

RESEARCH OF URBAN LOGISTICS INDICES ASSESSMENT

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Abstract

The article describes the analysis of urban logistics indices, which include Urban Mobility Index and The index of sustainable urban mobility (I_SUM). The disadvantages of existing indicators for assessing urban mobility are described. The article presents the system of indicators for the evaluation of urban transport system efficiency based on urban traffic forecasting, determination of route failure probability, gravitational model of freight traffic management and model of vehicle distribution between routes.

Key words: Urban logistics, indices, analysis.

Introduction

Modern society development and urbanization boost put forward new requirements for the entire system of municipal services. World practice of regional and urban management demonstrates the need for logistics tools, especially in transition economies and during economic crisis. Increasing consumer demands on their service level require additional costs for current municipal system improvement and development through logistics. Effective use of urban logistics tools allows to find resources for improving the efficiency of goods movement and transportation processes.

Highly competitive market conditions highlight the issues of transportation services that meet residents' needs with maximum benefit at minimum cost and timesaving. A citizen and its needs should be the focus now in urban development strategies. Therefore, urban transport system manage-

ment and development, and transport services characteristics are of current importance.

Characteristic of public transport system is an important component of urban mobility index whereas it determines the access of residents within agglomeration to high quality and economically feasible transport services.

Development of the methodology for urban mobility assessment is induced by the need to assess and compare the conditions of the various cities (Arthur D. Little 2014), with the objective of sustainable urban mobility index (Miranda, Rodrigues da Silva 2012) to develop a universal indicator, which can be used as a supporting tool for mobility management and for the formulation of sustainable policies.

However, these indices ignore the assessment of urban transport system functioning. Therefore, the analysis of public transport efficiency should include methods of population changes prognosis and the resulting changes in urban traffic (Royko et al. 2015), the method of route failure probability determination due to the vehicle breakdown, considering the congestion probability (Vakulenko, Dolya 2014), the conceptual provisions of the justification of passenger traffic solutions in city logistics (Dmytiryev et al. 2012), mathematical tools that can solve the problem of traffic management within the municipal area (Hubenko, Lyamzyn 2009), Intelligent Transport Systems in the fight against condensation in urban areas (Mel'nychenko et al. 2008), an economic-mathematical model of the optimal bus fleet distribution on the routes (Lytvyn, Volod'ko 2015). These methods allow to increase the quality level of municipal services, including transport services.

1. Urban mobility assessment indices

The problems of urban mobility vary in different countries and cities, and this leads to changes in urban planning and urban streams. Traditional approaches to planning urban transport systems can no longer meet the needs of residents and businesses operating in the city. This is mainly due to two main problems of transport demand on the one hand – the uncertainty demands, on the other – difficulties in effectively meeting the needs of the growing demand. In addition, the existing transport system provokes problems such as negative attitudes toward people who are not drivers; inequitable distribution of benefits and costs; financial burden for households, government and business; inefficiency, due to traffic congestion and dispersed land use; a large number of victims of road accidents; negative impact on the environment and quality of life; based on non-renewable resources that may be scarce in the future, and so on (Royko et al. 2015).

Nowadays a new planning paradigm is being gradually built, in which transportation planning, circulation planning and urban planning are now devised under a common approach, the mobility planning (Litman, Burwell 2006). This approach is based on the concept of sustainable development. If the concept of sustainable transportation is seen as an extension of the concept of sustainable development introduced by the UN (WCED 1987), it could be defined as the development that meets the current transport needs without jeopardizing the ability of future generations to meet these needs. In addition, the concept of sustainable development is often associated with economic, social and environmental aspects.

Improving sustainable urban mobility requires finding appropriate indicators to assess the level of sustainable urban mobility. However, there is no ideal method for solving this problem, and many options can be tailored to the needs of the city. Urban planning requires the involvement of experts from different disciplines, support citizens and enterprises. The choice of the method that should be used to assess urban mobility depends on the criteria for the city and tasks to be achieved.

The development of a new paradigm of sustainable urban mobility contributed to the emergence of new planning procedures and tools, including improved versions of traditional urban indicators. They allow to define the characteristics of many elements and functions that form the urban environment. Overall, the indicators that have been developed so far, helped assess the economic, social and environmental impacts of alternative scenarios and strategies. Some indicators have focused on specific aspects of sustainability, such as accessibility, mobility and environmental potential. However, the best results can be obtained through a combination of indicators to capture different characteristics and aspects of a phenomenon. This will provide a comprehensive analysis and help people who make decisions understand which strategies to comply with the objectives of sustainable development.

The index used for mobility assessment is Urban Mobility Index developed by Arthur D. Little consultancy. The Mobility Index help to assess cities on the basis of 19 criteria. 11 of these were related to how mature the city under examination was in terms of its existing infrastructure, from public transport's share of the modal split to smart card penetration. These indicators made up 58 possible points of the maximum of 100 available. The other 42 points were awarded on the basis of performance, with categories including the level of transport-related CO₂ emissions and the mean travel time to work (Figure 1).

Figure 1. Arthur D. Little Urban Mobility Index 2.0 assessment criteria

Arthur D. Little Urban Mobility Index 2.0 – Assessment criteria			
Maturity [max. 58 points]		Performance [max. 42 points]	
Criteria	Weight ³	Criteria	Weight ¹
Financial attractiveness of public transport	4	Transport related CO2 emissions	4
Share of public transport in modal split	6	NO2 concentration	4
Share of zero-emission modes in modal split	6	PM10 concentration	4
Roads density	4	Traffic related fatalities	6
Cycle path network density	6	Increase of share public transport in modal split	6
Urban agglomeration density	2	Increase of share of zero-emission modes	6
Smart card penetration	6	Mean travel time to work	6
Bike sharing performance	6	Density of vehicles registered	6
Car sharing performance	6		
Public transport frequency	6		
Initiatives of public sector	6		

Source: Arthur D. Little 2014.

This index has a significant lack of mobility, it can not be adapted to the specific conditions when certain indicators are not simply recorded. In these circumstances, the use of this index is impossible.

To solve problems related to the index of mobility calculation, individually for each city, with the lack of some indicators, the index of sustainable urban mobility was designed.

The index of sustainable urban mobility (I_SUM) is an assessment tool that can be used to reveal current urban mobility conditions or to anticipate the impacts of measures and strategies aiming at sustainable mobility. The index is formed by nine domains covering thirty-seven themes, which are further subdivided into eighty-seven indicators (Table 1).

Table 1. The index of sustainable urban mobility (I_SUM) framework

Domains (weights)	Dimensions weights			Themes (weights)
	<i>Soc</i>	<i>Eco</i>	<i>Env</i>	
Accessibility (0.108)	0.38	0.36	0.26	Accessibility to transport systems (0.29)
	0.40	0.32	0.27	Universal accessibility (0.28)
	0.38	0.30	0.32	Physical barriers (0.22)
	0.46	0.28	0.27	Legislation for users with special needs (0.21)

³ The maximum of 100 points is defined by any city in the sample for each criteria Source: Arthur D. Little Urban Mobility Index 2.0

Environmental aspects (0.113)	0.29	0.28	0.43	Control of environmental impacts (0.52)
	0.26	0.32	0.42	Natural resources (0.48)
Social aspects (0.108)	0.40	0.31	0.29	Support to the citizens (0.21)
	0.45	0.30	0.25	Social inclusion (0.20)
	0.39	0.30	0.31	Education and active citizenship (0.19)
	0.41	0.27	0.32	Public participation (0.19)
	0.35	0.30	0.35	Quality of life (0.21)
Political aspects (0.113)	0.33	0.34	0.32	Integration of political actions (0.34)
	0.33	0.40	0.27	Acquisition and management of resources (0.33)
	0.34	0.33	0.32	Urban mobility policy (0.34)
Transport infrastructure (0.120)	0.28	0.41	0.31	Provision and maintenance of transport infrastructure (0.46)
	0.33	0.35	0.33	Distribution of transport infrastructure (0.54)
Non-motorized modes (0.110)	0.32	0.29	0.39	Bicycle transportation (0.31)
	0.33	0.28	0.39	Pedestrians (0.34)
	0.28	0.32	0.40	Trips reduction (0.35)
Integrated planning (0.108)	0.31	0.37	0.32	Managers training (0.12)
	0.35	0.30	0.35	Central areas and historical sites (0.11)
	0.31	0.34	0.35	Regional integration (0.12)
	0.38	0.32	0.31	Planning process transparency (0.12)
	0.31	0.32	0.36	Planning and control of land use (0.14)
	0.32	0.35	0.33	Strategic and integrated planning (0.14)
	0.31	0.39	0.30	Infrastructure and urban facilities planning (0.13)
	0.31	0.35	0.35	Master Plan and urban legislation (0.12)
Urban circulation traffic (0.107)	0.37	0.38	0.26	Traffic accidents (0.21)
	0.39	0.31	0.30	Traffic education program (0.19)
	0.29	0.35	0.36	Freedom of movements and circulation (0.19)
	0.34	0.33	0.33	Traffic operation and enforcement (0.20)
	0.32	0.31	0.36	Private transport (0.21)
Urban transport systems (0.112)	0.35	0.33	0.32	Transit availability and quality (0.23)
	0.31	0.34	0.34	Diversity of transportation modes (0.18)

	0.34	0.35	0.31	Transit regulations and enforcement (0.18)
	0.37	0.33	0.30	Transit integration (0.22)
	0.38	0.37	0.25	Fare policy (0.19)

Source: Miranda, Rodrigues da Silva 2012.

The hierarchy of criteria of I_SUM started with the fifty-five Alternatives, which were defined after successive rounds of analyses, comparisons and combinations of concepts that expressed similar ideas.

It was designed to cover both traditional transportation topics and questions related to the new paradigm of sustainable mobility. In addition, it is flexible enough to be adapted to different urban contexts, as a result of the diversified and comprehensive structure of the index.

The structure suggested to I_SUM also allows evaluations based on a reduced number of indicators. This is the case when the data needed for the calculation of all eighty-seven indicators are not reliable or simply do not exist. However, if a reduced number of indicators is used, it is necessary to redistribute the weights of the indicators within each Theme. The same procedure may be needed for Themes and for Domains, in order to assure that the weights in each hierarchy level always sum up one.

However, these indices cannot identify the whole problems and identify the weak link in the city transport system, that are analyzed solely in terms of vehicle quantity of different types and their share in the total number of vehicles on the road, travel time to work of its residents. Out of focus is quality analysis of residents' movement in the city.

The use of these indicators is necessary for the assessment of urban mobility and for strategy planning and development, but is also appropriate to use additional indicators of development and existing problems in the urban transport system.

2. Methods of evaluation of a city transport system

Rapid society development in all spheres lead to the need of efficiency analysis of public transport system and instruments elaboration for it's improvement. It stipulates the increase of social, living and productive necessities of cities population. Under the circumstances, it is important to use such methods of urban transport system organization that will answer the requirements of all participants of transport process.

The question of traffic forecasting in the city has an important value as from the point of view of design, building, and reconstruction of highways or strengthening of road covering and in the context of struggle against urban transport infrastructure load. An increase of urban population leads to the increase of people and loads flows.

City traffic forecasting allows getting important information on management and the necessity special instruments application. Consequently, a complex prognosis requires not only adjustment of transport system existing in a city but also gives a possibility to plan a necessary amount and structure of investments in city development. For this purpose, it is important to take into account the city development prognosis, in particular:

- rates of housing development and influence of new settlements on traffic in its suburb,
- locations of large trade complexes and their consequences for city traffic.

There are a few general methodological approaches to traffic intensity forecast (Royko et al. 2015):

1. Methods that are based on the data of traffic intensity change for the last years (extrapolation methods): linear law of traffic intensity increase, equalization of compound interests, exponential and power equalizations, models of traffic intensities forecast with the use of logistic curve.
2. Methods that are based on the analysis of transport connections in the considered region. The basic feature of these methods is supposition that traffic intensity considerably depends on freight and passenger transportations.
3. Methods that are based on multivariable economic analysis. In a general view these methods are based on regressive and cross-correlation analyses and are described by such equalization:

$$N_t = A_1x_1 + A_2x_2 + A_3x_3 + \dots A_nx_n + B \quad (1)$$

where A_1, A_2, A_3, A_n are regression coefficients,

x_1, x_2, x_3, x_n are factors of traffic that influence intensity.

It is necessary to make an investment plan for prevention of city development problems, based on traffic forecast. Actually, it is the biggest potential for congestion decline.

Therefore, at the development of rout network and further public transport management the subject of probability of tram route failure is topical.

Methodology of determination of route failure probability due to the vehicle breakdown suggests that n trams are working on the route, at the breakdown of one unit the route work stops (Vakulenko, Dolya 2014).

A route works, if all transport vehicles work (event T') and stops if one event T_i come (accident or breakage of i transport vehicle), here events T_i are independent.

Probability of breakdown (accidents) of i transport vehicle:

$$P(T_i) = p_i, \quad (2)$$

where p_i , is probability of breakdown (accidents) of i transport vehicle.

Probability of faultless work of i of transport vehicle:

$$P(T'_i) = 1 - p_i = q_i \quad (3)$$

where is probability of faultless work of i transport vehicle.

Probability of stop of route work:

$$P(A) = 1 - P(T'_i) = 1 - \prod_{i=1}^n q_i = 1 - \prod_{i=1}^n (1 - p_i), \quad (4)$$

where n is an amount of transport vehicles on the route.

If the same type transport vehicles with the equal values of probabilities of breakdown work in the route then the probability of breakdown of the route can be defined as follows:

$$P(A) = 1 - (1 - p)^n, \quad (5)$$

It should be noted that probability of event “one transport vehicle does not work, other work” is possible to define with the formula:

$$P(B_i) = p_i \prod_{j \neq i}^n (1 - p_j), \quad (6)$$

with the further search of probability of appearance only one of events is described as follows:

$$P(\sum_{i=1}^n B_i) = \sum_{i=1}^n p_i \prod_{j \neq i}^n (1 - p_j), \quad (7)$$

Urban logistics includes freight transport management also.

A gravitational model of transport streams in urban region can be written as follows (Hubenko, Lyamzyn 2009):

$$\sum_{i=1}^{\infty} \tau_i \lambda^* + \Delta_t = \mu \frac{SP}{c^2}, \quad (8)$$

where λ^* is a value that characterizes the work-load of city transport communications close to the industrial enterprise in the moment of time t ;

$\tau_i = 0, 1, 2$ are lag coefficients (weight coefficients that represent consequence (weight) of influence factor);

Δ_t is a random error of equalization (determines the area of vibrations of efficiency index of city transport system);

S, P are entrance / exit freight traffic volume;

C is a cost for 1 tone freight processing;

μ is a coefficient of inconsistency of actions between the elements of municipal district.

There are also models of vehicle distribution between routes. These models are not optimization and do not take into consideration the economic indicators of vehicular process. Not complete indemnification of losses from local budgets, a swift increase of price on fuel oils materials and devaluation of hryvnya need applications of such models, that would take into account (maximize) the income of Road Transport Enterprise and provide necessary indexes of quality maintenance for passengers.

For this purpose it is advisable to apply a next model (Lytvyn, Volod'ko 2015):

$$\left\{ \sum_{j=1}^n A_j * q_j * \Pi_j \rightarrow \max; \gamma_i \leq \gamma^{allow}; \sum_{j=1}^n A_j = A_{RTE}; A_j \geq 0 \right\} \quad (9)$$

where A_j is an amount of busses on j route (plan of distribution);

q_j is a capacity of model of bus;

Π_j income of Road Transport Enterprise from one passenger seat use on j route;

γ_i is a coefficient of the use of vehicle capacity on the most high-usage track of j route;

γ^{allow} is an allowable coefficient of capacity use;

A_{RTE} is an available amount of busses;

n is an amount of attendant routes.

Conclusions

An evaluation of urban mobility potential is an important criterion of city development analysis in the whole and city logistic in particular. The marked indices of urban mobility estimation can be used for the analysis of city mobility potential; however, their deficiency is lack of some index components observations. For complete urban mobility research, it is important to analyze the efficiency of city transport system based on the offered indexes.

References

1. Arthur D. Little (2014), Future of urban mobility 2.0: Imperatives to shape extended mobility ecosystems of tomorrow, available at: http://www.adlittle.com/downloads/tx_adlreports/Arthur_D._Little___UITP_Future_of_Urban_Mobility_2_0.pdf (accessed: 5 June 2015).
2. Dmytriyev, M.M. et al. (2012) Kontseptsiya sitilohistyky i pasazhyrs'ki perevezennya, Visnyk NTU. No. 26, pp. 72-78.
3. Hubenko, V.K., Lyamzyn, A.A. (2009), Horodskaya lohistyka, Visnyk Pryazovs'koho derzhavnoho tekhnichnoho universytetu. No. 19, pp. 271-275.
4. Litman, T., Burwell, D. (2006), Issues in Sustainable Transportation, International Journal of Global Environmental Issues, Vol. 6, No. 4, pp. 331-347.

5. Lytvyn, V., Volod'ko, D. (2015), Rozrobka struktury kompleksnoho pokaznyka efektyvnosti optymal'noho variantu rozpodilu avtobusiv mizh marshrutamy, in: Problemy z transportnymy potokamy i napryamy yikh rozv'yazannya: Tezy dopovidey Vseukrayins'koyi naukovo-teoretychnoyi konferentsiyi, 26-28 bereznya 2015 r. L'viv: Vydavnytstvo L'vivs'koyi politekhniky, pp. 74-75.
6. Mel'nychenko, O.S., Krykavs'kyi, O.S., Mel'nychenko, V.Ye., Sopil'nyk, R.L. (2008), Lohistyka i misto: efekt vzayemodiyi, Visn. Nats. un-tu "L'viv. politekhnika". Lohistyka, No. 633, pp. 814-822.
7. Miranda, H. de F., Rodrigues da Silva, A. (2012), Benchmarking sustainable urban mobility: The case of Curitiba, Brazil, Transport Policy. No. 21, pp. 141-151.
8. Royko, Yu., San'ko, Ya., Sydorov, D. (2015), Prohnozuvannya zminy intensyvnosti rukhu v urbanizovanomu Prostowi, in: Problemy z transportnymy potokamy i napryamy yikh rozv'yazannya: Tezy dopovidey Vseukrayins'koyi naukovo-teoretychnoyi konferentsiyi, 26-28 bereznya 2015r., Vydavnytstvo L'vivs'koyi politekhniky, Lviv, pp. 13-15.
9. Vakulenko, K.Ye., Dolya, V.K. (2014), Upravinnya systemoyu mis'koho pasazhyrs'koho transport. Vostochno-Evropeyskyy zhurnal peredovykh tekhnolohyy. No. 3(69), pp. 33-37.
10. WCED (1987), Our common future (The Brundtland Report). United Nations, World Commission on Environment and Development. Oxford University Press, Oxford.