PV_4(IDC)+PV_4(NDC)= PDC\cdot(1+IF_M)^3+ADC\cdot(1+IF_M)^2+IDC\cdot(1+IF_M)+NDC \quad (10)$$

### 4.2 Cost Functions Correlation with the Performance

A previous research work sorted the main rail activities according to the neo-classical market structures: monopoly, oligopoly, free competition. Since the marginal cost theory provides different instructions for each market type, so does the account-oriented approach. This sub-chapter introduces the behaviour of the model in case of the two of most important market segment: the monopoly, and the free competition.
Performance-related cost, price and revenue curves for the railway company are presented in the Fig. 3.

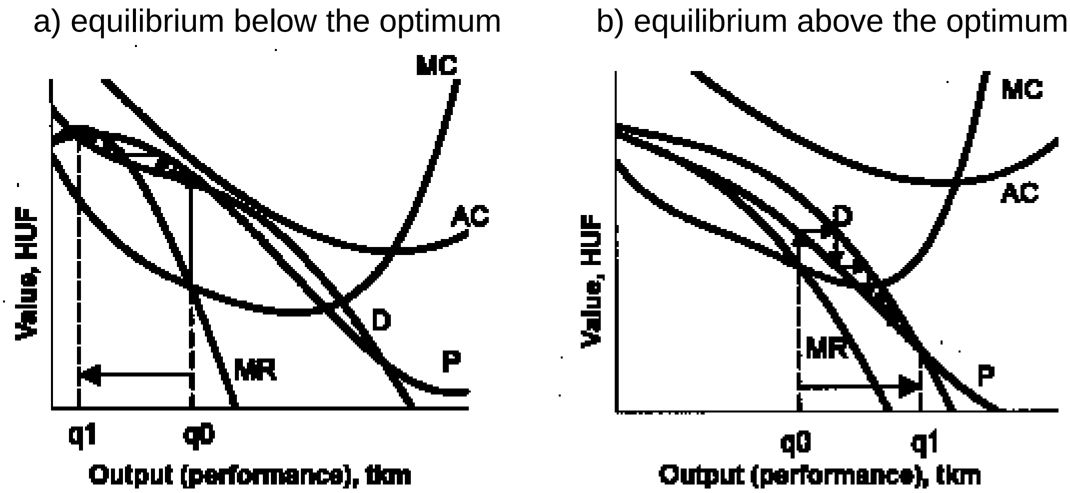


*Fig. 3. Cost curves of the account oriented marginal cost model in case of monopoly markets (MC: marginal cost; AC: average cost; D: demand; P: price function; MR: marginal revenue; q0: optimal output; q1 realised output)*

The theoretically optimal prices are set in the model similar to the marginal-cost theory: the MR=MC point provides the optimum. In this case, the MR function is derived from the price function (described in the 4.3 sub-chapter), because the demand is unknown. In this respect, the model contains a simplification: strictly speaking, the MR function should be derived from the demand function, but in this case it is assumed, that the demand and the price functions have more common points, and this simplification does not influence the optimum point.
At Fig. 3. on the graph a) the case is modelled, when the real output is smaller than the theoretical one. On the graph b) the greater real output is introduced. In both cases the equilibrium is provided as a result of a longer iteration that is shown by the short perpendicular lines in the graphs.
The demand and the marginal revenue functions have a negative slope in case of the monopoly: since the railway company is the only market actor, greater output (i.e. transport performance) is only possible at lower prices. To this shipment fields belong in Hungary the transportation of bulk goods, cereals, and some industrial raw materials (chemicals).
In case of free competition, the cost- and revenue curves are different as shown at Fig. 4. The demand function is equal to the marginal revenue function: the company has no influence to the prices of that market segment.

Therefore, the market equilibrium is reached in one great “quantity jump” as seen in Fig. 4.

a) equilibrium below the optimum b) equilibrium above the optimum

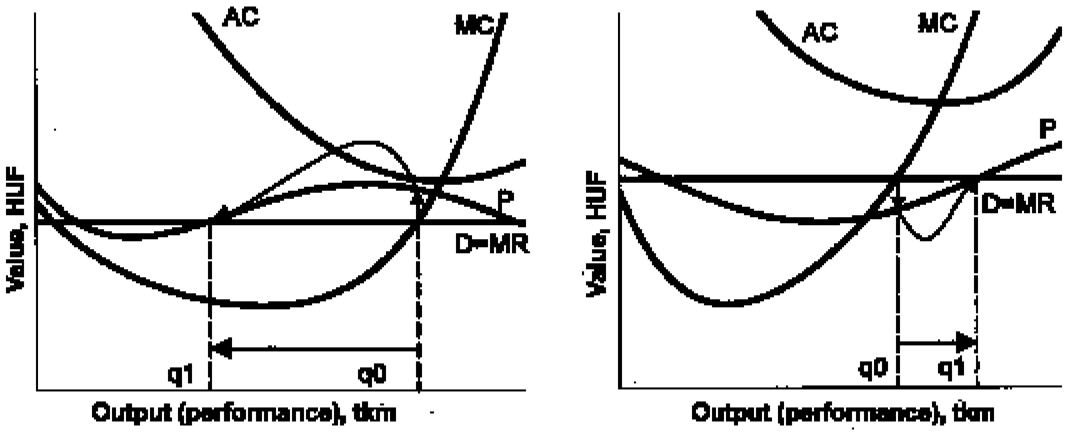


*Fig. 4. Cost curves of the account oriented marginal cost model in case of competitive markets (legend like at Fig.3)*

Also in case of competitive markets, both lower and higher real output is possible compared to the theoretical optimum: see graph a) and b).
Both in monopoly, and in competitive environment there is a need of the railway company to “fill the gap” between q1 and q0 in order to reduce the loss of the company (and to reduce the loss in the net social welfare). There are three possibilities for this:
1. Iterative modification of the price function, in order to make the real worlds intersection point (q1) closer to the theoretical optimum.
2. The fill of q1-q0 interval with administrative tools (like student discounts, dangerous goods price markups, etc.
3. Financing the loss from the state budget.

### 4.3 The Price Function of the Model

As mentioned already in the 4.2 sub-chapter, the account oriented approach does not use the market itself, but a special price function to provide prices for the railway activities. With this procedure it is possible to indicate all desired factors in the price.
First of all, core price components have to be identified in order to build factor-groups for the price function. Such a component could be the cost record elements (as described in the 4.1 chapter) or general economic data, key values from the transport policy, etc. These components are then broken down in a number of indicators (transport policy indicators can be e.g.: transport performance, modal split, capacity, etc.). When having the indicators, the current values of them have to be noticed, these will provide the independent variable for the function in case of each railway activity.
The next step is to provide the functionality between these variables and the price components. This is possible through regression-analysis or by using already developed function patterns (in this case only the parameters can change, not the function itself). When having all desired price-function

components, a weight matrix is used to give different emphasis for the different components.
As the result, the price function is provided, as shown in Fig. 5. below.

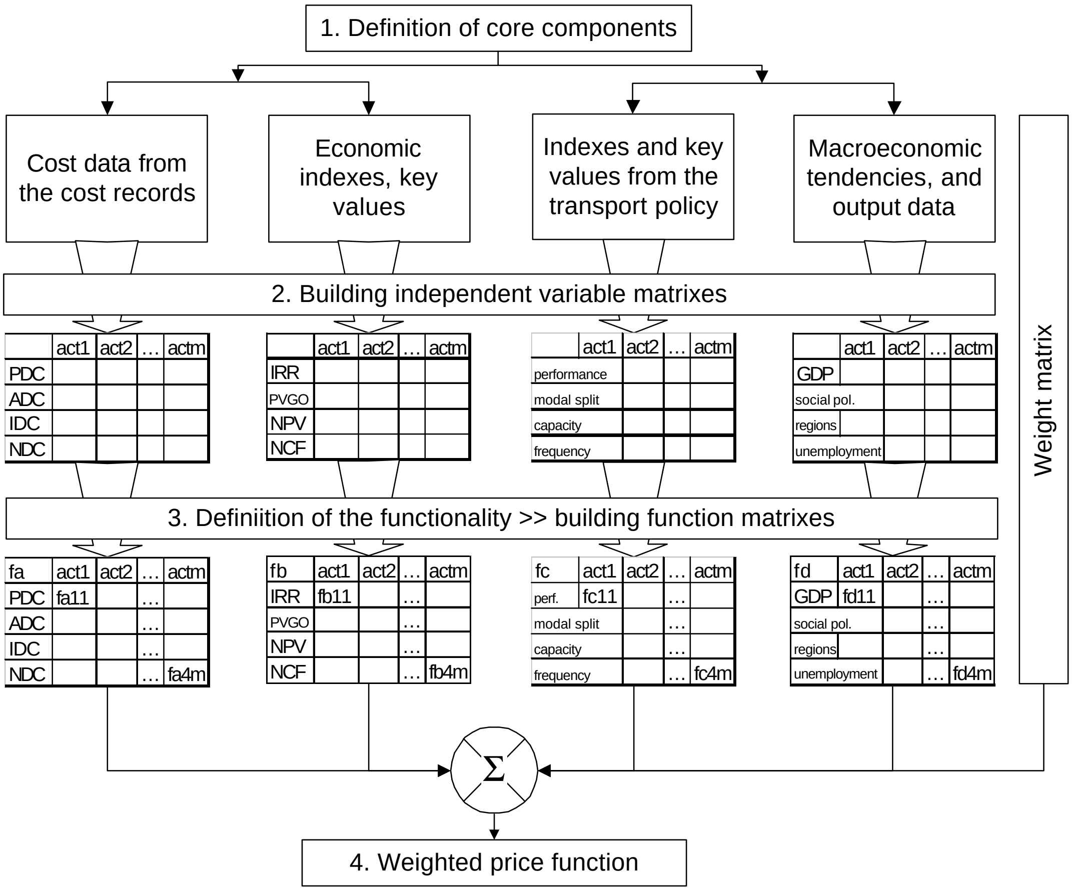


*Fig 5. Building the price function from internal and external data of the company*

The mathematical formula for the price function is:

$$P = [p_1, \quad \dots \quad, p_m] = [\mathbf{s}_1^{\mathrm{T}} \cdot \mathbf{t}_1, \quad \dots \quad, \mathbf{s}_{\mathrm{m}}^{\mathrm{T}} \cdot \mathbf{t}_{\mathrm{m}}] \qquad (16)$$

scalar multiplication of vectors, where:

1…m: number of railway activities;

$p_i$: price function of each service segments;

$\mathbf{s}_i^{T}$: linear vector, the i. row of the $\mathbf{S}_{m\times(n1+n2+n3+n4)}$-es weight-martix, i.e. the weight of the function elements of the i. railway activity (service), while: $\sum_{j=1}^{n_1+n_2+n_3+n_4} s_{ij} = 1$, and;

$\mathbf{t}_i$ vertical vector, the i. column of the $\mathbf{T}_{(n1+n2+n3+n4)\times m}$ function matrix, $n_i$: number of variables in each function-groups.

## 5. PRACTICAL EXECUTION OF THE MODEL

### 5.1 Structuring the Ground Data Terms

In the implementation path the first action is to structure the available ground data according to the needs of the model. This require the review of the company's ground processes: the disbursement cycle, the income cycle, the monetary cycle, and the production cycle. Connection of these is represented at Fig. 6 with grouped names. The cost-accounting information system is placed in the middle, since the co-ordination of all elements is intended from the information system.

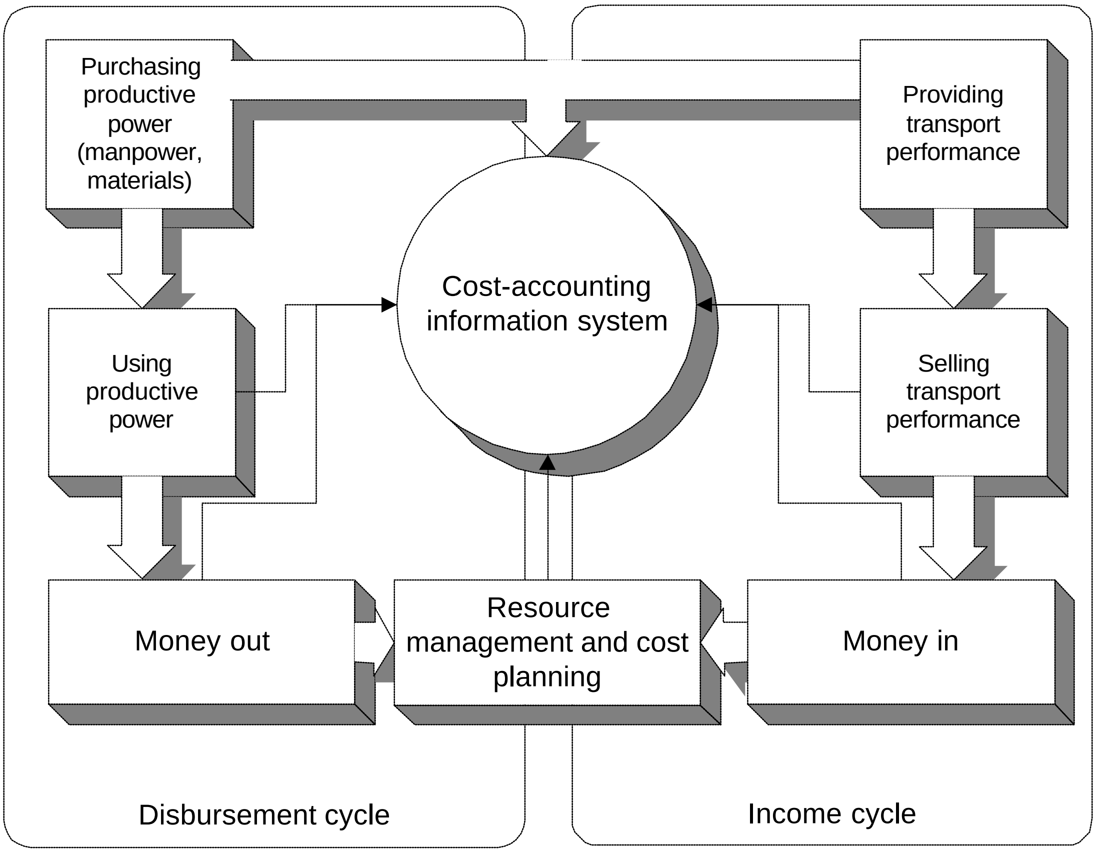


*Fig 6. Structure of the railway company's different basic cycles*

At Fig. 6. the Disbursement cycle and the income cycle is indicated directly. The production processes are to be find in the upper half of the figure, while the monetary ones are represented at the bottom. Their connection with the modelling procedures are with thin arrows. Thick arrows indicate the logical order between the elements.
As a result of this structure, all processes are fed into the model. This effects in a comprehensive working balance, i.e. means that no uncovered company process remains "outside" of the model. On this basis the decision-supporting and decision making can be started at the railway company.

## 5.2 The Decision Support Tool of the Model

The account-oriented marginal cost model is planned to work in the executive decision supporting system of the company. Since prices are not set according to the mechanism of the market itself, but according to the company's ordinance, the optimality of the prices are not ensured automatically: it is the management of the company that has to care about the actualisation of the prices that reflect the market changes. This is why it has been decided to operate the model as a part of the decision-supporting system, and not as a part of the accounting or policy making system. Fig. 7. shows the structure of the reviewed system.

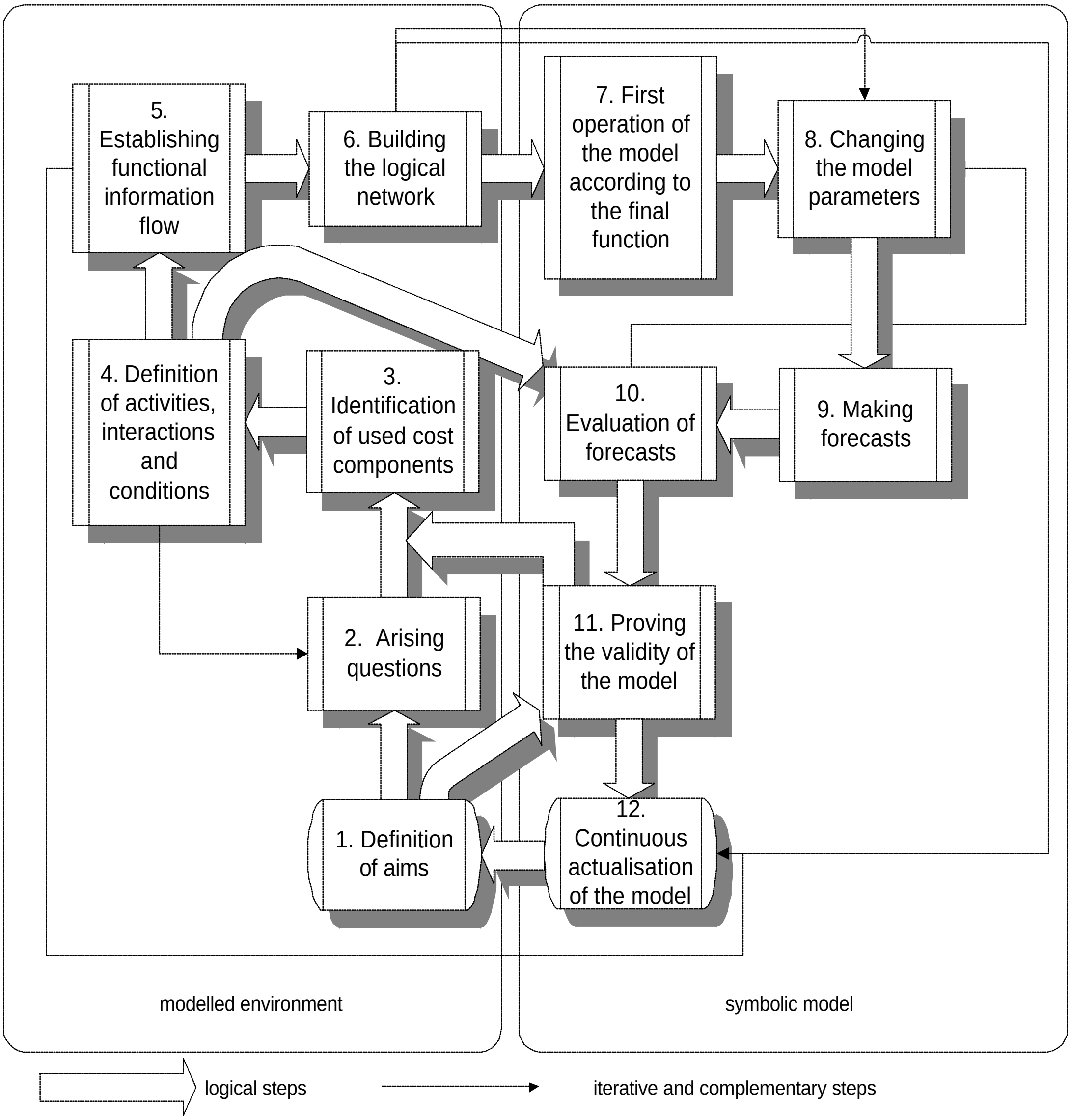


*Fig 7. Decision supporting system of the model*

In the first block (No. 1.-2.) the task is defined: the questions that the model can answer should be fixed here, and the aims of the model running is cleared. In the second block (No. 3.-6.) the real network of the model is built up. The necessary information is circumscribed, and the routes of the future information flow is created. In the third block (No. 7.-8.) the model calculations are carried out. This means the determination of the cost functions and the marginal cost for the desired railway activity. These functions can be produced for different time intervals, according to the need, arising from the first block. In the fourth block (No. 9.-10.) the results of the previous calculations are examined. These results can be used to construct the price function, to decide about some capacity constraints or to measure the effectiveness of a certain rail activity. The last block (No. 11.-12.) is only used in the case, when the questions arisen in the first block need continuous evaluation: for long term judgements more precise cost collection is needed. Therefore, when long-term examination is desired, the effectiveness and validity of the gathered data is required over a longer time period.

### 5.3 Implementation Steps of the Model

When scheduling the implementation of the model, network- and logical scheduling methods were used. The time constraints, and the logical order subalternation of the elements had to be taken into consideration, with special regards the possible parallel steps for the acceleration of the process.
The success of the model operation strongly depends on the proper processing of the implementation. Otherwise, when the model is not embedded accurately, the adequate result will not be able to serve the company's welfare. This is why the introduction of the model in the life of the company has to be planned carefully.
During the examination of the possibilities of the implementation, the process could be split into four major dimensions:
- constitutional process;
- planning process;
- establishment process and;
- information technology and database handling process.

There are many sub-steps of the implementation that can be carried out parallel with the main steps. This paper examines the main introductory steps that can be carried out in succession. These are as follows:
1. Definition of railway activities. This means the clarification of those activities that will "carry" the costs and the cost coverage will be calculated for. It seems to be applicable that these activities are equal to the products of the railway company (inland long distance trains, Inter City service, stopping trains, transport of trucks, bulk goods, liquids, frozen materials, etc.).
2. Elaboration of new index system. This is the practical realisation of data collection for the cost record. There are several indexes that need a new form, e.g. tonne-km is not a unique measurement unit for freight transport, since there are very big technological differences within the shipment of different types of goods.
3. Development of the internal information flow. Maybe the most important step of the implementation, because without the appropriate information routes the operation of the decision supporting system is impossible. To have electronic information flow is the primary aim, otherwise there will be much error in the transfer.
4. Accomplishment of documents. These are of considerable importance at the first stage of information collection. The need for proper information record occurs at the operational level, where the data about the real activities is born.

5. Development of the decision-support system. In this phase the operation of the decision support system is ready for trial usage. If any kind of difficulties are experienced, the previous steps can be reviewed and corrected.
6. Education of colleagues. Emphasis has to be made on the education of the first level workmates i.e. of those who will be responsible for data collection and record. Other and more complex education is desired for those colleagues who keep the decision support system in operation and provide the analysis of the cost functions.
7. Parallel operation of the current system and of the account-oriented marginal cost model. This should help to avoid any uncertainties till the new procedure becomes familiar to the users and to the company itself. However, this means considerable additional work for those who are affected by the system transfer.
8. Calculation of real average costs. Thank to the activity-based cost calculation tool of the account-oriented marginal cost model, firstly it becomes possible to calculate each activity's real average costs (instead of the current posterior distinctive calculation).
9. Decision system operation based on marginal cost information. This is the final aim of the implementation process, and should be used to help the owner (the state) to avoid the society's welfare loss as effective as possible.

## 6. BASIC MARGINAL COST CALCULATIONS WITH THE MODEL FOR THE FREIGHT TRANSPORT

According to the guide of the account-oriented marginal cost model, some calculation exercises have been carried out for separate activities of the railway market in Hungary. Two of these are the container-transportation, and the carload shipments. These two have different measurement unit: TEU (Twenty feet Equivalent Unit), and tkm (tonne-kilometre).
Cost components were identified as described in chapter 4.1, and separate functions for all cost-components have been calculated according to the regression-analysis. The time interval was chosen for one year, because the aim was to compare the asset capacity of the two different freight forwarding technology. For the calculation of marginal costs the aggregated variable cost function was the starting point. This function is shown by (11) for container transport, and by (12) for carload shipments. The independent variable x is expressed in TEU for container transport, and in tonne-kilometre for carload shipments.

$VC_{KN}=19724,9 \cdot e^{8,05789E-7 \cdot x}+109485 \cdot \ln x-1256860+272244 \cdot \ln x-3290350$ (11)

$VC_{KR}=2303,55 \cdot x^{0,298045}+0,0647825 \cdot x^{1,01616}+1,22503 \cdot 10^{-17} \cdot x^{3,49061}$ (12)

Calculating their first derivative results in the marginal cost function for both activities (i.e. (13) for container transport and (14) for carload shipments):

$MC_{KN}=0,0158941 \cdot e^{8,05789E-7 \cdot x}+109485 \cdot x^{-1}+272244 \cdot x^{-1}$ (13)

$MC_{KR}==686,56156 \cdot x^{-0,701955}+0,0658294 \cdot x^{0,01616}+4,276102 \cdot 10^{-17} \cdot x^{2,49061}$ (14)

Total revenue data comes from the accounts of the railway company as well:

$TR_{KN}=1706840 \cdot \ln x-12254900$ ·1000 HUF; (15)

$TR_{KR}=147722000 \cdot \ln x-2247250000$ ·1000 HUF, where x: 1000 tkm. (16)

The first derivative of (15) and (16) gives the marginal revenue function for each activity (17) and (18):

$MR_{KN} = 1706840 \cdot x^{-1}$ (17)

$MR_{KR} = 147722000 \cdot x^{-1}$ (18)

The two result functions for container transport (MC: 13 and MR: 17) can be represented in a common diagram shown by Fig 8. The current production interval is indicated by red tint.

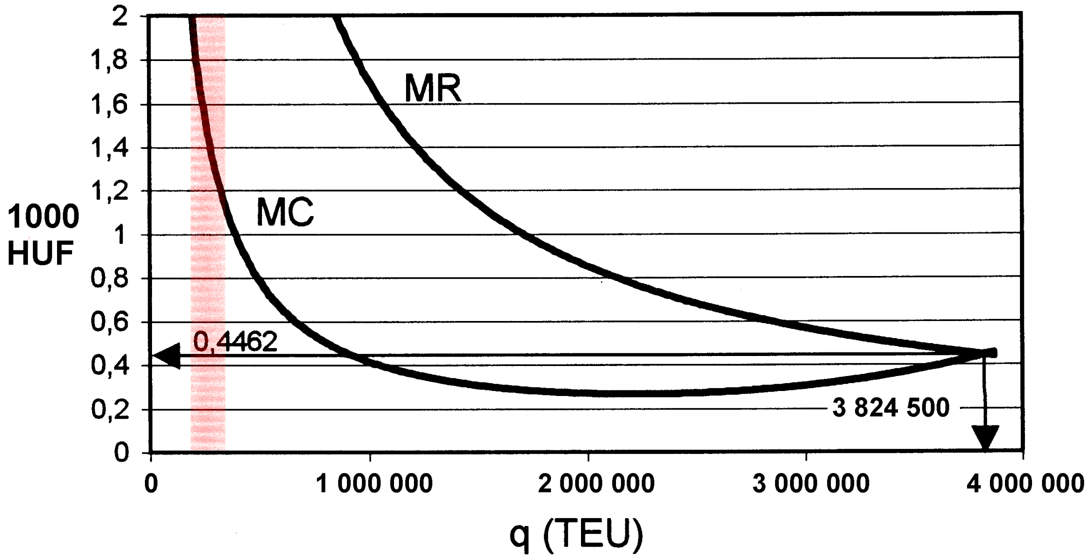


*Fig 8. Marginal cost and marginal revenue functions for container transport at the Hungarian State Railways*

Similarly, the two marginal functions for carload shipments (MC: 14 and MR: 18) are represented in Fig 9. Again, with red marks the current output level is indicated.

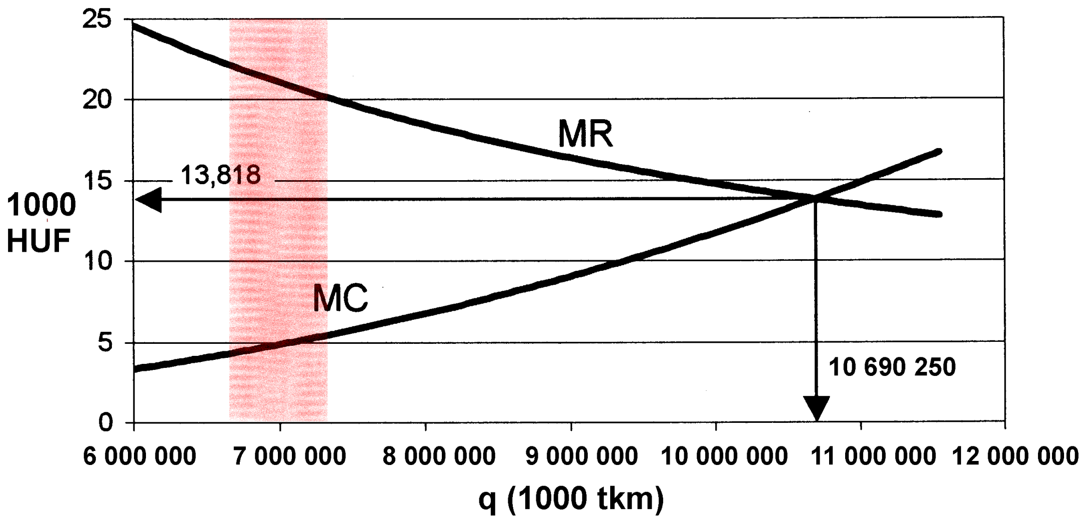


*Fig. 9. Marginal cost and marginal revenue functions for carload shipments at the Hungarian State Railways*

When considering the learning from both graphs, interesting conclusions can be made. First of all, it is important to mention, that the theoretical output level is more or less over the current performance. For container transport a

markup of approx. 20 is used, for carload shipments the situation is a bit better the markup is only 1,5-2 in this case. From the opposite point of view this means, that the available assets are not utilised properly at the railway company.
Other remark is, that the marginal costs are pretty low compared to average costs (these are not indicated in the diagrams now). This leads to the conclusion, that the share of fixed costs is relatively high in both freight transportation fields.
If we consider the fact, that the railway market was shrinked to its 60% in the last decade, it can be stated, that previously the assets for carload shipments were utilised nearly optimal.
The main lesson for the freight forwarding business branch of HSR is, that in both cases, but especially in container transport the transport performance has to be improved, otherwise it is difficult to bolster the high asset value at the railways.
However, there are some serious drawbacks of the current calculation that must be considered before making any judgements based on it. These are:
1. Different data collection system. The current statistics does not allow the proper construction of the mentioned cost records. This makes a certain error in the functions.
2. The analysis presumes constant asset value for the railways. The performance functions could only be put together with using more 10 years data, and the asset value changed meanwhile.
3. Changing accounting progress. During this time (the past 10 years) accounting standards have changed at the company. Therefore, the same account name can incorporate different contents.
4. Lack of reliable data. Some required data were missing during elaboration of the variable cost functions. This lack is not serious, but influences the reliability of the results.
These remarks are not very serious, but have to be examined separately before using the result for decision support at the railway company.

## 7. SUMMARY

The paper firstly introduced the marginal cost theory, its past and present, and analysed the pros and cons that influence its usage. The conclusion from this dissection was, that the marginal cost theory has serious advantages, but, at the same time some heavy drawbacks as well. These latter ones counteracts its immediate usage at the railway company.
To solve the problems arising from the marginal cost theory, a new model was developed, called “account-oriented marginal cost model” with high respect to the applicability. This reviewed the current data collection system and provided a new one in order to obtain clear picture about the marginal costs. It introduced a new price function that makes the basis for the company’s pricing policy in the market.
The implementation phase was elaborated carefully to support the proper work of the decision support system. This contained the elaboration of the new statistical system, the education of colleagues and the first steps of the application of the model.

To prove the validity of the model, some preliminary calculations were carried out in the freight transport field of the Hungarian State Railways. The paper examined the results of the first model running in the case of container transportation and carload shipments. The first outcome shows, that railway assets are utilised badly, i.e. under their optimal usage. This is an exclamation mark for the company to improve capacity utilisation.
The final conclusion is: if the microeconomic approach is replaced by an account-oriented one, it becomes easier to produce marginal costs for the railway company, and to drive important consequences for the owner.

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