The Costs Calculation And Modelling In Transport

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Abstract
Transport plays irreplaceable role in social and economic development of the society. The role of the public transport in the development of villages and cities or regions is also apparent and not only as a counterbalance to the individual transport. The public transport or the obligation of public service is defined as such an obligation that an forwarder - on the basis of his own business interests - would never undertake or would not undertake within then same extension or under the same conditions. There are many reasons why the state is interested in the capability to specify and distinguish particular sorts of transport costs and consequently the necessity of the unified method of costs calculation which this article deals with. Concurrently possible ways of using this method are presented on examples. The method does not consider the so-called external costs that are not included in the accounting of companies and that are difficult to be quantified. It only deals with internal costs.

KEY WORDS: costs, direct, indirect, tariff, costs calculation, public transport, automobile transport

General Interpretation of Costs

In general the basic prerequisite of economic efficiency of a company is profitability which can be expressed as a ratio of gained profit to costs necessary for carrying out a given performance. By the term performance we understand the number of production units described as the so-called cost units. In road transport these units are usually considered 1 kilometre (further divided into 1 driven kilometre and 1 kilometre written in the time table or 1 loaded kilometre) and 1 hour of waiting time (or 1 hour of operation).

Further it is necessary to consider that even though we can perceive a bus with a driver as a one indivisible whole, in fact the bus and drivers are often used in a different way (for example there will be more drivers on a bus or a driver will operate without using a bus).Therefore we have to perceive both the bus and the driver as a part of a transport set moving on a road. From this it logically follows that the driving bus costs are calculated as the sum of bus costs (driving costs and waiting costs) and all the drivers costs while the performance of each part of the transport set (bus plus driver) are measured in different units (1 kilometre of driving and 1 hour of waiting at a bus and 1 hour of driver´s work). While in road transport these units are enough for our purpose, in the rail transport, which is technologically much more complicated, we need to define many more such units.

Providing that a train (or transportation set) consists of 4 parts (1 locomotive, several cars, 1 locomotive crew, 1 train crew), we can analogically deduce that for the train drive costs calculation we will need these cost units: locomotive kilometre and hour, car kilometre and hour, locomotive crew work hour and train crew work hour. As the consumption of the locomotive drive (or for example the part of the fee for using the railway infrastructure) will depend on the weight of the train there is the necessity to quantify other unit costs, i.e. gross ton kilometres. There are also the costs relating directly the entire train (for example the part of the fee for using the railway infrastructure) which means that another unit is needed, i.e. train kilometres. Within the framework of operation there are a lot of other activities for which it would be necessary to define other cost units but to make it simpler let us consider them indirect costs.
However let us return to the calculation of bus drive costs. Even though we have defined the cost units - the bearer of costs - it is not sufficient. Now it is necessary to sort the costs in detail. First we have to determine what costs, or what kinds of costs, rise during certain activity. The costs that are clearly linked with a given unit (e.g. to make a bus drive off we need fuel, tyres etc.) we can mark as direct costs. The costs we have to expend but whose relationship towards a given unit is not so unambiguous can be considered indirect costs (expenditure, general costs). In the next step it is necessary to sort the costs into those which are not dependent on the production volume or the extension of transport performance – the so-called fixed costs and into the costs that are dependent on the performance (kilometres, hours) – the so-called variable cost.

Mathematical Modelling of the Costs in Transport

If we will model the costs, the modelling can be based on their division into fixed and variable costs or direct and indirect costs. In the first case the cost model is described by the following function: [1]

$$N = N_{fix} + n_1 \cdot V + n_2 \cdot V^2 + \cdots + n_{m-1} \cdot V^{m-1} + n_m \cdot V^m \quad (1)$$

N … total costs (monetary unit/year)
N_{fix} … fixed costs, independent of production (monetary unit /year)
V^k ... volume of production (pcs^k/year); k = 1,2,3, …, m
n_k ... coefficients of dependence (monetary unit /pcs^k); k = 1,2,3, …,m

If we want to know the value of cost per factory unit, we use the division of cost for the calculation purposes into direct and indirect costs. The direct costs can be directly measured per calculation unit, which means first of all material and direct pays. The costs that cannot be classified in such a way and that are common to more cost units are called indirect. If we consider the division into direct costs N_P and indirect N_{NP} to be of key importance, we will start from the relation for total costs N_C:

$$N_C = N_P + N_{NP} \tag{2}$$

The total cost will not be the key ones, it is necessary to focus on the unit costs where we can calculate the so-called tariffs. These tariffs may be dependent on number of hours of operation or on driven kilometres. Then we will set the tariffs per one kilometre:

$$ts_{km} = \sum_{l=1}^{n} n_{km}^{l} \tag{3}$$

where:
ts_{km} … tariff per one kilometre (monetary unit /km)
n_{km}^{l} … l-th type of unit costs

If we insert into formula (2) also the main cost items, we get a more detailed structure of the costs. Regarding the fact that the direct costs depend either on kilometre or operation hour and the indirect are measured per a time unit, we follow two rules when setting the tariffs per one kilometre:

- In the first step we will divide the independent cost by annual operation period of a vehicle and the calculated value is included into the costs of tariff per one hour of waiting
- The costs dependent on the number of operation in particular items of the calculation formula are divided by speed and the result will be presented in the costs per one driven kilometre

$$ts_{km} = n_{PH} + n_{PNEU} + n_{OST} + \frac{n_{HOD}^{P}}{v} + n_{ODP} + n_R \tag{4}$$

where:
n_{PH} … fuel unit costs (monetary unit/km)
n_{PNEU} … tyres unit costs (monetary unit/km)
n_{OST} … other direct costs, particularly material and maintenance costs (monetary unit/km)
v … travel speed (monetary unit/h)
n_R … unit indirect costs (monetary unit/km)
n_{ODP} … depreciation costs (monetary unit/rok)

or:

$$ts_{km} = c \cdot p_{PH} + n_{PNEU} + n_{OST} + \frac{n_{HOD}^{P}}{v} + \frac{N_{ODP} + N_R}{L} \tag{5}$$

where:
c … fuel consumption per kilometre (l/km)
p_{PH} … unit price of fuel (monetary unit/l)
n_p … other direct costs – repair works, direct pays etc. (monetary unit/km)
N_{ODP} … depreciations of a vehicle (monetary unit/year)
N_R ... indirect costs (monetary unit/year)
L … driven kilometres per annum (monetary unit/year)

The special item is the indirect costs. They are not generated directly along with the production of a given unit but a company expends these costs and therefore it is desirable to add them somehow to the direct costs per unit. In the case of running only one bus the calculation is unambiguous and it is similar to the calculations within the item of depreciation. However the question arises what the indirect costs of particular buses will be like if we ran more of them. The key to the indirect costs calculation, in other words how high the part of indirect costs will be assigned to each bus, is set by each company itself. Even though we can simply divide the total indirect costs by the number of buses (and each bus will bear the same part of indirect costs), this does not have to be desirable as the buses may differ in value of purchase price (CZK), transport performances (km), capacity (number of seats) or any other important parameter. For objectification of the division of indirect costs we can of course use various combinations of these magnitudes (e.g value of purchase price x transport performance etc.)

Regarding the fact the transport performance does not have to consist of only single drive but also waiting (e.g. rest, loading or unloading) it is necessary to set an hour tariff of costs. We can calculate it according to the following formula:

$$ts_{HOD} = n_{mzd}^{h} + n_{ost}^{h} + \frac{N_{ODP}+N_{R}}{T}, \text{ where} \quad (6)$$

ts_{HOD}	…	tariff per one hour of operation (monetary unit/hour)
T	…	time of operation (hour/year)
n_{mzd}^{h}	…	hourly rate of pay costs (monetary unit /hour)
n_{ost}^{h}	…	hourly rate of other costs, for example allowances (monetary unit/hour)

We can calculate the total costs of operation N_C as a sum of total costs of waiting and total costs drive costs according to the formula:

$$N_c = ts_{km} \cdot L + ts_{hod} \cdot T \quad (7)$$

Now we got into a phase when we can calculate particular costs per one driven kilometre for transport purposes (the so-called purpose kilometres). The number of these kilometres is logically lower because the availability, crossing and stabling kilometers or further indirect costs (e.g. drives to garage, to fill up and to check) are not included in them. These unitt costs will follow from this formula:

$$n_{ukm} = \frac{ts_{km} \cdot L + ts_{hod} \cdot T}{L_{ukm}} \quad (8)$$

n_{ukm}	…	one driven kilometre costs for transport purposes (CZK/Km)
L_{ukm}	…	number of driven kilometres for transport purposes (Km/year)

Practical Usage

The method of costs calculation is of course of key importance in economic activities of transport companies. But transport exceeds into the public sector as well. During the 20th century the public transport had to face the gradually increasing phenomenon of automobile transport. Despite its all merits for the mankind it became a problem due to the damage to the environment, particularly in cities. At the same time it lured public transport passengers away and thus an important part of revenues. The environment factor is one of crucial reasons why the state deals with public transport services so carefully. Then the legislative and social reasons follow. Through the transport policy the state wants to provide transport to schools for children (children cannot drive a car), to increase the opportunity to commute not only to work but other destinations. This can of course result in many positive economic phenomena – for example higher employment means a positive impact on the economy of public budgets nevertheless these phenomena can be badly quantified and verified. All this results in the fact that the state institutions are interested in a unified way of costs calculation and the method will be practically applied just when planning public transport services. [2]

Within the framework of science and research we can use the method of cost calculation for example when vehicles with alternative drive as buses with gas drive or nowadays more discussed electric buses will be put in use. As for them it will be crucial if they manage to compete with classic diesel drive buses. On one hand we can expect energy and maintenance savings on the other hand running electric buses will be very expensive due to depreciations and the necessity to change batteries at least once during the durability life of electric buses.

For the future the crucial point will be the fuel price and at the same time the development of new technologies. If we only consider the exchange of a classic fuel bus, then we can calculate the change of unit costs as a difference of those cost items at which a change can be expected: [3]

$$\Delta n_{km}^{i,j} = (c \cdot p_{PH}^{i} + n_{UDR}^{i} + n_{ALT} + \frac{N_{ODP}^{i}}{L}) - (c \cdot p_{PH}^{j} + n_{UDR}^{j} + \frac{N_{ODP}^{j}}{L}), \text{ where:} \quad (9)$$

$\Delta n_{km}^{i,j}$	…	change of unit costs linked with the change of a bus (monetary unit/km)
i	…	label for alternative fuel bus
j	…	label for classic fuel bus
p_{PH}	…	fuel price (monetary unit/l, m^3, kWh, according to the drive)
c	…	consumption of fuel (l, m^3, kWh/km, according to the fuel)
n_{ODP}	…	depreciation costs (monetary unit/year)
n_{UDR}	…	maintenance unit costs (monetary unit/km)
n_{ALT}	…	the costs linked with beginning of operation of alternative drive buses, e.g. filling station, operation

safety and others, (monetary unit/year)
L … driven kilometres by one bus (km/year)

If we take into account regular bus transport, where the factor of tariff per hour will be zero or negligible, we can express the total saving (which is the figure that can be of negative values) in this way:

$$\Delta N_{km} = \sum_{i=1}^{m}[\left(c \cdot p_{PH}^{i} + n_{UDR}^{i} + n_{ALT} + \frac{N_{ODP}^{i}}{L}\right) \cdot \mathrm{L}] - \sum_{j=1}^{m}[\left(c \cdot p_{PH}^{j} + n_{UDR}^{j} + \frac{N_{ODP}^{j}}{L}\right) \cdot L] \quad (10)$$

where:
m .... number of substituted vehicles (pcs)

Forwarders or their forwarding agents may use the method for creation of the so-called cost indexes that show the development of individual items of costs within time. This may influence the more transparent creation of prices for transport performance. The index for particular items of cost I_l can be set from the following formula:

$$I_l = \frac{n_{km(t)}^{l}}{n_{km(t-1)}^{l}} \quad (11)$$

$n_{km(t)}^{l}$ … l-th type of unit cost for period t
$n_{km(t-1)}^{l}$ … l-th type of unit cost for period t-1

In some cost items the forwarders will be significantly limited by the market, especially at fuels or pays. It is almost impossible for forwarders to influence these cost items regarding the situation on a market (both oil and labour market) [4]. The increase in fuel prices has affected the fuel cost item within this period. While in 2009 the fuel cost for bus forwarders were at the level of 5,52 CZK/km, in 2011 it was 7,36 CZK/km [5]. This trend slowed down a little in the first half of 2013 however it is a question where the movement of particular cost items will continue after the interventions of the Czech National Bank and the slump in oil prices between 2014 and 2015. We can assume pressure on pay increase that stagnated within the period of 2009-2013.[6]

Conclusion

A functional method of cost calculation in transport is necessary from many respects shown in this text. It is important both regarding the problems that strike the forwarders for example in the form of fluctuation of oil prices in last seven years and the impact of transport on its surroundings. Particularly from the cost standpoint it will be crucial within a long-term perspective particularly in road transport if there will be a transfer towards alternative drives. The cost (and therefore price) competitiveness will be a key parameter in this respect. The method of cost calculation in transport can be used for various purposes – from a company to a community as whole. It of course shows that it is very appropriate to incorporate the problems connected with cost modelling into teaching at technical schools with transport specialization. [7]

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