ΠP periodica polytechnica

Transportation Engineering
40/1 (2012) 3–9
doi: 10.3311/pp.tr.2012-1.01
web: http://www.pp.bme.hu/tr

RESEARCH ARTICLE

Rail infrastructure costing based on multi-level full cost allocation

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Received 2012-05-15, accepted 2012-10-18

Abstract

Due to charging issues costs of rail infrastructure use shall be determined as exactly as possible. At the same time rail infrastructure management is a very complex system characterised by a high ratio of indirect costs. There are several costing methods used in transport and logistics but none of them gives a transparent and traceable solution for allocating indirect costs. That is why the paper aims to elaborate a transport cost calculation model adopting and utilising the multi-level full cost allocation method. The developed model and the calculation process are specified for rail infrastructure management. The new cost calculation system delivers more reliable and accurate cost data of elementary rail infrastructure services by allocating indirect costs on a cause-effect basis. At the same time additional resources may be needed for the implementation of the model. Nevertheless, as rail infrastructure manager companies request more exact cost data they should consider the implementation of the proposed costing model.

Keywords

cost calculation · cost allocation · rail transport · infrastructure

Acknowledgement

This work is connected to the scientific program of the "Development of quality oriented and harmonised R+D+I strategy and functional model at BME" project supported by the New Széchenyi Development Plan (project ID: TÁMOP-4.2.1/B-09/1/KMR-2010-0002). Furthermore, this paper is prepared with the support of the project "Modelling and multi-objective optimization based control of road traffic flow considering social and economical aspects" of OTKA (project ID: CNK 78168).

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1 Introduction

The rail transport policy of the European Union has aimed to apply an open access model in which infrastructure management and train operation shall be separated from each other. The separation of these functions has enforced the introduction of access charges representing the prices of rail infrastructure use [21].

Several surveys have been conducted evaluating rail infrastructure charges used in European countries. Reviewing the outcomes of these surveys it can be stated that a wide variety of both structure and level of charges exists in the examined countries: there are one or more steps systems combined with one or more tiers in the charging mechanisms. Total as well as marginal costs or both of them are used for setting prices. Sometimes even quality characteristics and external effects are also included in the price, etc. [18, 23] .

The common feature of various rail infrastructure charging systems is that in order to determine the prices, the costs of rail infrastructure use need to be calculated. These costs have to be calculated as exactly as possible so that the prices reflect service costs. Nevertheless, rail infrastructure management systems are in general very complex, so their cost structures are mainly characterised by a high ratio of indirect costs. In the level of elementary rail infrastructure services even 100% of costs can be regarded as indirect cost because the items can not be allocated to the infrastructure use tasks directly.

Comparing track usage costs and the charges levied leads to the key conclusion that charging systems adopting the full cost approach recover more costs than those adopting the marginal cost methodology [8]. It does not mean that rail charging systems should be established on a full cost basis only. Nevertheless, it inspires the investigation of the full costs of rail infrastructure use. Considering the fact that the related cost items are mainly indirect costs a calculation method shall be applied which is able to allocate indirect costs in rail infrastructure management systems as exactly as possible. Such a calculation model can be used as a second best solution for certain marginal cost values too.

This paper synthesises the results of a research aiming to adapt the multi-level full cost allocation (MFCA) methodology to transport and logistics, in particular to rail infrastructure management. Preceding the effective adaptation a general costing model describing the basic mathematical background is also elaborated. However, before going into the details of modelling and its practical application, it is worth reviewing the relevant literature. Although several cost calculation examples can be found in transport and logistics, none of them corresponds entirely to the methodological features of the intended MFCA modelling.

2 Cost calculation in transport and logistics

The literature contains transport or logistics related costing methods on macro as well as on micro economic levels, where the latter examples are more significant from the point of view of MFCA modelling. Starting with the macro economic applications, the most common topic in this field is the determination of total and marginal social transport costs. Transport accounts have been used for collecting the internal and external cost items of various countries. Lacking data have been replaced by estimations and the different categories of transport costs in macro level have been harmonised [17]. A rail oriented macro calculation has been carried out by analysing the internal and external costs of urban rail transit. Based on the value chain theory, the internal cost has been divided into preliminary planning and designing cost, constructing cost and operating cost. The external cost has been classified into the cost of air pollution, traffic accident and noise pollution [14].

The micro level researches often analyse the cost structure of transport branches or companies. Some of them are related to rail transport. For example the costs of rail infrastructure use have been determined on the basis of commonly used cost drivers [8]. Early cost estimation models for urban rail transport utilising the multivariable regression and artificial neural network approaches have been applied to a data set of several projects by using 17 parameters available at the early design phase [12]. A cost allocation model has been built to share operation costs among multiple users of a single rail line. The model is based on multiple measures like gross tonnage, train hours or number of trains, etc. [21].

Empiric research has been done on calculating the operation costs of bus transit transport. It turned out that physical and geographical features are important influencing factors of the costs in the case of such transportation services [9]. Another finding is that collaborative planning of transport tasks may reduce the costs of operation. Collaboration, however, needs an adequate cost allocation technique used in the network of cooperating actors [10].

The activity-based costing (ABC) method has been used to determine the costs of road haulage services. It turned out that the adoption of ABC makes cost calculations more reliable as indirect costs are allocated on the basis of activities and their cost drivers [2]. Road freight transport has also been included into complex ABC analyses [19]. ABC models combined with other methods have been applied to evaluate the operational efficiency of air transport companies [16].

Activity-based costing techniques are often applied in logistics. It has been proved that ABC principles can be applied to distribution systems after an adequate adaptation [20]. The effectiveness of ABC can be increased through the automated collection of performance data in distribution systems [24]. Logistics costs in manufacturing companies can also be determined by using ABC [13]. Traditional costing regimes are not appropriate in the case of logistics service providers either. Additional techniques, like ABC, shall be applied as supplementary cost and performance management tools. Nevertheless, no general costing model exists. The parameters of the costing model shall be adjusted to the operational characteristics of the examined company [11].

ABC models can even be extended to supply chains and they contribute to the exploration of relevant cost drivers [14]. Nevertheless, an important condition of effective supply chain costing is the harmonisation of cost definitions and calculation procedures along the entire service chain [22]. It turned out that the improved and cause-effect based cost management of supply chains is more difficult in the service sector than in the manufacturing industry [1].

Summarising the experiences of the literature review it can be concluded that there are several attempts to calculate and analyse transport or logistics costs, even in the rail transport sector. Transport or logistics related MFCA applications, however, have not been developed and realised so far. It shall be noted that well documented MFCA models of other sectors have not been reported either. Thus the elaboration of the general MFCA model and its adaptation to rail infrastructure management may be a useful contribution to the theoretical and practical methodology of transportation economics utilising management as well as technology knowledge. Of course the relevant published research results, for example the proposed cost drivers or the principles of cause-effect based allocation procedure, are also taken into account during the modelling process.

3 Methodology

The adaptation of MFCA to rail transport needs a general model describing the algorithmic procedures of the calculation. Such a decision support system is not presented in detail by the literature so the first task is to set up the basic model of MFCA including the main mathematical formulas. The calculation framework is defined on the basis of former research results [3–7]. Nevertheless, these results have been improved and systematised, which has yielded a consistent and relatively simply applicable costing tool.

The proposed model illustrated by Figure 1 depicts the operation of the examined company. It enables the identification of operational units causing the indirect costs and also the relations between these entities. The relations between the units and the elementary products or services can also be explored through this modelling technique. The model consists of three types of elements: the cost objects, the profit objects and the performance relations connecting the objects to each other.

Indirect costs are first recorded in cost objects as primary costs. The primary cost of a cost object can be determined on the basis of the resources (e.g. workforce, means of production, extern services utilised, etc.) assigned. Cost objects are typically organisational units and pieces of equipment or machinery, depending on the operational characteristics of the company, and are arranged into a multi-level hierarchical structure. They can serve other cost objects or can contribute to the production of end-products or end-services. Each cost object shall be provided with an indicator measuring its performance. These indicators serve as cost drivers in the course of cost allocations.

Profit objects are the end-products or the end-services of the company which gain revenues. Direct costs can be assigned to profit objects directly while indirect costs are allocated through using the multi-level network of cost objects.

The relations between the objects represent the performance consumptions. These are the basis of cause-effect based indirect cost allocations. The allocation of indirect costs starts in the highest level of object hierarchy and goes to the lower levels. The process ends when all indirect costs appear in the profit objects. It shall be noted that intra-level relations or even feedbacks may theoretically exist in the model. Such kind of allocations can make the calculation very complex, which leads to iterative or heuristic solutions. That is why intra-level connections or feedbacks shall be ignored during the modelling process as far as it is possible, even if it mitigates the correctness and accuracy.

To support the mathematical description the following notation is introduced:

- cost object index: $k = 1 \dots n$;
- service cost object index: $i = 1 \dots n$ (these are the same cost objects but here they act as service providers);
- profit object index: $j = 1 \dots m$.

The total cost of a cost object is the sum of its primary cost and the (so called intern service) cost items allocated according to the relative performance consumption:

$$C_k = C_k^p + \sum C_i p_{ki} \tag{1}$$

where:

C_k total cost of cost object k;
C_k^p primary cost of cost object k;
C_i total cost of service cost object i;
p_{ki} performance intensity, i.e. the relative performance consumption of cost object k at service cost object i.

The total cost of a profit object is the sum of its direct cost and the (so called indirect operational) cost items allocated according to the relative performance consumption:

$$C_j = C_j^d + \sum_{i=1}^{n} C_i p_{ji} \tag{2}$$

where:

C_j – total cost of profit object j;
C_j^d – direct cost of profit object j;
p_{ji} – performance intensity, i.e. the relative performance consumption of profit object j at service cost object i.

The following restriction shall be taken into account for all i (i.e. the entire performance of each service cost object is consumed):

$$\sum_{k=1}^{n} p_{ki} + \sum_{j=1}^{m} p_{ji} = 1 \tag{3}$$

As mentioned above, the sequence of the calculation is fixed: the allocation has to be carried out starting with the higher levels and moving towards the lower ones. The cost of a given object can be calculated only if the total cost data of its service objects are already available.

Considering the ultimate or aggregated outputs of MFCA it can be concluded that its results are the same as the ones of the accounting system. The real added value of the model is the cause-effect based and traceable allocation of indirect costs. The more exact cost allocation makes it possible to ignore the arbitrary cost distribution techniques when determining the costs of elementary products or services in complex business-technology systems like rail infrastructure management.

4 Calculation model

After building up the general MFCA costing scheme the specific calculation model of rail infrastructure management is to be worked out. It means that appropriate cost and profit objects shall be selected and then their intern service connections or performance relations shall be investigated by adding also the suitable performance indicators and their dimensions. It is notable that the example model proposed in the following is one of the possible cost calculation systems of rail infrastructure management. Its elements and relations are based on documented or observed empirical information of relevant business and technology processes. So the model must be adjusted to the operation structure of the examined infrastructure manager (IM) company before the implementation.

Fig. 2 shows the specific MFCA model of rail infrastructure management based on the improved presentation of former research results [5]. Single infrastructure use tasks ($w = 1 \dots W$) have been selected as profit objects. No direct cost elements can be identified in this level. The cost objects can be classified into three groups:

1 the cost objects representing the general management or background intern services in the IM company like the general, the financial or the human management unit and the department for information technology (IT);

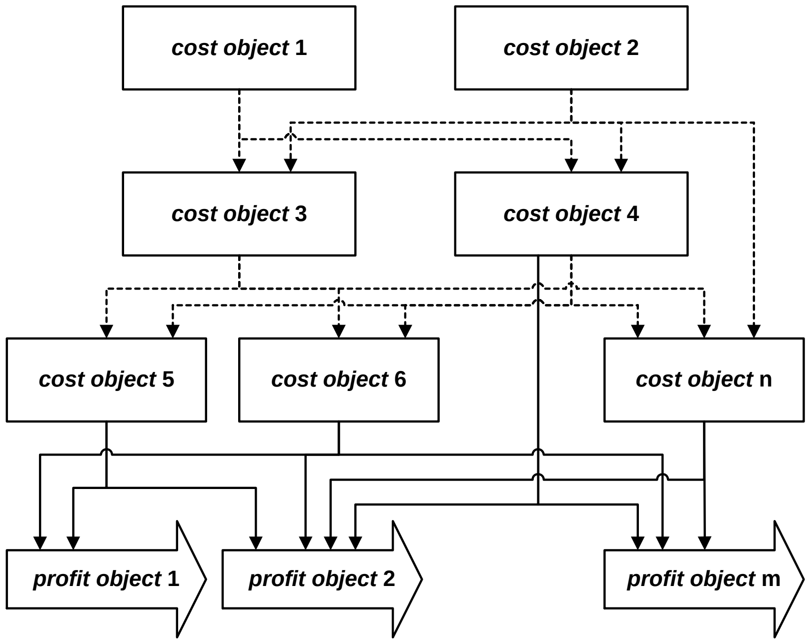

Fig. 1. The general MFCA model

2 the cost objects representing the units of operative and tactical control or execution like service planning, operative control, sales, infrastructure maintenance and the maintenance of communication, power and safety (CPS) equipment and there are also the station services (x = 1...X). These cost objects are served by the cost objects of Group 1 and serve the cost objects of Group 3 or the profit objects;

3 the cost objects representing the assets, namely the pieces of equipment and infrastructure like construction works (y = 1...Y), track sections (z = 1...Z) or electric wire sections (v = 1...V). They serve the profit objects.

The selected performance indicators and their dimensions are shown in Table 1. These indicators have been identified on the basis of practice. Nevertheless, the complementary application of mathematical methods like regression analysis or analytic hierarchy process (AHP) may refine the set of cost drivers [4, 7].

5 Calculation process

The effective calculation of elementary infrastructure use tasks can be performed by using Eqs. (1) and (2) on the basis of the cause-effect relationship network depicted in the specific MFCA model (see Fig. 2). The following gives a generalised guideline on the allocation procedure by using parameters instead of loading concrete data values into the model.

As mentioned before the sequence of the calculation steps is fixed. The first step is to calculate the total cost of the so called non-productive cost objects. These are not in connection with the profit objects and can generally be found in the higher levels of object hierarchy. The calculation sequence is also fixed within this group of cost objects as some of them are in service connection with each other. Table 2 shows how to calculate the total costs of non-productive cost objects by following the allocation sequence. The primary cost data shall be exploited form the general ledger while the allocated cost items can be calculated by using equation (1). Note that the substituted performance parameters refer to relative performance consumptions. For example dir.no.$_{finman/genman}$ = (the number of directions “consumed” by financial management) / (the number of directions “produced” by general management), and so on.

After having determined the total cost of non-productive cost objects the total cost of the so called productive cost objects can be carried out in the second step, similarly as in the first step (see Table 3). Such cost objects are in connection with the profit objects and can generally be found in the lower levels of object hierarchy.

The last step is to determine the total cost of profit objects, here of infrastructure use tasks. The calculation is performed by using equation (2), similarly as in the first and second steps. Note that no direct costs have been identified in this level so the total cost of a certain infrastructure use task consists of the allocated indirect cost items only (see Table 4).

6 Advantages and constraints of implementation

The example calculation has justified that the allocation of indirect costs in the MFCA model is transparent, traceable and is driven by cause-effect relations. So the calculated cost of an elementary rail infrastructure use task is probably more accurate than the result produced by the traditional costing regime applying arbitrary allocation principles, e.g. generalised average values or simple averaging, etc. If more accurate cost data of rail infrastructure services are available and they are utilised by the pricing regime the charging system will better reflect the operation costs and may contain less distortions.

Nevertheless, the outputs of the MFCA model may not be absolutely perfect even if they are generally more accurate than

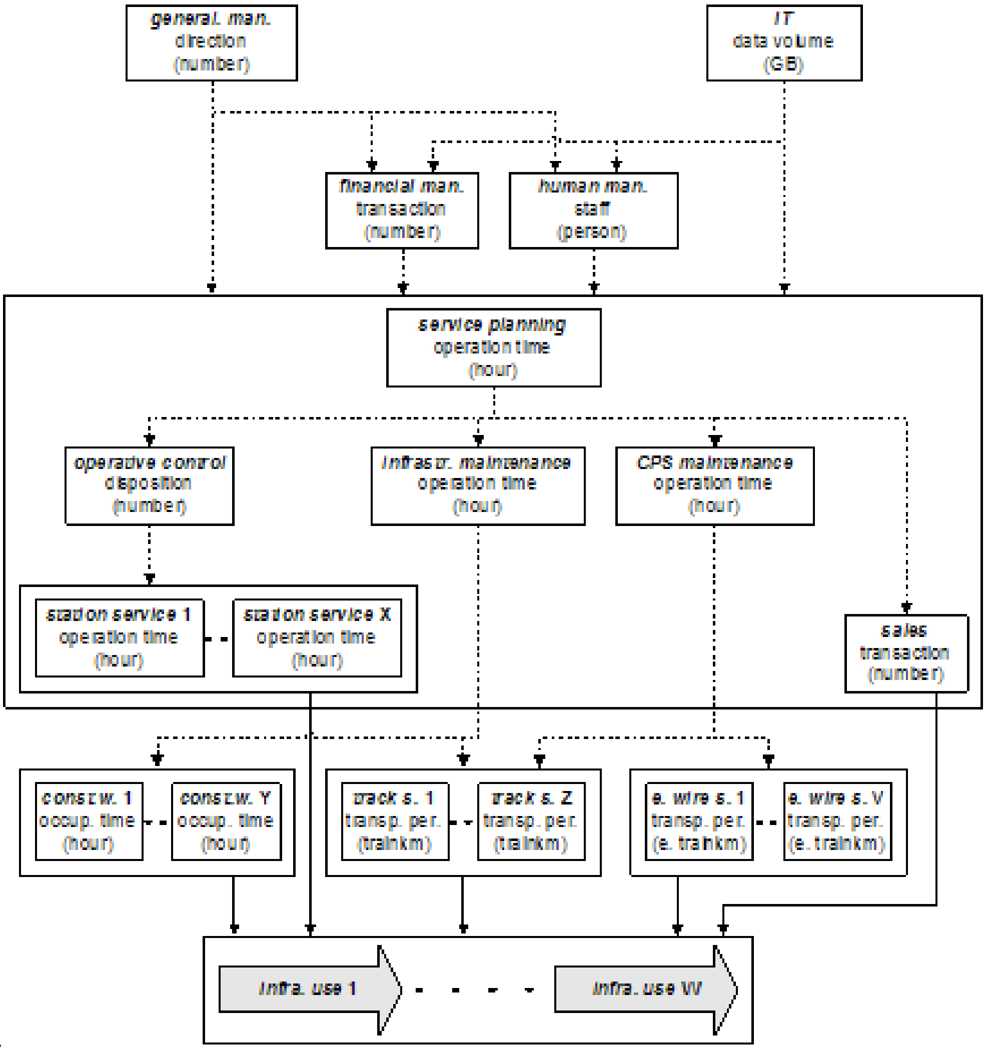

Fig. 2. The MFCA model of rail infrastructure management

Tab. 1. Performance indicators and their dimensions

cost object	*performance indicator*	*dimension (notation in the calculation)*
general management	direction	number (dir.no.)
information technology (IT)	data volume	gigabyte (data.GB)
financial management	transaction	number (trans.no.)
human management	staff served	person (person)
service planning	operation time	hour (op.hour)
operative control	disposition	number (disp.no.)
infrastructure maintenance	operation time	hour (op.hour)
CPS maintenance	operation time	hour (op.hour)
sales	transaction	number (trans.no.)
station service	operation time	hour (op.hour)
construction work	occupation time	hour (oc.hour)
track section	transport performance	train kilometre (trainkm)
electric wire section	transport performance	electric train kilometre (e.trainkm)

the traditional values. It is caused by the constraints of implementation. The first problem to be mentioned is the low quality of input data. It is usual that the general ledger is not able to deliver the primary and direct cost data in the requested format. Furthermore, the technology information systems produce a lot of natural parameters but their outputs may not be sufficient for

Tab. 2. Cost calculation of non-productive cost objects

total cost	***primary cost***	***allocated cost***
C_{genman}	C^p_{genman}	-
C_{IT}	C^p_{IT}	-
C_{finman}	C^p_{finman}	$C_{genman} dir.no._{finman/genman} + C_{IT} data.GB_{finman/IT}$
C_{humman}	C^p_{humman}	$C_{genman} dir.no._{humman/genman} + C_{IT} data.GB_{humman/IT}$
$C_{servplan}$	$C^p_{servplan}$	$C_{genman} dir.no._{servplan/genman} + C_{IT} data.GB_{servplan/IT} + C_{finman} trans.no._{servplan/finman} + C_{humman} person_{servplan/humman}$
$C_{opcontrol}$	$C^p_{opcontrol}$	$C_{genman} dir.no._{opcontrol/genman} + C_{IT} data.GB_{opcontrol/IT} + C_{finman} trans.no._{opcontrol/finman} + C_{humman} person_{opcontrol/humman} + C_{servplan} op.hour_{opcontrol/servplan}$
C_{inmain}	C^p_{inmain}	$C_{genman} dir.no._{inmain/genman} + C_{IT} data.GB_{inmain/IT} + C_{finman} trans.no._{inmain/finman} + C_{humman} person_{inmain/humman} + C_{servplan} op.hour_{inmain/servplan}$
$C_{CPS\,main}$	$C^p_{CPS\,main}$	$C_{genman} dir.no._{CPS\,main/genman} + C_{IT} data.GB_{CPS\,main/IT} + C_{finman} trans.no._{CPS\,main/finman} + C_{humman} person_{CPS\,main/humman} + C_{servplan} op.hour_{CPS\,main/servplan}$

Tab. 3. Cost calculation of productive cost objects

total cost	***primary cost***	***allocated cost***
$C_{statserv_x}$	$C^p_{statserv_x}$	$C_{IT} data.GB_{statserv_x/IT} + C_{finman} trans.no._{statserv_x/finman} + C_{humman} person_{statserv_x/humman} + C_{opcontrol} disp.no._{statserv_x/opcontrol}$
C_{constv_y}	$C^p_{constv_y}$	$C_{inmain} op.hour_{constv_y/inmain}$
C_{tracks_z}	$C^p_{tracks_z}$	$C_{inmain} op.hour_{tracks_z/inmain} + C_{CPS\,main} op.hour_{tracks_z/CPS\,main}$
C_{ewires_v}	$C^p_{ewires_v}$	$C_{CPS\,main} op.hour_{ewires_v/CPS\,main}$
C_{sales}	C^p_{sales}	$C_{genman} dir.no._{sales/genman} + C_{IT} data.GB_{sales/IT} + C_{finman} trans.no._{sales/finman} + C_{humman} person_{sales/humman} + C_{servplan} op.hour_{sales/servplan}$

the model, etc. Low data quality may lead to second best solutions like data transformations or estimations.

Another relevant problem is that the model does perfectly not reflect the operation of a company with an extensive service network and a complex operational structure, like a rail infrastructure manager. Some simplifications shall be accepted for the sake of applicability, so that the model can be implemented as a functioning decision support tool.

The constraints, i.e. simplifications or estimations, may mitigate the accuracy of MFCA costing models. Nevertheless, a non-perfect MFCA costing system may be even better than a traditional rail infrastructure costing regime. The accuracy of MFCA can be enhanced by improving the data collection mechanisms or through refining the operational model. These measures, however, will probably require additional resources. Thus a sound consideration of advantages and constraints is needed before deciding about the introduction of MFCA in transport sector, in particular in rail infrastructure management.

7 Conclusions

It can be stated that the adoption of MFCA method makes rail infrastructure costing more accurate and reliable, provided

Tab. 4. Cost calculation of profit object "infrastructure use w" (iu_w)

$C_{statserv_1} op.hour_{iu_w/statserv_1} + ... + C_{statserv_x} op.hour_{iu_w/statserv_x}$
$C_{constw_1} oc.hour_{iu_w/constw_1} + ... + C_{constw_y} oc.hour_{iu_w/constw_y}$
$C_{tracks_1} trainkm_{iu_w/tracks_1} + ... + C_{tracks_z} trainkm_{iu_w/tracks_z}$
$C_{ewires_1} e.trainkm_{iu_w/ewires_1} + ... + C_{ewires_v} e.trainkm_{iu_w/ewires_v}$
$C_{sales} trans.no._{iu_w/sales}$
Σ above = total cost of "infrastructure use w" (C_{iu_w})

that the adaptation to the operational characteristics is ensured. Distortions caused by the arbitrary allocation of indirect costs are reduced while the costs of elementary rail infrastructure services become visible. This information can be useful for better establishing rail infrastructure charging regimes.

The practical implementation, however, requires the detailed description of the calculation model and its algorithms, as well as the availability of high quality input data. It can lead to additional administrative expenditures. The modelling procedure may simplify the real operational conditions and estimations may also be needed to run the model properly. All these facts can reduce the reliability of the delivered costing information which is usually even better than the one of traditional costing.

Decision makers shall consider the advantages and the constraints of MFCA implementation when deciding about the scope of introduction. The advantages of MFCA can be utilised in companies where the management of indirect costs is difficult. As rail infrastructure managers are such companies it is worth considering the implementation of MFCA in this field along the principles and guidelines summarised in the paper.

References

1 **Askarany D, Yazdifar H, Askary S**, *Supply chain management, activity-based costing and organisational factors*, International Journal of Production Economics **127** (2010), no. 2, 238–248, DOI 10.1016/j.ijpe.2009.08.004.

2 **Baykasoglu A, Kaplanoglu V.**, *Application of activity-based costing to a land transportation company: a case study*, International Journal of Production Economics **116** (2008), no. 2, 308–324, DOI 10.1016/j.ijpe.2008.08.049.

3 **Bokor Z.**, *Elaborating cost and performance management methods in transport*, Promet – Traffic & Transportation **21** (2009), no. 3, 217–224, DOI 10.7307/ptt.v21i3.228.

4 **Bokor Z.**, *Improving transport costing by using operation modeling*, Transport **26** (2011), no. 2, 128–132, DOI 10.3846/16484142.2011.586111.

5 **Bokor Z.**, *Cost calculation models for rail transport*, Horizons of Railway Transport **2** (2011), no. 1, 5–19.

6 **Bokor Z.**, *Calculation model for transport costing*, Periodica Polytechnica ser. Transportation Engineering **39** (2011), no. 1, 43–47, DOI 10.3311/pp.tr.2011-1.08.

7 **Bokor Z.**, *Integrating logistics cost calculation into production costing*, Acta Polytechnica Hungarica **9** (2011), no. 3, 163–181, DOI 10.3311/pp.tr.2011-1.08.

8 **Calvo F., De Ona J.**, *Are rail charges connected to costs?*, Journal of Transport Geography **22** (2012), 28–33, DOI 10.1016/j.jtrangeo.2011.11.004.

9 **Cubukcu K. M., De Ona J.**, *Examining the cost structure of urban bus transit industry: does urban geography help?*, Journal of Transport Geography **16** (2007), no. 4, 278–291, DOI 10.1016/j.jtrangeo.2007.09.001.

10 **Frisk M., Gothe-Lundgren M., Jornsten K., Ronnqvist M.**, *Cost allocation in collaborative forest transportation*, European Journal of Operational Research **205** (2010), no. 2, 448–458, DOI 10.1016/j.ejor.2010.01.015.

11 **Griful-Miquela C.**, *Activity-based costing methodology for third-party logistics companies*, International Advances in Economic Research **7** (2001), no. 1, 133–146, DOI 10.1007/BF02296598.

12 **Gunduz M., Ugur L. O., Ozturk E.**, *Parametric cost estimation system for light rail transit and metro trackworks*, Expert Systems with Applications **38** (2001), no. 3, 2873–2877, DOI 10.1016/j.eswa.2010.08.080.

13 **Krajnc J., Logozar K., Korosec B.**, *Activity-based management of logistic costs in a manufacturing company: a case of increased visibility of logistic costs in a Slovenian paper manufacturing company*, Promet Traffic&Transportation **24** (2012), no. 1, 15–24, DOI 10.7307/ptt.v24i1.265.

14 **Li W., Yin S.**, *Analysis on cost of urban rail transit*, Journal of Transportation Systems Engineering and Information Technology **12** (2012), no. 2, 9–14, DOI 10.1016/S1570-6672(11)60190-6.

15 **Lin B., Collins J., Su R. K.**, *Supply chain costing: an activity-based perspective*, International Journal of Physical Distribution & Logistics Management **31** (2012), no. 10, 702–713, DOI 10.1108/EUM0000000006286.

16 **Lin W-CH., Collins J., Su R. K.**, *Financial performance and customer service: an examination using activity-based costing of 38 international airlines*, Journal of Air Transport Management **19** (2012), no. 1, 13–15, DOI 10.1016/j.jairtraman.2011.12.002.

17 **Link H.**, *Transport accounts – methodological concepts and empirical results*, Journal of Transport Geography **13** (2005), no. 1, 41–57, DOI 10.1016/j.jtrangeo.2004.11.004.

18 **Nash CH.**, *Rail infrastructure charges in Europe*, Journal of Transport Economics and Policy **39** (2005), no. 3, 259–278.

19 **Nurminen T., Korpunen H., Uusitalo J.**, *Applying the activity-based costing to cut-to-length timber harvesting and trucking*, Silva Fennica **43** (2009), no. 5, 847–870.

20 **Pirttila T., Hautaniemi P.**, *Activity-based costing and distribution logistics management*, International Journal of Production Economics **41** (1995), no. 1-3, 327–333, DOI 10.1016/0925-5273(94)00085-9.

21 **Resor R. R., Patel P. K.**, *Allocating track maintenance costs on shared rail facilities*, ITransportation Research Record **1785** (2002), 25–32.

22 **Schulze M., Seuring S., Ewering CH.**, *Applying activity-based costing in a supply chain environment*, International Journal of Production Economics **135** (2012), no. 2, 716–725, DOI 10.1016/j.ijpe.2011.10.005.

23 **Tánczos K., Farkas GY.**, *Problems and issues of defining user charges for railway infrastructure*, Periodica Polytechnica ser. Transportation Engineering **28** (2000), no. 1-2, 103–116.

24 **Varila M., Seppanen M., Suomala P.**, *Detailed cost modelling: a case study in warehouse logistics*, International Journal of Physical Distribution & Logistics Management **37** (2007), no. 3, 184–200, DOI 10.1108/09600030710742416.