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## ECOLOGICAL AND ECONOMIC EFFECTS FROM IMPLEMENTATION OF THE MODEL OF SOLIDARITY USE OF MOTOR TRANSPORT IN THE CONTEXT OF SMART CITY CREATION

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*Гончаренко О.С., Гриневич О.В. Еколого-економічні ефекти від впровадження моделі солідарного використання автотранспорту в контексті створення смарт-сіті.*

У статті обґрунтовано необхідність вирішення автотранспортних проблем суспільства використанням моделі солідаризації автомобільного транспорту в контексті управління міським господарством на основі впровадження системи смарт-сіті. Розглянуто сутність новітнього для наукової думки України поняття солідарного використання автотранспорту (кар-шерінгу). Автором систематизовано та доповнено види ефектів, спричинених системою солідарного використання автомобілів, серед яких екологічні, економічні та соціальні. У роботі розраховано еколого-економічні ефекти на основі відвернутих збитків від викидів в атмосферне повітря.

*Ключові слова:* еколого-економічні ефекти, кар-шерінг (car-sharing), автотранспортна система, система смарт-сіті (smart-city), солідарна економіка, дематеріалізація

*Goncharenko A.S., Hrynevych O.V. Ecológico-económico efectos de la implementación del modelo de uso solidario del transporte en el contexto de la creación de smart-city.*

В статье обоснована необходимость решения автотранспортных проблем общества использованием модели солидаризации автомобильного транспорта в контексте управления городским хозяйством на основе внедрения системы smart-city. Рассмотрена сущность нового для научной мысли Украины понятия солидарного использования автотранспорта (кар-шеринг). Автором систематизированы и дополнены виды эффектов, вызванных системой солидарного использования автомобилей, среди которых экологические, экономические и социальные. В работе рассчитаны эколого-экономические эффекты на основе предотвращенных ущербов от выбросов в атмосферный воздух.

*Ключевые слова:* эколого-экономические эффекты, кар-шеринг (car-sharing), автотранспортная система smart-city (smart-city), солидарная экономика, дематериализация

*Goncharenko O.S., Hrynevych O.V. Ecological and economic effects from implementation of the model of solidarity use of motor transport in the context of smart city creation.*

The article substantiates the necessity of solving motor transport problems of the society using the model of solidarization of motor transport in the context of urban management based on the introduction of smart-city system. In the article have been considered the essence of the newest concept for scientific thought in Ukraine of joint use of vehicles (car-sharing). The author systematized and supplemented the types of effects caused by the system of joint use of automobiles, including ecological, economic and social ones. The ecological-economic effects on the basis of reversed losses from atmospheric air emissions.

*Key words:* ecological-economic effects, car-sharing, motor transport system, smart city system, solidarity economy, dematerialization

The main positive social, economic and environmental effects have led to the intensification of the implementation of the concept of "smart city" in the daily life of settlements in countries all around the world. Global challenges such as climate change, structural restructuring of the economy, the transition to online retailing and entertainment, population aging, urban population growth, and pressure on public finances contribute to finding new ways for society to develop [1]. The European Union (EU) is steadfast in its efforts to develop a strategy for achieving "smart" urban growth for major cities-regions [2-3]. A number of programs have been developed by foreign scientists within the framework of the European Agenda [4] to strengthen innovation and investment in ICT services in order to improve public services and quality of life [3]. According to foreign experts, it is anticipated that the global market for smart city services will be \$ 400 billion per year by 2020 [5]. Undeniable proof of this is the examples of implemented technologies and the "smart city" programs in such cities as Milton Keynes, Southampton, Amsterdam, Barcelona and Stockholm [6].

According to the opinion of a number of scientists [7-9], one of the promising directions for implementing of smart-city concept is the solidarization of the public transport system aimed on solving of the socio-ecological and economic problems of the city. An example of solidarity motor transport is the business model, which in foreign literature received the name of car-sharing.

Taking into account the special relevance of this topic, the purpose of this article is to determine the ecological and economic effects from implementing the model of solidarity use of motor transport as a tool for creating a smart-city system in Ukraine, using the experience of the EU.

### Analysis of recent researches and publications

The analysis of scientific literature [8-9, 25-29] concerning the etymology of the concept of "smart-city" revealed that there are two main approaches to definitions of this concept. Proponents of one approach perceive the concept of "smart-city" as the automation of the management of the settlement [10]. In our study, we agree with the authors [11] that define smart-city as a system that integrates information and communication subsystems for

managing the settlement in order to achieve sustainable development for each individual separately and society as a whole. One of the key areas of the city economy, without which it is impossible to create comfortable living conditions for the city, is the transport system. For the purposes of our study was selected a public transport system, including individual and private motor vehicles, taking into account the socio-economic importance of this subsystem of the city's transport system. We believe that the research of other transport subsystems can be a continuation of research in the implementation of the concept of smart-city. We agree with the authors in [12], who determine the solidarity use of motor vehicles as one of the possible solutions to the problems of urban transport system.

### The main part

In the scientific literature [12], the term car-sharing refers to an alternative model of possession and use of a vehicle, which is a car ownership with another person or people that share the car with the right to use, that is, the share of a car with the right to use. Car-sharing is designed to quickly and conveniently satisfy the traditional need of a person to move from one place to another, and also allows him to obtain positive socio-ecological and economic effects both for an individual, and for society as a whole. The traditional car-sharing business model is based on car rental with the possibility of starting and ending use in a specially organized place (parking lot), or anywhere within the settlement. Payment for services is calculated according to the length of time of car use. As a rule, it is necessary to conclude a contract with the lessor once, all other relationships are carried out with the help of information and communication systems. In scientific literature, car-sharing is considered in the context of sustainable development of the transport system in the smart-city system [13,14,15], to solve the problem associated with its exponential growth of its size. It is expected that in the period from 1950 to 2050, the population of the Earth will increase three times [16], at the same time, the share of urbanization will increase from 29% to 69% [16]. According to the International Organization of Trade, the world car market is growing at an even faster pace [17], in year 1950 70 million of cars and buses were sold, and in 2010 it was already 700 million [17]. This means that between 2010 and 2050 the number of vehicles will increase threefold until the level of saturation by motor vehicles reaches approximately 850 cars per 1000 people [17]. Thus, given the relevance of this trend in the long term, the smart-city development strategy requires the implementation of innovative solutions to change the model of vehicle consumption in favor of the joint use of cars (car-sharing).

It should be noted that in Ukraine this model of solidarity use of motor vehicles is at the beginning of its existence. So, only in 2017, in Odessa and Kyiv, the first car-sharing services were opened in Ukraine. Due to the lack of statistical information for analyzing

and comparing the level of development of the car-sharing system, we consider it expedient to concentrate the attention on the analysis of EU experience using car-sharing that is aimed to build a smart-city system.

This business model has become particularly popular in Europe. For studying of the car-sharing experience was chosen Germany, which is the leader in the implementation of technologies for the solidarity use of cars. According to the German Car-Sharing Association [17], at the beginning of 2017 were registered 1,715 million participants of the car-sharing system. It means that 2% of the population of Germany is using this type of service. In 2016, the growth of registered members amounted to 455 thousand, or 26.5%. It should be noted that the most popular type of car-sharing with the so-called free parking, that is, when the car can be left or taken not in special parking lots, but in any place of the settlement. The share of this kind of car-sharing was almost 95% of the total increase. That means a rapid increase in the relevance for German citizens of the transition to innovative approaches of the use of vehicles. About 150 organizations provided services for the joint use of cars. The number of cars available for hire in 2016 was 9400, which are available in 4650 specialized parking lots, as well as 7800 automobiles with free parking spaces [18]. In recent years is increasing the number of settlements in which appears car-sharing, so their number in 2016 grew from 537 to 597, i.e. by 11% per year [18].

On average, in 2016, 48.4 clients used a car-sharing vehicle based on stationary parking lots, while at the same time 172.8 drivers used one free parking car. According to studies of the German Car-Sharing Association [18], one automobile of car-sharing replaces 9.52 private cars. The cost one hour of using an automobile in Germany based on stationary parking averaged 4 to 8 Euros, and for cars with free parking of 14 to 19 Euros. According to [19], the use of the car-sharing system is more advantageous for the consumer, on condition that the annual mileage of the car does not exceed 10,000 km a year. The calculations were carried out on the basis of a compact German car. The car-sharing system allows to average German citizen to save from 300 to 1500 Euro per year [17].

The rapid growth in the number of consumers who agree to switch to a model of co-use of cars is conditioned by the positive effects from the implementation of the car-sharing system. Conditionally we can divide them into ecological, economic and social. Table 1 schematically shows the types of effects, the processes that caused them and the parameters of their estimates.

It should be noted that in order to more fully assessment of the effects of the implementation of the system of solidarity use of motor vehicles, one must also take into account the reversed ecological and economic losses as they allow to assess the benefits of improving the quality of the atmosphere, energy and materials saving, improving of health, etc. Under

ecological and economic losses we understand the expenses of economic agents from violations of the environment (losses and additional costs for their prevention) [20].

Let's consider some of the main effects mentioned in Tab. 1 in details, to justify the possibility of switching to a model of compatible vehicle use. Consequently, the ecological and economic effects of the creation of motor transport system of car-sharing characterize the processes of its environmentally oriented dematerialization. The concept of dematerialization of socio-economic systems is considered in detail in [21], this process characterizes the decline in the use of material resources at all stages of the product life cycle. Quantitatively, it can be represented by an indicator of the level of dematerialization [22]. We can present a generalized ecological-economic effect in absolute terms as the size of material input that is not used for private cars, which can be replaced by a car-sharing system. Considering that one automobile of car-sharing can

replace about 10 private cars, as already mentioned earlier, and the amount of material inputs consumed at all stages of the life cycle of the car is approximately 489,881 kg [22], then the ecological-economic effect of using car-sharing of one car will be 4408 tons (9 cars \* 489 881 kg). If we consider the level of dematerialization in relation to the service unit (MIPS) provided by the car, then the effect will be expressed in a tenfold reduction of materials per kilometer of displaced passengers.

The ecological and economic effects during the use of the car-sharing motor vehicle system can be assessed in accordance with the methodology for estimating environmental losses from the environmental impact of motor vehicles described in detail in [23]. Thus, based on the effects presented in tab. 1, we can present the following main effects, taking into account the reversed ecological and economic losses as a result of the implementation of the car-sharing model when implementing the smart-city system.

Table 1. Types of effects caused by the system of solidarity use of cars

Effect category	The process that caused the effect	Parameters	Examples of possible effects from the implementation of the car-sharing system	
Ecological	Creation of a motor transport system	Material consumption / energy consumption	1) positive effects from dematerialization of automobiles	
			2) reduction of energy consumption due to optimization of transport flows and reduction of the number of cars	
			3) increasing the level of dematerialization of the infrastructure to provide a smart-city system	
	Use of the motor transport system	Emissions of pollutants	Emissions into the atmosphere	1) reduction of emissions associated with the operation of engines for private cars, car-sharing and motor vehicles
				2) reduction of the formation of dust particles and other abrasive materials
				3) reduction of emissions from cold start of engine due to reduction of average engine stop time and temperature
		Land use	car-sharing model with stationary parking	1) change in maximum, medium and distributed traffic noise from the motor transport system in the municipal area, for example, through restructuring of the use of cars and public vehicles that are moving in rush hour
				2) changing the level of vibrations on the roads due to changes in the average mass of vehicles or public transport
				3) reduction in the average loss of liquids for car maintenance due to reduced age of the car and better car maintenance
	Waste of motor transport system	Circulation of material flows / utilization of waste	1) changing the area needed for public transport infrastructure	
2) reduction of the total surface area required for all vehicles of all systems of motion at one point at a certain time, for example, the total number of cars requiring parking				
Economic			3) long-term planning of the city's development taking into account the increase in the density of buildings due to changes in the number of private cars and the need for space for their maintenance.	
			1) decrease of road wear due to reduced traffic in the city, such as movement frequency, density, length, etc.	
			2) decrease of parking places	
Social			3) etc.	
			1) improving the efficiency of vehicle utilization	
			2) the effect of closing the cycle of rotation of toxic materials	
			3) improving the efficiency of managing the processes of utilization of cars, as a result of reducing the number of owners, increasing the ability to control the processes, the use of standardized management models, etc.	
			1) Savings from the combined use of one car by several owners instead of a few private cars	
			2) Reduction of car repair payments due to reduced traffic volume, due to reduced number of vehicles	
			3) Effects for city budget – reduction of the cost of maintaining roads, infrastructure, parking, etc.	
			1) wider choice of mobility options, such as the availability of different car models for different consumer needs and integration with public transport systems in terms of pricing and infrastructure	
			2) increasing the attractiveness of the city due to lower car traffic, for example for tourists	
			3) socialization and impulse for post-materialist values	
			4) more open access to mobile movement by representatives of different sections of the population groups	

Source: systematized and added by the author on the basis of [24]

The effect of reversed emissions into the atmosphere, including dust and other abrasive materials, associated with a decrease in the number of vehicles and optimization of the system of motor vehicles in general, can be calculated taking into account the

values of environmental and economic losses from the emissions to the atmosphere 1 kg of pollutants in settlements with a population of more than 500 thousand people (tab. 2) for visibility of calculations it is accepted to use emissions of carbon monoxide (CO).

Table 2. Calculation of the ecological and economic effect of reversed emissions of carbon monoxide (CO) into atmospheric air during the implementation of the car-sharing model

Component	Economic losses from atmospheric emissions of 1 gram of pollutant in the settlement with a population of more than 500 thousand people. (USD)	Average car-sharing automobile emissions (grams / km)	Average emissions of private cars (grams / km)	Ecological-economic effect of the reversed emissions (CO) in the atmosphere (thousand dollars / km)
Carbon Oxide (CO)	17.66	98	153.9	986.98

Source: calculated by author based on [23,18]

Basing on tab.2 we can conclude that the implementation of the system of use of a car based on the car-sharing system results reversed environmental and economic damage of nearly 990 thousand dollars USA per 1 km. That is, if the average annual mileage of the car is 10 thousand km, the reversed ecological and economic damage for the year is almost 10 million dollars USA. Data analysis shows that such effects are achieved due to several reasons, namely, for the maintenance of a certain number of passenger-kilometers it is required a smaller number of car-sharing automobiles than private ones, on average car-sharing cars are more modern, that is, with higher

energy efficiency, in car fleets of the car-sharing system is much higher fate of electric cars.

The ecological and economic effects of changes of noise and vibration levels, land use, and motor transport system waste can be calculated on the basis of reversed environmental and economic losses due to changes in the traffic intensity and the philosophy of moving citizens within the city. We mean the transition to public transport, cycling, as well as a more streamlined planning of travel arrangements, etc. Calculations and possible effects can be summarized in tab. 3.

Table 3. Ecological and economic effects from changes in noise and vibration levels, land use, motor transport system waste due to the implementation of car-sharing

Type of damage	Average compact car	Under the condition of mileage of 1 car 10.000 km a year	With 20.000 cars in Odessa	Under the condition of replacement of 10 private cars by 1 car-sharing automobile	Ecological and economic effect
Losses from noise pollution, USD / km	0.016	160	3200000	32000	3168000
Losses from vibration, USD / km	0.96	9600	192000000	1920000	190080000
Damage from water pollution and hydrological violations, USD / km	0.024	240	4800000	48000	4752000
Losses from waste disposal, USD / km	0.004	40	800000	8000	792000
Total, USD		10040	200800000	2008000	198792000

Source: calculated by author based on [23,18]

According to data of analysts of the well-known information-analytical group "Avtokonsulting" the number of cars in Ukraine in 2016 amounted to 202 cars per 1,000 people. That is, for example, in Odesa, with a population of about 1 million 100 thousand people, there are about 20 000 cars. Thus, calculations are given in tab. 3 show that with the condition that one car of the car-sharing system replaces 10 private cars, as already noted before, the ecological-economic effect is calculated on the basis of reversed ecological-economic losses from noise, vibration, water pollution and hydrological violations, losses

from the waste disposal is about \$ 199 million USD per year.

### Conclusions

The article analyzes the theoretical basis of the smart-city concept in order to identify the main directions of improving the functioning of the city's economic system. It was revealed that one of the key areas of the city economy, without which it is impossible to create comfortable living conditions for the city's inhabitants, is the transport system. At the same time, the solidarity use of the motor transport system leads to positive ecological and economic

effects. Thus, on the basis of the integration by the author of the methodological approaches, it is calculated that the ecological and economic effect at the stage of the use of conditional 20000 cars, which is typical for the Ukrainian city of Odesa, taking into account the reversed ecological and economic losses from noise, vibration, water pollution and hydrological violations, losses from the disposal of waste is about \$ 199 million USD per year. Also on the basis of the method of calculating of

dematerialization level it is presented the generalized ecological-economic effect from unused private cars, which can be substituted for one automobile of car-sharing, will be 4408 t. Consequently, the study can be an informational basis for representatives of the government and business in making environmentally-directed decisions on the development of a high-tech and efficiently functioning urban economy based on the implementation of the smart city concept and the solidarity use of the transport system.

### Abstract

The article substantiates the necessity of solving motor transport problems of the society using the model of solidarization of motor transport in the context of urban management based on the introduction of smart-city system. In the article have been considered the essence of the newest concept for scientific thought in Ukraine of joint use of vehicles (car-sharing), which is urged to quickly and conveniently satisfy the traditional need of a person to move from one place to another, and also allows to get positive socio-ecological and economic effects, as for an individual, and for society as a whole. To analyze the theoretical basis of the car-sharing system was used the methodological experience of the EU countries and empirical data on the results of the use of this system in Germany became the basis for determining the ecological and economic effects of its implementation. The author systematized and supplemented the types of effects caused by the system of joint use of automobiles, including ecological, economic and social ones. The ecological-economic effects on the basis of reversed losses from atmospheric air emissions, from noise pollution, from vibration, from water pollution and hydrological disturbances, from waste disposal were calculated in the work.

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