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INTERRELATION OF EXTERNAL COSTS OF ROAD TRANSPORT AND FINANCIAL AND LOGISTICS INDICATORS OF THE EU COUNTRIES

Lidia Savchenko, Oleksander Tsapenko. *"Interrelation of external costs of road transport and financial and logistics indicators of the EU countries". Internal costs refer to the direct monetised costs for a person or organisation undertaking an activity. They are costs that a business bases its price on. External costs are not included in price and consist on the cost of disposing of the product at the end of its useful life, the environmental degradation caused by the emissions, pollutants and wastes from production, the cost of health problems caused by harmful materials and ingredients and social costs associated with increasing unemployment due to increasing automation. In such way, external costs or externalities refer to the economic concept of uncompensated social or environmental effects.*

The countries of the European Union have long been engaged in converting indirect losses from transport into financial units. The latest existing 2019 Handbook on External Costs of Transport considers not only marginal external costs, but also total and average external transport costs across the EU, Switzerland and Norway.

Our goals in this research are:

- identification of factors that have a significant impact on the total external costs of transport at the country level;*
- determining of the degree of such influence;*
- determination of interdependence (multicollinearity) of factors of influence;*
- determination of the direction of influence (direct or inverse dependence);*
- making conclusions regarding the possibility of determining the external costs of the country based on the selected factors.*

On the basis of correlation-regression analysis, factors were determined that have a clear relationship with the external costs of road transport - the country's GDP, the amount of transport work produced by the country in tkm and the amount invested in road infrastructure. Values of Multiple R and R-square of the regression model (very next to 1) allow us to make a conclusion that these three factors are sufficient to explain the variable (external costs) at a reliability level of 95%. All factors are statistically significant and should be

involved in the model. Another important result is the sign with which the coefficients are present in the model: with an increase in % of GDP and transport work, external costs will increase, however, with an increase in investment in road infrastructure, the value of external costs of transport will decrease.

Finally, the regression equation of the country's external transport costs as a function of the three aforementioned indicators was obtained. A very good representation of the statistical data with the resulting regression model can be observed. It can be assumed that this model can be used to predict external costs of road transport and transfer the methodology to countries outside the EU, for example, Ukraine..

Keywords: external costs of transport, road infrastructure, transport work, infrastructure investment, correlation, regression.

Лідія Савченко, Олександр Цапенко. «Взаємозв'язок зовнішніх витрат автомобільного транспорту та фінансово-логістичних показників країн ЄС». Внутрішні витрати стосуються прямих грошових витрат для особи чи організації, які здійснюють певну діяльність. Це витрати, на яких бізнес базує свою ціну. Зовнішні витрати не входять у відпускну ціну та складаються з вартості утилізації продукту в кінці терміну його корисного використання; витрат від погіршення навколишнього середовища, спричиненого викидами, забруднювачами та відходами виробництва; вартості проблем зі здоров'ям, спричинених шкідливими матеріалами та інгредієнтами; соціальних витрат, пов'язаних зі зростанням безробіття через зростання автоматизації. Таким чином, зовнішні витрати або зовнішні ефекти відносяться до економічної концепції некомпенсованих соціальних або екологічних ефектів.

Країни Євросоюзу давно займаються переведенням непрямих збитків від транспорту у фінансові одиниці. Останній існуючий Довідник із зовнішніх витрат на транспорті за 2019 рік розглядає не лише маржинальні зовнішні витрати, а й загальні та середні зовнішні транспортні витрати в країнах ЄС, Швейцарії та Норвегії.

Наші цілі в цьому дослідженні:

- визначення факторів, що мають значний вплив на загальні зовнішні витрати транспорту на рівні країни;
- визначення ступеня такого впливу;
- визначення взаємозалежності (мультиколінеарності) факторів впливу;
- визначення напрямку впливу (пряма чи обернена залежність);
- формулювання висновків щодо можливості визначення зовнішніх витрат країни на основі обраних факторів.

На основі кореляційно-регресійного аналізу визначено фактори, які мають чіткий зв'язок із зовнішніми витратами автомобільного транспорту – ВВП країни, обсяг транспортної роботи, виробленої країною в ткм, та сума інвестицій у дорожню інфраструктуру. Значення Multiple R і R-квадрат регресійної моделі (що є дуже близькими до 1) дозволяють нам зробити висновок, що цих трьох факторів достатньо для пояснення змінної (зовнішніх витрат) з рівнем надійності 95%. Усі фактори є статистично значущими і, отже, повинні бути задіяні в моделі. Іншим важливим результатом є знак, з яким коефіцієнти факторів присутні в моделі: зі збільшенням ВВП і транспортної роботи зовнішні витрати зростають, однак зі збільшенням інвестицій в дорожню інфраструктуру величина зовнішніх витрат на транспорт зменшиться.

Нарешті, отримане рівняння регресії зовнішніх транспортних витрат країни як залежність від трьох вищезгаданих індикаторів. Можна спостерігати дуже гарне представлення статистичних даних за допомогою отриманої регресійної моделі. Можна припустити, що дана модель може бути використана для прогнозування зовнішніх витрат на автомобільний транспорт і перенесення методології в країни поза ЄС, наприклад, в Україну.

Ключові слова: зовнішні витрати на транспорт, дорожня інфраструктура, транспортна робота, інвестиції в інфраструктуру, кореляція, регресія

Людия Савченко, Александр Цапенко. "Взаимосвязь внешних издержек автомобильного транспорта и финансово-логистических показателей стран ЕС". Внутренние расходы касаются прямых денежных затрат для личности или организации, осуществляющих определенную деятельность. Это затраты, на которых бизнес основывает свою цену. Внешние расходы не включаются в отпускную цену и состоят из стоимости утилизации продукта в конце срока его полезного использования; потерь от ухудшения окружающей среды, вызванной выбросами, загрязнителями и отходами производства; стоимости проблем со здоровьем, вызванных вредными материалами и ингредиентами; социальных расходов, связанных с ростом безработицы из-за роста автоматизации. Таким образом, внешние затраты или внешние эффекты относятся к экономической концепции некомпенсированных социальных или экологических эффектов.

Страны Евросоюза давно занимаются переводом косвенных убытков от транспорта в финансовые единицы. Последний существующий Справочник по внешним расходам на транспорте за 2019 год рассматривает не только маргинальные внешние расходы, но и общие и средние внешние транспортные расходы в странах ЕС, Швейцарии и Норвегии.

Наши цели в этом исследовании:

- определение факторов, оказывающих значительное влияние на общие внешние расходы транспорта на уровне страны;
- определение степени такого воздействия;
- определение взаимозависимости (мультиколлинеарности) факторов воздействия;
- определение направления воздействия (прямая или обратная зависимость);
- формулирование выводов о возможности определения внешних расходов страны на основе выбранных факторов.

На основе корреляционно-регрессионного анализа определены факторы, которые имеют четкую связь с внешними затратами автомобильного транспорта – ВВП страны, объем транспортной работы, производимой страной в ткм, и сумма инвестиций в дорожную инфраструктуру. Значения Multiple R и R-квадрат регрессионной модели (которые очень близки к 1) позволяют сделать заключение, что этих трех факторов достаточно для объяснения переменной (внешних затрат) с уровнем надежности 95%. Все факторы статистически значимы и, следовательно, должны быть задействованы в модели. Другим важным результатом является знак, с которым коэффициенты факторов присутствуют в модели: с увеличением ВВП и транспортной работы внешние издержки возрастут, однако с увеличением инвестиций в дорожную инфраструктуру величина внешних расходов на транспорт снизится.

Наконец, получено уравнение регрессии внешних транспортных расходов в стране как зависимость от трех вышеупомянутых индикаторов. Можно наблюдать очень хорошее представление статистических данных с помощью полученной регрессионной модели. Можно предположить, что данная модель может быть использована для прогнозирования внешних расходов на автомобильный транспорт и переноса методологии в страны вне ЕС, например в Украину..

Ключевые слова: внешние расходы на транспорт, дорожная инфраструктура, транспортная работа, инвестиции в инфраструктуру, корреляция, регрессия.

Introduction. Internal costs refer to the direct monetised costs (planning, construction, management, maintenance,

disposal) for a person or organisation undertaking an activity [1]. They are costs that a business bases its price on. They include

costs like materials, energy, labour, plant, equipment and overheads [2]. External costs are costs that are NOT included in what the business bases its price on. These include:

- the cost of disposing of the product at the end of its useful life

- the environmental degradation caused by the emissions, pollutants and wastes from production

- the cost of health problems caused by harmful materials and ingredients

- social costs associated with increasing unemployment due to increasing automation [2].

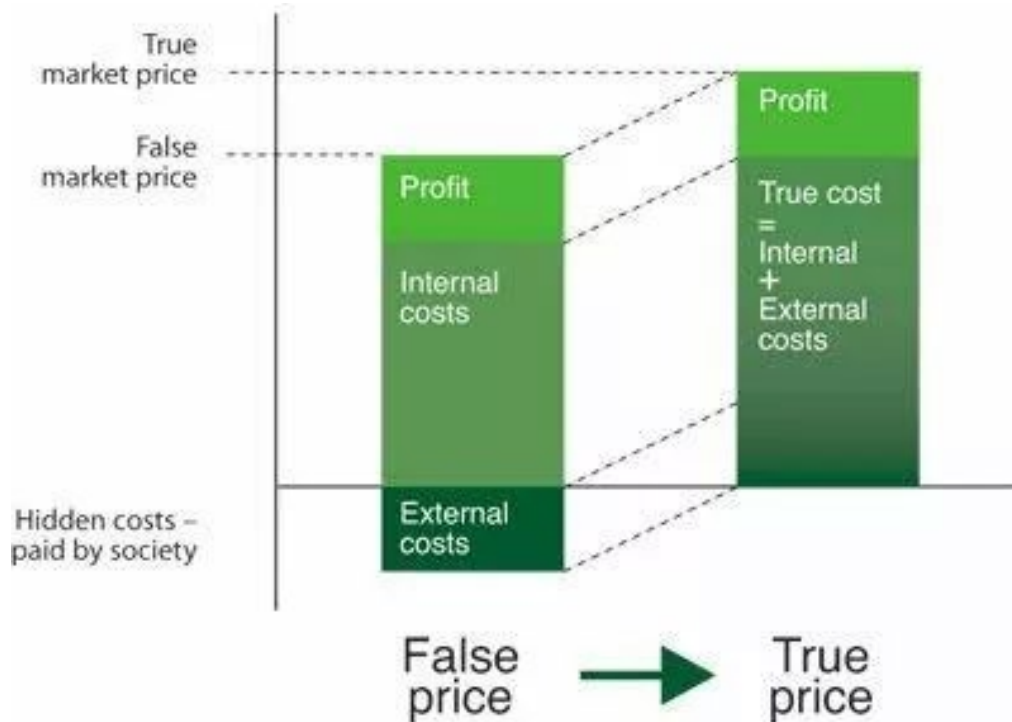


Figure 1 – External costs and true price [2]

The **goals** in this research are:

- identification of factors that have a significant impact on the total external costs of transport at the country level;

- determining of the degree of such influence;

- determination of interdependence (multicollinearity) of factors of influence;

- determination of the direction of influence (direct or inverse dependence);

- making conclusions regarding the possibility of determining the external costs of the country based on the selected factors.

Literature analysis. Two British economists are credited with having initiated the formal study of externalities, or "spillover effects": Henry Sidgwick (1838–1900) is credited with first articulating, and Arthur C. Pigou (1877–1959) is credited with

formalizing the concept of externalities. Although Henry Sidgwick (1838-1900) first articulated the idea of spillover costs and benefits (externalities), Arthur C. Pigou (1877-1959) receives most of the credit for formalizing the concept. Pigou, a British welfare economist (meaning that his economic theories focuses on maximizing the well-being of society), studied at King's College in Cambridge and later served as the chair of political economy at Cambridge from 1908 to 1943. The previous chair, Alfred Marshall, significantly influenced Pigou's thinking, as both were concerned about how to use economic theory to promote social well-being [3].

The word externality is used because the effect produced on others, whether in the

form of profits or costs, is external to the market.

External costs (also known as externalities) refer to the economic concept of uncompensated social or environmental effects. For example, when people buy fuel for a car, they pay for the production of that fuel (an internal cost), but not for the costs of burning that fuel, such as air pollution. The aim of the "polluter pays" principle and environmental taxes is that these externalities are internalised (e.g. by putting an eco-tax on fuels) [1].

An external cost is a cost not included in the market price of the goods and services being produced, i.e. a cost not borne by those who create it [4].

An external cost is a negative effect to a third party from the production or the consumption of a good [5].

An external cost is the cost incurred by an individual, firm or community as a result of an economic transaction which they are not directly involved in. External costs, also called

'spillovers' and 'third party costs' can arise from both production and consumption [6].

Most transactions create external costs – examples include [6]:

- Purchasing consumer goods commonly creates waste in terms of packaging, as well as other environmental costs including carbon emissions resulting from travelling to stores and outlets.

- Environmental costs can also arise from the production process, including direct costs from emissions and costs from transportation and distribution.

- Excessive fishing can deplete fish stocks and lead to unemployment in the fishing industry in the future.

Where the goods are 'demerit goods', such as cigarette and alcohol consumption, governments may impose taxes to discourage consumption and reduce external costs. Information failure may result in a lack of awareness of external costs, and hence a sub-optimal level of consumption.

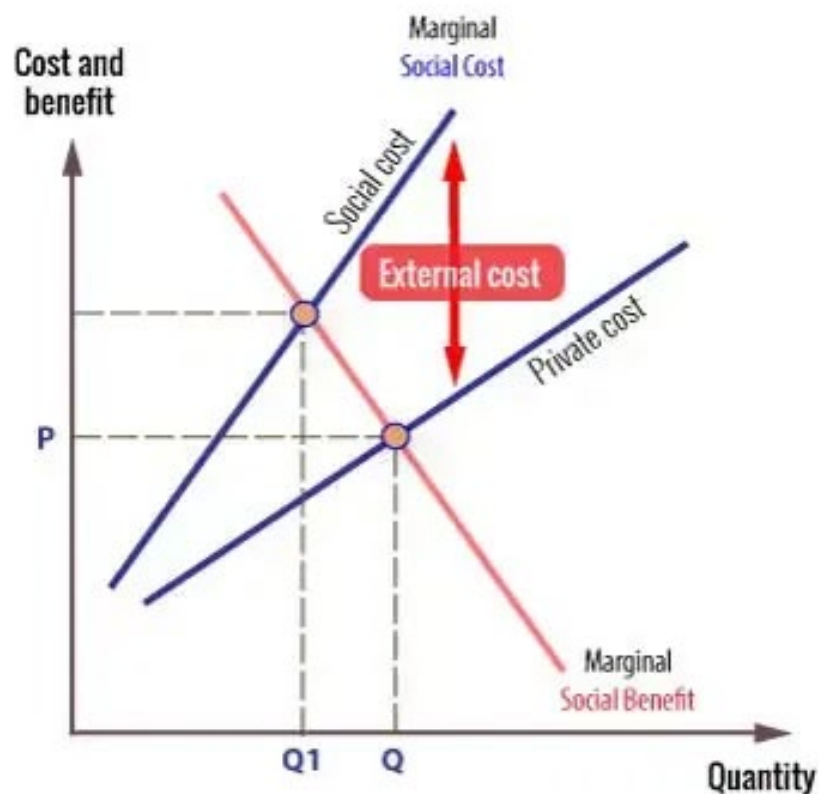


Figure 2 – Dependency between social, private and external costs [6]

An external cost, such as the cost of pollution from industrial production, makes the marginal social cost (MSC) curve higher than the private marginal cost (MPC). The socially efficient output is where $MSC = MSB$, at Q_1 , which is a lower output than the market equilibrium output, at Q . Net welfare loss can exist in two situations. Firstly, it exists when the marginal cost to society of a particular

economic activity, such as manufacturing 200,000 computers, is greater than the marginal benefit to society. Secondly, it can exist when the marginal benefit of a given economic activity, such as producing 50,000m computers, is greater than the marginal cost. The first situation can occur when the market produces 'too much', and the second when it produces 'too little'. [7].

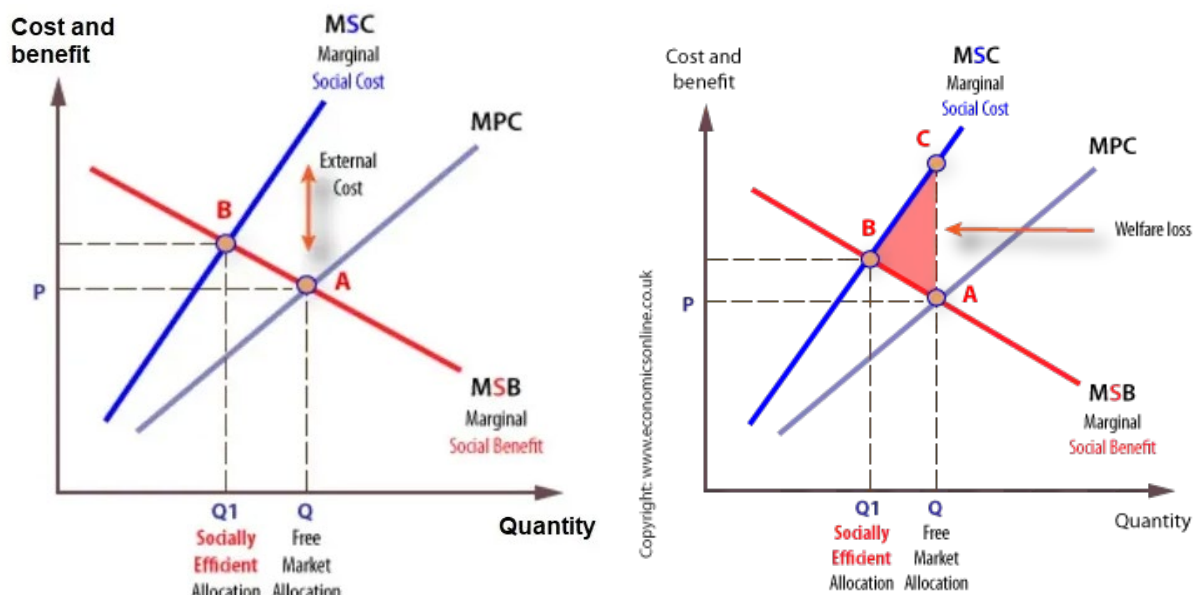


Figure 3 – Formation of welfare loss [7]

The countries of the European Union have long been engaged in converting indirect losses from transport into financial units. In relevant studies, reference books, instructions and regulations, such costs are called external.

In 2008 the European Commission commissioned the first Handbook on External Costs of Transport, as part of the IMPACT study [8]. The 2008 Handbook focus was on marginal external costs of transport as a basis for the definition of internalisation policies (in line with the marginal social cost pricing principle). It covered all main external cost categories, including air pollution, climate change, noise, accidents and congestion.

In 2014, the Handbook was updated to reflect new developments in research and policy [9]. Furthermore, the scope was broadened: next to the external costs of transport, infrastructure wear and tear costs

for road and rail transport were covered as well.

The latest existing 2019 Handbook [10] is an update to the 2008 and 2014 versions. It considers not only marginal external costs, as was the focus of previous Handbooks, but also total and average external transport costs across the EU, Switzerland and Norway. In addition, data on external costs were prepared for some non-European countries to compare with European figures.

The latest vision of the European Commission is to take into account these types of external costs of transport:

- costs from traffic congestion;
- costs from traffic accidents;
- costs from traffic noise;
- costs from air pollution;
- costs from climate change;

- other costs that presented in the studies only conceptually, without a verified methodology for their calculating.

The second classification of external costs of transport is their division into total and marginal. According to [5], external marginal cost is the cost to a third party from the consumption/production of one extra unit. In [10] marginal costs show the total costs by their types (congestion, accidents etc.), and the marginal ones allow to determine the value of the costs depending on the road conditions, the distance traveled, the number of passengers and cargo transported.

It should be noted that external costs of transport are determined not only for the most common mode of transport, road transport, but also for other modes of transport, namely:

- aviation;
- railway;
- marine;
- internal water.

Presentation of the main results.

Although existing methodologies cover studies on monetization of external costs of non-road modes of transport, however, some difficulties are obvious. One of them is the imperfect statistical database for EU countries

for non-road modes of transport. Another is the lack of scientific research, tested on practical examples. Thus, unfortunately, the latest Handbook for determining the external costs of transport do not contain equally verified methodologies for all modes of transport.

Among other, Handbook of 2019 has information about total external costs of road transport in each country of the EU. The latest data is from 2016 but they are supposed to show also current dependency.

These values of external costs of road transport were taken as the resulting indicator (Y).

The following indicators were taken as factors influencing external costs of road transport:

- the country's GDP in % from total EU GPD in 2016 (X1);
- number of tkm performed by country in 2016 (X2);
- the volume of investments in road infrastructure by country in 2016 (X3).

Performed transport tonne-kilometres were taken from [11] and show such numbers by countries (Fig. 4).

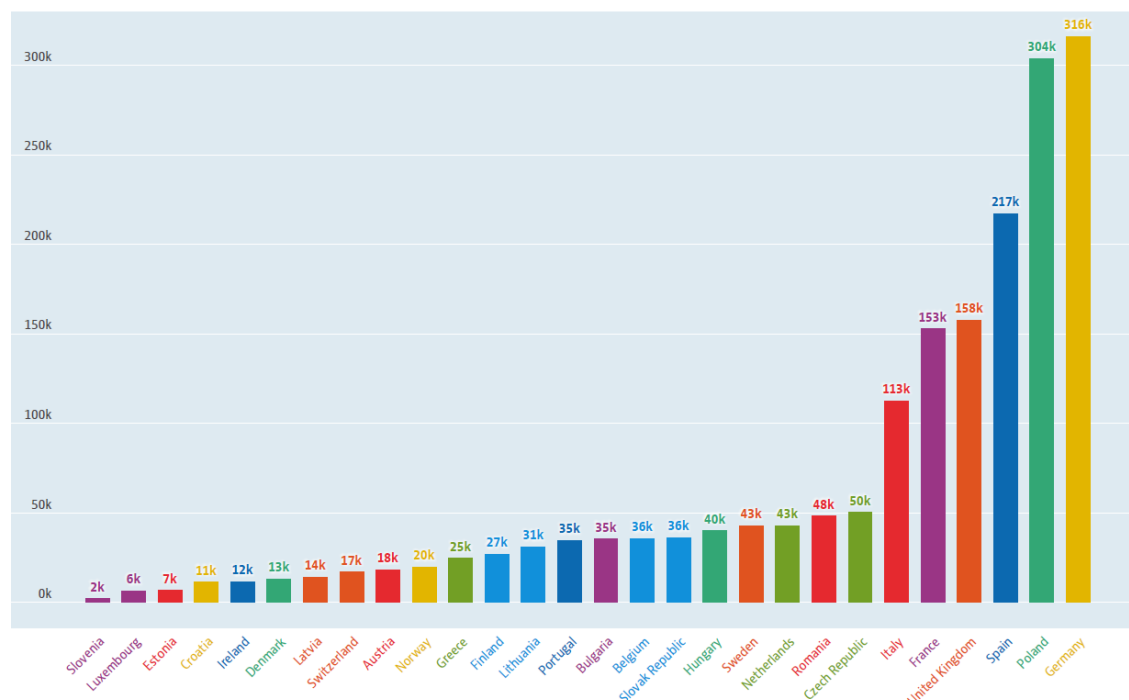


Figure 4 – Freight transport performance (road transport, mln tkm, 2016) [11]

Information about investment into road infrastructure in 2016 is shown in Fig. 5.

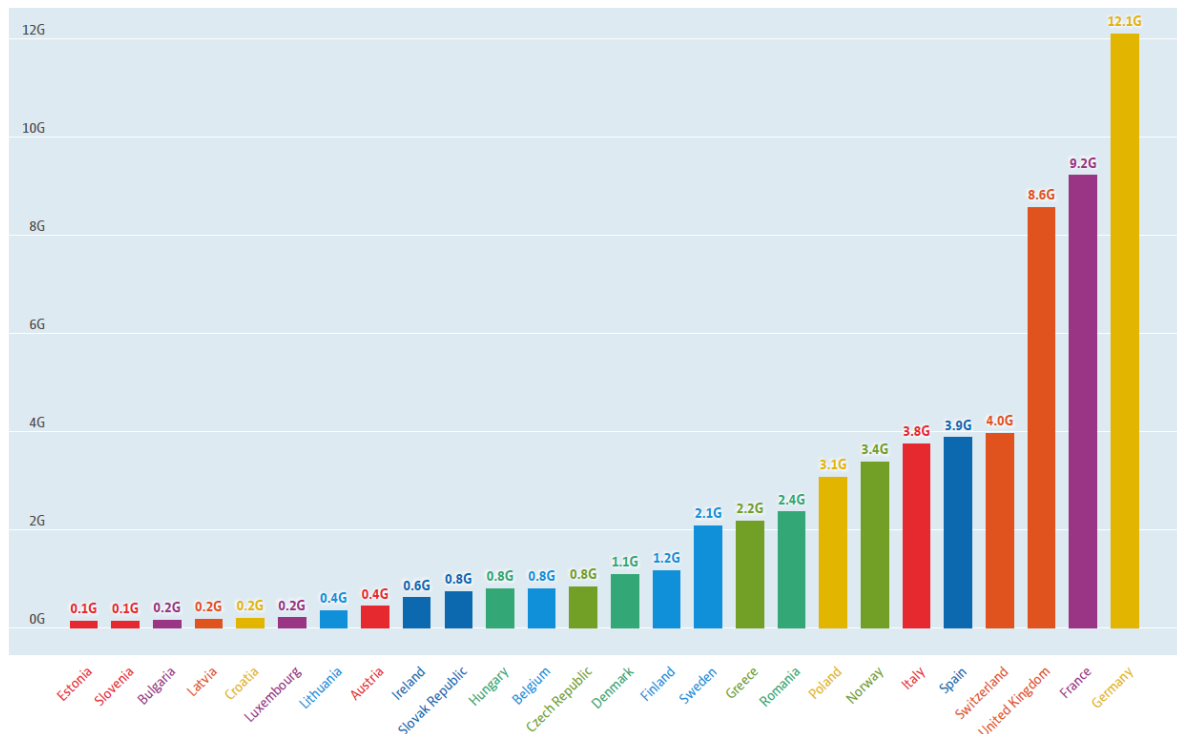


Figure 5 – Infrastructure investment in road transport (euro, 2016) [12]

Financial indicators of GDP in countries of the EU in 2016 was found in the Eurostat website (Fig. 6).

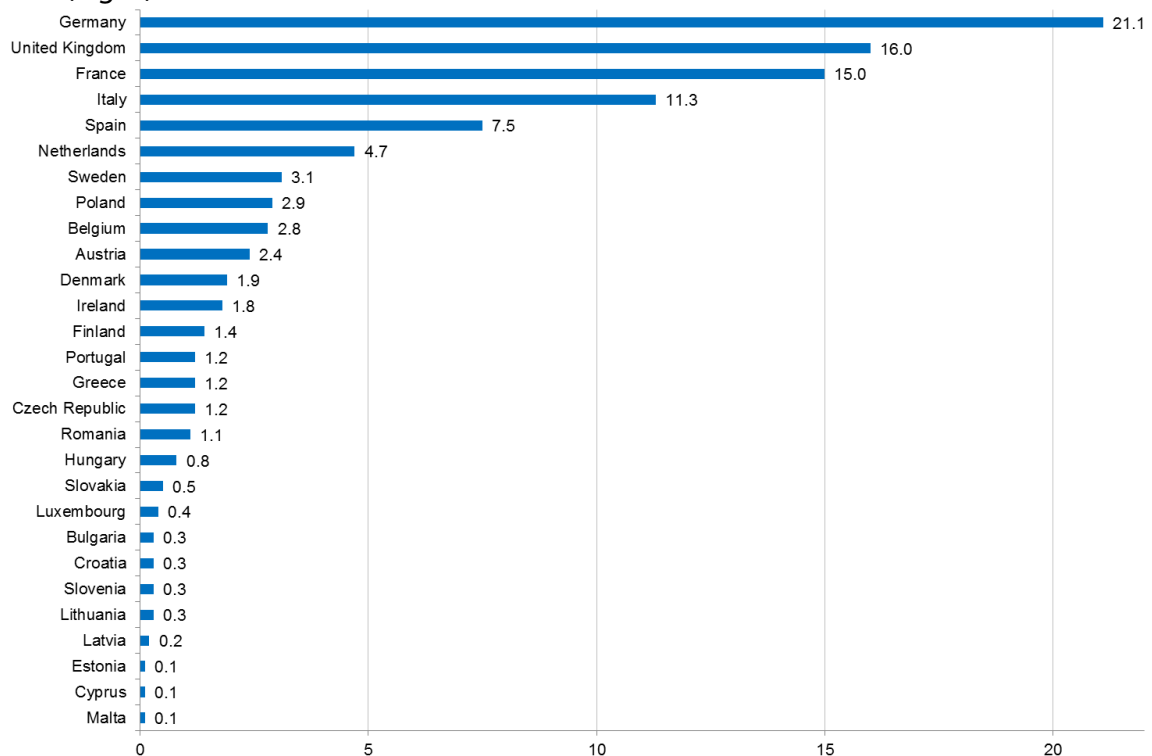


Figure 6 – Share in the EU GDP (% , 2016) [13]

Unfortunately, due to old statistics, information was not found in open sources for all EU countries in 2016. Therefore, the worksheet with initial data contains information only for those countries that belonged to the EU in 2016 and for which it was possible to obtain statistical data on all the above factors of influence (Table 1).

It should be noted that for the possibility of direct comparison of the degree of influence of each factor on external costs, the units of measurement (Fig. 4-6) were transformed to those that made it possible to obtain approximately the same order of numbers for all factors (resulting and influencing).

Table 1. Statistics about external costs of road transport, performed work, investment in the infrastructure and GDP by countries of the EU in 2016

Country	Total external costs (bn €)	% of EU GDP	Performed tonne-kilometres (bn tkm)	Infrastructure investment in road transport (10 mln €)
Austria	18,30	2,40	18,09	44,40
Belgium	26,40	2,80	35,58	81,00
Bulgaria	6,50	0,30	35,40	16,31
Croatia	5,00	0,30	11,34	19,74
Czech Republic	13,60	1,20	50,31	84,92
Denmark	8,20	1,90	12,94	109,95
Estonia	1,50	0,10	6,72	14,86
Finland	7,40	1,40	26,85	117,80
France	109,10	15,00	152,80	921,60
Germany	165,70	21,00	315,77	1209,00
Greece	12,80	1,20	24,56	218,70
Hungary	11,10	0,80	40,01	80,27
Ireland	14,30	1,80	11,56	62,20
Italy	115,00	11,30	112,64	375,50
Latvia	2,30	0,20	14,23	19,00
Lithuania	3,90	0,30	30,97	35,70
Luxembourg	3,20	0,40	6,45	21,35
Poland	40,20	2,90	303,56	307,54
Portugal	16,80	1,20	34,68	7,90
Romania	21,20	1,10	48,18	236,68
Slovakia	5,40	0,50	36,11	75,14
Slovenia	2,70	0,30	2,14	14,90
Spain	64,30	7,50	216,99	388,00
Sweden	15,30	3,10	42,69	208,63
United Kingdom	99,40	16,00	157,66	856,14

Next, regression analysis was performed and such values were obtained (Table 2).

Table 2. Regression statistics

Multiple R	0,99
R Square	0,97
Adjusted R Square	0,97
Standard Error	7,96
Observations	25

Values of Multiple R and R-square (very next to 1) allow us to make a conclusion that these three factors are sufficient to explain the variable (external costs) at a reliability level of 95% (that is by default in the MS Excel).

In our case the F Statistics is less than 0,05 (2,49E-16), which indicates that the

explanatory variables (factors X₁, X₂, X₃) have a statistically significant association with external costs.

The most important results were obtained about the coefficients of the regression equation, their boundaries as well as errors and t-statistics (Table 3).

Table 3. Regression Coefficients, Errors, P-values, t Statistics

	Coefficients	Standard Error	t Statistics	P-value	Lower 95%	Upper 95%
Intercept	1,67	2,04	0,82	0,42	-2,58	5,92
Factor X ₁	8,86	1,07	8,26	0,00	6,63	11,09
Factor X ₂	0,09	0,03	3,20	0,00	0,03	0,15
Factor X ₃	-0,05	0,02	-2,22	0,04	-0,09	0,00

P-values tell us whether or not each explanatory variable is statistically significant. All factors are statistically significant (values are from 0,00 to 0,04 that is less than 0,05). It means that all factors should be involved in the model.

The work [14] shows no significant correlation between transport work and infrastructure investment, which confirms the absence of multicollinearity.

The coefficients for each explanatory variable (8,86; 0,09; -0,05) show the average expected change in the response variable, assuming the other explanatory variable remains constant. For example, for each additional % of EU GDP, the external costs of transport are expected to increase by 8,86, assuming that all other factors values remain constant.

As for the coefficient for the intercept, it means that the expected external costs for a country with 0 values of all factors X is 1,67. Of course, this looks like nonsense, since with zero GDP, and with the absence of transport performance and investment in infrastructure, the external costs of transport cannot take place. However, here it should be remembered that the value of this coefficient is only an estimate, that is, an average. If we

talk about the interval in which it can change, then its upper and lower limits (at a 95% reliability level) are (-2,6; 5,9).

Another important result is the sign with which the coefficients are present in the model: the factors X₁ and X₂ have a positive sign, and the factor X₃ has a negative sign. This can be regarded as the direction of the influence of the factor on the resulting value. That is, with an increase in % of GDP and transport work, external costs will increase, however, with an increase in investment in road infrastructure, the value of external costs of transport will decrease. This fact should be taken into account by all countries when assessing the feasibility of infrastructure investment projects. If, in addition to the direct economic component, the external costs of transport are taken into account, this may tilt the balance towards the expediency of launching the project.

The last step is to show the regression equation and illustrate the difference (and similarity) between the real values of external costs of transport for each country and the theoretical values calculated using the regression equation.

Regression is:

$$Y = 1,67 + 8,86 \cdot X_1 + 0,09 \cdot X_2 - 0,05 \cdot X_3,$$

where Y is external costs of road transport in bn euros;
 X₁ is the country's GDP in % from total EU GPD in %;

X_2 is performed transport work by country in bn tkm;
 X_3 is the volume of investments in road infrastructure by country in 10 mln euros.

Now we can show the real and theoretical (obtained using the regression equation) data

of external costs of road transport in the graph (Fig. 7).

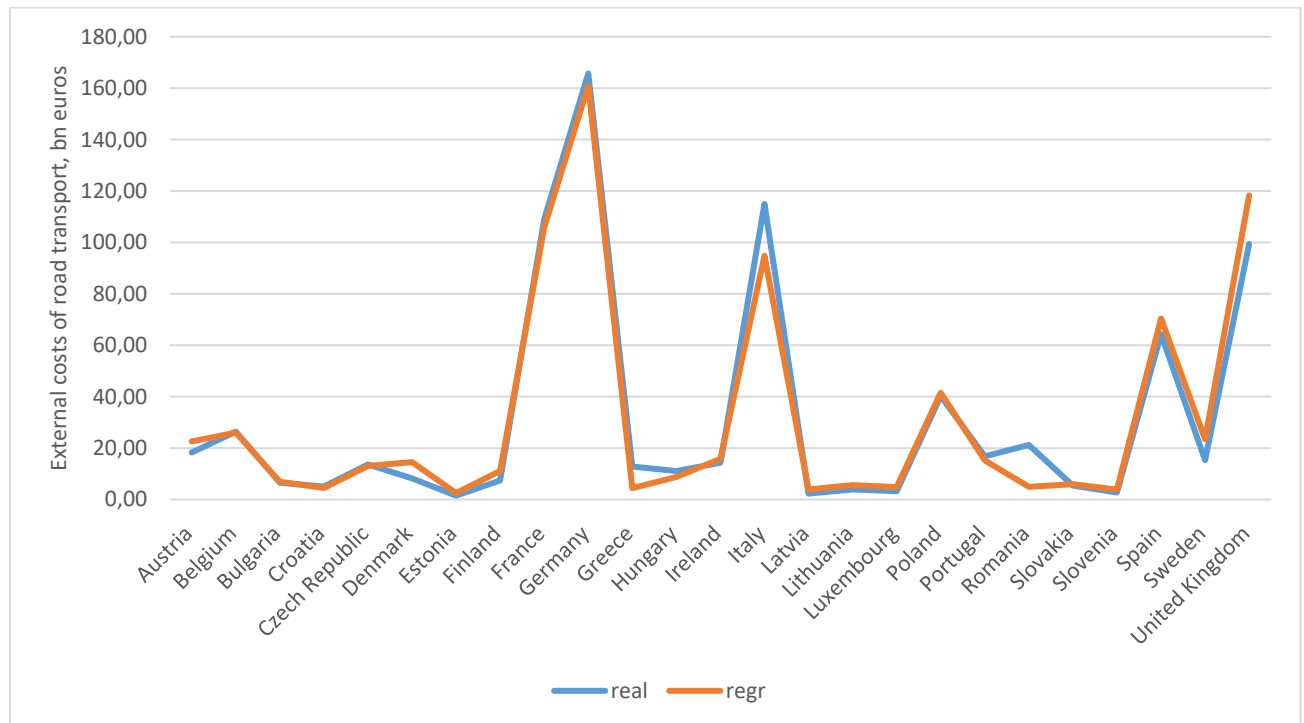


Figure 7 – Real and theoretical values of the external costs of road transport

Conclusions. To sum up, on the basis of correlation-regression analysis, factors were determined that have a clear relationship with the external costs of road transport - the country's GDP, the amount of transport work produced by the country in tkm and the amount invested in road infrastructure. Values of Multiple R and R-square of the regression model (very next to 1) allow us to make a conclusion that these three factors are sufficient to explain the variable (external costs) at a reliability level of 95%. All factors are statistically significant and should be involved in the model. Another important result is the sign with which the coefficients are present in the model: with an increase in % of GDP and transport work, external costs

will increase, however, with an increase in investment in road infrastructure, the value of external costs of transport will decrease.

We can observe a very good representation of the theoretical data with the resulting regression model. It can be assumed that this equation can be used both now and in the future to predict external costs of road transport and transfer the methodology to countries outside the EU, for example, Ukraine.

It should be added that in the context of road transport, there is mostly talk of negative externalities, which is undoubtedly necessary, but there is very little discussion of positive externalities, the contribution of transport to country's economic growth (and therefore positive GDP growth).

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