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FACTORS DETERMINING THE DEVELOPMENT OF INTELLIGENT TRANSPORT SYSTEMS

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Abstract. *Purpose* – foreign and Lithuanian researchers analyse the benefits of ITS (Intelligent transport systems) application and development opportunities in various aspects. Due to the rapid development of technology, most authors emphasise the need for new or at least repeated research on intelligent transport systems ITS. The aim of this article is to evaluate the factors determining the development of ITS after theoretical substantiation.

Research methodology – the primary data was collected from the following databases: Eurostat, OECD, World Bank. This study uses the analysis of scientific literature, expert survey, multi-criteria assessment (SAW and COPRAS methods).

Findings – the results of this article indicate which factors determine the development of ITS the most: investments, the aim to increase road safety, well-developed infrastructure. It also identifies which of the chosen for analaysis countries has the greatest potential for developing of ITS – Germany.

Research limitations – firstly, due to the lack of statistics only eight countries are included and the period of analysis is only two years. Another limitation is that experts from only two countries completed the survey.

Practical implications – research on the development of ITS is carried out in order to analyse the country that has the biggest opportunity to develop ITS and the factors affecting the mentioned development. The results can be beneficial for ministries of transport in different countries for planning the application of ITS.

Originality/Value – current study contributes to the existing literature by examining the specific factors affecting the development of ITS that were not analysed earlier. This article differs from others as includes some Northern ,Western European and Baltic countries. Findings can be used by government in planning the installation of ITS to get the maximum benefit from it.

Keywords: intelligent transport systems, congestion, safety, development of intelligent transport systems, multi-criteria evaluation.

JEL Classification: F63, F64, O33, O44, Q01, Q53, Q55, Q58, R11, R41, R42.

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Introduction

With increasing globalisation and an evolving economy, the demand of high-quality transportation services increases (Rodrigue, 2020). In 2019, 74.9 million cars were sold worldwide, which makes personal vehicles one of the most popular modes of transport (Statista, n.d.). Large number of personal vehicles in use causes problems in the transport system, such as increased accidents, prolonged congestion duration. According to the World Health Organization, about 1.35 million people die on the world's roads every year. For this reason, some countries lose around 3% of GDP (World Health Organization, 2015). ITS are used in various countries to solve problems in the transport system and increase the efficiency of transportation. Increasing cooperation between countries in the implementation of ITS and the encouragement of global institutions to apply them requires to complete additional research on the development, benefits and significance of intelligent transport systems for countries.

Research problem: What factors determine the development of ITS? *The object* of research is intelligent transport systems. *The aim* of this article is to evaluate the factors determining the development of intelligent transport systems after theoretical substantiation.

The first part of the article contains a scientific literature analysis of ITS including principles of classification, advantages and importance of ITS, principles of application of ITS globally.

In the second part a system of fifteen factors determining the development of ITS based on the methodology of the factors determining the development of ITS is created. Moreover, used expert evaluation, SAW and COPRAS methods are described.

In the third part the results of completed expert evaluation and multi-criteria assessment are presented. According to experts, the most ITS development is determined by investments, high accident rates, well-developed infrastructure and the least by tourism development, Internet speed. The results of SAW and COPRAS methods are similar and state that the most opportunities and reasons to develop ITS out of the analysed countries has Germany.

1. Theoretical aspects of intelligent transport systems

Intelligent transport systems affect infrastructure and vehicles and are beneficial for the transport system and drivers or passengers (Perallos et al., 2016). Intelligent transport systems (ITS) increase the efficiency of the transport system and infrastructure, which leads to faster dissemination of information on a global scale (Haseeb, 2017). ITS benefits passengers by helping to shorten travel times and increase safety (Haseeb, 2017). Increasing globalisation and technological development are also expanding the number of scientific research on intelligent transport systems. Researchers study the use of ITS, the principles of classification, analyse and evaluate the factors determine the development of ITS. There is no single official definition of the concept of ITS, and various authors define it in their research based on documents, standards and other research related to the transport system and ITS. Almost every ITS definition identifies ITS as an information and communication technology, which is located in infrastructure or vehicles and performs specific functions (traffic management, safety enhancement, reduction of pollution and congestion, improvement of transport system efficiency and quality of service) (Janušová & Čičmancová, 2016; Sarkar & Jain, 2018).

1.1. Classification of intelligent transport systems

The scientific literature presents different ITS classification methods. For example, ITS are categorized by scope (Hassanpour et al., 2016; Janušová & Čičmancová, 2016), mode of transport (Hassanpour et al., 2016; Janušová & Čičmancová, 2016), management (Katerna, 2019), location (Małecki et al., 2014), functions performed and services provided (Jarašūnienė, 2007; Giannopoulos et al., 2012; Janušová & Čičmancová, 2016; Sarkar & Jain, 2018). Jarašūnienė (2007) and Janušová and Čičmancová (2016) state that ITS are deployed either in infrastructure or in vehicles. This is one of the simplest ways of classifying ITS, as it does not delve into the functions performed by ITS, the nature of its operation.

Thus, there is no formal ITS classification model. Countries, cities or ITS associations can classify intelligent transport systems at its discretion. The scientific literature provides models for ITS classification by scope, mode of transport, management, ITS location, functions performed and services provided. The authors do not indicate the most appropriate way of ITS grouping; yet seek for new ITS classification techniques.

1.2. The importance of the application of intelligent transport systems in the transport system

ITS collect, process and provide data in a high-quality and efficient way, reduce traffic congestion, increase safety by quickly detecting accidents and removing obstacles on the road, inform drivers about the traffic situation and help them to choose the optimal route, facilitate parking and e-payment (Road Network Operations & Intelligent Transport Systems, n.d.). ITS benefits users of the transport system: road users, passengers, public transport passengers, people with reduced mobility, institutions involved in transport activities (Road Network Operations & Intelligent Transport Systems, n.d.).

Toulouki et al. (2017) conducted a study on the benefits of ITS in Greece. The authors used a survey method and found that most respondents believed that the application of ITS could increase the personal income of the population, shorten travel time and encourage them to choose a more environmentally friendly way to travel. The authors also argue that ITS can improve the quality of public transport services (Toulouki et al., 2017). In terms of economic benefits, ITS can reduce the cost of producing and trading goods and services, can have a positive impact on real estate value, rent and annual income, create new jobs (Toulouki et al., 2017). In order to assess the economic benefits of ITS, it is important to identify the financial damage caused by problems in the transport system that ITS are expected to solve. The main costs in the transport sector are caused traffic jams and traffic accidents, and policy makers seek to reduce their impact on society (Vencataya et al., 2018).

Janušová and Čičmancová (2016) note that ITS are used to solve problems in the transport system and increase passenger safety, reduce travel time and fuel consumption. With the necessary information collected and processed by ITS, the most effective solutions on transport system services can be offered to road users (Janušová & Čičmancová, 2016).

In terms of the economic benefits of individual ITS systems, the electronic road toll system in the US has been found to increase mobility and generate around 1 billion USD per year, and red-light cameras increase safety, which can be valued at around 1 billion USD

per year (United States Department of Transportation, n.d.). It has also been found that a traffic management system in the US increases mobility and the economic benefits of this system can be estimated at 276.5 million USD per year, and the driver information system increases mobility, which can be estimated at 543.1 million USD (United States Department of Transportation, n.d.).

This means that intelligent transport systems can provide the necessary real-time information on traffic, reduce the number of accidents, congestion, greenhouse gas emissions, increase the quality of services, expand exports, as well as encourage passengers to choose public transport or other environmentally friendly modes of transport.

1.3. Application of intelligent transport systems in the context of globalisation

Globalisation is defined as a worldwide phenomenon characterised by the convergence of trade, production, labour and other links between different countries, the absence of economic borders (Merriam-Webster, n.d.). This process is dependent on bridging distances through technology and affects the environment, culture, political systems, economic development and the quality of life of people in societies around the world (Brondoni, 2014).

ITS is an innovation that brings social and economic benefits to countries and users of transport systems in different parts of the world. The size of the global ITS market in 2018 was estimated at 23 billion USD (Global Market Insights, n.d.) and at 26.58 billion USD at 2019 (Grand View Research, n.d.). The overall annual growth rate of the global ITS market is projected to increase more than 5 percent in a period from 2019 to 2025 (Global Market Insights, n.d.). It is also projected that in 2025 the ITS market will reach 34 billion USD (Global Market Insights, n.d.) and in 2027 – 37.6 billion USD (Grand View Research, n.d.). It is stated that North America in the forecast period 2019–2025 will be the first in the world market (Global Market Insights, n.d.). Such growth is expected due to the application of ITS in various countries around the world in order to reduce traffic congestion and due to the development of the Internet of Things, automation of transport systems (Global Market Insights, n.d.). The development of the global ITS market is also determined by the accidents around the world – 1.35 million of people die on the roads every year, which costs 518 billion USD (Centers for Disease Control and Prevention, n.d.). The application of ITS is accelerating because of the passengers and drivers wanting to know the traffic situation in different regions and public authorities using innovative and advanced traffic data analysis technologies to help increase traffic efficiency (Grand View Research, n.d.). ITS are also being deployed worldwide due to the need for reduction of the negative environmental impact made by vehicles.

The positive results of ITS application encourage the countries around the world to deploy them within their own country. However, the transport system and infrastructure of some countries are not suitable for new technologies, and countries do not have sufficient funds to upgrade the infrastructure and vehicle fleet (Wang et al., 2016). Weak economies and institutional policies hinder ITS deployment in developing countries (Khan et al., 2014). High unemployment and low income per capita lead to a lack of public support for ITS and new technologies deployment (Khan et al., 2014). Also according to Khan et al. (2014),

investment in ITS deployment is usually at the bottom of the priority list. Due to weak institutional support in developing countries, there is a lack of competent specialists required for the planning, design and operation of ITS infrastructure (Khan et al., 2014).

The wide variety of ITS also makes it difficult to choose the most effective ITS solution. Purchasing inferior equipment results in a loss of financial resources and does not provide the expected benefits. Also, due to a large number of ITS manufacturers, some entities prefer their own domestic manufacturer, in which case foreign companies do not receive revenue, or choose products offered by the world's leading company. Therefore domestic companies suffer economically.

Another problem in global application of ITS is the inefficient cooperation between countries, lack of information sharing (Sampson et al., 2019). Although global ITS congresses are held annually, not all participants are sufficiently motivated to make changes in their country.

The development of ITS in the context of globalisation may be hampered by the lengthy process of systems deployment. Also, if an ITS is deployed in a country by a company from another country, data protection is essential.

Properly developed laws and documentation are important for the development of ITS in the context of globalisation (Sampson et al., 2019). The adoption of different standards or laws may restrict trade between countries and reduce the number of possible alternatives of ITS (Sampson et al., 2019).

To conclude, the problems related to the global development of ITS are experienced and must be solved by the countries planning to install ITS, their institutions, ITS deployment companies, ITS development investors, ITS users, and road users.

2. Methodology on implementation of intelligent transport systems development

An analysis of the scientific literature found that the authors used different methods to evaluate the development and benefits of ITS. For example, Toulouki et al. (2017) used a survey method in their study of the benefits of ITS, and Plaksin et al. (2015), Vencataya et al. (2018) calculated the cost of congestion. A cost-benefit analysis is often used to assess the socio-economic profitability of investments in ITS development (Öörni, 2019). This approach also makes it possible to compare investments in ITS with investments in other activities (Öörni, 2019). In order to perform a cost-benefit analysis, separate methods are needed to assess safety, pollution, traffic efficiency and to determine the monetary benefits (Öörni, 2019). Some countries determine the value of human life, the economic damage caused by a person injured or killed in a traffic accident (Öörni, 2019). Veryard (2016) argues that cost-benefit analysis alone is not sufficient enough to determine the impact of ITS on the economy at the macroeconomic level (Veryard, 2016). The cost-benefit analysis has certain limitations, such as the inability to take into account certain impacts that cannot be determined by any methods (Öörni, 2019). Consequently, in the economic and social evaluation of ITS, the cost-benefit analysis must be combined with other methods – an example of a multi-criteria analysis is provided (Öörni, 2019).

Thus, the existing studies on the economic impact of ITS lack of research into comparison of possibilities of ITS installation in different countries. The most important thing in research is to collect all the necessary data, and most authors suggest completing surveys, traffic monitoring, or data collection from ITS. Some authors argue that the impact of ITS on the economy is manifested through the impact on safety, the environment and the efficiency of the transport system. This also encourages the development of ITS. Most of the authors used cost-benefit analysis and correlation regression analysis to analyse specific cases of ITS application in a certain territorial unit.

In this study, based on scientific literature, a system of factors determining the development of ITS is created. For the analysis of main factors SAW and COPRAS methods based on multi-criteria utility theory are used. The weighting factors for the coefficients of ITS development are determined by expert evaluation.

2.1. Expert evaluation method

The expert assessment is performed by interviewing ITS experts. The selected experts must meet the following criteria: have a Bachelor's or Master's degree, work in the field of ITS for at least three years, have experience in cooperation with foreign countries in the field of ITS (Table 1).

Table 1. Eligibility of experts (source: compiled by the authors)

Experts	I	II	III	IV	V	VI	VII	VIII	IX
Bachelor's degree	+	+	+	+	+	+	+	+	+
Master's degree		+	+		+	+	+	+	+
Duration of work in ITS area in years	3	15	7	5	12	9	6	12	7

During the research, based on scientific literature, a system of factors determining the development of ITS is formed (Table 2). According to the authors, these factors are the main indicators of the development of ITS as they are essential installation of ITS, their frequency of use and prevalence in a global environment.

Experts rate factors from one to ten in order of importance. The survey was sent to experts in ITS area in different countries, however, answers from nine ITS experts from Lithuania and Latvia were received. Since more than three experts are interviewed, the Kendall concordance coefficient is calculated, which will indicate the degree of agreement between the opinions of several experts (Podvezko, 2005):

$$W = \frac{12\tilde{S}}{k^2\left(n^3 - n\right)}; \tag{1}$$

$$\tilde{S} = \sum_{i=1}^{n}\left(R_j - \frac{\widetilde{R_1} + \widetilde{R_2} + \cdots + \widetilde{R_n}}{n}\right)^2 = \sum_{i=1}^{n}\left(R_j - \frac{k\left(n+1\right)}{2}\right)^2. \tag{1.1}$$

In the formula $\widetilde{R_j}$ is the sum of the j ranks, n is the sample size, k is the number of experts.

Table 2. List of factors determining the development of intelligent transport systems (source: compiled by the authors)

	Factors determining the development of ITS	Authors, citing relevant factors
1.	Internet speed	Brondoni (2014), Choosakun et al. (2021)
2.	Investments	Wang et al. (2016), Choosakun et al. (2021), Sampson et al. (2019), United Nations (2017)
3.	Development of cross-border trade	Brondoni (2014), Sampson et al. (2019)
4.	Labour movement	Brondoni (2014)
5.	The aim to reduce traffic congestion	Taie and Elazb (2016), Khan et al. (2014), Hasegawa (2015)
6.	The aim to increase road safety	Centers for Disease Control and Prevention (n.d.), Khan et al. (2014), Hasegawa (2015)
7.	Tourism development	Taie and Elazb (2016)
8.	The aim to reduce the negative impact of transport on the environment	Grand View Research (n.d.)
9.	The increasing number of research studies	Wang et al. (2016), Choosakun et al. (2021)
10.	Effective international cooperation on intelligent transport systems	Sampson et al. (2019), Wang et al. (2016), United Nations (2017), Hasegawa (2015)
11.	Success stories (good practices)	United Nations (2017), Wang et al. (2016)
12.	Documentation, strategies focused on smart mobility	Sampson et al. (2019), Choosakun et al. (2021), Lu et al. (2018), European Commission (2016)
13.	Well-developed infrastructure	Wang et al. (2016)
14.	Active involvement of the public and private sectors	Lu et al. (2018), Choosakun et al. (2021), European Commission (2016)
15.	A large number of specialists	Khan et al. (2014)

The closer the value of the concordance coefficient W is to 1, the more consistent the opinions of the experts are (Podvezko, 2005).

2.2. SAW method

SAW method is used in this article to find the factor that is an essential reason for each country to develop ITS. The simple additive weighting method is one of the simplest and most widely used methods based on weighted average (George et al., 2018). The advantage of this method is that it is a proportional transformation of the primary data (George et al., 2018). To apply the SAW method, a weight must be assigned to each factor (George et al., 2018). After completing a survey, the obtained expert data are nornalised according to the formula:

$$r_{ij} = \frac{r_{ij}}{\sum_{j=1}^{r_{ij}} r_{ij}}, \tag{2}$$

where r_{ij} – the value of the i indicator for the j object (Ginevičius & Podvezko, 2008). Later, weighting factors w are assigned, the sum of which must be equal to 1 (Ginevičius & Podvezko, 2008):

$$\sum_{i=1}^{m} w_i = 1 . \tag{3}$$

The significance of the indicator is calculated by dividing the sum of the average indicators by the average evaluation value of each indicator according to the formula (Ginevičius & Podvezko, 2008):

$$\frac{\sum_{j=1}^{n} \overline{t}_j}{t_j} . \tag{4}$$

S_j is the value of the multi-criteria evaluation of the j alternative according to the formula (Ginevičius & Podvezko, 2008):

$$S_j = \sum_{i=1}^{m} w_i r_{ij} . \tag{5}$$

The highest value of S_j obtained is the best (George et al., 2018). According to the obtained S_j values, the sample sizes are ranked from the best (highest S_j value) to the worst (lowest S_j value).

2.3. COPRAS method

COPRAS method is used in this article for ranking alternatives of ITS develompent in different countries. This means, that the country with the biggest opportunity to develop ITS and the factors determining this development the most are selected. COPRAS (COmplex PRoportional ASsessment) is a complex of complex proportionality assessment and multi-objective decision-making methods used to determine the effectiveness of alternatives (Karaca et al., 2019). The COPRAS method is simply applicable, allows the calculation of both maximum and minimum criteria, indicates the degree of utility (Organ & Yalçın, 2016). Alternatives can be compared and the best and worst of them can be identified. The principle of the method is that the relative significance Q_i of the comparative alternatives is determined according to their positive (S_{+i}) and negative (S_{-i}) properties (Simanavičienė, 2011). The higher the value of Q_i is, the more effective is the alternative (Simanavičienė, 2011).

$$S_j = \frac{r_{ij} w_i}{\sum_{j=1}^{n} r_{ij}} . \tag{6}$$

In this formula, w_i is the weight of the i indicator, r_{ij} is the normalised value of the i indicator for the j object. Using the COPRAS method, the significance, degree of utility and priority of the options considered can be determined (Organ & Yalçın, 2016). In the first stage, data is normalised according to the formula:

$$d_{ij} = \frac{x_{ij} \cdot q_i}{\sum_{j=1}^{n} x_{ij}} , \tag{7}$$

where: x_{ij} is the value of criteria i in solution variant j; m – number of criteria; n – number of variants to be compared; q_i is the significance of criteria i. The sum of the dimensionless

estimated values d_{ij} obtained for each criteria x_i is always equal to the significance q_i of this criteria (Viteikiene & Zavadskas, 2007):

$$q_i = \sum_{j=1}^{n} d_{ij} . \tag{8}$$

In the second stage, the sums of minimising (their lower value is better) S_{-j} and maximising (their higher value is better) S_{+j} estimated and normalised indicators are calculated (Viteikiene & Zavadskas, 2007). They are calculated according to the formula (Viteikiene & Zavadskas, 2007):

$$S_{+j} = \sum_{i=1}^{m} d_{+ij} ; \tag{9}$$

$$S_{-j} = \sum_{i=1}^{m} d_{-ij} . \tag{10}$$

In any case, the sums of the S_{+j} and the S_{-j} of all objects are always respectively equal to the sum of the maximasing and minimising criteria (Viteikiene & Zavadskas, 2007):

$$S_{+} = \sum_{j=1}^{n} S_{+j} = \sum_{i=1}^{m} \cdot \sum_{j=1}^{n} d_{+ij} ; \tag{11}$$

$$S_{-} = \sum_{j=1}^{n} S_{-j} = \sum_{i=1}^{m} \cdot \sum_{j=1}^{n} d_{-ij} . \tag{12}$$

In the third stage, the relative significance of the compared options is determined. It is determined on the basis of the positive S_{+j} and negative S_{-j} properties that characterise them (Viteikiene & Zavadskas, 2007). In the fourth stage, the objects are prioritised . The higher the Q_j, the higher the efficiency (priority) of the variant is (Simanavičienė, 2011). Q_j is calculated according to the formula (Viteikiene & Zavadskas, 2007):

$$Q_j = S_{+j} + \frac{S_{-\min} \cdot \sum_{j=1}^{n} S_{-j}}{S_{-j} \cdot \sum_{j=1}^{n} \frac{S_{-\min}}{S_{=j}}} . \tag{13}$$

In the fifth stage, the efficiency *Nj* of the variant a_j is determined according to the formula (Viteikiene & Zavadskas, 2007):

$$N_j = \left(\frac{Q_j}{Q_{\max}} \right) \cdot 100\% . \tag{14}$$

Depending on the degree of utility obtained, sample sizes are ranked from largest to smallest (Karaca et al., 2019).

Expert survey will contain fifteen factors that determine the development of ITS, while only quantitative factors will be used for SAW and COPRAS methods. The period of analysis is 2018–2019 years. This selection is based on the latest Horizon 2020 work programme

(2018–2020), which is concentrated on establishment of smart, green and integrated transport, and the presence of data. The countries for the analysis where chosen according to the cooperation in application of ITS globally, location (regions).

3. Results

3.1. Expert evaluation of the factors affecting the development of ITS

A questionnaire listing all the factors affecting the ITS development was created during this study. ITS experts were asked to rate each factor on a scale from one to ten (1 – the factor is not important at all for development of ITS, 10 – the factor is very important for development of ITS). Estimates of the factors affecting ITS development are presented in Figure 1.

Analysing the results of the survey, it is possible to determine which factors, according to experts, have the greatest impact on the development of ITS in the context of globalisation. The experts gave the highest rates to the following factors: success stories, active involvement of the public and private sectors, investments, effective international cooperation on ITS, the aim to increase road safety, well-developed infrastructure. According to experts, the least ITS development is determined by the following factors: tourism development, a large number of specialists, Internet speed.

The calculation of the Kendall concordance coefficient showed that the expert opinions were consistent (a value of 0.704 was obtained). Subsequently, only quantifiable factors were selected and their significance was calculated in order to perform calculations using the SAW and COPRAS methods.

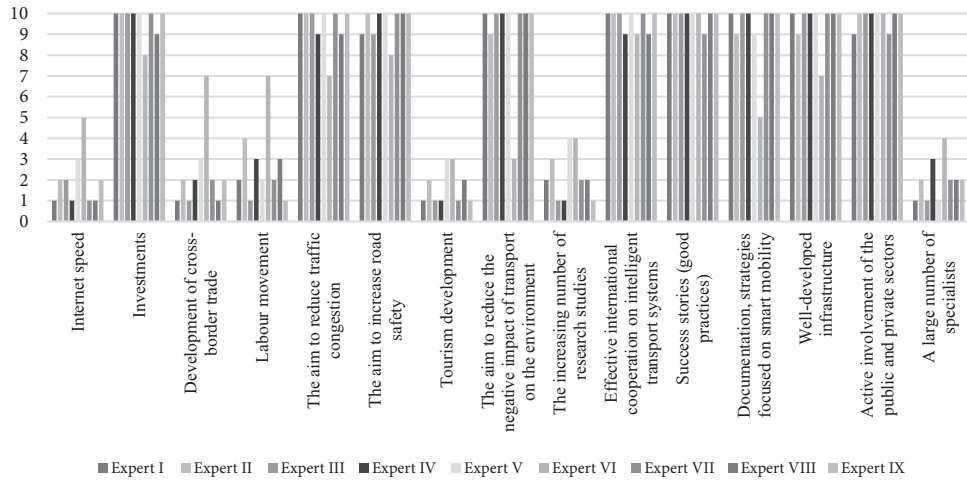

Figure 1. Results of the survey of experts determining the factors affecting the development of ITS (source: compiled by the authors)

3.2. SAW method application

The following indicators describing the factors affecting the ITS development were selected for the analysis: Internet speed (X1 – average Internet speed), investment (X2 – foreign direct investment), development of cross-border trade (X3 – export of goods and services), labour movement (X4 – number of immigrants), the aim of reducing congestion (X5 – hours lost due to congestion), the aim of increasing road safety (X6 – the number of credible accidents), tourism development (X7 – the number of tourists), the aim of reducing the negative impact of transport on the environment (X8 – CO_2 emissions in the transport sector), the increasing number of research studies (X9 – number of students), well-developed infrastructure (X10 – length of motorways). Primary data (2018–2019) was collected in the following databases: Eurostat, OECD, World Bank. Table 3 shows the calculations performed using SAW method using different coefficients w.

The values of S_j obtained are ranked from highest to lowest. It can be said that the country with the highest S_j value has the most opportunities for ITS development. With different coefficients, Germany is in first place, while Latvia is in the last. Calculations with the same coefficients gave very similar results (Figure 2). In this case, Germany is in the first place, while Lithuania is in the last.

Table 3. Normalised values of factors determining the development of ITS and results of SAW method (S_j values) using different coefficients (source: compiled by the authors)

Country	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	Sj	Rank
1. Germany	0.098	0.111	0.542	0.637	0.128	0.904	0.319	0.396	0.499	0.614	0.433	1
2. Norway	0.143	0.044	0.045	0.034	0.128	0.011	0.047	0.131	0.046	0.028	0.066	5
3. Latvia	0.127	0.038	0.006	0.008	0.126	0.012	0.067	0.013	0.129	0.009	0.044	8
4. Denmark	0.122	0.071	0.061	0.046	0.113	0.009	0.266	0.213	0.050	0.062	0.093	4
5. Sweden	0.145	0.382	0.075	0.094	0.135	0.042	0.061	0.044	0.069	0.100	0.132	2
6. Finland	0.126	0.053	0.032	0.022	0.095	0.013	0.027	0.049	0.047	0.043	0.050	7
7. Netherlands	0.129	0.255	0.226	0.138	0.108	0.002	0.162	0.122	0.142	0.129	0.130	3
8. Lithuania	0.109	0.046	0.013	0.021	0.167	0.009	0.050	0.032	0.019	0.015	0.051	6
w	0.03	0.17	0.04	0.05	0.16	0.16	0.03	0.16	0.04	0.16		

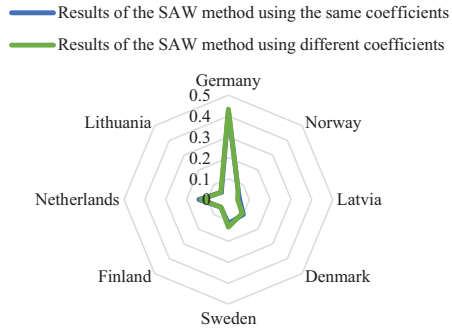

Figure 2. Results of the SAW method in the analysis of the factors affecting the development of ITS (source: compiled by the authors)

Thus, the SAW method was used to identify the countries with the highest and lowest ITS development potential. In both cases, Germany was in first place, while Latvia and Lithuania were in the last.

3.3. COPRAS method application

The same data was used for the calculations using COPRAS method. The previously calculated coefficients w are used. The data is normalized and it is determined which factors increase the development of ITS and which decrease it. Subsequently, further calculations are performed according to the formulas presented in the methodology section: the significance Q of each alternative is calculated and the degree of utility N_j of each country is determined. According to the obtained results, the countries are ranked from the best value of the degree of utility N_j to the worst (Table 4).

Table 4. Results of the COPRAS method in the study of the factors affecting the development of ITS (source: compiled by the authors)

Country	Calculations using different coefficients			Calculations using the same coefficients		
	Significance of the alternative	Degree of utility (%)	Priority	Significance of the alternative	Degree of utility (%)	Priority
1. Germany	0.43281705	100.00	1	0.42459424	100.00	1
2. Norway	0.06632158	15.32	5	0.06573722	15.48	5
3. Latvia	0.04391646	10.15	8	0.05352005	12.60	6
4. Denmark	0.09326894	21.55	4	0.10127889	23.85	4
5. Sweden	0.13203673	30.51	2	0.11470350	27.01	3
6. Finland	0.05026559	11.61	7	0.05075755	11.95	7
7. Netherlands	0.13034610	30.12	3	0.14140653	33.30	2
8. Lithuania	0.05102750	11.79	6	0.04800199	11.31	8

Analysing the results of the degree of utility, it can be stated that the country with the greatest value has the most opportunities for ITS development. With different coefficients, Germany is in the first place, while Latvia is in the last (Figure 3).

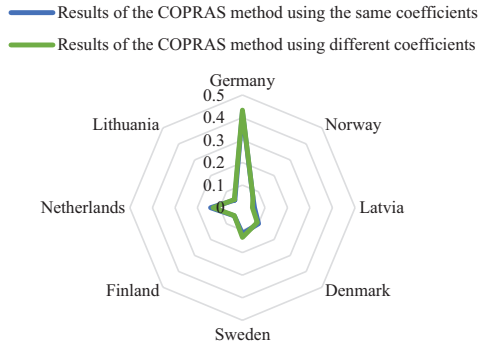

Figure 3. The results of the COPRAS method in the analysis of the factors affecting the development of ITS (source: compiled by the authors)

After completing calculations with the same coefficients, Germany is in the first place, Lithuania is in the last place.

This research complements the results of existing articles by analysis of specific countries and factors which were not explored earlier. Many authors concentrate on the economic benefits of ITS in certain cities or countries, however, there is a deficiency of comparison of different countries in global ITS development.

The future model could contain more descriptive indicators for analysis and examine the indicators of ITS benefits, which will make it possible to identify the area that will benefit most from ITS development. Secondly, more countries could be selected for analysis for more accurate results. Current research focuses only on opinions of experts, for this reason, the future model could use more statistical data on ITS.

Conclusions

1. An analysis of the scientific literature has identified the problems arising in the field of ITS in the current conditions of globalisation. The difficulties are mainly faced by companies selling ITS and countries planning to install ITS. The problems are caused by high competitiveness, migration, insufficient funds for ITS application and insufficient cooperation with other countries around the world in the implementation and application of ITS.
2. On the basis of the reviewed scientific works, it was determined that other authors offer to use a multi-criteria evaluation method for the analysis of ITS development. Based on the scientific literature, a list of factors determining the development of ITS has been compiled.
3. The value of the Kendall concordance coefficient W obtained from the expert assessment of the factors determining the development of ITS in the context of globalisation indicates that the expert opinions are mutually consistent. Consequently, the experts have been properly selected and their estimates can be used in further calculations.
4. A completed multi-criteria assessment of the factors of ITS development using the SAW method has identified the countries with the highest and lowest ITS development potential. With both different and equal coefficients, Germany is in the first place, while Latvia (when the coefficients are different) and Lithuania (when the coefficients are the same) are in the last.
5. The COPRAS method has been used to identify the strongest country in terms of ITS development. It was found that the country with the most ITS development opportunities with both different and the same coefficients is Germany, and the weakest – in the first case is Latvia, in the second – Lithuania.

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