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Enterprise in the economic calculus of the impact of road investments

The social division of labour causes a widespread exchange of labour and its effects, both productive and non-productive. The spatial (geographical) division of labour and production deepens this exchange. Consequently, transport needs arise, and the basic function of the transport system becomes their satisfaction.

Transport, apart from the basic function of the movement of people and material goods, fulfils a series of additional functions. For example, it activates the less developed areas, maintains the administrative and political compactness of regions and countries, contributes to the formation of the defence potential of the country, balances the cultural level of regions [Banak et al., 2014]. To fulfil these functions, there is a need for a complete, modern, branch technical infrastructure – linear and point. Its development cannot be analysed in isolation from the effects on the functioning of the production companies.

Gravity and potential models

To maintain the methodological order, it must be noted that the scope of the research on the transport needs is not particularly popular among economists and economic geographers, especially at the macro-level. The economic practice brings this type of considerations to the micro-level of particular economic entities, so companies that analyse individual conditions of the transport service when making decisions related to location. Relatively simple mathematical and statistical methods, called the methods of potential gravity and common interaction in space, can be used in the analysis of various kinds of gravity between the areas of a specific region and its central unit(s). According to W. Isard [1965], the measure of gravity between the units takes the following form:

$$I_{ij} = G\frac{w_j(F_i)^{\alpha} \times w_i(F_j)^{\beta}}{d_{ij}^{\mu}}$$

where:

I_{ij} – gravity measure between units i, j

w_i, w_j – mass weights F_i, F_j

α, β – mass indices F_i, F_j

μ – distance index

Whereas the formula of the demographic potential defining the impact force of particular settlements is as follows:

$$iV = G\sum_{j=1}^{n}\frac{w_j(F_j)}{d_{ij}^{\mu}}$$

where:

iV – potential created in the unit n by mass of the group of units

G – constant factor

The models of gravity and potential are a classic tool for calculating the potential transport needs and transport relations, resulting from the services provided to nodal regions of settlement. At the same time, they allow to synthesise spatial phenomena, by using substantial simplifications. A more detailed analysis of the type "who is the carrier?" "how much is carried?" "from where?" "where to?", requires the application of the linear programming method. Minimising the widely understood transport distance (thus, the cost) is most frequently encountered in the location calculus of a specific economic entity. With the application of the linear programming, all current or future transport tasks, resulting from handling particular components of the material goods production processes or services, are then optimised [Buga, Nykowski, 1974]. In Poland, the development of the service sector, major structural changes of the industry, agriculture, internationalisation of the economy associated with the increasing importance of the communications connections with the world, the development of infrastructure of the regions or administrative units, have been examined using the factor methods [Chojnicki, 1978; Chojnicki, Czyż, 1975].

A significant portion of studies on the transport issues are the works on shaping the road network in Poland, which have widely used graph methods [Taylor, 1974]. As a result, the progress of the methodology of spatial research (here: quantitative) contributed to the intensification of the search for better manners of the practical functioning of transport and the directions of development of technical infrastructure of the individual modes of transport, and in the recent years, particularly road and rail transport.

The method which is most commonly used in the research on the streams of transport in the country currently, according to many authors, is the balance sheet method. It is based on the quantitative determination of the major load groups in the transport relation system, made on the basis of the analyses of balances of the flows of goods – intra- and interregional. Most generally, such a balance dependence can be presented in the form of the known mathematical model in the following way:

$$z = \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} x_{ij} \Rightarrow \min$$

in the conditions:

$$\sum_{i=1}^{m} x_{ij} = a_i \qquad (i = 1,\ldots, m)$$

$$\sum_{j=1}^{n} x_{ij} = b_j \qquad (i = 1,\ldots, n)$$

$$x_{ij} \geq \quad (i = 1,\ldots, m; j = 1,\ldots, n)$$

$$\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j$$

$$a_i > 0 \qquad b_j > 0$$

where:

z – balanced transport task

x_{ij} – searched delivery amount addressed from the supplier D_i to the recipient O_j

$a_1, a_2, \ldots, a_m$ – adequate amounts of the resource of goods at the suppliers $D_1, D_2, \ldots, D_m$

$b_1, b_2, \ldots, b_n$ – adequate demand for this good reported by recipients $O_1, O_2, \ldots, O_m$

c_{ij} – factors determining the costs of transport of a unit of goods between the supplier D_1 and the recipient O_j

The model searches for a system of deliveries that provide the lowest total cost of transports. Thus, it is a task of linear programming, in which, during calculations, all numerical data obtained in each iteration, is compiled in the so-called transport table. It is obtained by combining the table of flows (movements) representing specified acceptable solutions, and the exit data table with C_{ij} coefficients, and if necessary, with their appropriately transformed values.

Here, a problem of completeness and accuracy of A_m, B_n and C_{ij} coefficients is crucial, but often overlooked in the studies. For example, R. Domański [1972] pointed to the need for a detailed analysis of the "communication" behaviour of people, in the form of a function of travel time, travel cost, and other features. They must be constructed correctly, even more because the dependencies between the regions that are taken into account are expressed in the function of distance, understood as general transport costs, and as a trend to use a specific mode or means of transport. The costs of transport continuously change, and the demand trends are dynamic phenomena by themselves, shaped by sets of conditions of different nature [Brdulak, Pawlak, Krysiuk, 2012].

Indexing methods

Here, we omit the issue of completeness and scope of spatial studies of transport functioning in Poland. These studies are incidental, fragmentary, and undertaken most often by the way of scientific research for a scientific degree or title (for example, doctoral dissertations [Brdulak, Pawlak, Krysiuk, 2012; Hoszman, 2014]). The more detailed studies on transport, discussed in this elaboration, are exceptions. Attention should be given to the tendency of analytical exploration of the impact of infrastructure transport investments on the social and economic development. It took place especially in the years after the Polish accession to the European Union and the inflow of major financial resources largely intended for infrastructure investments. The most interesting studies in terms of methodology include those conducted by the Institute of Geography and Spatial Organisation PAS (IGiPZ PAN) for the former Ministry of Regional Development. Their synthesis is contained in the report developed for the needs of The Technical Assistance Operational Programme (2007-2013) [Komornicki, 2010].

The purpose of the research of IGiPZ PAN was to assess the impact of transport infrastructure investments on the growth of competitiveness of the regions. It was conducted on the three spatial levels:

- national, (communes, districts),
- regional (provinces),
- local (case studies).

The case studies were concerned with two categories: transport investments in the selected districts, and also linear medium-sized and large investments (the EU contribution above PLN 20 million). The main source of primary information at the level of the case studies were social surveys of IGiPZ PAN [Komornicki, 2010]. The selection of the research subject was dictated by the following criteria:

- spatial and socio-economic position,
- functional and settlement position,
- type of support from the structural funds,
- branch of transport,
- size of the project.

It should be emphasised here, somewhat anticipating the conclusions of these considerations, that the methodological proposal of the discussed studies is highly useful for the professionals dealing with the effects of infrastructure investments in transport. It particularly applies to the universal situation of the limited nature of financial resources for research, the impossibility to organise more numerous research teams, short time spent on research, individualisation of the scientific works for degrees. Naturally, the objectives, scope and methods of research always will have to be adapted according to feasibility. For example, for individual doctoral candidates, it will be extremely difficult to fully apply the research methods used by the professionals of IGiPZ PAN, which included [Komornicki, 2010]:

- desk research analyses, consisting in studying of programme documentation, strategic studies, statistical studies, expert opinions, design documentation, literature studies;
- indexing methods (including isochrone);
- qualitative social research (in-depth/expert interviews, CATI, questionnaires, and expert panels).

The studies of economic nature require a careful selection of the used indicators, as they will be an important component of the conducted economic calculus.

In the discussed spatial analyses, these indices include for example:

- travel time shortening index (WSCP), which is easy to be converted to the costs of operation of the means of transport, e.g. passenger motor vehicle, heavy goods vehicle;
- time-demand efficiency ratio (WECP), based on the supplementation of the WSCP index with the number of potential traffic participants, and costs of time;
- transport bottleneck index (WWGT);
- accident and collision rate index (WWiK).

Travel time shortening index (WSCP) has the following mathematical form [Komornicki, 2010]:

$$WSCP = \frac{-(CP_{t_1} - CP_{t_1-t_2})}{CP_{t_1-t_2}}$$

where:

$WSCP$ – travel time shortening index

$CP\ t_1 - t_2$ – travel time in the year t_1 excluding the investments completed in the year t_2

$CP\ t_1$ – travel time in the year t_1

In a combination with the traffic speed model, it is an original calculation formula, developed and implemented by the professionals from the Institute of Geography and Spatial Organisation PAS.

The transport bottleneck index (WWGT) is a relation of the computational traffic volume on a section of the road to the capacity of this road section, according to the formula:

$$WWGT_i = \frac{Q_i}{P_i}$$

where:

$WWGT_i$ – transport bottleneck index on section i

Q_i – computational traffic volume on section i

P_i – capacity of section i

In the analyses of IGiPZ PAN, it was assumed that the traffic volume on the road bottleneck is higher from the road capacity. According to this, the WWGT index takes the value greater than one. The WWGT index higher than 1.5 in practice means a critical condition of our roads [Komornicki, 2010]. The computational traffic volume Q is calculated according to the formula:

$$Q = Q_0 + Q_d f_d + Q_c f_c$$

where:

Q – computational traffic volume

Q_0 – average daily traffic volume of passenger vehicles

Q_d – average daily volume of traffic of light goods vehicle (delivery trucks)

Q_c – average daily volume of traffic of goods vehicles (with trailers and without trailers), buses and tractors

f_d – coefficient of the impact of light goods vehicles in traffic

f_c – coefficient of the impact of heavy goods vehicles and tractors in traffic

A synthetic measure of road traffic collision and accident rate remains, according to the proposal of the IGiPZ PAN professionals, the accident and collision rate index (WWiK):

$$W_{L_i} = \frac{4\,W_i + 8 \times Z_i + 2 \times R_i + K_i}{L_i}$$

where:

W_{Li} – macro indicator of accident and collision rate in the year

W_i – number of killed in the district (region) in the year

Z_i – number of killed in the district (region) in the year

R_i – number of injured in the district (region) in the year *i*

K_i – number of collisions in the district (region) in the year *i*

L_i – number of residents of the district (region) in the year *i*

Using these indexing methods allows to get the picture of the direction and forces of the phenomena associated with the changes in the road network. We can perform an economic calculation of particular projects, with a fuller look at the development of the transport network, and determine the economic results of its quantitative and qualitative changes. Proper allocation of the indices to an individual company (producer or user of services) allows to calculate the qualitative changes in the road infrastructure for specific economic entities.

Methods for evaluation of investment profitability

In the practice of the Polish road and railway industry, currently dominating is an economic calculus strictly defined in terms of frames and procedures, applied in the applications for financing of specific projects. It seems necessary to supplement this practice with independent, possibly comprehensive problem studies, related to the infrastructure development of particular modes of transport and spatial infrastructure networks. The problem of accuracy of the economic calculus in the applications for the EU funding is illustrated, for example, by the practice of a reviewer of such applications – the Centre for EU Transport Projects (Centrum Unijnych Projektów Transportowych – CUPT) in Warsaw. Usually, all applications are overestimated by approximately one-third and it is regardless of assuming of a 10% cost reserve for unforeseen circumstances and events. The Polish side sometimes agrees to such calculations, as when the invoices for execution of the works are accurately handled, reserves are created, which, at the consent of the EU institutions, can be spent only on other transport investment projects. But when the companies calculate the cost of building of 1 km of an expressway at more than $ 100 million, it can be interesting not to an economist, but rather a prosecutor, as indeed happened several times already.

Among the methods of economic calculation, used while assessing the infrastructure investments in road industry and other branches of transport, we can distinguish between absolute and relative methods of assessing the profitability of investment projects:

- absolute methods – evaluation of individual projects and business ventures,
- relative methods – selection of the most efficient and cost-effective project among many variants possible to be implemented.

Another criterion of the division of the methods of economic calculation is the matter of taking into account of the variation of the value of money in time in the algorithm. Here, we distinguish [Rogowski, 2006]:

- simple methods which do not take into account the changing value of money in time, and are based on profit, as the measure of the net benefit;
- complex methods, taking into account

the variability of value of money in time, risk, complexity of investment projects.

Although the simple methods of economic calculations involve risk, they have a number of advantages, such as the fact that they do not require detailed data and quickly provide information on comparable projects. Thus, they become extremely useful in regional, point studies of linear infrastructure in the less urbanized areas, where the size of investment projects need not to be large. Annual values applied in these methods are nominal values, undiscounted at the time of the evaluation, which leads to a balanced treatment of the effects and expenditures, regardless of the time of their occurrence [Rogowski, 2006]. In practice, these suggestions have been used, for example, while evaluating the economic efficiency of the creation of the Logistic Centre in Małaszewicze [see Brdulak, Zakrzewski, 2013a, b, 2008].

In the economic analysis of the effects of infrastructure investments in road industry, simple methods of the period of return are of limited use. However, they are used in evaluating and comparing the assessments of projects by the investor, who pays for the investments. From this point of view, with the correct and comprehensive calculation, they can be an important decisive premise in the process of preparing a specific investment project. The remaining problem is that the investor in infrastructure is usually the state, which takes into account a number of non-economic considerations (social, overall development, integration, regional, local, political, legal and international, defence, and many others) in their decisions. In general, the methods of investigating the return period allow to make a selection, among many investment projects, of an option aiming at recovering the incurred expenditures as quickly as possible.

The return period is the number of years in which the incurred investment expenditures are returned in the form of the economic effect of these investments. The advantage of the methods of the return period is simplicity and communicativeness of the message, and the disadvantage – the lack of an objective decision-making criterion, lack of consideration of the value of money in time, as mentioned above, not taking into account the effects after the return period, and basing on the accounting results, and not on cash flows. When we add that infrastructure investments are capital intensive and lengthy, and their long-term effect can often be estimated with a specified probability, it makes the application of these methods limited.

An example here are the simple rates of return of investment expenditures:

$$ROI = \frac{Z_0}{I_c} \times 100\%$$

ROI (*Return of Investment*)

where:

Z_o – operating profit

I_c – total investment expenditures

$$ROE = \frac{Z_n}{I_{kp}} \times 100\%$$

ROE (*Return of Equity*)

where:

Z_n – net profit

I_{lp} – total investment expenditures financed with own contribution

Simple return rate of the investment expenditures ROI requires determination of the operating profit of the investor. This is relatively simple for smaller projects, e.g. investments in infrastructure-related services (including petrol stations, gastronomy, hotel services). But this calculation remains almost unreal from the point of view of the entity investing in large infrastructure project (e.g. motorway, railway line), with its complex, long-term, multidimensional effect on the developed space. Similarly, the net profit in the rate of return on equity ROE can be distinguished only incidentally on a larger scale with specific road projects, when the payment for the use of the built sections of motorways or expressways is assumed, and we are able to predict the future incomes from this title to the National Road Fund.

The problems with the provision of a comprehensive and reliable information input arise, naturally, also while discounting of the future value of capital and the application of the assumed methods of the economic calculus. Nevertheless, efforts should be made to make the complex methods of evaluation of investment projects, such as the method of the *Net Present Value* (NPV), applicable. The NPV method expressed mathematically is the sum of all net benefits (net cash flows) obtained in the entire economic cycle of life of the investment project, which are discounted before they are summed up, that is they are reduced to one moment of time in order to unify their value of money.

To determine the NPV it is needed to [Rogowski, 2006]:

- assess the value of net cash flows in the entire economic cycle of the infrastructure investment project,
- assess the discounted value for each net cash flow,
- add up the discounted net cash flows.

The result of adding up is treated as a cumulated net benefit of the given investment project, that is the NPV searched for. We should obtain the value of NPV > 0.

Another methodological assumption claims that this method is based on the discounted (operating) cash flows, on the calculation of the entire duration of the investment project (t = 0,1,2,…, n-1, n), and on the adoption of a conservative assumption concerning the bank rate which is adopted at the level of the cost of obtaining the capital for implementation of the project (weighted average cost of capital). The economic rationale requires that the cost of capital was lower from the rate of return expected by investors [Brdulak, Zakrzewski, 2013 a].

NVP is calculated according to the following formula:

$$NPV = \sum_{t=0}^{n} NCF_t \times CO_t$$

where:

NCF_t – net cash flows in the subsequent years of the calculation period

CO_t – actor of the current value (discount factor) for the subsequent years of the calculation period (proper for the adopted level of the interest rate)

$t = 0,1,2\ldots,n$ – the next year of the calculation period.

If the entire expenditure is borne in the year t = 0, which is difficult with more serious infrastructure investments, the above formula takes the form:

$$NPV = \sum_{t=0}^{n} \frac{D_t}{(1+i)^t} - I_t$$

where:

D_t – net cash flows associated with the current functioning of the project (without participations) in subsequent years of the calculation period

I_t – capital expenditures in subsequent years of the calculation period

i – annual interest rate

$t = 0,1,2\ldots,n$ – – the next year of the calculation period

Investment projects are reasonable in the case of NPV > 0. Only the non-economic considerations may in exceptional cases justify NPV = 0. K. Leszczyński finds that a clear social criterion in the economic calculation in the long term (in the discount formula) is to maximise the net present value (NPV = max > 0), assuming that it is correctly calculated [Leszczyński, 1997]. This criterion is the sum of the net present clean profit in the discount period. Meeting of this means that any new entity, created as a result of the implementation of the investment project will be in a dynamic economic equilibrium. Reaching NPV = max > 0 indicates that the given investment project is optimal (economically justified), as each zloty in the investment expenditures will provide profit which is not less (greater, although in the extreme case also equal is adopted) than the limit profit rate of return r is, in each year of the discount period.

The above findings lead to the final reflection that the point, financially limited research on the effects of car transport infrastructure investments should be limited to a deliberate choice of the analysed indicators of the impact of these investments on the social and economic environment, according to the possibly simplified research methodology. The applied research methods must provide a chance to formulate conclusions, even partially intuitive, of an expert nature.

The Polish and foreign experience prove the validity of this direction of spatial research. It seems that only in this way, with the existing resource limitations, we are able to assess the desired direction and force of the changes of the constantly increasingly complicated social and economic space of the countries, regions and entrepreneurial local environments.

Application of the induced traffic model

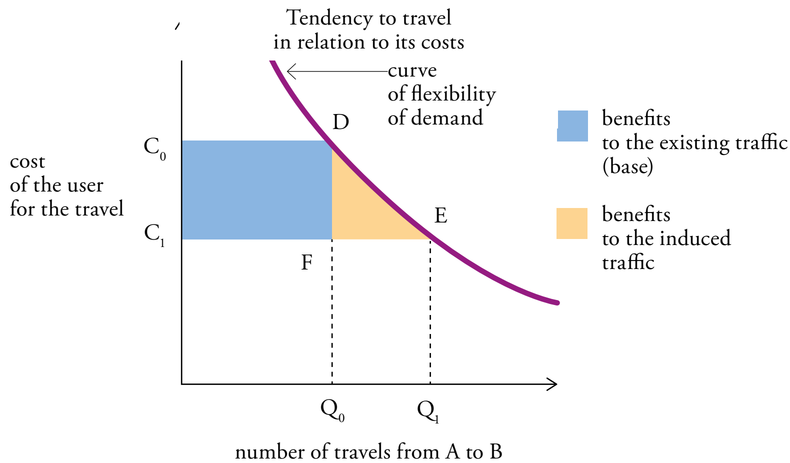
A methodological solution, which provides a chance to solve the above dilemmas of research is the proposal which consists in determining the so-called induced traffic on the built or modernised sections of the road network, after the elimination of the so-called "bottlenecks", or introduction of major changes in the traffic organisation. This issue involves modelling of travels, which in turn is closely connected with the change of the condition of the transport infrastructure.

According to one of the approaches [Szarata, 2013], the transport system can be divided into two basic components: demand – the number of travels generated or absorbed by a given area, and supply – construction objects, which are used for the intended travels (e.g. road system, tram tracks, railway lines). A very important parameter of this system is the time, as the system is subject to change over time, while maintaining its basic properties.

In the studies conducted in Canada (Hamilton, Ontario) [Doherty et al, 1997], a database concerning the travels made by the users of the system in the long term was used to determine when the respondents planned a specific activity, how often they changed the attributes assigned to the decisions related to this activity, and of which part of the activity they gave up. These studies were the inspiration for similar analyses carried out in Germany and the USA. The models based on activities are a very good tool taking into account the influence of different external factors on the decisions about whether to pursue a particular travel or give it up.

In the Motor Transport Institute in Warsaw, there are studies carried out on the impact of the infrastructure investment effects on the change in the num-

Rysunek 1 **Graphical depiction of the tendencies of the users to travel in relation to its costs**



Source: own elaboration on the basis of: The Department of Transport [1994].

ber of road travels. The role of these types of analyses is significant not only from the point of view of the analyses of the functional efficiency, but also from the position of the economic efficiency of a given infrastructure investment. Current approaches often overlook the induced traffic in the analyses of the economic efficiency, which leads to underestimation / overestimation of this value. Many analyses use the works with the constant demand for the transport services, which can be sufficient and there is no reason to complicate the calculations by introducing the variable of demand value. But the lack of taking into account of the induced traffic can lead to overestimation of the benefits in the networks of high level of transport congestion. For large investments in urban areas, where the level of road congestion is usually high, it is important to determine the economic efficiency, taking into account the share of the induced traffic. Figure 1 presents the relation between the cost of the travel and the number of induced travels.

Figure 1 shows the number of people willing to travel between points A and B. With the cost of travel C_0, this value equals Q_0. When the cost of travel falls to the value C_1, the number of travels increases to Q_1. The aggregated benefit for the travelling between points A and B, due to the reduction of travel costs is C_0DEC_1. This benefit can be considered in terms of two components.

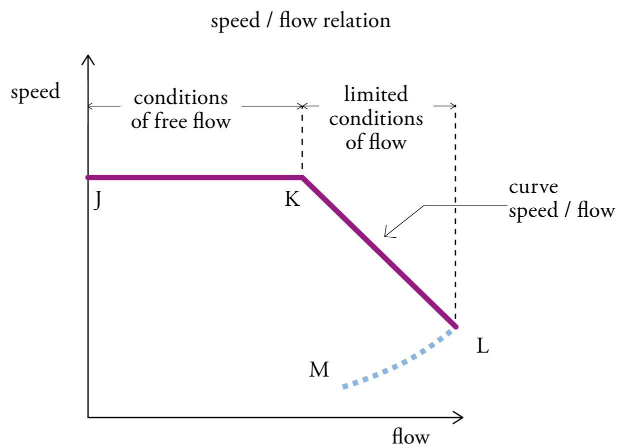
For the number of travels Q_0 they are carried out at the cost C_0. When the road is improved, the cost of travel drops to C_1. Travels Q_0 obtain a profit, which is equal to the full difference of costs (C_0- C_1).

Secondly, there are travels which are induced by the reduction of their costs. They obtain a benefit comparable to the difference between the willingness to bear the costs of travel, and the actual costs. This difference is the DEF area. If the change in the costs is not too high, it is reasonable to assume that the demand curve is linear in the right direction.

In this case, the average increased number of travels receives benefit that is equal to the half of the changes in costs. Therefore, any benefits of the user can be recorded as a formula at the bottom of the page [The Department of Transport, 1994].

This is the so-called “rule of half”. To cope with complex road networks, they can be extended by a more than one mo-

Figure 2 **Relation of speed to flow**



Source: own elaboration on the basis of: The Department of Transport [1994].

dule and many different pairs of destinations.

However, it should be noted that the total user profit is not the same as the change in the total cost of the user (its reduction) related to the travel. Figure 1 shows that if the cost of the user for the travel drops from C_0 to C_1, the efficiency gains equal C_0DEC_1, then the general cost of the user related to the travel may drop or rise depending on the elasticity of the demand.

To continue the analysis, also the supply side should be considered, or a capacity of the road network. As an example, we take the starting point of a single travel as A, and its destination as B, the travel is a single road. The results are generalised for numerous particular pairs, destinations, and many roads. The cost borne by the user during the travel, is mostly the cost of time and the cost of vehicle use. The cost of travel between A and B depends on the distance, physical features of the road, and the encountered traffic density. The last two of these factors are closed around the relation speed/flow.

The simple speed/flow relation contains such component as the speed in the free run, determined by the physical features of the road, depending on the size of traffic (congestion). It applies to the range of flow (conditions of free flow), i.e. section JK in Figure 2, where K is the maximum free flow. The flows higher than K may occur, but at the cost of reduced speed – section KL on the curve. In this section, the individual speeds of vehicles are forced by the presence of other vehicles, although the flow is still smooth and uninterrupted. Section KL, with regard to the speed/flow relation, is referred to as the limited flow, with some delays imposed on the users of vehicles, when the congestion increases (traffic, flow level).

In reality, there is another element, more difficult to define, which occurs when the traffic grows, temporarily increasing the congestion, which exceeds the capacity of a given route. Its consequence is upsetting the stability of flows, sometimes characterised as a "shocking wave of travellers", leading to the disruption of the free flow. It is the LM section

$$(C_0-C_1)Q_0 + \tfrac{1}{2}(C_0-C_1)(Q_1-Q_0) = \tfrac{1}{2}(C_0-C_1)(Q_0-Q_1)$$

C – the cost of travel made by the user

Q – number of travels from point A to point B with unstable conditions of congestion, when both speed and flows decrease. In this situation, often stoppages occur, long lines are formed, and the delay quickly accumulates.

Figure 3 presents a simplified version of the curve depicting the relation of speeds to flows. Having the knowledge on the value of time (monetary) and the relation between speed and operating costs, this curve (JKL) can be presented as the cost curve. The cost curve marked S_0 specifies the level of costs of the user borne for the travel at every possible traffic intensity. In the area of the free flow JK, the curve is horizontal, because speed, time and costs of the travel will not depend on the level of traffic. With another forced flow in the section KL, the costs of travel increase with the intensity of traffic, because additional traffic intensity is associated with lower speed and longer travelling time. In the area of unstable flow (jamming) in the section LM, significant delays increase, lines occur, the travel cost increases, and the number of travels is virtually the same. The dependencies presented on the graphs graphically show the behaviour of passengers, their willingness to take the travel in relation to its costs and the relation of speed to flow.

The simplified formula that allows to determine the overall costs of the users associated with the given investment is:

$$K_{cat.}^{:} = \frac{(K_0 - K_1) \times (G_0 + G_1)}{2}$$

where:

K_0, K_1 – generalised cost of travel, before and after the investment, respectively

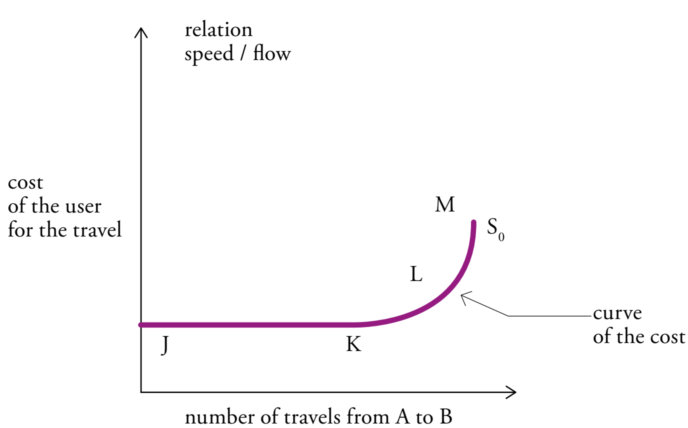
G_0, G_1 – number of travels, before and after the investment, respectively

Naturally, the determination of value G0, G1 is not simple, but the mere fact of seeing the problem is significant. The analysis of the induced travels taking into account simulation models were conducted for such agglomerations as, among others: Belfast, Cardiff, London and Norwich [Shiftan, et al., 2002]. In Poland, the results of the emergence of new road investments (existing and planned) were examined for the car transport enterprises, under comprehensive research of economic efficiency of these projects.

Infrastructure, and reduction of costs of a company

Development of infrastructure results in reduction of costs of transport. It is a significant factor that influences both supply and demand side of production. By lowering the costs of transport, production companies benefit, together with transport companies, who lower their own costs and thus they can be more competi-

Figure 3 **Relation of speed to flow in a simplified version**



Source: own elaboration on the basis of: The Department of Transport [1994].

tive on the market of services. This whole situation can lead also to lowering of the costs of the product itself. Lowering of the transport costs is significant, especially to carriers. Price competition on the market of vehicle freight transport requires the carriers to know the formation of unit costs of transport. It is a prerequisite for strengthening the competitive position of the company, which gives the chance to continue operation on the market of vehicle transport services. The knowledge on the formation of the levels of unit costs and the structure of the kinds of costs is necessary to build the prices for the transport services, while keeping the high quality of services by the transport companies. An average cost of one vehicle-kilometre for other national markets of the EU equals PLN 3.85, and for the eastern markets PLN 3.64. The median of this value reaches the amount of PLN 3.74 per 1 vehicle-kilometre.

When analysing the contribution of each category in the structure of costs of one vehicle-kilometre (Table 1), the largest value is the group of propellants and consumables, then there is remuneration and delegations of drivers, tolls, insurances, repair services, repairs, amortisation, other costs, that is credits and leasing. In the case of Eastern markets, there is a relatively large share of other costs of the transport activity of the company (7.7% compared to 2.7% for the EU countries).

The development of infrastructure allows to achieve benefits related to the reduced congestion, lower pollution of air, noise level, or lower number of accidents. These benefits not only apply to the human natural environment, but also result in the reduction of transport costs. Traffic on the motorway is much smoother, which in turn has an impact on the reduced fuel consumption. It is a so-called "eco-drive", that is smooth and safe drive, providing measurable benefits in the form of an average saving up to 15% of the fuel consumed, without extending the time of the ride. To use an example of a vehicle, which consumes 35 l/100 km of fuel and travels 100 thousand kilometres per year, then for every one hundred kilometres two litres of fuel can be saved [Zbyszyński, Krupiński, 2012]. Assuming the level of 15% of saving related to the smooth ride, according to the data from Table 1, PLN 0.21 can be saved on average per one vehicle-kilometre. Also, a phenomenon of the so-called "air pocket" is important, which is often used by heavy goods vehicles, especially on motorways

Table 1 **Participation of particular categories in the structure of costs of one vehicle-kilometre on the EU markets and on the Eastern markets**

specification	markets of the EU countries	eastern markets
Average cost of one vehicle-kilometre of the course in PLN, including:	**3,85**	**3,64**
propellants and consumables	1,54	1,28
repair services, repairs and tyres	0,18	0,18
amortisation or loss of the fleet market value	0,17	0,17
other capital costs (leasing, credit)	0,08	0,08
remuneration and delegations of the drivers and social insurances payable by the employer	0,92	0,95
insurance of the means of transport and tax on the means of transport	0,29	0,29
tolls	0,56	0,42
other costs of transport activities of the company	0,10	0,28
number of surveyed companies	43	49

Source: K. Bentkowska-Senator, Z. Kordel, J. Waśkiewicz [2015].

and expressways, where the heavy goods vehicles can drive directly behind each other in groups of varying size, which does not impede motion of other vehicles. Another factor is the issue of congestion. The change from a smooth drive to a drive interrupted by forced stops can cause an increase in fuel consumption from 20 to 40%. Small and medium traffic does not affect fuel consumption as much as congestions, and we deal with them often in urban areas that do not have a ring road, and they are located near important traffic arteries. A faster travel time for a given section is also a better efficiency of use of the driver working time, as well as the time of the travel itself, which also reduces transport costs. Both, the issue of congestions, as well as efficiency of the use of the driver, are more individual, and in order to present examples, detailed and specific calculations should be made. But the issue of economic benefits associated with the reduction of transport costs is obvious.

The benefits that have been achieved thanks to the construction of the 21 km long, motorway ring road of Mińsk Mazowiecki will be described below. In general, in 2014, the average daily traffic on the ring road of Mińsk Mazowiecki during all days was 12,424 vehicles per day. The gains resulting from the reduction of accident rates was estimated on the basis of unit costs of road accidents and collisions. According to the data of the National Road Safety Council, in 2013, the costs related to road safety were:

- kunit cost of a mortal casualty – PLN 1.97 million,
- unit cost of a seriously injured person – PLN 2.21 million
- unit cost of a slightly injured person – PLN 30.4 million
- unit cost of a traffic accident – PLN 953 million
- unit cost of a traffic collision – PLN 41.8 million.

From the data of the General Directorate for Roads and Motorways, it transpires that among 352 accidents in 2014, 5.4% were the accidents that happened on the motorways. When calculating the differences between a motorway and an expressway, and other roads, for all categories mentioned above, we achieve benefits resulting from the decreased accident rate on the motorway A2, and taking into account the ring road of Mińsk Mazowiecki, amounting to PLN 5.96 million per year.

In the report prepared for the European Commission *Update of the Handbook on External Costs of Transport*, "DG Mobility and Transport" of 2014, there was a calculation of the costs related to congestion, air pollution, noise and maintenance of infrastructure. On the basis of these data, the benefits that are achieved on a motorway, and not on a national road of different type, can be calculated. Numerical data are prepared in a division into all European Union member states, and are different depending on the country, road type, and vehicle class. The calculations of costs of congestion are related to the reduction of costs resulting from the reduced congestion on a motorway. In the case of the ring road of Mińsk Mazowiecki, it is necessary to compare the motorway with the main road, which previously ran through the city. In the report, we find the division into costs of congestion in the metropolitan, urban and rural area. For this section, the calculations for the metropolitan area have been adopted, as Mińsk Mazowiecki is also a part of the Metropolitan Area of Warsaw. Profits, resulting from the construction of the ring road of Mińsk Mazowiecki, and the reduction of the congestion of passenger cars equal PLN 140.53 million annually. For heavy goods vehicles (light duty, trucks, buses), the profits of congestion reduction equal PLN 146.55 million annually. The benefits related to the reduced air pollution equal PLN 2.86 million for passenger cars and PLN 10.07 million for heavy goods vehicles. Lower noise level means the benefits in the amount of PLN 3.77 million for passenger cars and PLN 10.39 million for heavy goods vehicles. The calculation should also take into account the costs of wear of the surfaces of the built section of a motorway, its maintenance, repairs, etc. In total, for passenger cars and heavy vehicles, these costs amount to PLN 3.14 million per year.

When calculating the benefits of construction of the 21-kilometre section of the motorway that constitutes a ring road of Mińsk Mazowiecki, annually we receive benefits in the amount of PLN 317 million. The entire investment cost PLN 765 million, so it is easy to count that the return occurred in less than 2.5 years. It is an almost unbelievable result that strongly deviates from the Western European standards, where the time of return on an investment of this kind is several or several dozens of years. This proves that in the case of Mińsk Mazowiecki, we were dealing with the so-called "catastrophe of a bottleneck", the effect of which was a communication paralysis.

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