Using of Sensitivity Analysis in Road Transport Pricing

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Abstract: The paper deals with the issue of sensitivity analysis and its possible use in price formation in passenger road transport. The input variables are selected on the model example. Based on the calculation, the sensitivity of the output to these input variables is determined, and the question how these inputs affect the overall result is answered.

Keywords: Sensitivity analysis, transportation, costs, pricing

1. Introduction

Sensitivity analysis is a calculation method that examines the effect of changing the input variables on their outputs (results).

Sensitivity analyses can be divided by several aspects - by scope, focus and complexity. In terms of scale, partial and total sensitivity analyses can be distinguished. For Partial sensitivity analyses, the influence of only several selected inputs is tested. In the case of complete sensitivity analyses, the influence of all input parameters is tested. Sensitivity analysis can be focused on criteria or decisions. In case of focusing on criteria, the main purpose of the analysis is to determine the influence of the individual parameters and then to determine the order of their importance to the output. Focusing on decisions means trying to find boundary values for inputs where there is a meaningful change in results - for example, when the order of each solution variant changes. In terms of complexity, one-dimensional and multidimensional analyses are distinguished. One-dimensional sensitivity analysis always changes the values of only one input and the other model parameters remain constant. In this way, the influence of the test input variable on the result can be determined unambiguously without distortion. The drawback is the fact that in real-time applications, only one input changes occur very rarely and therefore, the tested scenario is purely theoretical. This deficiency can be removed by Multidimensional sensitivity analyses that

simultaneously change the values of multiple input variables and evaluate their combined effect on the output of the calculation. The disadvantage of this type of testing can be its difficulty and complexity.

In general, Sensitivity analysis can be performed for each calculation model regardless of its application. By default, the sensitivity to the input values is determined especially in investment decision making as part of this contribution the authors focused on the possibility of application in the context of pricing in passenger road transport.

Sensitivity analysis was used by Du, Nicholson (1997) for Analysis of Degradable transportation systems or by Jourquin, Beuthe (1996) for analysis on the relative road costs. Olso Tzeng, Lin, Opricovic (2005) used sensitivity analysis in Multicriteria analysis of alternative-fuel buses for public transportation [1-3].

2. Data and Methods

Sensitivity analysis, which is sometimes also called as What-if analysis, serves as a tool for a cross-calculation of the selected variables. Thanks to this analysis, it is possible to calculate the sensitivity of the selected indicator to individual changing components.

Sensitivity analysis responds to the question which factor will mostly affect the company's profit. In pricing it is important to focus on profit-creating components. In addition, if the company can use sensitivity analysis it can significantly increase its readiness and ability to cope with changing factors. Due to the sensitivity analysis, if one of the factors which influence the profit changes (either upwards or downwards) the company can assume its impact on the final price and respond to this change quickly and effectively.

In the following example, a sensitivity analysis calculation is performed. It can be used as a tool for determining the price for services in road transport mode. Sensitivity analysis was used according to Schmitt-Grohé and Uribe, (2003) [4,5].

The company's profit is determined by the difference in costs and revenues. In this case, the profit is zero (i.e. at the break-even point) it consists of the four following components:
• Volume of transport q per year (in this case mileage),
• variable cost per 1 km,
• fixed costs for the base period (a year);
• cost per km.

The key question in using sensitivity analysis is changing of factor (the components of profit) mostly affects the company's profit. Using the calculations of the individual sensitivity components, it examines their possible changes and their sensitivity to change. For example, if it examines the

price it answers the question of what is the minimum possible price for which the company is willing to sell its product and which is not loss-making (i.e. it will generate profit or cover costs).

3. Division of Costs for Calculating the Sensitivity Analysis

Sensitivity analysis calculations include estimating of costs which affect profits. For this reason, it is important to divide the costs into variable costs and fixed costs. The variable costs are calculated per unit, in this case per one kilometre. On the other hand, fixed costs must relate to the base period of one year. Total costs are calculated according to the formula given in formula (1):

$$N = v \times q + F, \text{[CZK]} \tag{1}$$

Where:

N are total costs [CZK]; v are variable unit costs per 1km [CZK/km]; q is the number of kilometres travelled [km]; F are fixed costs [CZK] per basic period (year).

The calculated cost per kilometre is presented below in Tables 1, 2 and 3, which show in detail variable and fixed costs. The data entered in the Tables together with the expected capacity are the real values for the company ABC in the year 2016. Because of the required anonymity, the name of the company is fictitious [5,6].

Table 1 Calculation of variable cost per kilometre. Source: ABC's internal materials

Variable costs of using a car in 2016		
Annual mileage	5,000	km
Fuel consumption	5	l/100 km
Average price of fuel	33	CZK/l
Price of fuel per year	*8,250*	CZK
Price of a summer tire set	4,800	CZK
Price of a winter tire set	4,800	CZK
Mileage to replace the tire set	50,000	km
Years to replace summer tires	17	yrs
Years to replace winter tires	24	yrs
Summer tires costs per year	*282*	CZK
Winter tires costs per year	*200*	CZK
2 Switches of tires per year	*1,000*	CZK
Average Repairs and maintenance per year	*5,000*	CZK
Costs of the year	**14,732**	**CZK**
Variable costs of a car per km	**2.95**	**CZK**

Table 2 Calculation of annual fixed costs per one vehicle. Source: ABC's internal materials

Fixed costs per car		
Highway tolls	*1,500*	CZK
Annual insurance	*5,000*	CZK
Annual compulsory liability	*2,000*	CZK
Purchasing price of car	250,000	CZK
Number of years of use	10	yrs
Price of car on sale	82,500	CZK
Annual loss for the purchase of a car	*16,750*	CZK
Annual Fixed costs per car	**25,250**	**CZK**
Fixed costs of a car per 1 km	**5.05**	**CZK**

Table 3 Calculation of total costs per kilometre Source: authors

Variable costs of a car per km	**2.95**	**CZK**
Fixed costs of a car per 1 km	**5.05**	**CZK**
TOTAL COSTS of a car per 1 km	**8.00**	**CZK**

4. Application of Sensitivity Analysis on Model Example

To demonstrate how to determine the sensitivity analysis, a calculation will be made in the following example. The calculation is made for one model vehicle. The basis for the calculation is as follows [6-8]:

• expected (estimated) capacity (qK) ... 8,000 km/year,

• service price (C) ... 8.00 CZK/km,

• variable cost / kilometre (v) ... 2.95 CZK,

• fixed costs / year (F) ... 25,250 CZK.

The sensitivity analysis calculation has the following steps:

(a) determining the break-even point,

(b) the safety factor for the expected use of the vehicle,

(c) profit on the expected use of the vehicle,

(d) sensitivity of demand, price, variable costs and fixed costs in the expected use of the vehicle.

Procedure:

(a) The first step is to determine the break-even point (BZ) which indicates the minimum mileage required for the equality of revenues and costs. The number of kilometres at the break-even point is q_{BZ}, the calculation procedure according to formula (2).

$$v \times q_{BZ} + F = C \times q_{BZ}, \tag{2}$$

q_{BZ} needs to be expressed from this formula:

$$q_{BZ} = \frac{F}{C - v} = \frac{25250}{8 - 2,95} = 5000 \ km$$

The break-even point corresponds to 5,000 km. In case of this volume, the company does not generate any profit but revenues cover all costs.

b) The safety coefficient (BK) related to the expected use of the vehicle indicates how large the reserve of expected mileage compared to the required mileage is. Otherwise, how much % may the mileage drop without the occurrence of loss [6,9].

$$BK = \frac{q_K - q_{BZ}}{q_K} \times 100 = \frac{8000 - 5000}{8000} \times 100 = 37{,}5\%$$

The expected mileage (8,000 km) may fall by up to 37.5%, i.e. to 5,000 km, and this drop will still not create loss.

c) Profit at expected mileage

$$Z_{qk} = V - N = C \times q_K - q \times q_K - F = 8 \times 8000 - 2{,}95 \times 8000 - 25250 = 15150{,}-CZK$$

If the service expectation is fulfilled and there will be an annual mileage of 8,000 km for one vehicle this vehicle will earn 15,150 CZK on profit per year.

d) The sensitivity of individual components indicates the percentage change in the range in which their values can move without the company's activity being unprofitable. The individual components are expressed based on the following relation (3) [10]:

$$C \times q_c - v \times q_c = F \tag{3}$$

Sensitivity of demand, i.e. quantity q_c, is examined for the expected amount of kilometres

Expression of the minimum q_c:

$$q_c = \frac{F}{C - v} = \frac{25250}{8 - 2{,}95} = 5000 \ km$$

Sensitivity (S_{qc}):

$$S_{qc} = \frac{q_K - q_c}{q_K} \times 100 = \frac{8000 - 5000}{8000} = 37{,}5 \ \%$$

Sensitivity of Demand indicates that the expected plan of 8.000 km can drop by a maximum of 37.5% to 5.000 km. If the annual mileage was below this value it would lead to loss.

Sensitivity of price (S_c) per unit (kilometre) is calculated from the formula:

$$S_C = \frac{C - C_C}{C} \times 100 = \frac{8 - 6{,}11}{8} \times 100 = 23{,}63 \ \%$$

This calculation represents the possibility of decreasing the set price of 8 CZK up to 23.63 %, to the price 6,11 CZK.

$$C_C = \frac{F + v \times q_K}{q_K} = \frac{25250 + 2,95 \times 80000}{8000} = 6,11 \; CZK$$

C_C is minimal price that will generate zero profit from mileage 8.000 kilometres.

Sensitivity of the variable costs (S_v), i.e. costs which are changing the value along with changing of mileage. This sensitivity is calculated as follows:

$$v_c = \frac{C \times q_K - F}{q_K} = \frac{8 \times 8000 - 25250}{8000} = 4,84 \; CZK$$

According to the calculation of Sensitivity of the variable costs, they can be increased to a unit price of 4,84 CZK/km without affecting the demand or the cost of the service.

$$S_v = \frac{v - v_c}{v} \times 100 = \frac{2,95 - 4,84}{2,95} \times 100 = -64,2 \; \%$$

The variable costs per unit may be increased by up to 64.2% compared to the original variable costs.

Sensitivity of the fixed costs (S_F), i.e. costs which are fixed for the base period (year). Fixed costs do not change with varying mileage.

$$F_C = (C - v) \times q_K = (8 - 2,95) \times 8000 = 40400 \; CZK$$

$$S_F = \frac{F - F_C}{F} \times 100 = \frac{25250 - 40400}{25250} \times 100 = -60 \; \%$$

Annual Fixed costs may increase by 60% without affecting the occurrence of loss. In case of such an increase, the profit will be zero. Revenues will cover the costs.

5. Final Order of Sensitivities

Once these partial calculations have been made, the results can be sorted according to sensitivity reaction to the change. This order is displayed in the following Table 4.

Table 4 Final order of sensitivities. Source: authors

Order	Sensitivities	Change (v %)	Basic value	Break-even point
1.	Price	↓ 23.63	8.00- CZK	6.11 CZK
2.	Demand	↓ 37.5	8,000 km	5.000 km
3.	Fixed costs	↑ 60	25,250,- CZK /yrs	40,400,- CZK /yrs
4.	Variable costs	↑ 64.2	2.95 CZK /km	4.84 CZK /km

6. Evaluation of the Proposed Use of Sensitivity Analysis

Sensitivity analysis enables a company to determine which components affect its profits. Based on previous calculations, it is possible to use sensitivity analysis to determine pricing as the company can have a reliable overview of important areas. Looking at Table 4 with the order of sensitivity, it can be stated that the most sensitive to change is price so it is important for the company to be alert to the changes that may affect the price significantly. Just a small change of another factor can be a complication in the acceptability of the market price. For example, if fixed costs rise due to the purchase of a more expensive car the price is not so flexible that it can respond smoothly [11-13].

7. Conclusion

Using sensitivity analysis enables us to focus on the components that affect profits. Once it is defined and quantified it is clear what component is sensitive to change and able to respond to it. Through this analysis, the company will have a clear idea of the component it should focus on and try to avoid its excessive fluctuations.

By applying this method to a real pricing process, companies in the field of competition can greatly influence their competitive position and become more flexible to price changes. At the same time, however, it is necessary to take into account the preservation of the attractiveness of the service offered and to ensure the effective linking of new procedures with a focus on the quality provided.

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