MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY
FACULTY OF ENVIRONMENTAL SAFETY,
ENGINEERING AND TECHNOLOGIES
DEPARTMENT OF ECOLOGY

APPROVED TO DEFENCE
Head of the Graduate Department
_____ V.F. Frolov
«_____»__ _____ 2020

MASTER THESIS

(EXPLANATORY NOTE)

SPECIALTY 101 «ECOLOGY»
Training Professional Program "ECOLOGY AND ENVIRONMENTAL PROTECTION"

Theme: «Car-free city project for Opole»

Done by:
student of the EC-202m group, Oleksandra A.Kolotylo
(student, group, surname, name, patronymic)

Scientific Supervisor:
Ph.D., Associate Professor of the Ecology Department, Margaryta M. Radomska
(academic degree, academic rank, surname, name, patronymic)

Consultant of the chapter «Labor Precaution»: _____ Viktoria V. Kovalenko
(signature) (S.N.P)

Standards Inspector: _____ Andrian A. Iavniuk
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KYIV 2020

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
ФАКУЛЬТЕТ ЕКОЛОГІЧНОЇ БЕЗПЕКИ,
ІНЖЕНЕРІЇ ТА ТЕХНОЛОГІЙ
КАФЕДРА ЕКОЛОГІЇ

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач випускової кафедри
_____ В.Ф. Фролов
«_____» _____ 2020 р.

ДИПЛОМНА РОБОТА

(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ МАГІСТРА

ЗА СПЕЦІАЛЬНІСТЮ 101 «ЕКОЛОГІЯ»
ОПП ««ЕКОЛОГІЯ ТА ОХОРОНА НАВКОЛИШНЬОГО СЕРЕДОВИЩА»

Тема: «Проект міста без автомобілів для м. Ополє»

Виконавець:
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Консультант розділу «Охорона праці»: _____ Коваленко В.В.
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Нормоконтролер: _____ Явнюк А. А.
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КИЇВ 2020

NATIONAL AVIATION UNIVERSITY
Faculty of Environmental Safety, Engineering, and Technologies
Ecology Department
Direction (speciality, major): specialty 101 “Ecology”, TPP “Ecology and Environmental Protection”
(code, name)

APPROVED
Head of the Department
_____ Frolov V.F.
«____» _____ 20__

MASTER THESIS ASSIGNMENT
Oleksandra A. Kolotylo

1. Theme: «Car-free city project for Opole» approved by the Rector on October 11, 2019, № 2364/ст.

2. Duration of work: from 14.10.2019 to 09.02.2020

3. Output work (project): the scientific literature on the subject of master thesis; cartographic material; statistics data; methods of assessment of environmental and economic efficiency; methods for calculating environmental impacts of cars.

4. Content of explanatory note: (list of issues): history of the automotive industry, characterization of the impact of car using on people, analysis of "city without cars" projects implementation in different countries, review of transport infrastructure in Opole, environmental and economic efficiency assessment, calculation of automobile impact on the city center of Opole, recommendations for improving the environmental situation, project of a city without cars for the Opole city.

5. The list of mandatory graphic (illustrated materials): tables, figures.

6. Schedule of thesis fulfillment

№ з/п	Task	Term	Advisor's signature
1	Receiving of topic assignment, the search of the literature and methodology development	14.10.2019 – 20.10.2019	
2	Preparation of the main part (Chapter I)	21.10.2019 – 10.11.2019	
3	Preparation of the main part (Chapter II)	10.11.2019 – 17.11.2019	
4	Preparation of the main part (Chapter III) and drafting explanatory note for the first preliminary presentation	17.11.2019 – 10.12.2019	
5	First preliminary presentation of the diploma work	16.12.2019	
6	Preparation of the main part (Chapter IV)	12.12.2019 – 02.01.2020	
7	Preparation of the main part (Chapter V) and drafting explanatory note for the second preliminary presentation	03.01.2020 – 22.01.2020	
8	Second preliminary presentation of the diploma work	23.01.2020	
9	Formulation of the conclusions and recommendations of the diploma work, editing, consultation with standard's inspector, remarks and recommendations consideration	23.01.2020 – 26.01.2020	
10	Finalizing, signatures receiving, plagiarism verification, preparation to the final protection (presentation)	27.01.2020 – 04.02.2020	
11	Protection (presentation) of the final version of the diploma work at the department	05.02.2020	

7. Consultant(s) of certain chapter(s):

Chapter	Consultant (academic rank, S.N.P)	Date, signature	
		Given by	Accepted by
Labor Precaution	Viktoria V. Kovalenko, Ph.D., Assoc. Prof. of the Civil and Engineering Safety Department		

8. Date of task issue: «____» _____ 20__

Diploma (project) advisor: _____ Margaryta M. Radomska
(advisor's signature) (S.N.P.)

Task is taken to perform: _____ Oleksandra A. Kolotylo
(graduate's signature) (S.N.P.)

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
Факультет екологічної безпеки, інженерії та технологій
Кафедра екології
Напрям (спеціальність, спеціалізація): спеціальність 101 «Екологія», ОПП «Екологія та охорона навколишнього середовища»
(шифр, найменування)

ЗАТВЕРДЖУЮ
Завідувач кафедри
_____Фролов В.Ф.
«____» _____ 20__ р.

ЗАВДАННЯ
на виконання дипломної роботи
Колотило Олександри Анатоліївни

1. Тема роботи «Проект міста без автомобілів для м. Ополє» затверджена наказом ректора від «11» жовтня 2019 р. №2364/ст.

2. Термін виконання роботи: з 14.10.2019 р. по 09.02.2020 р.

3. Вихідні дані роботи: наукова література за темою магістерської дипломної роботи, картографічний матеріал, статистичні дані; методи оцінки екологічної та економічної ефективності; методи розрахунку впливу автомобілів на навколишнє середовище.

4. Зміст пояснювальної записки: історія розвитку автомобільної індустрії, характеристика впливу використання автомобілів на людей, аналіз впровадження проектів «місто без автомобілів» у різних країнах, огляд транспортної інфраструктури в місті Ополе, оцінка екологічної та економічної ефективності, розрахунок автомобільного впливу на центр міста Ополе, рекомендації для поліпшення ситуації, проект міста без автомобілів для міста.

5. Перелік обов’язкового графічного (ілюстративного) матеріалу: таблиці, рисунки.

6. Календарний план-графік

№ з/п	Завдання	Термін Виконання	Підпис керівника
1	Отримання завдання, пошук літературних джерел по темі, напрацювання методології роботи	14.10.2019 – 20.10.2019	
2	Підготовка основної частини (Розділ I)	21.10.2019 – 10.11.2019	
3	Підготовка основної частини (Розділ II)	10.11.2019 – 17.11.2019	
4	Підготовка основної частини (Розділ III) та підготовка до першого попереднього захисту	17.11.2019 – 10.12.2019	
5	Перше попереднє представлення роботи на кафедрі	16.12.2019	
6	Підготовка основної частини (Розділ IV)	12.12.2019 – 02.01.2020	
7	Підготовка основної частини (Розділ V)	03.01.2020 – 22.01.2020	
8	Друге попереднє представлення роботи на кафедрі	23.01.2020	
9	Формулювання висновків та рекомендацій, косметичні правки, консультація з нормоконтролером, урахування зауважень	23.01.2020 – 26.01.2020	
10	Дооформлення, отримання підписів, перевірка на плагіат, підготовка до захисту	27.01.2020 – 04.02.2020	
11	Захист готової роботи на кафедрі	05.02.2020	

7. Консультація з окремого(мих) розділу(ів):

Розділ	Консультант (посада, П.І.Б.)	Дата, підпис	
		Завдання видав	Завдання прийняв
Охорона праці	Коваленко В. В., к.б.н., доцент каф. цивільної та промислової безпеки		

8. Дата видачі завдання: «____» _____ 20__ р.

Керівник дипломної роботи (проекту): _____ Радомська М.М.
(підпис керівника) (П.І.Б.)

Завдання прийняв до виконання: _____ Колотило О.А.
(підпис випускника) (П.І.Б.)

ABSTRACT

Explanatory note to thesis «Car-free city project for Opole»: 141 pages, 18 figures, 33 tables, 83 references, 8 formulas, 4 annexes.

Object - organization of urban public transport network.

Subject – reduction of private transport impacts on the environment.

Aim of research – develop the project of the car-free city for Opole and evaluate its environmental and economic efficiency.

Methods of research – information search, analysis and synthesis, comparative analysis, mapping, visual observations, mathematical calculations, questionnaire.

The practical value of the work is the development of organizational solutions for the improvement of environment quality in cities through the reduction of traffic flow.

The results of the master thesis may be used for the implementation of principles of sustainable cities and improvement of public environmental awareness in the sphere of road infrastructure management.

CAR-FREE CITY, ENVIRONMENTAL EFFICIENCY, ECONOMIC EFFICIENCY, QUESTIONNAIRE, AIR POLLUTION, NOISE POLLUTION.

РЕФЕРАТ

Пояснювальна записка до дипломної роботи «Проект міста без автомобілів для м. Ополє»: 141 с., 18 рисунків, 33 таблиці, 8 формула, 83 літературних джерел, 4 додатків.

Об’єкт дослідження: організація міської мережі громадського транспорту.

Предмет дослідження: зменшення впливу приватного транспорту на навколишнє середовище.

Мета роботи: розробити проект міста без автомобілів для Ополе та оцінити його екологічну та економічну ефективність.

Методи дослідження: пошук інформації, аналіз та синтез, порівняльний аналіз, картографування, візуальні спостереження, математичні розрахунки, анкетування.

Результати, новизна та значущість: полягають у розробці організаційних рішень щодо покращення якості довкілля у містах за рахунок зменшення потоку руху.

Результати магістерської роботи рекомендовані та можуть бути використані для реалізації принципів сталого розвитку у містах та підвищення рівня екологічної обізнаності населення у сфері управління дорожньою інфраструктурою.

МІСТО БЕЗ АВТОМОБІЛІВ, ЕКОЛОГІЧНА ЕФЕКТИВНІСТЬ, ЕКОНОМІЧНА ЕФЕКТИВНІСТЬ, ОПИТУВАННЯ, ЗАБРУДНЕННЯ ПОВІТРЯ, ШУМОВЕ ЗАБРУДНЕННЯ.

CONTENT

INTRODUCTION

Relevance of the topic. Over the past years, researchers have revealed that one of the most powerful air pollutants in cities is transport, in particular private cars. It is also known that air pollution has a direct impact on human health. As the example, it can result in respiratory diseases, including asthma or changes in lung function, cardiovascular diseases, adverse pregnancy outcomes, and even death. Another problem is the contribution to climate change.

Cars also produce electromagnetic and noise pollution, vibration, pollution of water bodies, changes in the chemical composition of soils and damage to pedobiota, generate lots of waste, which impairs life of living organisms.

To improve the situation many countries are working on introduction of programs for control and mitigation of air pollution. Among the possible approaches to this solution of this problem is creation of car-free cities.

The aim of the master thesis - develop the project of car-free city for Opole and evaluate its environmental and economic efficiency.

The main tasks of the work are:

1) to study the development of transport infrastructure in cities;

2) to analyze environmental and social issues of urban transport.

3) to compare the organization of urban transport in European cities.

4) to develop the alternatives to the organization of urban transport

5) to calculate potential environmental and economic efficiency;

6) to choose the best alternative and design of its structure and arrangement.

Object - organization of urban public transport network.

Subject – reduction of private transport impacts on the environment.

Methods of research – information search, analysis and synthesis, comparative analysis, mapping, visual observations, mathematical calculations, questionnaire.

Personal contribution of the author **–** research and analysis of literature, study of major environmental problems due to cars in the city, conduction of the social survey, calculations and interpretation of the results.

Scientific novelty **-** the concept of a city without cars was further developed, first developed a project for the city of Opole; for the first time the components of ecological and economic efficiency of city projects without cars have been selected.

Practical value – improves the quality of the environment in city, created new model as example for others small cities, allows to supplement the state budget for environmental purposes.

Approbation **-** Radomska M., Kolotylo O. Car-free cities for sustainable development of urban infrastructure: тези доп.SDEV'2020, II Міжнародний науковий симпозіум "Сталий розвиток - стан та перспективи" (12-15 лютого 2020 р.) Lviv-Slavske, Ukraine.

Publications **-** one scientific journal.

CHAPTER 1

CARS AS A SIGN OF THE MODERN WORLD

In the second half of the twentieth century the depth of transformative processes in the world has reached such level that involved all spheres of life in modern society. Planetary scale processes that significantly intensified the interconnections of people, communities, and states were named global [1].

And though for today the term "globalization" has many conflicts of definition summarizing we can say that globalization is a formation of global interdependence within the human community in all of social, economic, religious, informational and environmental spheres of human life [2].

Globalization, as a qualitatively new phenomenon, involves processes that have different mechanisms of action, areas, and forms of detection, consequences. These processes are interconnected, interdependent and create a system [1].

As the transportation industry has influenced humanity and their interdependence at all levels from local to global, therefore, it has become an integral and important part of globalization.

1.1. Cars and society

Car-related history begins before the outbreak of the first war. Such a period is called inventive - when the main task was to materialize the idea of creating operating machines and generalizing experience. In general, the history of designing a car is divided into three periods in the specialized literature, the last two are engineering (by the 40's the foundations of the theory and calculation of the car were developed, fast, comfortable machines became possible, their mass production started) and designer (in the foreground there were the

problems of compliance of the machine to customer needs convenience and safety of its use, its technical qualities).

The official year of birth of cars is 1886, although the development of its construction began long before that. For example, the first steam car that actually worked is considered a "steam cart" by Frenchman Nicolas-Joseph Cugnot, which was made back in 1769. However, the XIX century steam engine had many imperfections. The steam car was not reliable enough and virtually unavailable to the general public. Therefore, the car required another engine, more compact, easy to launching and economical. This engine was the internal combustion engine. By the end of the nineteenth century, a typical layout with the engine behind (under the seat) was developed; it had a belt drive from the engine to the transverse shaft, further the chain drive to the rear wheels. But soon in the 1890s, the chief designer of the French company "Panhard Levassor" proposed a new layout of the car and it is generally preserved to this day.

Although the first car, by history, did not appear in the United States, however, it was America that made the car a cult product. The beginning of the automotive industry in the United States is 1896 since the first company on the release of American cars was created. The owners and creators of this company were the Durray Brothers who decided to release as many as 13 crews with internal combustion engines. The machines were uncommon for those years, sold poorly and in 1898 the brothers were forced to close the company. But brothers' historical experience is invaluable - they were the first to think up with "mass" production of cars. And in 1908, there were already 485 car companies in the United States [4].

There are many reasons for such rapid and high popularity. On the plus side, these are access to remote places and mobility comfort provided by the automobile, allowing people to geographically increase their social and economic interactions; expansion of residential areas and suburbs development; development of tourism, opportunities to explore new places; appearance of many new jobs, educational options and academic mobility; development and

improvement of road infrastructure; accelerated information exchange and appearance of various special services.

The downsides include:

- environment pollution;

- problematic ttraffic of cars - congestion in cities;

- road accidents leading to injuries and fatalities, among drivers, passengers and pedestrians;

- deterioration of the living standards and health of the population as a whole;

- reduced contact with neighbors (A Nation of Strangers (1972) blamed the geographic mobility enabled by the auto for loneliness and social isolation) [5].

Political factors also play an important role in the development of the automotive industry and have direct impact on the profitability of this industry. Taxes and subsidies are examples of this. For example, recently eco-friendly vehicles have started receiving higher government support for their low environmental impact. Such government rules and regulations heavily affect the revenues of the vehicle brands. Some companies have caused such factors to move their manufacturing to countries where the wage related regulations are lenient [6].

Equally important is the economy. To understand how powerful the economy is, it is enough to mention the economic crisis during which the automobile sector suffered a huge fall for some time. Because the global automobile industry is a multi billion industry with several large brands competing for market share. Since its foundation in the 19th century, this sector has grown to become an important part of the world economy in terms of revenues [6].

When the economic conditions are not good, the sales of vehicles fall. If the economic conditions are good, the sales of vehicles remain high. The sales are generally higher in the developed countries. In the developing and under-developed markets, they are comparatively low. The developed markets see higher sales as the purchasing power of the customers is higher. In these markets, the sales of the higher priced vehicles are also higher. The lower

priced variants are generally in demand in the developing and underdeveloped markets. Thus, the sizes of the economy and the economic conditions globally have a major impact on the profitability of the auto industry in various markets.

There are various angles to analyze the importance of the economic factors for the industry. The most common is the purchasing power of the customers. It dips during economic downturns. Industries are dependent heavily on the purchasing power of the customers. If a large number of brands have focused on bringing low cost cars to the market, it is because they know they can tap into a larger customer segment this way [6].

Overall, the automotive industry directly affects technological progress and better than many statistics, it shows the solvency of the population and by this reflects living standards. The automotive industry plays an important role in the development of social production and the economy as a whole, being, on the one hand, a major consumer of material, labor and financial resources, and on the other, one of the major manufacturers of industrial products [7].

1.2. The current level of vehicles development

In 1998, global car production was 53 million units, in 2000 – 58.4 million units, on the eve of the global financial and economic crisis in 2007 - 73.3 million units. In 2009, it decreased by 12.4% compared to the previous year and amounted to 61.8 million units. In 2010, the global automotive industry began to emerge from the global recession and car production increased by 25.8% compared to 2009 and reached 77.8 million units. World car production in 2014 amounted to 89.7 million units, which is 2.6% more than in 2013 and is 45.2% higher than in 2009. Analyzing the current state of the global car market it should be noted that the geographical situation is significantly different in different regions of the planet.

China has been the world leader in motor vehicle production since 2010 (26.4% of world production in 2014), outstripping of American, Japanese and European companies. The second place was taken by the USA (13.0%), the third - by Japan (10.9%) [8].

Table 1.1

12 countries – the largest manufacturers of vehicles from 2000 to 2014 (thousands of units)

№	Rating in the world produc-tion (2014 year)	Country	2000	2010	2011	2012	2013	2014		2014/ 2013,%
								thousands of units	% to the total	
1	2	3	4	5	6	7	8	9	10	11
1	1	China	2069	18264	18418	19272	22117	23723	26,4	7,3
2	2	USA	12800	7761	8653	10326	11066	11661	13,0	5,4
3	3	Japan	10140	9625	8398	9943	9630	9775	10,9	1,5
4	4	Germany	5526	5906	6311	5649	5718	5908	6,6	3,5
5	5	Republic of Korea	3144	4272	4657	4562	4521	4525	5,0	0,1
6	6	India	801	3536	3936	4175	3881	3840	4,3	-1,5
7	7	Mexico	1935	2345	2680	3002	3052	3365	3,7	10,2
8	8	Brazil	1681	3382	3406	3423	3712	3146	3,5	-15,3
9	9	Spain	3032	2388	2354	1979	2163	2403	2,7	11,1
10	10	Canada	2962	2071	2134	2453	2380	2394	2,7	0,6

Continuation of table 1.1

1	2	3	4	5	6	7	8	9	10	11
11	11	Russia	1202	1403	1988	2233	2175	1887	2,1	-13,6
12	12	Thailand	325	1644	1458	2429	2457	1880	2,1	-23,5
13	Together indicated countries		45617	62597	64393	69446	72872	74507	83,0	3,6
14	Other countries in the world		12754	15261	15715	14842	14428	15230	17,0	5,5
15	Total in the world		58374	77858	80108	84288	873008	89737	100	2,6

In terms of last year's figures, 2018 saw a 1.3% decline in passenger cars worldwide. China remains the leader in machine production, but the "fall" of production was as much as 2.3% there. Such data are reported by the International Organization of Motor Vehicle Manufacturers (OICA).

It is known that almost 5 million 969,000 passenger cars were manufactured in China in the first three months of 2018. Japan ranks second with just over two million cars. In the island country, output fell by only 0.4%. The German automotive industry is in third place, which also experienced decline by 5.7% and ended the quarter with a figure of one million 969 thousand. India has consolidated its fourth position, increasing its passenger car output by almost 6% to one million 73,000 units. South Korea closes the top five, with 877,000 passenger cars produced at the plants from January to March, 6.8% less than last year. Also the top 10 in terms of production consistently included the United States, Spain, Brazil, France and the United Kingdom [9].

According to the consulting company "LMC Automotive" 94 million new cars and light commercial vehicles (LCV) were sold in the world in 2018, which is by 0.5% less than 2017. In this way, a negative result was recorded for the first time since 2009 (Table 1.2).

The most popular brands are: Toyota – 8.6 million cars (+ 1.9%) Volkswagen - 6.9 million (+ 1.8%) and Ford - 5.6 million (-9.1%). Model Leaders: Toyota Corolla - 1.2 million cars (-1.7%), Ford F-Seriess - 1.1 million (+ 0.4%) and Toyota RAV4 - 0.8 million (+ 3.6%) (Table 1.3-1.4).

Table 1.2

Leading countries in the sales of new cars in 2018

№	Place	Countries	2018 year million pieces	2017 year million pieces	+-
1	2	3	4	5	6
1	1	China	23,499	24,718	-5,1
2	2	USA	17,327	17,235	0,5
3	3	Japan	4,391	4,386	0,1
4	4	Germany	3,436	3,441	0,2
5	5	India	3,395	3,229	5,1
6	6	Brazil	2,475	2,176	13,7
7	7	Great Britain	2,367	2,541	-6,8
8	8	France	2,173	2,111	3,0
9	9	Canada	1,087	2,041	-2,6
10	10	Italy	1,910	1,971	-3,1
11	11	Russia	1,801	1,596	12,8
12	12	South Korea	1,653	1,793	-0,9

Table 1.3

The best-selling brands of new cars in the world in 2018

№	Place	Brand	2018 year million pieces	2017 year million pieces	+-
1	2	3	4	5	6
1	1	Toyota	8,754	8,593	1,9

Continuation of table 1.3

1	2	3	4	5	6
2	2	Volkswagen	6,942	6,817	1,8
3	3	Ford	5,560	6,118	-9,1
4	4	Honda	5,025	5,080	-1,1
5	5	Nissan	4,971	5,025	-1,1
6	6	Hyindai	4,535	4,434	2,3
7	7	Chevrolet	4,151	4,138	0,3
8	8	Kia	2,900	2,794	3,8
9	9	Mercedes	2,584	2,525	2,3
10	10	Renault	2,553	2,665	-4,2
11	11	BMW	2,132	2,075	2,7
12	12	Peugeot	1,995	2,067	-3,5
13	13	Audi	1,819	1,859	-2,2
14	14	Maruti	1,633	1,621	0,8
15	15	Mazda	1,611	1,563	3,1
16	16	Jeep	1,591	1,406	13,2
17	17	Fiat	1,481	1,645	-10,0
18	18	Geely	1,455	1,258	15,6
19	19	Suzuki	1,437	1,408	2,1
20	20	Buick	1,344	1,448	-7,2
21	21	Skoda	1,278	1,208	6,2
22	22	Changan	1,254	1,426	-12,1
23	23	Mitsubishi	1,216	1,016	19,7
24	24	Wuling	1,107	1,133	-2,3
25	25	Citroen	1,067	1,032	3,3

Table 1.4

Top most popular cars in the world in 2018 [10]

№	Place	Country	Brand	Amount
1	1	2	3	4
1	1	USA	Ford F Series	909330
2	2	China	Nissan Sylphy	481216
3	3	Japan	Honda N-box	241870
4	4	India	Suzuki Alto	234471
5	5	Brazil	Chevrolet Onix	210451
6	6	Germany	Volkswagen Golf	172434
7	7	France	Renault Clio	151434
8	8	Thailand	Toyota Hilux	149336
9	9	South Korea	Hyundai Grandeur	113101
10	10	Russia	Lada Vesta	108363
11	11	Great Britain	Ford Fiesta	95996
12	12	Mexico	Nissan Versa	91320

Electric vehicle sales for the first time exceeded the millionth mark last year. Moreover, demand is growing at an incredible pace: 391 thousand were sold in 2016, in 2017 - already 727 thousand, and last year's result - 1 million 261 thousand clean electric vehicles. The main demand is concentrated in China (769 thousand), followed by the United States (209 thousand) and Norway (46 thousand). However, the best-selling electric car in the world was the American Tesla Model 3 sedan (138 thousand units), and Tesla itself with the result of 230 thousand cars tops the ranking of electric brands. Chinese BAIC (152 thousand) and BYD (95 thousand) follow it, and Nissan stands only after those (92 thousand). The second place in the charts of models is the electric hatchback BAIC EU 200 (92 thousand), and on the third - Nissan Leaf (85 thousand) [11].

According to the analytical agency "AUTOSTAT" the market volume of new passenger cars in Ukraine in January-September 2019 amounted to 63.4 thousand units, which is almost 12% more than a year ago. The leader of the Ukrainian car market is Renault, which sold 10070 cars during the reporting period - 1.5 times more than a year earlier. In this way, approximately every sixth car bought by Ukrainians is produced by this French brand. But every seventh car has a Toyota logo - for 9 months, sales of the Japanese brand amounted to 8870 units, an increase by a quarter. In third place is taken by the Korean KIA: 5300 customers chose this brand of cars, and its result grew by 71%. Next comes the Japanese Nissan (4110 pcs. and + 12.5%) and Korean Hyundai closes the top five (3760 units and + 4.4%).

The rating of the most popular models in the Ukrainian car market is led by the KIA Sportage crossover, which, according to the results of 9 months of this year, sold around the country in the amount of 4170 cars. It is followed by the Renault Duster crossover (3480 pcs.), Toyota RAV4 crossover (2980 pcs.), Renault Logan sedan (2850 pcs.) and Renault Sandero hatchback (2000 pcs.) [12].

In Poland, the growing sales of new cars are mainly due to the high level of activity of the institutional client. For a long time companies have been the driving force behind the registration of new cars. Although in December they bought 2.10% less passenger cars than a year ago, but throughout 2018, company purchases increased year-on-year by 13.40%. Individual buyers constituted a clear minority among car dealership customers. They still prefer used vehicles with a large share of imports of such cars.

According to data from the Central Register of Vehicles and Drivers in December 2018, 52 373 passenger cars and delivery vans with a GVW of up to 3.5t were registered in Poland, i.e. by 3.42% (-1 856 units) less than a year ago and by 5.20% (+2 589 units) more than in November 2018. Accumulated data (600,790 items) show an increase in sales in 2018 by 9.76% (53 399 items).

Renault was awarded the title of market leader in 2018, followed by Fiat, Ford, Volkswagen and Peugeot. The most frequently purchased van model in 2018 is Renault Master, Fiat Ducato, Iveco Daily, Mercedes Sprinter and Peugeot Boxer [13].

1.3. Influence of cars on the environment

Having an important place in a person's life - the car not only has positive sides, one of the major problems facing humanity today is the environment quality degradation, and it is considerably conditioned by transport.

The impact of road transport on the environment is manifested by:

• while driving cars;

• during maintenance;

• the functioning of the infrastructure that ensures its operation.

The greatest impact from the car is at the stage of its operation, while impacts of maintenance are less distributed, but more intensive. The stage of the operation is determined by the rate at which its resource is already used, that is, the total mileage from the beginning of operation to its decommissioning and disposal. Researchers have also found that up to 35% of total vehicle emissions are caused by the condition of the road surface and the organization of traffic.

Everyday operation of cars consumes running materials, such as petroleum products, natural gas, atmospheric air, water for cooling systems of the internal combustion engine and car wash, land resources expropriated for the construction of roads, railways, airfields, pipelines, river, and seaports and other objects of transport infrastructure. It is accompanied by a wide range of negative consequences for the environment, including:

• pollution of the atmosphere and release of unpleasant odors

• pollution of the water bodies;

• consumption of natural resources;

• change in the chemical composition of soils and damage to pedobiota;

• loss of agricultural lands and green spaces, degradation of plants;

• toxic waste generation, including industrial waste, sludge, boiler slag, ash and debris;

• noise, electromagnetic and vibration effects;

• direct thermal pollution and contribution to climate change;

• negative impact on building materials, historical architectural and sculptural monuments and other works of art;

• corrosion of metals, deterioration of leather and textile products;

• activation of adverse geodynamic processes such as water erosion, wetlands, mudflows, landslides and landslides.

At the same time, it is equally important to emphasize the injuries and deaths of humans and animals, the material damage caused by accidents and catastrophes [14].

According to statistics, cars of the world are already emitting more than 400 million tons of carbon oxides, 100 million tons of hydrocarbons, hundreds of thousands of tons of lead and many other harmful compounds every year. It should not be forgotten that they "eat" a lot of oxygen. For example, a Volga car takes 100 times this most valuable substance for breathing, and a ZIL-130 truck is two hundred times more than one person consumes.

There are few important factors, which increase the magnitude of transport impacts on the environmental and human health in the end:

• The activity of the bulk of road transport is concentrated in places with high population - cities, industrial centers;

• Harmful emissions from cars are delivered in the lowest, ground level of the atmosphere, which is the level of the basic living activity;

• Exhaust gases from car engines contain highly concentrated toxic components, which are major pollutants of the atmosphere [15].

1.3.1 Effect of transport on ambient air

Road transport releases carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxides (NO_x), sulfur dioxide (SO_2), ozone, benzene and fine particulate matter into the atmosphere every day, having a variety of impacts on human health (Table 1.5).

Table 1.5

Human health and environment impacts of transport emissions components [16]

№	Substance	Impact on humans and / or the environment
1	2	3
1	Carbon monoxide (CO)	***On human.*** By reacting with blood hemoglobin, leads to oxygen starvation. Therefore, the direct effect of carbon monoxide is to reduce the ability of the blood to transport oxygen. Carbon monoxide is lighter than air, so it evaporates quickly in open areas, is especially dangerous when inhaled directly from the exhaust pipe or in poorly ventilated areas.
2	Carbon dioxide (CO_2)	***On human.*** It is not a toxic substance, but high concentration and combination with low oxygen concentration lead to: headaches, dizziness attacks, impaired memory and ability to concentrate, difficulty sleeping, tinnitus, double vision, photophobia, loss of eye mobility, blemishes, increased blind spots, lack of adaptation to darkness and personality changes.
		On environment. It is referred to greenhouse gases, which contribute to climate change and the greenhouse effect. An increase in CO_2 emissions has increased the acidity of the oceans by 30%, affecting a wide range of organisms.

Continuation of table 1.5

1	2	3
3	Nitrogen oxides (NOx)	***On human.*** It irritates mucous membranes, provoke asthma and respiratory allergic reactions. Nitrogen dioxide affects the respiratory tract and the lungs, alters blood composition (reduces hemoglobin content), reduces the resistance of the human body to diseases, leads to oxygen starvation of tissues, enhances the action of carcinogens, promoting the emergence of malignant neoplasm.
		On environment. NOx emissions from the combustion process are mainly emitted in the form of nitric oxide (NO), which can be oxidized to nitrogen dioxide (NO2), which is a powerful air pollutant. Volatile nitrogen oxides penetrating the atmosphere pose a serious danger to the environment. They are capable of causing acid rain.
4	Sulfur dioxide (SO2)	***On human.*** In combination with other contaminants and moisture, it irritates the eyes, nose and throat, adversely affecting the lungs.
		On environment. Sulfur dioxide and nitrogen dioxide cause acid rain, which increase soil acidity, destroy structural materials, affect crop yields, and human health. Air pollution causes irreparable damage to cultural sites, accelerating their aging.

Continuation of table 1.5

1	2	3
5	Ozone	***On human.*** Ozone is one of the most toxic and ubiquitous air pollutants. It affects the respiratory, cardiovascular and central nervous system. Early death and problems in reproductive health and development are also shown to be associated with ozone exposure. It appears to be a weak mutagen and to produce chromosomal abnormalities. Defects in defense against airborne infection are present in animals, which are more susceptible to airborne infection after ozone exposure.
6	Fine particulate matter (PM2.5, PM10)	***On human.*** Mainly affect the respiratory and cardiovascular systems.

Also transport is one of the largest sources of greenhouse gas emissions due to burning fossil fuels. In 2017, transport was responsible for 28.9% of greenhouse gas emissions. Over 90 percent of the fuel used for transportation is petroleum based, which includes primarily gasoline and diesel [17]. The vehicle's level of CO_2 emissions is linked to the amount of fuel consumed and the type of fuel used.

Another problem with cars that only happens in cities is thermal pollution, as heat generated by transport falls into the "trap" due to poor ventilation (ventilated urban canyons) [18]. This phenomenon is called urban heat island. It occurs when a city experiences much warmer temperatures than nearby rural areas. The difference in temperature between urban and less-developed rural areas has to do with how well the surfaces in each environment absorb and hold heat [19].

Vehicle emissions also contribute to the formation of urban smog and global warming [18]. As a result of oxidation of gasoline vapor and other substances from traffic emissions

under the action of the sun's rays, photochemical smog is formed. Smog causes irritation to the eyes, nose and throat, damages crops, forest plantations and promotes corrosion of metals and other materials.

1.3.2. Effect of transport on soil

Motor vehicles emit heavy metals such as nickel, mercury, chromium, cadmium, zinc, iron, arsenic, manganese, and beryllium. Among them arsenic, mercury, cadmium and lead are highly toxic in very low concentrations. The accumulation of heavy metals in soils changes their chemical and biological properties. Metals accumulate in living organisms and enter the food chains. Although heavy metals can remain in atmospheric air for up to 10 days and can be transported up to 2000 km the, most of the traffic related pollution resides along the roads. This impedes the economic use of roadside lands in agriculture, but also complicates the cultivation of protective green spaces in cities.

Some components of pollution are dissolved and penetrate to groundwater and then enter rivers and with drinking water can enter the human body.

The width of the roadside line pollution is affected by a number of dynamic and stationary factors. The first of these include: weather and climatic conditions of the respective territory (humidity, precipitation characteristics, the recurrence and strength of the wind); traffic intensity, the ratio of the main types of vehicles. The pollution of the soil surface by transport and road emissions accumulates gradually depending on the number of vehicles, driving through the track, the road, the highway and is stored for a very long time even after the lane is cleared (road closure, tracks, thoroughfares or complete elimination of road and asphalt pavement). If the future generations abandon cars in their modern form the transport contamination of soil will be the most painful and grave consequence of the past [20].

1.3.3. Effect of transport on water

Environmental studies about automobile impact on the environment typically focus on air pollution or noise but often ignore water pollution. Pollutants from motor vehicles or from transportation infrastructure include sediments (from construction or erosion), oils and grease (from leaks or improperly discarded used oil), heavy metals (from car exhaust, worn tires and engine parts, brake pads, rust, or used antifreeze), road salts, as well as fertilizers, pesticide, and herbicides (used alongside roads or on adjacent land).

Indeed, the Environmental Protection Agency (EPA, 1997) estimates that up to 1/2 of suspended solids and 1/6 of hydrocarbons reaching streams originate from freeways. Vehicle-related particulates in highway runoff come mostly from tire and pavement wear (~ 1/3 each), engine and brake wear (~ 20%), and exhaust (~ 8%). Each year, approximately 185 million gallons of improperly discharged used motor oil pollute streams, lakes, and coastal areas. This should be cause for concern since one gallon of used oil can contaminate 1 million gallons of water.

One the impact source on the water is poorly designed system of stormwater runoff on the highway. Heavy metals in stormwater runoff are of particular concern because of their toxicity, pervasiveness, and persistence. The heavy metals can make highway runoff chronically toxic to receiving waters. In this waters pollutant concentrations are two to ten times higher for urban than for non-urban highways. However, non-urban highway runoff shows greater concentrations of total suspended solids, pesticides, and ammonia, which points to agriculture. However, a simple linear relationship between annual average daily traffic and transportation-related pollutants is unlikely because of weather patterns and surrounding land use. In fact, some pollutant pressure exhibit seasonal variations: winter, for example, brings high concentrations of chlorides and sulfates from deicing salt [20].

The detectable levels of zinc, lead, copper, and nitrate/nitrite are reported in road runoff, with urban levels two to five times those of rural levels. It is important to note that heavy metals in highway runoff are not necessarily toxic because toxicity depends on

chemical form and availability to aquatic organisms. However, some heavy metals bioaccumulate in the food chain and can become toxic to humans over the long run.

There are three main sources of NPS pollution for surface waters. Of these, used oil is likely the main hydrocarbon source to runoff. According to the National Oil Recyclers Association (NORA 2001), it accounts for 40% of the oil pollution of the harbors and waterways. Additionally, improperly disposed of used oil filters may account for 5% of used oil discarded into the environment. Yet, used oil is the "single largest environmentally hazardous recyclable material". Like crude oil, used oil can have devastative impacts on aquatic life; moreover, the refined products such as motor oil and gasoline are more toxic than crude oils. The thing is they disperse more readily into water, soft tissues absorb them more easily, and they contain more toxic chemicals added to boost engine performance, compounds produced during engine operation, or wastes mixed-in during disposal.

Another source of non-point source pollution is used coolant/antifreeze, which typically consists of 95% ethylene glycol, a clear, colorless, sweet-tasting and highly toxic liquid. Used coolant/antifreeze is especially a problem for Do-It-Yourselfers (DIY) because current engine design makes it almost impossible to avoid spilling some product when it is changed.

In addition, operating motor vehicle disc brakes contribute heavy metals to non-point source pollution. Disc brakes are open to the environment, so each time semi-metallic brake pads squeeze against the wheels' rotors, tiny amounts of metal dust, often copper, but sometimes also zinc and lead, are deposited along the roadway and washed to water bodies by rain or snow. While used oil and used coolant/antifreeze pollution mostly affect surface waters, gasoline spills from leaking underground storage tanks (LUSTs) are a major source of groundwater pollution [21].

1.3.4. Noise pollution

The worldwide tendency to increase urbanization leads to an increase in acoustic load. It is known that the average noise generated by vehicles increased by 12-14 dB.

In general, the noise level depends on the intensity, speed and nature of the traffic flow. A number of factors affect the intensity of traffic noise: number, speed of traffic flow; engine type; composition and quality of traffic flow. In addition, the noise level from transport is determined by the type and quality of the pavement (the defective pavement of any type with potholes, open seams and other inconsistencies of the surface increases the noise level by 8-12 dB), planning solutions of the territory (longitudinal and transverse profile of streets, building architecture, traffic lights) and the presence of green plantations. Each of these factors can change the noise level up to 10 dB. So moving a car creates noise with an intensity of 70 ... 80 dBA, bus - 80… 85 dBA, truck - 80 ... 90 dBA. Therefore, the increase in truck traffic, especially with diesel engines in combination with cars, creates a heavy noise regime in cities. A moderate increase in vehicle speed causes an increase in noise levels of 6-9 dB, and a maximum acceleration of 15-20 dB. Therefore, the noise level at the intersections is 3-6 dB higher than the areas with constant traffic.

The suburban territoriesare exposed to the impacts of noise for 18-20 hours a day, sometimes around the clock. In the middle, road noise varies between 65 and 80 dB, and near houses within 100 meters, transport noise reaches 57 - 65 dB [22].

According to a recent study by the World Health Organisation Regional Office for Europe (WHO, 2011), 20% of the population of EU countries is exposed to traffic noise levels of above 65 dBA during the day and 30% is exposed to levels of over 55 dBA at night, which translates as a loss of 61,000 disability-adjusted life years (DALYs) [23].

Research results show that traffic noise makes up 80% of all external noise in the million cities of Ukraine. In particular, Kyiv most traffic flows create noise and reach the level near 85 dB, which exceeds the admissible standards (for residential areas, the rate is 50 dB during the day and 45 dB at night, and on the highways 65 dB). Acoustic discomfort on

the Dnipro motorways with heavy traffic is 82-92 dBA (short-term periodic noise can reach 100 dBA) [22].

At many city streets in Ivano-Frankivsk, the equivalent sound level exceeded 80 dBA, while the equivalent sound level must not exceed 55 dBA. On more "safer" streets, 45-60 dBA was recorded. The best indicators were obtained from the streets with green areas [24].

So, the noise level in the big cities of Ukraine is over the standard over the permissible values in the majority by 2 to 12 dBA.

On the Katowice city streets were evaluate to create the noise of 70 dB. But the noise level fluctuated in the 55-65 dB value range [25].

47% of Warsaw residents are exposed to road noise influence. However, most of them will receive a noise load of more than 60 dB (A). At night, this percentage increases [26].

According to numerous research, noise also has negative impact on the human body. About 60-80% of the noise that accompanies a person in a residential development is created by traffic flow. Transport noise is one of the most dangerous parametric pollution of the environment. It can cause irritation and aggression, hypertension (increase in blood pressure), hearing loss. At excessive levels, noise affects the hearing organ, central nervous system, and cardiovascular system. According to laboratory tests, changes in the nervous system in 2/3 of cases begin before hearing loss begins (cochlear neuritis). It also affects metabolism and inhibits oxidation processes [26].

To prevent the negative effects of prolonged noise on a person during sleep and rest, the equivalent adjusted indoor noise level shall not exceed 30 dB. Road-related sounds both inside and outside urban areas are the most important source of noise pollution in the EU. About 125 million people are potentially exposed to noise in excess of 55 dB. According to research in the UK among people, who had abnormal blood pressure and heart rate, the use of noise barriers in the long run reduces the level of cardiovascular disease in comparison with those who are constantly exposed to the harmful effects of car noise [27].

1.3.5. Management and recycling of the car

Another thing worth noting is the management of transport wastes, because they are generated at all stages of the car's life cycle - both during its production and during its operation, maintenance and decommissioning. When the vehicle is decommissioned, all auto components are also included in the waste, for example, batteries, tire covers, bumpers, engine parts and more. Just having an abandoned car becomes a dangerous environmental pollutant at the end of its life cycle, since it stores all the components and materials that have been used to create it (lubricants, petroleum products, glass, rubber products, etc.). Most of these can be secondary resources. The main environmental problems during the recycling of a car are urban landfill pollution, air pollution during tire burning, pollution of water bodies soils, as waste oils and coolants are often discharged to soil and groundwater [28].

As an example, one of the pending situations related to cars and their environmental impact is the so-called Volkswagen emissions scandal, also known as Dieselgate, or Emissionsgate. It happened in 2015, when new Volkswagen cars were put up for sale but upon receipt a notice of violation of the Clean Air Act to German automaker Volkswagen Group by the United States Environmental Protection Agency (EPA), it was found, that Volkswagen had intentionally programmed turbocharged direct injection (TDI) diesel engines to activate their emissions controls only during laboratory emissions testing which caused the vehicles' NO_x output to meet US standards during regulatory testing, but emit up to 40 times more NO_x in real-world driving. Volkswagen deployed this programming software in about eleven million cars worldwide, including 500,000 in the United States, in model years 2009 through 2015 [29].

The cars were subject to return. Currently, a huge number of these cars are in the desert next to the Victorville logistics airport in California, northeast of Los Angeles and the football stadium in Detroit and a paper mill in Minnesota, but the number of cars grew so fast that these places filled up immediately [30].

1.4. Conclusions to Chapter 1

So, the rapid development of mankind provoked the creation of a car, which by this time has become an integral part of our lives. This improved living conditions, influenced the development of tourism, made it possible to travel long distances faster and with comfort, causing real global changes, including transformation of urban infrastructure and roads construction. But on the other hand such is the development of the transport industry and its use have led to severe environmental pollution that influenced the health of people in general (pollution of air, soil, water, as well as exposure to noise and vibration) and has even become one of the causes of climate change. Since the second half of the XX century the big cities began to suffer from smog, greenhouse gases, and the urban heat island effect. That proves the importance of consideration and implementation of different methods of assessing environmental and economic efficiency and methods for calculating the environmental impact of cars.

CHAPTER 2

ASSESSMENT OF ECONOMIC AND ENVIRONMENTAL EFFICIENCY OF PROJECTS

2.1. Concepts and types of efficiency of environmental protection projects

Environmental and economic efficiency is the ratio of the total economic and environmental costs to the integrated environmental and economic effects. It is a complex assessment of the space and time of interaction between economic activity and the environment. Determining environmental and economic efficiency involves the environmental impact assessment of the economic activity, identifying the relationship between the economic and environmental subsystems with the preliminary identification of key environmental protection problems and disproportion of economic development.

Determination of real environmental and economic efficiency is an extremely difficult problem. Social, moral, environmental consequences of damage caused by the economic activity are not amenable to the quantitative expression and cannot be reflected in the economic valuation. The assessment of environmental and economic efficiency of production is complicated by the need to account both direct economic effect and some projected long-term effects and consequences in the foreseeable future. The complexity of adequate assessment of benefits and losses, caused by the economic activity, has led to the fact that environmental and economic efficiency is often defined as the ratio of costs for environmental protection and the traditional economic effect [31].

The overall efficiency of the project is characterized by the system of indicators that reflect the correlation of benefits and costs of the project from the perspective of its participants. One of the project's efficiency indicators is the economic efficiency indicator,

which takes into account the economic benefits and costs of the project including the assessment of environmental and social impacts and enables for monetary measurement.

Economy efficiency issues in project planning are addressed at different scales and stages of planning. Accordingly, the methods used in the different stages of project planning and evaluation are also distinguished:

- at the stage of technical analysis and planning project budget, when not all business conditions are known, the choice is made by simplified partial analysis;

- the stage of final decision the project as a whole should be considered, taking into account the results of the partial analysis and then make positive or rejecting draft decision. This is done through global models, which account all conditions of the financial sphere.

General economic analysis includes a description of the general economic situation joint presentation of project costs and benefits that affect national economic entities reassessment of costs and results by national and economic criteria, etc.

It is also necessary to carry out the environmental and social expertise of the future project and to make the general conclusions [32].

Socio-environmental analysis of the project has become increasingly important lately since consideration of environmental and social risks and consequences of the project implementation is an important condition for evaluating the social efficiency of the project, compliance of the project with the safety standards and standards of responsible financing.

The main purpose of environmental analysis is to detect potential damage to the environment, define the system of measures to reduce the negative impacts and calculate the funds needed to implement environmental protection measures.

Indicators of the environmental efficiency of the project include:

• availability of environmental protection program in the;

• reduction of environmental pollution as a result of project implementation;

• reduction of the payment and fines for the negative impact on the environment;

• decreased number of accidents in the project implementation process.

The purpose of the analysis of social aspects is to evaluate the project impacts on living conditions and living standards. Also, the analysis should account cultural and demographic characteristics of the population of the project area, impact the local culture and traditions and the attitude of the population to the project implementation [33].

2.2. Methods of assessing environmental and economic efficiency

2.2.1. SWOT analysis

One of the main strategic management tools for complex evaluation of internal and external factors, influencing the development of a project is SWOT analysis. SWOT analysis - is a process of establishing connections between the most characteristic of the enterprise opportunities, threats, strengths (advantages), weaknesses, its implications can be used later to formulate and select enterprise strategies. It is conducted to investigate the environment, which a specific project implemented in.

SWOT analysis is only a tool and it does not contain the definitive information for management decisions, but allows streamlining the process of reflecting all available information using thoughts and evaluations. SWOT analysis allows formulate a general list of enterprise strategies, taking into account their particularities - adapting to the environment or formation of influence on it. The widespread use and development of SWOT analysis are explained by the fact that strategic management is associated with large amounts of information to be collected, processed, analyzed, used, and therefore there is a need to find, develop and apply methods of organizing such work.

The main purpose of the SWOT analysis is to obtain reliable data on the opportunities and threats for the project implementation.

SWOT analysis has both advantages and disadvantages compared to other methods. Its main advantage is the simplicity and low costs of implementation, as well as the flexibility and availability of many options. It is also the systematization of knowledge about internal and external factors, influencing the strategic planning process; the opportunity to determine the competitive advantages of the enterprise and to form strategic priorities, periodically diagnose the market and resources of the enterprise. The disadvantages of SWOT analysis to consider are: inability to account for all factors; subjectivity of choice and ranking of factors of external and internal environment; poor adaptation to an ever-changing environment [34].

2.2.2. PEST analysis

PEST analysis (sometimes referred to as STEP) - is, for the most part, a marketing tool, designed to identify P - political, E - economic, S - social and T - technological aspects of the external environment, affecting the investigated problem.

The policy is studied because it regulates the authorities, which in turn determine the environment of the project and the acquisition of key resources for its activities. The main reason for studying economics is to create a picture of state-level resource allocation which is the most important condition for financing events. Equally, important consumer preferences are determined by means of the social component PEST-analysis. The last factor is the technological component. The purpose of its analysis is to identify trends in technological development which are often the cause of market changes and losses as well as new products such as xenobiotics, super-toxicants and more. The factors in the figure 2.1. are discussed in more detail.

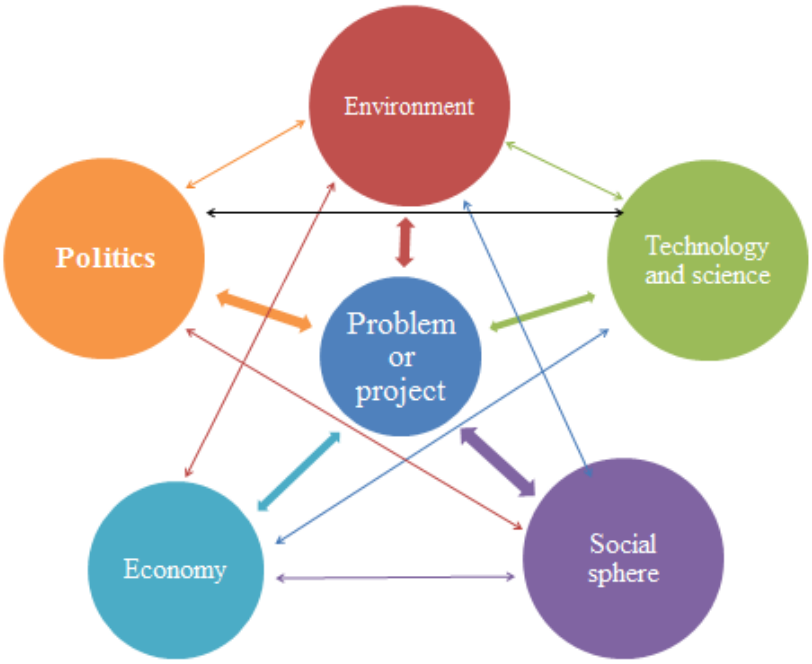

Fig. 2.1. Five-component PEST - analysis

The political environment is one of the most important factors what needs to be studied first in order to have a clear idea of the intentions of federal (municipal, local) authorities concerning the development of society, regulation of the mechanism of money circulation in the country, resources provision, changes in legislation, regulation and taxation, as well as the means by which the authorities will implement their policies.

The economic environment is one of the most important factors that determine the proper functioning of any organization. Thus, the state of the global economy can greatly affect the cost of the resources needed to implement system management measures. In essence, the analysis of the economic component of the macro-environment is aimed at understanding how resources are formed and distributed. The weak economy of the state sharply reduces the ability to ensure the effective implementation of system management measures. Among the main indicators analyzed in the study of economics are the following: the value of the gross national product, inflation rate, employment rate, balance of payments, economic growth rate, unemployment rate, interest rates, productivity, levels of taxation, population structure, etc.

The social environment takes into account information about demographic situation, social protection of the population, health and safety of workers, traditions, dominant values and attitudes of people, etc. Another important aspect is medical demographic, as environmental pollution and ecosystem balance can affect human health.

The technological environment is both an internal variable and an external factor of great importance. The rate of technological change is steadily increasing. This analysis allows you to see in time the possibilities of scientific and technological progress to create the means of reducing the anthropogenic impact on the environment. In addition, the technological and scientific level characterizes the available project implementation and problem-solving tools.

It is now also advisable to introduce the fifth component of this analysis, environmental or environmental factors (natural changes, cataclysms, catastrophes, etc.) because if to consider the use of this method in ecology, the environmental situation at the level of the system under review should be taken into account.

The analysis is performed according to the scheme "factor - system". The results of the analysis are presented in the form of a matrix, the basis of which are the factors of the macro-environment, predicate - is the power of their influence, which is estimated in points, ranks and other units of measurement.

PESTLE analysis is an extended two-factor Legal and Environmental version of a PEST analysis. Other formats are sometimes used, such as SLEPT analysis (plus legal factor) or STEEPLE analysis: socio-demographic, technological, economic, environmental (natural), political, legal and ethnic factors. A geographical factor can also be taken into account.

After analyzing the problems and doing the necessary research, the next step is to analyze the goals. The purpose of the analysis is to:

- prepare a description of the situation in the future when the problems are resolved;

- check the hierarchies of goals;

- build cause and effect relationships (scheme named "target tree") between the goals and the means of achieving them.

Thus, the negative moments found in the "problem tree" are transformed into positive goals in the "goal tree". This example gives a clear idea of the desired situation in the future. Often, the goal tree reflects some of the goals that could not be achieved in this project, and therefore there is a problem with choosing a strategy.

In the "target tree", different target groups of the same type define the strategy. One or a combination of several strategies can be chosen as the main strategy for future actions. The most realistic and achievable strategy is selected by a number of criteria, such as stakeholder priorities, financial resources, terms, etc. In ecology, priority is given to the life and health of the population, the conservation of the environment and the biodiversity of living organisms.

The final strategy is adopted after formulating the purpose of the project. The choice is based on a comparison of several goals of the same level. The goal of the project, located at the top of the goal tree, often contains a multi-component program, in which "junior" goals require the implementation of small projects.

The realization of the project and the achievement of the stated goal depends not only on the external factors considered above but also on the ability of the organization or team to implement the intended project or environmental measures to address the objectives of the analysis [34].

2.3. Calculation of the traffic-related environment pollution

2.3.1. Calculation of air pollution

The emission of the i-th pollutant (g / s) by a moving motor stream to highways (or its section) with a fixed length L (km) is determined by the formula:

$$M_{L1} = \frac{L}{1200} \sum_1^k M_{ki}^L \cdot G_k \cdot r_{V_{ki}}, \quad (2.1)$$

where $M_{ki}^L \cdot$ (g / km) - specific mileage emission of *i*-th harmful substance by cars of the *k*-th group for urban operating conditions, determined by table; *k* - is the number of car groups;

G_k - the actual highest traffic intensity, i.e. the number of cars in each of *k* groups, passing through a fixed section of the road per unit of time in both directions in all lanes;

r_{Vki} - correction coefficient taking into account the average speed of traffic flow (*Vk,i*, km/h) on the selected motorway (or its section), determined by table.

L (km) - the length of the road (or its section) from which the length of the queue of cars before the prohibiting signal of the traffic light is excluded, and the length of the corresponding intersection zone (for intersections at which additional examinations were conducted).

Traffic intensity is the number of vehicles that passed the cross-section of the street or roads per unit of time. At the same time, this is one of the most important parameters, which determines the environmental impact of transport. Traffic intensity can be expressed in actual units (auto/h), as well as in consolidated units (one hour) when traffic flow is reduced to a conditional car on the basis of a comparison of the dynamic dimensions of the vehicles.

Table 2.1

Value of mileage emissions (g / km) for various vehicle groups

№	Name of the car category	№ Categories	CO	Emissions, g / km					
				NOx (in terms of NO2)	CH	Soot	SO2	Formaldehyde	Benz (a) pyrene
1	2	3	4	5	6	7	8	9	10
1	Cars	I	1,5	0,5	0,3	0,5•10-2	1,2•10-2	1,8•10-3	0,2•10-6
2	Vans and minibusses up to 3.5 t	II	8,4	1,8	2,1	3,4•10-2	2,6•10-2	7,8•10-3	0,6•10-6
3	Freight from 3.5 to 12 t	III	6,8	6,4	4,8	0,38	4,8•10-2	2,1•10-2	1,8•10-6
4	Freight over 12 t	IV	7,3	7,6	6,0	0,45	7,0•10-2	2,4•10-2	2,2•10-6
5	Buses over 3.5 t	V	5,2	4,8	4,2	0,28	4,0•10-2	1,8•10-2	1,8•10-6

It should be noted that on roads with a high level of vehicle traffic there are less uneven movement and stable values of peak period intensity. For two-lane roads with oncoming traffic, the intensity of traffic is characterized by the total amount of oncoming traffic. However, if the road has a dividing strip and counter-flows are isolated from each other, then the total intensity of the opposite directions does not determine the traffic conditions, and characterizes only the operation of the road as a structure. For such roads, the intensity of traffic in each direction is of particular importance [36].

Table 2.2

Coefficient values r_{Vk1}, taking into account changes in the amount of emitted harmful substances depending on the average speed [35]

№	Movement speed (V, km/h)															
		10	15	20	25	30	35	40	45	50	60	75	80	100	110	120
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	r_{Vk1}	1,35	1,28	1,2	1,1	1,0	0,88	0,75	0,63	0,5	0,3	0,45	0,5	0,65	0,75	0,95
2	r_{Vk1} (NOx)	1, 0	1, 0	1, 0	1, 0	1, 0	1, 0	1, 0	1, 0	1, 0	1, 0	1, 0	1, 0	1, 0	1,2	1,5

2.3.2. The economic costs of traffic noise

Losses through the traffic noise on linear conflict objects are calculated according to the cost of damage to human health.

Річні нормативні (по відношенню до прийнятого нормативу Li ≈ 35 дБА) Annual regulatory (relative to the adopted standard) losses are determined:

$$П=\Sigma(k_{Li}\cdot N_i)Ф\cdot S\cdot C_в\cdot k, \text{ UAH/hour} \quad (2.2)$$

where k – social coefficient of environmental losses (k =1,5); N_i – specific number of consumers of environmental impact, human/km; Ф – annual time fund, hour; S – the length of the study area, km; $C_в$ – specific hourly cost of GDP (under normal environmental conditions $C_в$=0,3 UAH/human*hour.

The estimated value of the annual time fund is most often accepted Ф=3600 hour/year (300×12 = 3600 hour/year).

The number of consumers of environmental impact will be determined taking into account drivers and passengers, pedestrians and the number of residents of surrounding buildings.

Number of drivers and passengers N_1, which are come under the influence by noise is calculated:

$$N_1=(40\cdot\Delta A+1,5)\cdot Q/V, \text{ human/km} \quad (2.3),$$

where ΔA – part of public transport in the flow; Q – traffic intensity auto/hour; V – speed of flow movement, km/hour.

Number of pedestrians N_2, which are affected by noise is calculated:

$$N_2 = \Sigma Q_п/V_п \text{ , human/km} \quad (2.4),$$

where $\Sigma Q_п$ – total pedestrian traffic intensity (including traffic on crossings and sidewalks), human/hour;

$V_п$ – pedestrian speed, km/hour (accepted $V_п$ = 4 km/hour sidewalks; $V_п$ = 5 km/hour crossing).

For approximate calculations, the number of inhabitants of adjacent homes N3, depending on the type and purpose of the building is accepted:

$$N_3 \approx (0,7\ldots1,0)\ N_{вік}, \text{ hour/km} \quad (2.5),$$

where $N_{вік}$ – number of windows adjacent (to 50 m) buildings, overlooking the street under study, window/km; k_{Li} – the coefficient of specific losses of national GDP income to increased noise level for each consumer category:

$$k_{Li} = 1,8\cdot10\text{-}7\cdot Li3,39 – 0,0312 \quad (2.6),$$

where Li – reduced noise level to the consumer [37].

2.4. The methodology of conducting surveys

The poll is one of the major ways to learn about social phenomena and processes. The survey method is based on a system of questions offered to the interviewee and answers which provide the necessary information. There are two types of polls, related to the form of communication (written or oral) between respondent and interviewer: questionnaires and interviews. Each survey option represents one of the largest varieties of social and psychological communication, due to a number of conditions: the content of the questionnaire or interview (list of questions), quality of work of the interviewer or interviewer, the questionnaire or the interviewer, poll situation, the conditions of its holding, etc. A variety of aspects of people's lives their subjective attitudes as well as evaluation of events, etc. can be the object of information.

The most common type of survey in practice is the questionnaire. It can be group or individual. Group questionnaire is widely used at the place of work, training. During the individual questionnaire, questionnaires are distributed at workplaces, at the place of study, residence, and their return date is predetermined.

The extreme popularity of the survey is explained by the variety and quality of sociological information, which you can get with it. This method is based on the statements of individuals and is conducted in order to identify the subtle nuances in the opinions of the respondents. The main part of the questionnaire contains blocks of questions for the respondents.

In terms of subject matter, the questionnaires are divided into questions about the facts, questions about knowledge, question about the respondent's opinion, and questions about motives.

By their logical nature, questions are classified as follows:

- basic questions, the answers to which are the basis for making conclusions about the phenomena under study;

- filter questions are asked to screen out incompetents when interviewed for research problems;

- control questions are used to test the robustness, truthfulness and consistency of the answers, to determine their accuracy and sincerity;

- the questions that can help the respondent to understand the basic question correctly, to find the correct answer.

By the nature of answers, questions are divided into the following types:

- open questions provide a free answer;
- closed-ended questions - where there are only certain answer options: 1).., 2)…, 3)…;
- the semi-closed-ended question is based on adding a phrase to the list. The question gives an opportunity not to write the answers given in the questionnaire, but also to express something;
- the question-menu propose the respondent to choose any combination of the options offered;
- scale questions - the answer to this question is given in the form of a scale, in which it is necessary to mark one or another indicator;
- dichotomous questions: where the answer is Yes or No.

According to the type of research tasks, polls are:

• standardized - aimed at obtaining statistical information,

• focused - collects data in a specific situation,

• in-depth - aimed at obtaining search information.

Respondents are distinguished by their level of competence:

- mass survey - the opinion of non-specialists on this or that topic;

- mass survey in cooperation with the researcher - provides informational assistance to the respondent by the interviewer in understanding the situation being analyzed;

- symptomatic survey - sufficient knowledge of the respondent of general information without a deep understanding of the goals and objectives of the research;

- expert survey - survey of specialists in the problem under study.

The main stages of the survey are:

- preparatory phase - it involves the development of a survey program;

- operational stage - the process of questioning itself;

- final (resultant) stage - processing and analysis of the received information, preparation of the report.

So, using the questionnaire method, we can gather the main mass of sociological information, but make it more authentic, it can be combined with other methods of questioning and observation, questioning and free interview [38].

The processing of questionnaire data is conducted in two directions: quantitative and qualitative. Due to their large volume, mass survey data is primarily subject to quantitative analysis: they are grouped together, which allows extending (extrapolate) the findings to a fairly wide range of phenomena, which are relevant to the questioning.

In the course of quantitative processing of questionnaires certain coding is used, that is, all the answers received belong to one or another group of analysis. Which groups of analysis will be identified depends on the purpose of the study and the content of the answers received [39].

Therefore, one of the effective data processing tools is to bring the data to scale (a means of capturing the results of measuring the properties of objects by ordering them into a certain numerical system, in which the relationship between individual results is expressed in appropriate numbers). In the process of ordering, each item in the sample is assigned a specific score (the so-called scale index), which determines the position of the result on the scale. The scale makes it possible to quantify and compare the obtained results.

At the end, an analysis of the results is carried out, which can be presented in the form of graphs or a report [40].

2.4.1. Creating a survey for research

The given research work involves interviewing residents of Opole using the specially developed list of questions.

The first two questions were filter questions that were asked to screen out incompetent and not interested individuals when interviewed for research problems. So, if people responded in the negative to the first question – no further survey was conducted, if positive - continued. Questions 3-7 were basic and related to the research topic, first and foremost to find out how people feel about this situation and whether they are ready for changes in the city's transportation infrastructure to improve the environmental situation.

Table 2.3

List of questions created for the survey

№	1. Do you think that transport threatens people health in cities?			
1	2	3	4	5
1	No	Yes		
2				
3		2. Do you think that there is too much transport in the center?		
4		No	Yes	
5				

Continuation of table 2.3

1	2	3	4	5
6		3. How do you feel about the perspectives to limit private transport movement in the center? • Positive • Negative • Did not think about it	3. Which type of transport is excessive? • private • public • there is a problem in city planning, but not in number of cars	4. How do you feel about perspectives of limitation/prohibition of transport in the center? • Positive • Negative • Did not think about it
7			5. Are you ready to use the bike? • Yes • No • Did not think about it	6. Are you ready to use only public transport? • Yes • No • Did not think about it
8			7. Are you ready to pay the money for entry into the center? • Yes • No • Did not think about it	

2.5. Conclusions to Chapter 2

The environmental and economic efficiency is a complex assessment of interaction between economic activity and the environment in space and time. The efficiency indicators of the project must include assessment of economic, environmental and social impacts in monetary dimension. Methods for assessing such environmental and economic efficiency include the SWOT analysis and the PEST analysis, which have been considered in the chapter. Methods of calculating the traffic-related pollution of the environment are also considered. To evaluate urgency of the problem and social acceptance of the proposed project the interviewing of Opole residents was planned based on the specially developed list of questions.

CHAPTER 3

EXPERIENCE IMPLEMENTATION OF CITY PROJECTS

3.1. Advantages and disadvantages of cars usage

It's hard to imagine your life without cars in today's world. In most cases, attention is paid to car reliability, safety, comfort, price, and cost of use when buying it. But few people think about the advantages or disadvantages of using it as a whole.

The first benefit is that the car is a fairly comfortable vehicle for transportation within and outside the cities. The vehicle is maneuverable and agile. It does not depend on the mode of operation that is you can sit and go at any time. And thanks to modern technologies the design of many machines makes people have aesthetic pleasure even from the look of the car itself. People are "shielded" from external factors of irritation while inside this mode of transport (for example, from extraneous sounds or even people, how it happens in urban transports when the whole crowd fills the whole space, stepping into your comfort zone making everyone around more aggressive). Comfort can also be attributed to the availability of cabin heaters during cold weather seasons and air conditioning during hot. In addition to this presence of luggage compartment works as one of the main positive criteria for cars allowing transportation of luggage [41].

As for the disadvantages, concerning the car - this is, first of all, an environmental factor, discussed in Chapter 1. Another drawback (already more economical) there are high operating costs. This also includes the cost of refueling the car, storage, use of car wash stations and installation of alarms, purchase of additional chemicals for glass, repairmen and maintenance, etc [41].

Except economic issues, there is a serious organizational downside, which is parking the car. Often, car owners have the problem of parking a car because of the lack of parking space, no parking space available or their chaotic location. So, often cars park on the sidewalks, in green areas, and in main urban squares [42]. According to the Telegraph, the average driver spends 20 minutes finding a parking space. This is 5 days of continuous whirling around the city per year if parking is needed once a day (and second at home) [43].

In large cities, the average storage space for cars at the place of residence is 30-35%, and the availability of parking places does not, on average, exceed 25% of the required number. The situation is also complicated by the uncontrolled parking of vehicles, which is why the roadways of most streets in the central part of the cities use only 30-50% traffic, which in turn leads to a reduction in the traffic capacity of the road network [44].

Therefore, against this background, it is important to remember that problems with car parking spaces are one of the causes of transport congestion. Because cars parked along the roadway reduce its effective width, which not only increases traffic congestion but also reducing traffic speeds and reducing the city's road network. This is because an area busy with car parking exceeds the area of city streets and roads, which used for traffic. At the same time, this problem is affecting not only big cities but also in average [45]. Also, major cities suffer from congestion due to the rapid increase in the number of cars: the intensity of movement increases, increasing the level of loading of major roads, congestion is created and the average speed is reduced [44]. The negative effects of congestion include waste of time, delay of passengers on the way (which leads to a delay, later incurring economic losses or penalties), fuel overconsumption, stress, and irritation, reducing the efficiency of emergency services, there is an accumulation of atmospheric air pollution in one place [46].

Particular attention should be paid to road accidents, as they are among the top ten causes of mortality worldwide, (fig.) wherein 2016 was killed 1.4 million people by road injuries, (74% of whom were boys and men) [47].

Also such vehicular accidents are the leading cause of death among 15 to 29 year old youths around the world. Injuries from road accidents are also the ninth leading causes of death across all age groups worldwide. Analyzing the age category in more detail, one can see that road accidents ranked the first between 5 and 14 as a cause of death in 2017, only then comes cancer and malaria (fig.3.1.) And at the age of 15 to 49 - the fourth position, after cardiovascular disease, cancer and HIV/AIDS (fig. 3.2) [48].

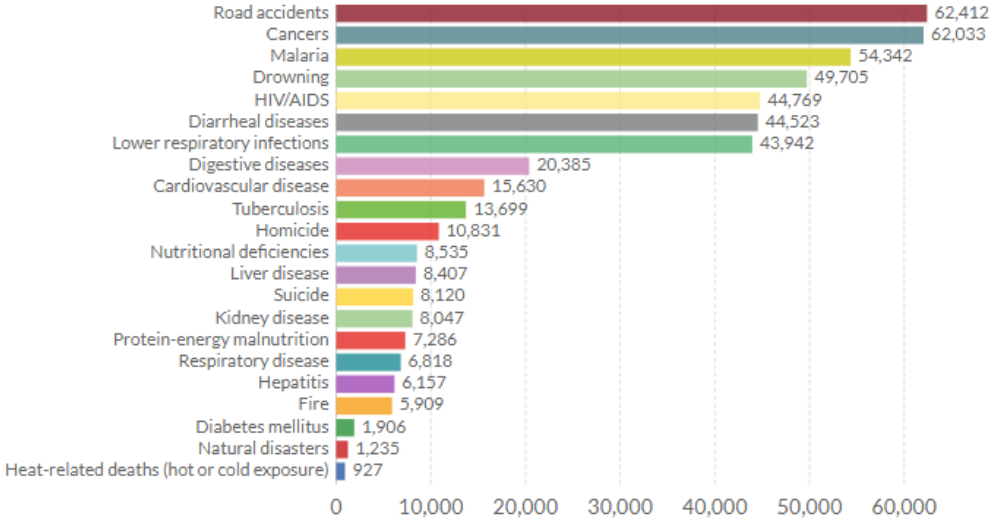

Fig. 3.1. Causes of death in 5-14 year olds in 2017 in the World

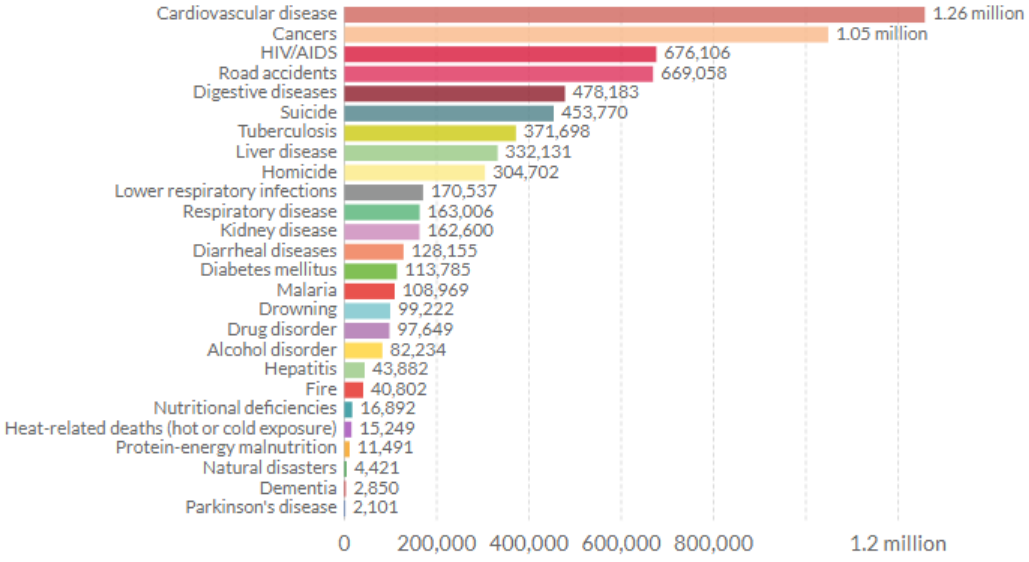

Fig. 3.2. Causes of death in 15-49 year olds in 2017 in the World

An estimated 85% of pedestrians are killed when struck by a vehicle at 60 kilometres per hour. By comparison, 5% are killed when struck by a vehicle at 30 kilometres per hour [49].

As for the city of Opole, the Opolska police register data on road accidents with mortality every year on its website. So, in 2018 in the city itself there were 6 cases during which 9 people were killed. All the cases were related to the car: 4 road accidents are a car raid on pedestrian, 1 road accident between a car and a train, and 1 accident with a truck.

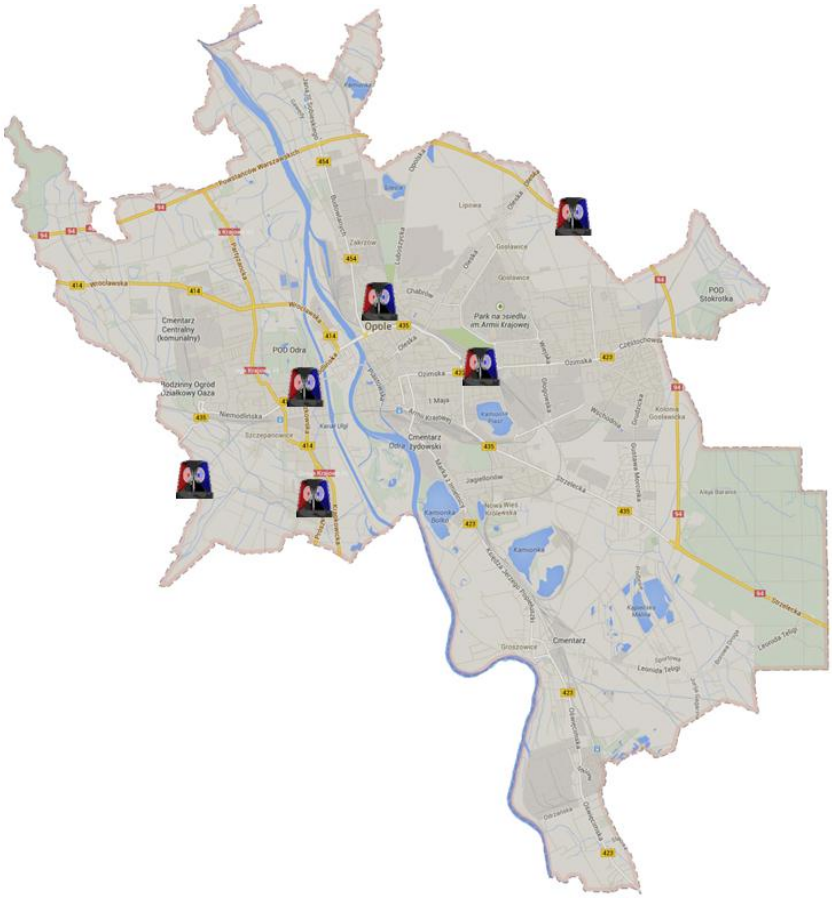

Fig. 3.3. The map of Opole road accidents with mortality in the 2018 year

Opole
(miasto na prawach powiatu)

Wypadki – 6 **Zabitych – 9**

Lp.	Data i godzina	Lokalizacja	Opis zdarzenia:
1.	18.01.2018r. godz. 15:20	Opole, ul. Luboszycka 13	- najechanie na pieszego - uczestnicy: samochód osobowy - pieszy - zabitych – 1 (pieszy) - przyczyny: nieostrożne wejście na jezdnię zza pojazdu lub przeszkody
2.	27.02.2018r. godz. 19:00	Opole, ul. Lipcowa	- zderzenie pojazdów boczne - uczestnicy: samochód osobowy - pociąg - zabitych – 4 (kierujący, pasażerowie) - przyczyny: nieustąpienie pierwszeństwa przejazdu
3.	29.05.2018r. godz. 19:00	Opole, ul. Ozimska 95	- najechanie na pieszego - uczestnicy: samochód osobowy - pieszy - zabitych – 1 (pieszy) - przyczyny: nieustąpienie pierwszeństwa pieszemu na przejściu dla pieszych
4.	04.06.2018r. godz. 10:00	Opole, ul. Niemodlińska 37	- najechanie na pieszego - uczestnicy: samochód osobowy - pieszy - zabitych – 1 (pieszy) - przyczyny: nieustąpienie pierwszeństwa pieszemu na przejściu dla pieszych
5.	25.10.2018r. godz. 15:21	Opole, ul. Powstańców Warszawskich, DK94C	- zderzenie pojazdów czołowe - uczestnicy: samochód osobowy – samochód ciężarowy - zabitych – 1 (kierujący) - przyczyny: niedostosowanie prędkości do warunków ruchu
6.	14.12.2018r. godz. 17:20	Opole, ul. Prószkowska 82, DW414	- najechanie na pieszego - uczestnicy: samochód osobowy - pieszy - zabitych – 1 (pieszy) - przyczyny: nieostrożne wejście na jezdnię przed jadącym pojazdem

Fig. 3.4. Example of registration of information about the fatal road accidents in the Opole city on the official police website [50]

By the way, according to the EU report on the situation on roads for 2018, Poland ranks fourth in the number of deaths in road accidents, second only to Romania, Bulgaria and Lithuania [51].

3.1.1. Hypokinesia and hypodynamia

In the modern world, there has been a significant degradation of motor activity in human life. A motor deficit causes over three million deaths annually worldwide (WHO, 2009). It is a risk factor leading to poor health, and one of the factors, contributing to the increase of such leading causes of death and diseases as cardiovascular diseases, type 2 of the diabetes and some types of cancer [52].

In this way, technological progress has also reduced need for walking, work on housework, grocery shopping and self-catering - decreased physical activity in the socio-cultural sphere. Due to such a sedentary lifestyle, automation of work, work in forced posture, the development of new diseases was caused, such as hypokinesia and hypodynamia, which have had a significant impact on living standards and longevity.

And one of the main reasons for the development of such diseases is using a personal vehicle. Thus, with the development of science and technological progress, people often move more and more by cars, to save time and increase travel comfort, and for many modern people all the physical exercise a day is limited to the road from the entrance to the car [53].

3.1.2. Erosion of social ties in society

And another negative impact, what connecting with cars is not just a decrease in the physical mobility of people and it is even an increase in loneliness among people.

Donald Appleyard was investigating how automotive traffic isolates us from one another and diminishes our human connections [Livable Streets].

Appleyard did his research in San Francisco in 1969, looking at three categories of streets: light traffic (2,000 vehicles per day), medium traffic (8,000 vehicles), and heavy traffic (16,000). What he found was that residents of lightly trafficked streets had two more neighborhood friends and twice as many acquaintances as those on the heavily trafficked streets.

In 2008, Joshua Hart, a researcher at the University of the West of England, set out to test Appleyard's hypothesis in the U.K. city of Bristol and encountered parallel results to Appleyard's. People on the heavily trafficked street felt besieged by cars; people on the quieter street felt much more of a sense of community. "Traffic is really the main thing- life has changed tremendously because of the car. Neighbors don`t see each other like they used

to, because people get out of their front door, get in the car, and visa versa when they get home". During the research, one mother said that she actively discouraged her children from forming friendships across the street, in order to avoid crossing the busy road on a regular basis - direct evidence that traffic flows can hinder the development of social networks [54].

Although on the other hand the auto`s greatest impact occurred in the region`s rural reaches where the new technology broke the chronic isolation and loneliness of life, made urban life and its attractions and distractions more readily available to country residents, and provided a means to get to that mill job while still retaining the family farm.

Although on the other hand the auto`s greatest impact that occurred in the region`s rural reaches - is broken the chronic isolation and loneliness of life. And give the possibility to work in big cities.

To summarize all the advantages and disadvantages, the authors have created a table 3.1.

Table 3.1

Advantages and disadvantages of automobiles using

№	Advantages	Disadvantages
1	2	3
1	1. Comfortable vehicle for transportation: - Maneuverable and agile; - Does not depend on the mode operation;	1. Negative influence on environment 2. and living organisms; 3. High operating costs; 4. Parking the car;

Continuation of table 3.1

1	2	3
	- Makes people have aesthetic pleasure; - Gives the protection from external factors; - The presence of luggage compartment works; - Gives the possibility traveling on a long-distance. 2. Improved the work of special services; 3. Tourism development; 4. Expanding horizons for rural residents	5. Transport congestion (that provokes waste of time, fuel overconsumption, stress etc.) 6. Road accidents; 7. Degradation of motor activity of people; 8. Increasing loneliness.

3.2. The main features of cities without cars

The anti-car arguments which were described in the first part of this chapter are convincing: cars, plus the entire infrastructure that accompanies them, congest roads and take up valuable space. They also divert investment and interest from public transport. And of course, they're deadly - with air pollution and crashes. Thus, both scholars and authorities are looking for the solutions to reduce traffic at the urban areas. Different methods are used from a total ban on cars to only limitation [55]. All these levels of restrictions are termed as a car-free city (Fig.3.5).

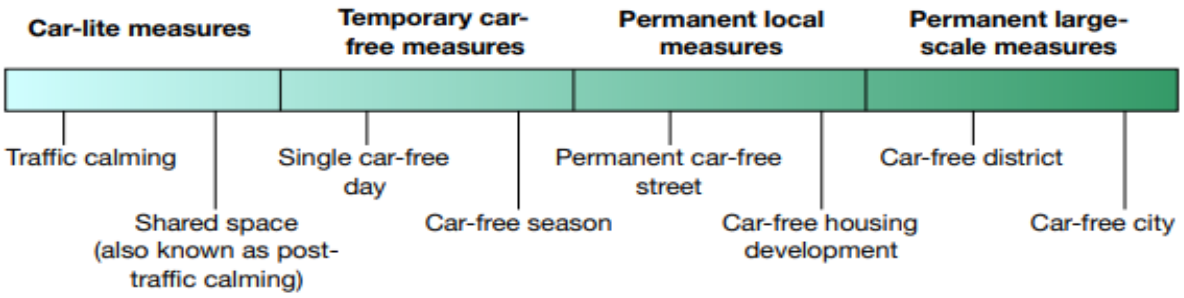

Fig. 3.5. The car-free spectrum

On one side of this spectrum are areas that discourage vehicle use without an absolute ban. Such areas are sometimes termed “traffic-calmed” areas or even “car-lite” areas. In this case, cities and communities permit full motorized vehicle access but deter unfettered use and speeds through road design. On the other side of the spectrum are cities and communities that completely prohibit motorized vehicles. In between a traffic-calmed area and a completely car-free city is a range of other possibilities that vary by both the spatial and temporal nature of the vehicle restriction. Rather than encompassing the entire surface of a city, a motorized vehicle ban may be limited to a particular district or precinct. Vehicle restrictions may also vary by the time of day, day of the week, and even the season of the year.

In general, a car-free city implies the complete absence of any motorized vehicle travel at all times. Cities that are completely free of any motorized vehicle transport are quite rare. Just Venice (Italy) and the medina of Fez (Morocco) are probably the closest of any major urban areas to the true meaning of a car-free city. In Venice’s case, this aversion to the automobile is due to its unique geography and the need to retain historical character.

Such zones without cars create the pedestrian-scale city that is a much finer grain place - sized for people walking. It is a world away from suburbia, which is sized for cars. You can't walk in suburbia, and you can't drive in places like Venice. A walking city is the most enjoyable, comfortable and sustainable [56].

The experiences of some European cities suggest that there must be a phased transition. And there may need to make exceptions for an emergency, electric and delivery vehicles as well as drivers or passengers with disabilities [57]. Even within cities that are almost completely car-free, there are times when exceptions are permitted, such as the use of emergency vehicles. There are also many examples of cities that permit small electric vehicles to assist with the movement of goods and the transit of the elderly or disabled persons (e.g., Zermatt, Switzerland).

There also exist several smaller island cities that are also largely car-free include Capri, Landau (Hong Kong), Gulangyu (China), Buyukada (Turkey), and Fire Island (US).

Some of these island cities have largely retained a car-free nature due to the following factors:

- The difficulty of developing car-based infrastructure within the given topography;
- The relative inaccessibility of the locales;
- Existing densities and short distances between key destinations;
- Local customs and preferences.

Most car-free cities have another characteristic in common. Virtually all these cities are tourist destinations. A car-free city is a highly attractive environment for people wishing to escape the stressful atmosphere of their home cities. A car-free strategy for a city may thus be appropriate for urban areas that are seeking to position themselves as a tourist destination.

For some cities, creating a large-scale car-free area can be a strategic decision built upon a sound analysis of the economic, social, and quality-of-life advantages.

For most cities and communities, the abandonment of motorized vehicles will not happen overnight. However, cities and communities may choose an intermediary step that at

least begins to shift the balance in urban design away from the primacy of the automobile. Measures that restrict private vehicle movements and speeds are a basic step in this process.

A car-lite area may also be defined by the type of vehicles permitted. Some areas may limit car use to only local residents. In other instances, car taxis may also be permitted. While such areas are not car-free, they do represent a potential reduction in the volume of motorized traffic. Such restricted access areas also can act as buffer regions that help provide a safe transition from car-free zones to car-dependent areas. This premise also holds for areas implementing traffic calming measures.

Areas that do not prohibit vehicles but strictly limit parking may also be considered as a part of the car-free project. The banning of all on-street parking can be the start of returning a community to its residents. The lack of parking provision is an effective incentive to encourage residents and visitors to seek transport alternatives. A visually car-free street can also help send a psychological message to everyone that children, pedestrians, cyclists, and other non-motorized users have priority.

Car-free areas can also be defined on a temporal basis: they be car-free during designated hours of the day or during designated days of the year. “Car-free days” are a limited one-day experiment in banning motorized vehicles from street access. A Car-Free Day can encompass an entire metropolitan area or be conducted on a neighborhood basis. Car-free days are typically undertaken annually on a week-day to demonstrate the viability of alternatives during a normal workday. However, some cities, have implemented permanent Car-Free Days that occur each weekend on a particular street or in a particular neighborhood. There are also seasonal events, such as street closures during summer months, which allow residents to make the best use of an area based on seasonal climate patterns. Many festivals also necessitate a temporary car-free approach due to the nature of the event and the amount of people drawn to the area. And car-free days are increasingly high profile events that can be useful in awakening a city and its residents to the possibilities of a different urban

environment. The principal premise behind such days is the idea of creating a “pattern break” in which awareness of transport alternatives is promoted. On today the date of 22 September is now recognised as the International Car-Free Day.

Car-free days may also be triggered when pollution levels reach a certain critical point. Italian cities have particularly adopted this technique to fight acute pollutant levels. In February 2005, the city of Vicenza (Italy) forbid motorized vehicles for a period of one week in order to clean the air of a persistent smog formation.

Shopping streets are perhaps the most common examples of car-free areas. They typically do allow some exemptions from motorized vehicle restrictions. Shops may be given special delivery hours to bring in goods and products. London’s Covent Garden is a well-known example of how pedestrianization can lead to an area’s regeneration.

Today the area stands as one of London’s premier tourism destinations. Likewise, London’s Carnaby Street is a high-profile example of how pedestrianization can regenerate an area and provide a dramatic boost to retail shops.

Car-free zones are also typical in many parts of the developing world. City centers in North Africa, Asia, and Latin America often quite naturally become car-free areas due to the narrow streets and human-scale form of the centers. The historical cores of older cities in Asia, Latin America, and Europe are frequently pedestrianized in a similar manner to car-free shopping streets. The ancient central streets of these cities make the automobile rather impractical, especially once any sizeable volumes of traffic are reached.

Herewith the prohibition of motorized vehicles in historical centers can be helpful in cities achieving status as World Heritage Sites under auspices of the United Nations Educational, Scientific and Cultural Organisation (UNESCO). Motorized vehicles are not just damaging to human health, but exhausts and vibrations can damage the built environment, especially in the case of ancient historical centers. Further, the noise and presence of vehicles deter from the ambiance and reverence of important historical sites.

Accommodating bicycle usage in the car-free environment should be a top design priority. The bicycle is an ideal non-polluting vehicle to ease travel beyond distances convenient by foot. A well-designed car-free environment in conjunction with bicycle use means that residents can access most day-to-day needs quite easily.

Cycleway infrastructure can take a variety of forms depending on local circumstances. The options can include fully segregated cycleways as well as examples of cycleways integrated within the roadway or pedestrian path. In developing cities, the proper width of the cycleway should accommodate the myriad of work bikes that are utilized for both informal vending and cargo loads.

However, given the difference in speed between bicycles and pedestrians, some caution must be involved in handling the non-motorised mix within denser communities. Just as cars have the ability to overwhelm cyclists from the streets, cyclists can potentially create similar problems for pedestrians.

Thus, in zones with dense pedestrian movement, cyclists may be requested to dismount from their bikes and walk through the area. In other instances, separation of the two modes may be a solution. The coloration of the cycleway surface is one high-profile technique used to differentiate bicycle space. There are also various other mechanisms for physically segregating the lane. Rent-a-bike facilities can be particularly useful for casual users. One of the most well-known examples is the “Free City-Bike” program of Copenhagen. Uniquely designed bicycles are distributed throughout Copenhagen at special bicycle rental stations. A person only needs to insert a 20 DKr coin (US$3.30) to gain access to a bicycle. Upon returning the bicycle at any station, the coin is fully returned to the user. If the bicycle is parked away from a bicycle station, then anyone can return it and collect the 20 DKr coin. The brightly painted advertisements on bicycles help to pay for maintenance. While bicycle theft had plagued many of the initial attempts at city-bike programs, modern technology in combination with simple design changes has largely eliminated this concern.

The Copenhagen bicycles are fitted with a chip to permit GPS-based tracking. Further, the shape and size of the bicycle components are unique to the City-Bike and thus rendering theft of components to be ineffective.

The provision of shower and wash-up facilities for cyclists can also be an important infrastructure component, especially for cities with warm climates. Persons arriving at the office by bicycle will likely wish to freshen-up before proceeding to work.

Public transport likewise supports pedestrian zones by allowing access without the need for private vehicles. Public transport essentially frees up a considerable amount of urban space that would otherwise be required to move an equal number of persons by private vehicle.

Parking is also a relevant issue for some car-free shopping streets and car-free housing projects. Car-free housing projects that permit car ownership will likely need to develop parking areas just outside the housing development. Likewise, some parking provision is typically made for visitors to the area.

The key to successful parking in both these instances is insuring that the parking facility does not deter from the car-free experience inside the car-free zone. The chosen location should ensure that noise from vehicles, either from operation or through car alarms, does not penetrate the car-free area [58].

3.3. Examples of implemented projects

Recently, the concept of "city without cars" is beginning to gain momentum and has more and more interested countries in it.

Norway could be an example of this. Since 2015, the head of Norwegian capital, Oslo, has announced that it plans to completely get rid of cars at least in the city center. At the beginning of this project, many opponents of this idea were identified so at the beginning of

giving up the idea of a ban on entry, they began to clean parking spaces and build a network of cycle paths. By 2019, the area inside the central ring road will be prohibited for cars. The administration has also promised to introduce a cash levy for those who ride a car during rush hours (in addition to the existing traffic jams tax). Norwegian pension funds will no longer invest in companies making money on the extraction of oil, gas, and coal. Thanks to these measures, by 2025, the city will be able to abandon fossil fuels.

In Paris, the number of cars, working on diesel fuel, was halved and limited to 20 km/h. In just a day, the level of air pollution returned to normal, and the congestion decreased by 40%. France is currently the leader in the number of diesel cars in Europe (diesel costs cheaper gasoline) but the intention of Mayor Anne Hidalgo is to ban them completely by 2020. Pedestrian and bicycle infrastructures are being developed in parallel (for example, it is planned to double the total length of bike lanes and bring it up to 1400 km). Also, for a better understanding of the "city without cars" for the residents of Paris staged a real day without cars, when the streets of the city, including the Champs Elysees, temporarily put pedestrians and cyclists in undivided power.

Hamburg plans to close some of the streets for cars and simultaneously develop a "green network" - cycle paths connecting parks and recreational areas and covering 40% of its territory. City officials hope that by 2050 they will reduce greenhouse gas emissions by 80% [59].

In 2017, a research on car-free perspectives commissioned by the Department of the Environment, Transport and Climate protection was conducted in Berlin, and the result was the refurbishment of 12 motorways on the cycle highway [60].

In Madrid, the administration has allocated an area of 3.5 square kilometers in the city center, where the entry of cars (except residents) is prohibited. This area should gradually expand and by 2020 should cover the entire center. As an alternative, citizens will be offered new pedestrian zones and an updated bus network. Madrid also became the first European

city that launched a full-fledged electric bicycle rental system. Also, following the example of Paris, on days when emissions exceed the norms, they will forcibly limit the number of diesel vehicles on the roads. Public transportation on these days will work for free. Diesel bans are also being considered in Dublin, London and Brussels.

In Milan, a system for promoting car abandonment is in operation - when leaving the car at home, you can get a free subway ticket.

In Bogota (the capital of Colombia) - the first event that was dedicated to the city without cars took place in 1974 thanks to which, once a week, 120 km of roads in the Colombian capital is closed to cars and give away to pedestrians and cyclists. Also, more than 300 km of bicycle lanes were built [59].

Government of Finland's capital of Helsinki, instead of a ban on diesel cars, has developed a 10-year plan to create an on-demand mobility system. All public transport, including ferries, vans, and bicycles will be available to order through the Whim smart phone app. The idea is to make the system so attractive to citizens in order to use the integrated transport network was cheaper and more convenient than own car [62].

Diesel cars are planned to be banned in London by 2020. The first stage was a "pledge" for diesel cars driving through the central streets during rush hours. Owners of such cars have to pay $ 13 a day. In July 2017, the UK announced a complete ban on the sale of new diesel cars by 2040. In 2018, owners of diesel and gas cars of the environmental class "Euro-4" (released before 2005) will pay $ 29 daily for the use of the capital's roads between 7 am and 7 pm. In April 2019, the law will be strengthened: the charging for cars on Euro-6 diesel and Euro-4 gasoline will start. Since October 25, 2021, the ban should extend to all London and North Ring Roads and will apply to freight transport. As a result, car owners have to face a $ 32 daily fee for using any car.

In December 2016, a plan to ban the entry of diesel cars into the center by 2025 was announced in Athens. Also, the city periodically restricts the entry of cars on diesel fuel,

choosing even or odd numbers as a reason for the ban. If the owner has the "appropriate" number - the passage is closed. The ultimate goal of Athens is to remove all cars from the center.

In 2000, the Tokyo government banned all diesel vehicles, except for those with exhaust gas purifiers. This reduced air pollution has decreased dramatically and now residents can see Mount Fuji.

The mayor of the Spanish city of Pontevedra has created a 300,000 square foot pedestrian zone in the historic city center, banned street parking and instructed to stop cars, passing through the city. The mayor replaced the central land parking lots with underground ones, most of the parking lots are out of town. As a result of its actions, emissions into the atmosphere have decreased by 70%, and the population increased by 12,000 [62].

In some cases it is difficult to change the situation and immediately transform into cities without cars. The possible option is to build a separate, new city, which by design will be adjusted to all standards of "green city" from the very beginning. An example is the city of Masdar, located in the United Arab Emirates of Abu Dhabi, it was estimated that 50,000 people would live in a zero-emission city, and 40,000 will come to work every day. One of the main features of the city – is the total ban on cars. The transportation of passengers and cargo was intended to be provided by the CyberCab system - also called PRT (Personal Rapid Transit). These are small cabins for 3-6 people or several units of cargo, a hybrid of a tram and taxi, looking like light truck. They go by separate roads without drivers. About 100 CyberCab stations were also planned, but only two were built. During the construction, the project failed, so changes were made. As the infrastructure to protect pedestrians from moving cabs was too expensive, and the new mode of transport could not meet the needs of residents, electric cars and buses were introduced. They are flexible and fit into the concept of Masdar as an "emission-free city". The project is expected to be completed by 2030 [64].

In addition to the Chinese city of Chengdu Tianfu, a small town for about 80,000 people is being developed to serve as an example of modern urban planning. The cars will be allowed in the city, but there will be no need for them, because offices, schools, shops are all within walking distance, that is, it takes about 15 minutes to get to any desired location [65].

Switzerland should also be considered a separate entity, because in this country, especially in the mountainous part of Switzerland, there are villages and towns where private motor transport is completely prohibited. Only hotels, taxis and utilities can have a car, and this car should be electric. Transport with internal combustion engines in such settlements is absent completely. Zermatt is one example of such towns. First of all, getting into a car is impossible. All travelers have the opportunity to leave their vehicle only in the neighboring town of Tesh (approximately six kilometers from Zermatt). Next, you can get there either on foot or by train, which runs every twenty minutes. The city itself has its own special "Swiss" electric cars (fig.3.6), created in the town by the Stimbo aluminum company. They are light and do not rust. Its cost is from € 70,000 to € 200,000. Similarly, this company produces electric buses.

Fig. 3.6. "Swiss" electric car

In addition to these types of taxis, horse-drawn transport is allowed. In general, Zermatt is one of the most environmentally friendly resorts in the world [66].

Another interesting town is Houten, located in the Netherlands. In 2008, he won the nomination "The Bicycle City". It is almost impossible to see a car there. In the seventies of the last century, Houten began to build up actively; at that time it was only a small village with four thousand inhabitants. At the same time, a strategic decision was made to encourage the use of bicycles by citizens, renouncing them on any occasion to take the car. During that period, a bypass (Rondweg) was laid. The trick is that you can get to the car from one area to another only by this detour - there are no direct routes to the neighboring area. For bicycles, of course, there is no such restriction, as a result it is faster to go to friends to another part of the city by bicycle than by car. Almost everywhere, where the bicycle and motor roads intersect, the tunnels are laid. The whole city is riddled with "bike-streets" (fietsstraat). A special sign reminds drivers that the cars are "guest" - they can drive, but they must be patient and courteous [67].

Table 3.2

Summarizing information on projects of cities without cars

№	City	Scale	The essence of the program	Year of implementation
1	2	3	4	5
1	Oslo	City center	• ban on cars from the city center; • cleaning parking spaces and build a network of cycle paths; • introduction of a cash levy for those who ride a car during rush hours.	By 2019

Continuation of table 3.2

1	2	3	4	5
2	Paris	whole city	• ban on diesel cars completely; • development of pedestrian and bicycle infrastructures, • staging real day without cars	By 2020
3	Hamburg	40% of city streets	• closure of some streets for cars • development of a "green network"	By 2050
4	Berlin	whole city	• refurbishment of 12 motorways on the cycle highway	From 2017
5	Madrid	City center	• new pedestrian zones and an updated bus network; • 3.5 square kilometers in the city center are forbidden for cars (with further ban on all city center in the future); • launching of a full-fledged electric bicycle rental system; • limitation on the number of diesel vehicles on the roads on the days when emissions exceed the norms, • public transportation will work for free	By 2020

Continuation of table 3.2

1	2	3	4	5
6	Milan	whole city	• free subway ticket if leave the car at home	---
7	Bogota	120 km roads of city	• once a week, 120 km of roads is closed to cars, • 300 km of bicycle lanes were built	since 1974
8	Helsinki	whole city	• creation of an on-demand mobility system	10-year plan, by 2025
9	London	whole city and city center	• ban on diesel cars, by forbidding the sale of new diesel cars by 2040; • taxes, resulting $ 32 daily fee for using any car	From 2017 to 2040
10	Athens	Center city and periodic extends to the whole city	• ban on the entry of diesel cars into the center (periodically restricts the entry of cars on diesel fuel, choosing even or odd numbers as a reason for the ban)	From 2016 to 2025
11	Tokyo	whole city	• ban on all diesel vehicles, except for those with exhaust gas purifiers	2000

Continuation of table 3.2

1	2	3	4	5
12	Pontevedra	City center	• 300,000 square foot pedestrian zone was created in the historic city center, • banned street parking and instructed to stop cars, passing through the city; • replaced central land parking lots with underground ones; • most of the parking lots are out of town	---
13	Masdar	whole city	• "Emission-free city" is planned as the city without cars except electric cars and buses; • transportation of passengers and cargo is provided by the CyberCab system	By 2030
14	Chengdu Tianfu	whole city	• the small town offers possibility to reach everything in about 15 minutes	From 2012 to 2020

Continuation of table 3.2

1	2	3	4	5
15	Zermatt	whole city	• leaving vehicles only in the neighboring town of Tesh; • own special "Swiss" electric cars; • horse-drawn transport is allowed	Already
16	Houten	whole city	• encourage the use of bicycles by citizens, renouncing them on any occasion to take the car; • a bypass is laid; • it is faster to go to another part of the city by bicycle than by car; • comfortable interconnections between bicycles and highways (laid tunnels)	Since 1970s

3.4. Conclusions to Chapter 3

Multiple issues raised by cars in cities have forced governments and municipalities to look for new solutions. A new method of combat is the idea of "car-free city". For the most part, this is a ban on entry into the city centers, various types of car taxes for residents, holding various festivals during which the city is closed for cars on one day, bicycle and pedestrian zones are also being built. A new feature was the construction of absolutely new cities - a project that makes the city so comfortable that people do not want to use the car. Based on examples of the struggle of different cities with cars, the project of the city of Opole was proposed - as a city without cars.

CHAPTER 4

CAR-FREE CITY PROJECT FOR OPOLE CITY

4.1. Prerequisites for project implementation

4.1.1. General information

Opole is the capital of the Opolskie Voivodship situated in the south of Poland, near the border with the Czech Republic (Trzebinia-Bartulovice – 54 km) and Germany (Olszyna – 240 km). It occupies the area of 96 km^2 and has 126 000 residents (approx. 12% of the population of the voivodship), together with adjacent communes, it comprises an urban agglomeration inhabited by over 262 000 people. The population density is approximately 1350 people/km2. The value of this indicator is over eleven times higher than the average in the region, which is 120 people/km^2. This indicates that the city of Opole is the most densely populated area in the voivodship behind Brzeg. This forms a range of impacts on the natural environment and decreases the overall quality of living environment [68].

The city of Opole is a developed industrial center in which over 19,000 enterprises conduct business activity. It has one of the highest entrepreneurship indexes among Polish cities – 162 enterprises per 1 thousand inhabitants. The city is in the sphere of activity of investors such as Zott GmbH, Danone, Remondis International, Ahlers AG, Kludi Armaturen, Monier, ESAB, Tower automotive. In addition, the existing Opole Subzone of the Walbrzyh Special Economic Zone contribute to the future economic and production center of the city. As a result, Opole is characterized by a large percentage of professionally active people (over 49 thousand) and young people, making 36 percent of the total Opole population. Such an intensive activity has its unavoidable pressure on the environment, being significantly transformed by now.

Opole is also a highly developed academic center with a total of 36,000 students at 4 Opole universities [69].

Opole is located in the Silesian Lowland which is joined to the Odra valley and Pradolina Wrocławska, occupying most of the city's area, and extends to the east the Opole Plain and to the west the Niemodlin Plain [70].

The relief is formed by the activity of the Odra River with its tributaries and postglacial formations [71].

Opole is one of the warmest cities in Poland with mild climate, suitable for rest and recreation [72].

Nature basis. The natural system of Opole includes the areas of the city's ecological corridors stretching along the Odra River, areas of urban arranged and unorganized green spaces and water reservoirs. The natural warp area covers 4552 ha (30% of the city area) in Opole. The sealing is 12%, and the share of biologically active areas is 91% of the area. Forest and shrub areas also belong to the natural matrix of the city of Opole.

There are valuable natural areas in the city of Opole, including monuments of nature (29 trees - maple trees, oaks, small-leaved linden, ginkgo biloba, stinging elm, field maple, common beech) and three ecological grasslands ("Grudzicki Grąd", "Łąki" in Nowa Wieś Królewska, "Kamionka Piast"). The first of the abovementioned is a habitat for rare and protected plant species with a total area of 3.15 ha. "Łąki" is a peat bog with an area of 3.14 ha, protecting valuable natural ecosystems of oak-hornbeam. The third ecological site is "Kamionka Piast", with an area of 22.60 ha created to preserve the natural values of the carbonate rock quarry, including mainly the geological profiles of the Upper Cretaceous rocks, as well as endangered plant communities. The international ecological corridor - the Odra Valley runs through Opole [70].

4.1.2. Transport infrastructure

Opole has convenient railway, international highway and airport connections. Urban transport is also developing on a stable basis. An example of this is the installation of vending machines for public transport tickets near each bus stop in this year and the purchasing of electric buses. The quality of roads is improving as well. In recent years, the bicycle rental facilities have also appeared.

One of the problems in the city is the large number of cars. This is due to the poorly developed urban transport infrastructure on the outskirts of Opole, that is why residents are forced to use the car to get to work in the city of Opole (every day, a large proportion of visitors come from neighboring settlements).

The second problem is low number of quality bike paths. Although the popularity of cycling among city dwellers is increasing in recent years - the number of city bikes users grew by as much as 30 percent since 2014 – currently there is no the adequate road infrastructure for a pleasant and safe journey. In general, there are 43 paths in Opole with a total length of 35 km, which is not enough for a city with the area near 96 km². In addition, most of these tracks are mixed with pedestrian paths, making it difficult to travel. And also they are made in recreational areas that can be seen on the map (Fig.4.1)

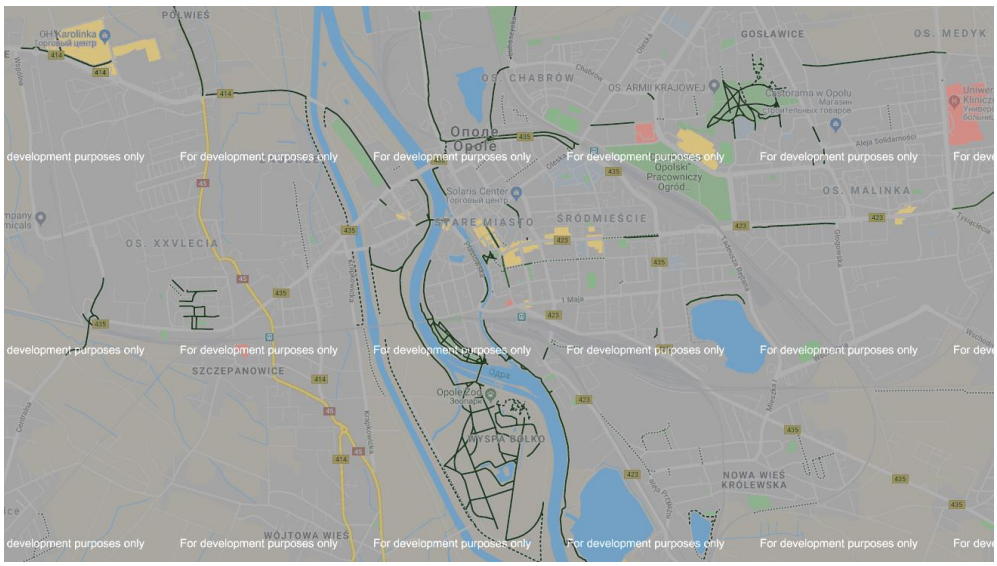

Fig. 4.1. Map of cycle paths in Opole

Another problem with Opole's transportation infrastructure is parking. In Opole city has two parking zone (fig.4.2) where are near 3000 places for parking, 123 parking meters. It covers the very center of Opole and partly the island of Pasieka. Parking payable is from Monday to Friday between 8-17. Parking is free on Saturdays, Sundays and public holidays. Entry to the zone is marked with a sign D-44. The immobilization of the vehicle at all parking spaces inside the zone is connected with the obligation to immediately purchase the parking ticket. Payments are made on weekdays from 8.00 to 17.00. The first 15 minutes are free of charge. The penalty for unpaid parking is 40 zł [73].

Despite the fact that the parking is paid in the central part of the city, the location of the parking spaces is complicated by narrow roads, leading to blocking of the pedestrian sidewalk and roadway, which worsen pedestrian passage and traffic in many areas of the city.

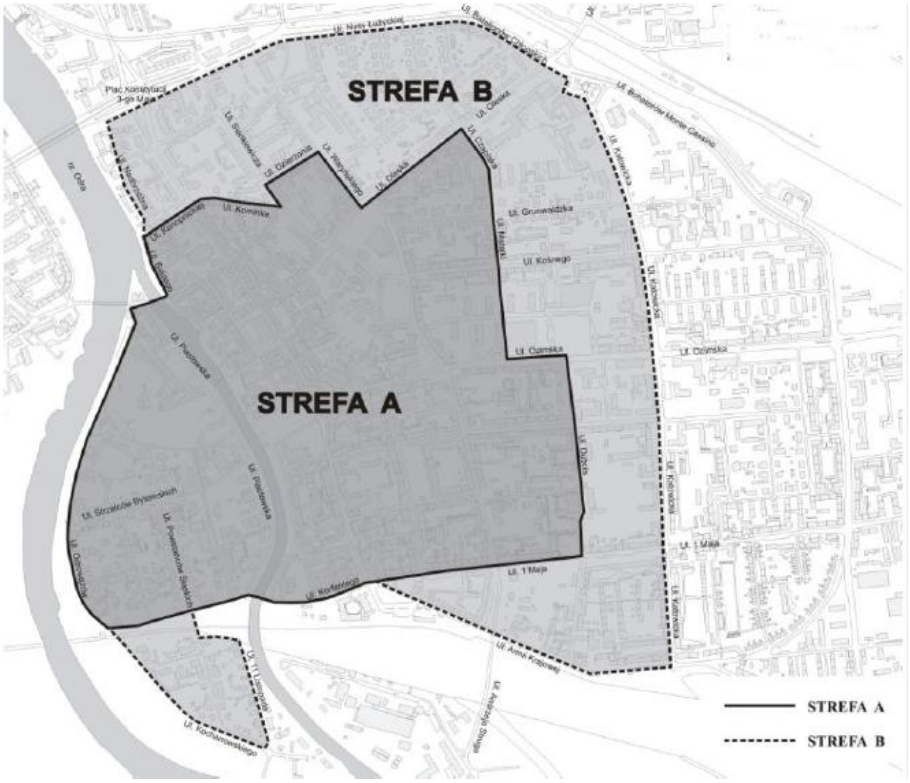

Fig. 4.2. Plan of a paid parking zone in Opole (zone A; zone B) [74]

4.1.2.1. Pollution

Particular attention should be paid to the environmental situation in the city especially the impact of residents' cars on the environment as a whole.

In 2012-2016, the particulate matter PM10 and benz-a-pyrene concentrations exceeded standards. Other pollutants are within the limits of safe concentarion. The sources of emissions are local heating systems, domestic boiler rooms and stoves, road transport and fugitive dust emissions from roads and industrial areas [70].

Noise pollution in Opole. The most important source of excessive noise in Opole is road noise. The area of the areas with exceedances of noise standards is 1,194 km^2 and it is inhabited by 11,608 people.

Areas with particularly high noise pollution levels are the following street sections:

- Niemodlińska Street on the section from Wrocławska Street to Wojska Polskiego Street;
- Wrocławska Street near the intersection from Niemodlińska Street and from the intersection to Czysta Street;
- the intersection of Władysława Jagiełły Street at Plac Klasztorny;
- Nysy Łużyckiej Street from Luboszycka to Wrocławska;
- Stanisława Spychalskiego Street from Księdza Norberta Bonczyka to Licealna;
- Partyzancka Street from Wrocławskiej to Północna Street.

4.2. The description of the project

Having considered the major transportation issues and environmental problems of the city of Opole, it is proposed to limit the entry of transport into the city center by blocking several sections of the highway. These are the streets of Rynek (Ratusza), plac Świetego Sebastiana, ul. Edmunda Osmańczyka, Mały Rynek – Staromiejska, Mały Rynek – Muzealna (Fig.4.3).

Selected streets provide entering and leaving the center. By blocking streets for private transport it is possible to make this area (highlighted in the Fig.4.4) free of cars – except for special services. It is important to emphasize that this area is historic, which is why it is a very popular destination for both tourists and residents of the city. Also it is located within residential buildings, which are very close to the selected highways. There are no green areas in the area.

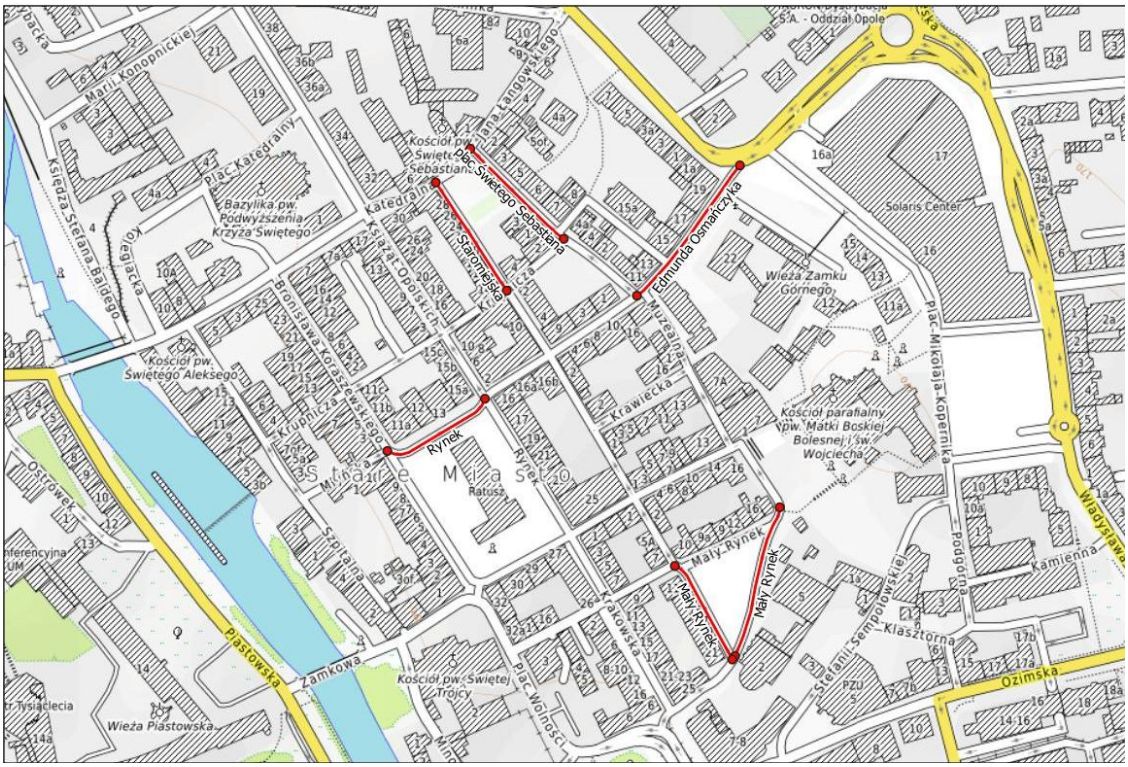

Fig. 4.3. Selection streets in the center for entry limiting

The proposed restrictions, in the first place, will help to reduce the impact of road transport (in the form of air and noise pollution) on residents and users (pedestrians) of the territory. And the vacated area will be available for the construction of bicycle infrastructure and landscaping.

Fig.4.4. The cars-free area

4.2.1. Basic project proposals

In general, the project itself is to block main city center roads for private car entry. As it is a popular area for many visitors and residents of the city – quite a large number of people are daily exposed to noise pollution and the effects of air pollution. When banned from the entry to downtown, car parking spaces will also be removed. The released roads are planned to be converted into bike lanes, bicycle parking, and areas for landscaping and recreation. To encourage the population to use a green vehicle – there will be an increase in the number of bike places that can be rented. On the other hand, parking spaces outside the city center for cars are 1.5 times more expensive - so that it is not profitable to use the car. To improve the car parking situation we offer to build underground and aboveground parking spaces. It is important to improve urban transport on the outskirts of the city and its

neighboring settlements, including development of new ways, introduction of new stops and bus routes for easy transportation of residents of the surrounding areas to the city.

4.3. Organizational component of the project

To implement the proposed change in the transport infrastructure of the city of Opole (in this case – blocking of roads for transportation, redesign of park cars places for bicycle, installing benches, landscaping streets etc.), appeal to governing bodies is obligatory. In the city of Opole, the main responsible authorities for city road management are City president and Municipal Road Administration in Opole. According to the Act on public roads - authorities supervising the management of traffic on the roads may order a change of traffic organization due to important general public interest or the need to ensure transit traffic. The President of the city manages traffic on public roads located in cities with powiat rights, with the exception of highways and expressways. The voivode oversees traffic management on voivodship, powiat, and commune roads as well as on public roads located in cities with powiat rights and in the capital city of Warsaw. The minister competent for transport supervises traffic management on national roads.

The submitted project must be evaluated by authorities. For this, the managing authority should set up a commission consisting of, in particular, a representative of the Police and a representative of the road management and consult an expert, auditor or expert on the impact of planned traffic organization on its safety, and also consult an expert on the impact of the planned traffic organization on the environment, in particular as regards noise and air pollution. After considering the submitted traffic organization project, the traffic management authority may approve the traffic organization in whole or in part.

Currently, some provisions give the opportunity to introduce local regulations for parking and changes in road management in cities:

- the Act on public roads, on the basis of which a paid parking zone operates;

- the Act on electromobility and alternative fuels, which allows creating transport free zones - the commune council may establish entry bans for vehicles that do not meet certain exhaust emission standards;

- the Act on public-private partnership (ppp), which allows creating downtown paid parking zones, in which parking fees may exceed PLN 9 per hour;

- the Regulation of the Minister of Infrastructure on detailed conditions for managing traffic on the roads and supervision over this management.

The Regulation of the Minister of Infrastructure includes Article 6 that states:

1. Traffic organization shall be approved, on the basis of a traffic organization project, by a traffic management authority competent for a given road.

2. In case of closing a road or traffic restrictions imposed on the road that leads tio the need to diversion of roads of different categories, a temporary traffic organization shall be approved by the traffic management authority for the road, on which the restrictions have been introduced.

Road managers issue permits; manage planting, maintaining and removing elements of green spasces along the road; introduce restrictions or closure of roads and road bridge facilities for traffic and designation of detours when there is a direct threat to the safety of persons or property; counteract adverse environmental transformations that may arise or arise as a result of road construction or maintenance; maintain pavements, engineering structures, traffic safety devices, and other road-related devices.

Thus, the most important thing is to develop a project and get permission for its implementation by the city's governing body.

4.4. Assessment of environmental and economic efficiency

The positive outcomes of the project can be attributed to environmental, social and economic components. The analysis of these components is performed with the method of SWOT analysis.

Table 4.1

SWOT-analysis of project

№	Strengths	Weaknesses
1	2	3
2	- improving the environmental situation (reduction of emissions and noise pollution); - economic benefits - increased incomes;	- long process; - inconvenience during project implementation; - additional load of the nearness roads; - additional costs;
3	Opportunities	Threats
4	- stimulating the urban population to more active lifestyle; - encouraging use of environmentally friendly vehicles or urban vehicles; - expansion of green spaces or recreation facilities at the released land;	- congestion of adjacent roads; - opposition from population.

Thus, we believe that environmental efficiency of the project is provided by the direct changes: reduction of emissions and noise pollution, as well as land use improvement through making land previously occupied by transport infrastructure available for any green spaces expansion or social activity and recreation facilities. The economic benefits are

indirect and reflect the monetary equivalent of the environmental gains, as well as increased incomes due to usage of public transport and improved health of the residents.

4.4.1. Calculation of the environmental benefits from the project

To express the benefits of the project in monetary equivalent, the following parameters were defined:

- volume of emissions reduction due to decreased traffic;
- level of noise reduction due to decreased traffic;
- cost of the newly released land areas in the city center;
- incomes.

The basic parameter for evaluation is the intensity of traffic at the studied area. For the purpose of economic calculation, accounting the diversity of car flow during a day, the intensity of traffic at these sections was defined in the morning, afternoon, and evening and recalculated to annual values (Table 4.2).

Table 4.2

The traffic intensity at the studied area

№		Mały Rynek – Muzealna		Rynek		Mały Rynek – Staromiejska		ul. Edmunda Osmańczyka		plac Świetego Sebastiana	
1	2	3		4		5		6		7	
1		w-days	w-ends	w-days	w-ends	w-	w-days	w-ends	w-days	w-ends	w-
2	Per day	1064	649	818	412	1335	956	1077	703	2072	1081
3	Per year	263872	75933	202864	48204	331080	111852	267096	82251	513856	126477
4	Together	339805		251068		442932		349347		640333	
5	Total	2023485									

Later, by the formula (2.1) the traffic-related emissions of the following pollutants were calculated CO, NO_2, CH, Soot, SO_2, Formaldehyde, Benz (a) pyrene

The combined data on pollution intensity at the studied area are given in Table 4.3-4.7.

Separate calculations were used for CO_2 with the assumption that a typical passenger vehicle emits about 4.6 metric tons of carbon dioxide per year. Thus, emissions of CO_2 make up 107566,86 tonn/km per year.

Table 4.3

The combined data on pollution intensity on Mały Rynek – Muzealna area

№	Mały Rynek – Muzealna				
1	1	2	3	4	5
1	**Pollutant**	**Weekday**	**Weekend**	**Total**	**Annuals**
2	**CO**	163,026906	83,87001	246,896916	90117,3743
3	**NO_2**	48,360648	26,127045	74,487693	27188,0079
4	**CH**	35,875287	17,5424445	53,4177315	19497,472
5	**Soot**	0,6352458	0,29054445	0,92579025	337,913441
6	**SO_2**	1,0319085	0,59557953	1,62748803	594,033131
7	**F/h**	0,18249412	0,09647247	0,27896658	101,822803
8	**B/p**	0,000018443	0,000010231	0,000028674	0,010465967

Table 4.4

The combined data on pollution intensity on Rynek

№	Rynek				
1	1	2	3	4	5
1	**Pollutant**	**Weekday**	**Weekend**	**Total**	**Annuals**
2	**CO**	83,5875	40,9725	124,56	45464,4
3	**NO_2**	26,3025	12,7575	39,06	14256,9

Continuation of table 4.4

1	2	3	4	5	6
4	**CH**	17,955	8,5725	26,5275	9682,5375
5	**Soot**	0,330975	0,141975	0,47295	172,62675
6	**SO_2**	0,58455	0,2907	0,87525	319,46625
7	**F/h**	0,09713250	0,04711500	0,1442475	52,650337
8	**B/p**	0,000010193	0,000004995	0,000015188	0,005543438

Table 4.5

The combined data on pollution intensity on Mały Rynek – Staromiejska area

№	Mały Rynek – Staromiejska				
1	1	2	3	4	5
2	**Pollutant**	**Weekday**	**Weekend**	**Total**	**Annuals**
3	**CO**	128,114787	80,192484	208,307271	76032,1539
4	**NO_2**	38,9233185	25,350918	64,2742365	23460,0963
5	**CH**	27,72140625	16,618059	44,3394653	16183,9048
6	**Soot**	0,487403925	0,27558774	0,76299167	278,491958
7	**SO_2**	0,851700165	0,58468758	1,43638775	524,281527
8	**F/h**	0,14545237	0,09308479	0,23853716	87,0660621
9	**B/p**	0,000014992	0,000009975	0,000024967	0,009112778

Table4.6

The combined data on pollution intensity on Edmunda Osmańczyka Street

№	Ul. Edmunda Osmańczyka				
1	1	2	3	4	5
2	**Pollutant**	**Weekday**	**Weekend**	**Total**	**Annuals**
3	**CO**	126,932952	72,060768	198,99372	72632,7078

Continuation of table 4.6.

1	2	3	4	5	6
4	**NO_2**	38,741172	22,865436	61,606608	22486,4119
5	**CH**	27,515106	14,897178	42,412284	15480,4837
6	**Soot**	0,49098084	0,24713148	0,73811232	269,410997
7	**SO_2**	0,84690852	0,52890756	1,37581608	502,172869
8	**F/h**	0,14459562	0,08383993	0,22843555	83,3789765
9	**B/p**	0,000014915	0,000009008	0,000023923	0,008731898

Table 4.7

The combined data on pollution intensity on plac Świetego Sebastiana

№	plac Świetego Sebastiana				
1	1	2	3	4	5
2	**Pollutant**	**Weekday**	**Weekend**	**Total**	**Annuals**
3	**CO**	236,195652	115,972164	352,167816	128541,253
4	**NO_2**	72,939867	36,3710655	109,310933	39898,4904
5	**CH**	50,3114535	24,15468825	74,4661418	27180,1417
6	**Soot**	0,86929689	0,400291815	1,26958871	463,399877
7	**SO_2**	1,62909747	0,833580825	2,4626783	898,877578
8	**F/h**	0,27065115	0,13395378	0,40460493	147,6808
9	**B/p**	0,000028326	0,000014274	0,000042600	0,015548909

Noise pollution was also calculated on selected road sections.

Table 4.8

The intensity of cars for the morning, lunch and evening per day on each of the selected roads

№	Selected road sections	Weekdays (car/hour)			Weekends (car/hour)		
		Morning	Lunch	Evening	Morning	Lunch	Evening
1	1	2	3	4	5	6	7
2	Mały Rynek – Muzealna	103	91	72	70	54	38
3	Rynek	91	83	31	54	32	17
4	Mały Rynek – Staromiejska	115	92	127	89	70	98
5	ul. Edmunda Osmańczyka	93	54	122	65	42	69
6	plac Świetego Sebastiana	216	168	133	102	99	67

Table 4.9

Calculated noise pollution

№	Time	Mały Rynek – Muzealna	Rynek	Mały Rynek – Staromiejska	ul. Edmunda Osmańczyka	plac Świetego Sebastiana
1	1	2	3	4	5	6
2	Working morning	97,69	96,23	98,99	96,48	106,43
3	Working lunch	96,23	95,14	96,36	90,07	103,46
4	Working evening	93,46	83,52	100,16	99,69	100,71
5	Holiday morning	93,13	90,07	95,97	92,26	97,57
6	Holiday lunch	90,07	83,90	93,13	87,10	97,22
7	Holiday evening	85,92	76,43	97,10	92,96	92,62

It should be noted, that noise pollution in the city center exceeds the acceptable level in all cases, especially on the Świetego Sebastiana plac.

The economic efficiency was determined, multiplying the values obtained by the cost per tonne of emissions (Table 4.10) [61; 63].

Table 4.10

Monetary value of air pollution

№	Pollutant	Per year (g/km)	Tax rate, UAH per 1 tonne	EE in UAH	Tax rate, Zł/kg	EE in zloty
1	1	3	4	5	6	7
2	**CO**	412787,89 (412,788 kg)	*92,37	38,1292	0,11	45,40668
3	**CO_2**	107566,86 Ton	*10UAH /ton	1075668,6	0,30 zł/Mg	32270,058
4	**NO_2**	127289,91 (127,29 kg)	*2451,84	312,095	0,54	68,7366
5	**CH**	88024,54 (88,025 kg)	*138,57	12,198	1,47	129,3968
6	**Soot**	1521,843 (1,522 kg)	*92,37	0,1406	0,36	0,54792
7	**SO_2**	2838,8314 (2,839 kg)	*2451,84	6,9604	0,54	1,53306
8	**F/h**	472,59898	*6070,39	2,8689	1,31	1,92963
9	**B/p**	0,04940299	*3121217,74	0,15293967	388,99	0,019217
10			Total	1076041,1440 UAH	Total	32517,63 zł

The economic costs of traffic noise were calculated on the basis of human's health recovery, using the methodology presented in Chapter 2.

The intermediate parameters of losses due to noise pollution are given in Table 4.11. The results of calculations (Table 4.12) prove that noise pollution reduction will bring a considerable financial effect, depending on the level of car traffic reduction.

Table 4.11

Calculations the number of drivers, passengers, pedestrians and residents of adjoining homes which are affected by noise

№	Street	Number of drivers and passengers (N_1, people / km)	Number of pedestrians (N_2,people / km)	Number of residents of adjoining homes (N_3, people / km)
1	1	2	3	4
2	Mały Rynek – Muzealna	2,68	79,175	25,6
3	Rynek	2,64	105,5	74,4
4	Mały Rynek – Staromejska	3,7	56,675	46,4
5	ul. Edmunda Osmańczyka	2,78	318,325	55,2
6	plac Świetego Sebastiana	4,93	48,175	65,6

Table 4.12

Results of annual regulatory loss due to noise

№	Mały Rynek – Muzealna	Rynek	Mały Rynek – Staromiejska	ul. Edmunda Osmańczyka	plac Świetego Sebastiana
1	1	2	3	4	5
2	UAH/hour				
3	97841,9	127748,79	65469,428	284562,01	91260,115
4	Total: 666 882,26				
5	UAH/year				
6	428547584	559539716	286756094	12463816020	399719305
7	Total: 2 920 944 300				

It is also proposed to increase the cost of parking places by 1,5 times. Then, in Zone A, the price will be equal to the price for parking places in Warsaw, and Zone B is equal to the past price of Zone A (table 4.13).

Table 4.13

Price changes for parking places in zones A and B

№	Time	Zone A	Zona A (with change)	Zone B	Zone B (with change)
1	1	2	3	4	5
1	1/2 hour	1.00 zł	1.50 zł	0.50 zł	1.00 zł
2	First hour	2.00 zł	3.00 zł	1.00 zł	2.00 zł

Continuation of table 4.13

1	2	3	4	5	6
3	Second hour	2.40 zł	3.60 zł	1.20 zł	2.40 zł
4	Third hour	2.80 zł	4.20 zł	1.40 zł	2.80 zł
5	Every next hour	2.00 zł	3.00 zł	1.00 zł	2.00 zł

Also, we offer to introduce a minimum parking fee of 0.50 zł, which is equivalent to 15 minutes of parking. Funds for parking places will go to the state budget.

Increased use of public transport - if the residents, normally using cars in the center, switch to public transport, then the estimated amount that will added to the public transport budget will make up: 2023485*3*3 = 18211365 zł/year.

Summing up the area of released territories in the city and taking prices for 1 ha of land in Opole Voivodeship for 2019, the cost of the freed land is calculated: 0,20088 ha*47714 zł/ha = 9584,79 zł.

So, the total environmental and economic efficiency of the project (Table 4.14) is considerable. However, it will be flattened due to necessary expenses on public transport development, organization of bicycle route, project analysis and legal substantiation.

Table 4.14

Environmental and economic efficiency of the project

№	Position	Sum
1	1	2
2	Prevented losses due to noise	876283290 UAH/year
3	Monetary value of air pollution	1076041,1440 UAH/year or 32517,63 zł/year
4	Income to the municipal budget from added public transport	18211365 zł/year

Continuation of table 4.14

5	The cost of the released land	9584,79 zł/year
6	**Total in UAH**	993.973.409,8 UAH/year or 993.105.481,5 UAH/year
7	**Total in zł**	155.172.731,5 zł/year or 155.308.345,3 zł/year

Another important factor of the project success is perception by the residents, which must be evaluated and the recommendations on the information campaign must be developed.

4.4.2. Results of the survey

The survey was based on the list of questions (table) compiled to obtain a general social opinion about the perspectives of car-free area in the center of Opole. The poll was conducted among the population of the city of Opole - 50 people of all ages. According to the level of competence of the respondents - the survey was a mass one (opinion of non-specialists on this or that topic was taken).

To the first two questions, the answer should be yes, and then the survey was conducted further. But when interviewed, 11 people answered “no” to the first question. Other people answered "yes" to the first two questions and were taken through the whole survey. The results are presented on the Fig. 4.5-4.6.

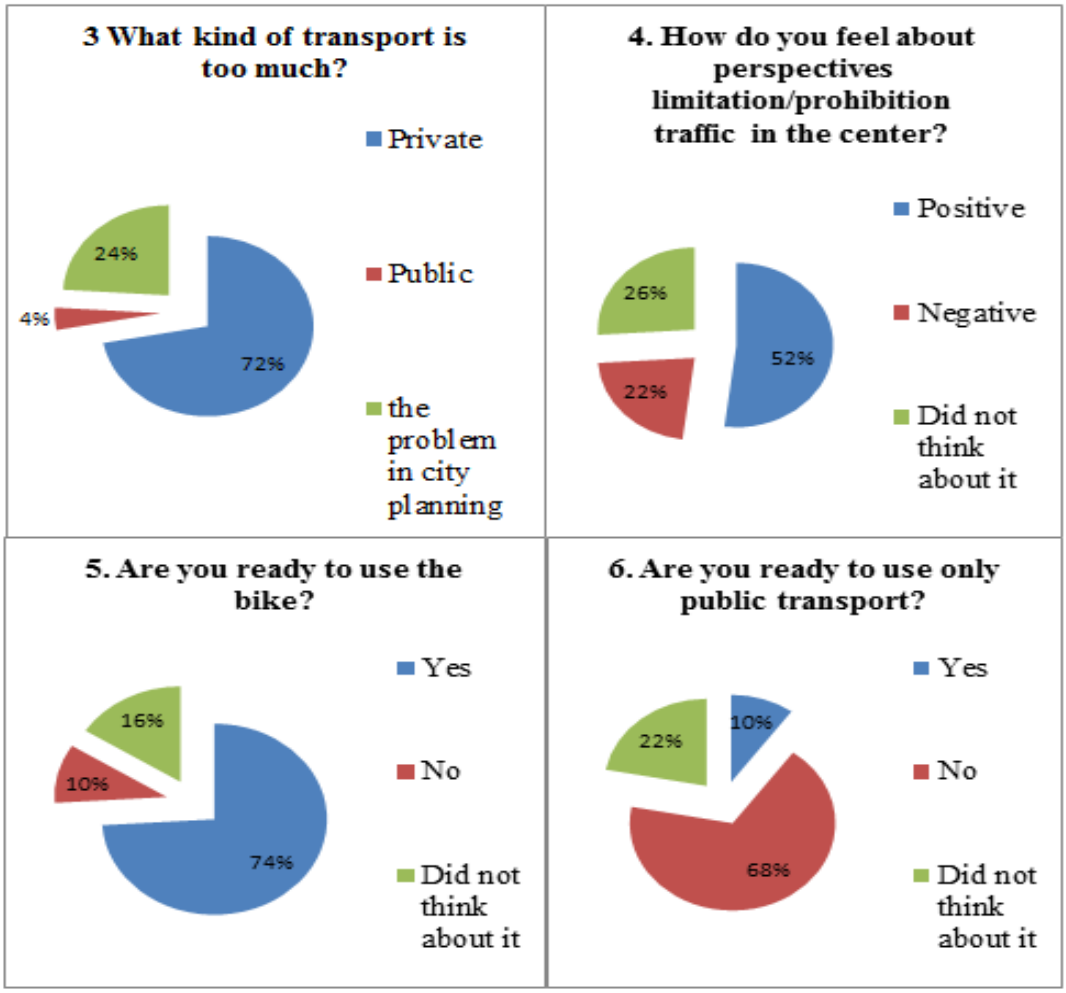

Fig.4.5. Poll results for 3-6 questions

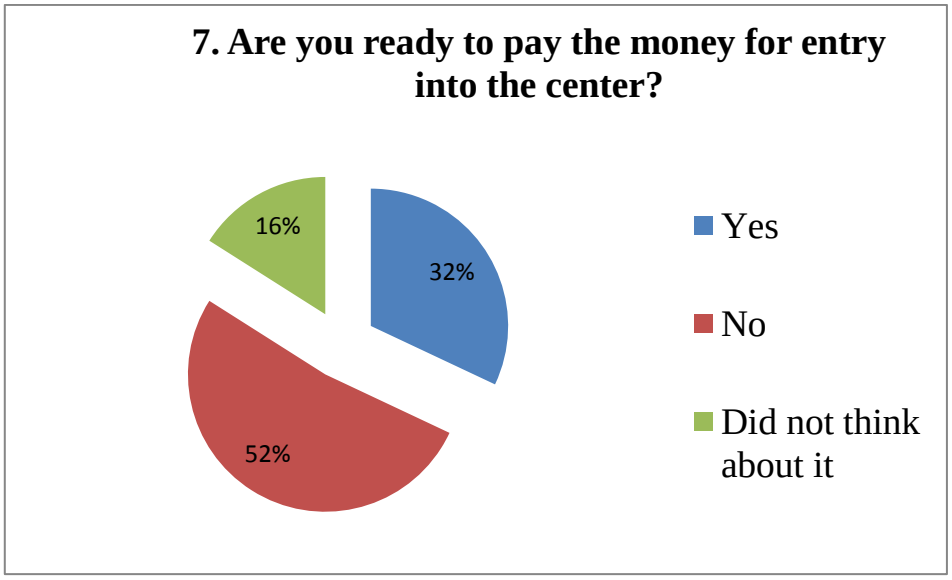

Fig. 4.6. Poll results for 7 question

The results of the survey shown that most of the population understands the environmental situation, created by cars in the city, that is, recognize that the car has an impact on their health. And most people also agree that in the city center the source of environmental problems is private transport.

But at the same time, the people are not yet fully prepared for the changes in the city in order to improve the situation, as about half of those surveyed are not ready to use only public transport, and are not ready to pay extra for entry to the center. And one-third of them is not ready for it or didn't think about cars banning in the center. On the other hand, about 70% are interested in using a bicycle to move around the city.

Therefore, it is offered to remove parking areas on the block parts of the center, instead benches and bike parks should be set up to provide comfortable conditions and space for pedestrians and cyclists.

It is also proposed to reduce parking spaces in zone A and increase payment for parking space in zone B (to be equal to the price of zone A). In doing so, some of the old homes could be converted into multi-story underground and ground parking spaces for cars. It is important to supplement these parking areas with public transport stops and bicycle rental facilities, providing comfortable cycling infrastructure for easy city travel.

It is also important to improve urban transport infrastructure for residents from the surrounding area and encourage people to use urban transport more. The municipality can introduce a bonus system when purchasing a ticket for transport. Bonuses can be used as a discount at a movie theater or at certain coffee shops or cafes.

4.4.3. Recommendations for project support

Important propositions for the support of the project by the city's residents are:

- to carry twice a year the campaign "One day without cars", when the main streets of the city will be blocked to enable using roads for hiking or biking;

- environmental awareness – hold festivals in popular places in the city, where issues about the impact of the car on the environment and human health will be presented – for children, this can be done in the form of games;

- promotion tickets – for drivers who leave the car in special parking places on the outskirts of the city, or those who use public transportation – during purchasing a ticket, can receive bonuses (or discounts) for shopping, cafes, cinemas or theaters;

- improving cycling infrastructure – small things that improve the bicycle using can also be one of the reasons to replace a car on a bicycle. Separate lanes, parking places near shops, and residential buildings, or parks, or special footrests while waiting for the green traffic light. The special bike maintenance spots (pump the wheels, basic tools) are of great value;

- posts on the internet about the impacts of cars and perspectives of the project;

- radio and TV series about the transport problems of the city and ways of their solution;

- publications in local newspapers with discussion of possible alternatives and solutions;

- distribution of information through the advertising spots and billboards;

- competition for the best city improvement proposals related to the urban transportation infrastructure and the environment.

4.5. Conclusions to Chapter 4

So, Opole is a city of south of Poland that occupies the area of 96 km^2 and has 126 000 residents. Transportation infrastructure has both its positives and negative attributes. The positive factors are the authorities' interest in improving conditions, repairing urban roads, installing ticketing machines at bus stops and bicycle rental systems, and buying new electric buses. On the other hand, according to the survey conducted - the city has excessive traffic pressure.

To characterize the intensity of environmental pressure the traffic intensity was calculated and annual emissions of pollutants (CO, CO_2, NO_2, CH, Soot, SO_2, formaldehyde and benz (a) pyrene) and noise levels were established. The economic costs of the given impacts were calculated in terms of Ukrainian and Polish regularities. The results show, that banning traffic on the selected streets will give economic benefits of over 993.973.409,8 UAH/year or 993.105.481,5 UAH/year (155.172.731,5 zł/year or 155.308.345,3 zł/year).

However, the survey among local population shows that even though people understand the deteriorating effects of cars on the environment and health, they are not ready to make their life less comfortable and quit using cars in the center to improve the situation. To improve the situation the recommendations on information campaign for the support of the project were developed.

CHAPTER 5

LABOR PRECAUTION

The purpose of the chapter "Labor precaution" is to analyze the safety conditions of an environmentalist in an office space, identify harmful and dangerous factors in the production environment and the working process and compare them with current standards, as well as develop measures to improve the management system of labor precaution and creation of working conditions that accord the requirements of regulatory acts on labor precaution.

The subject of the thesis will be the ecologist (number by the Ukrainian occupational classifier - 2211.2, by the Polish - 213302).

Selected workplace of the subject for analysis and development of labor precaution measures - office space № 9, workplace №1 (fig. 5.2, 5.3), namely the premises of an environmental firm ZWP Emitor (Olimpijska Street 6, Opole) (fig.5.1).

Fig. 5.1. Office space of an environmental company ZWP Emitor (Olimpijska Street 6, Opole)

5.1. Analysis of working conditions in the workplace

5.1.1. Workplace organization

The size of the office building – 16м(Д) x 10м(Ш) x 7м(В)

Ceiling height – 3,5 м

Number of floors – 2

The total area of the building – 320 $м^2$

Total floor space (on one floor) – 160 $м^2$

Area of the work space – 24 $м^2$

Room equipment – wooden and textile products, paper, computers and office equipment.

The main production process - working with documents.

The workplace is in the building ZWP Emitor (Olimpijska Street 6, Opole city), office space №9, workplace №1 (fig.5.2, 5.3). Number of workplaces - 3 (fig. 5.2). The working space is 24 m^2, workplace - 24/3=8 m^2, and the volume – 24 x 3,5 / 3 = 28 m^3, that accords regulatory values (According to НПАОП 0.00-7.15-18 «Requirements for the safety and health of employees during working with screen devices» from the calculation for one workplace, equipped with a PC, the following standards have been set : area – no less 6,0 m^2; volume – no less 20,0 m^3) [75].

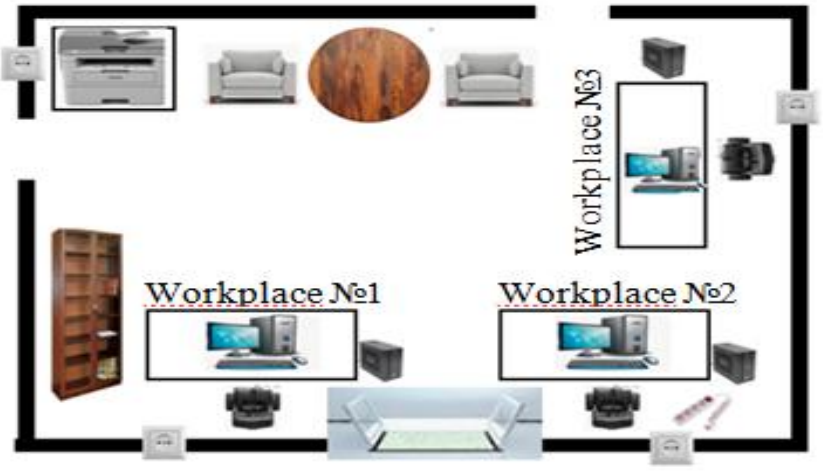

Fig. 5.2. Workplaces in offices

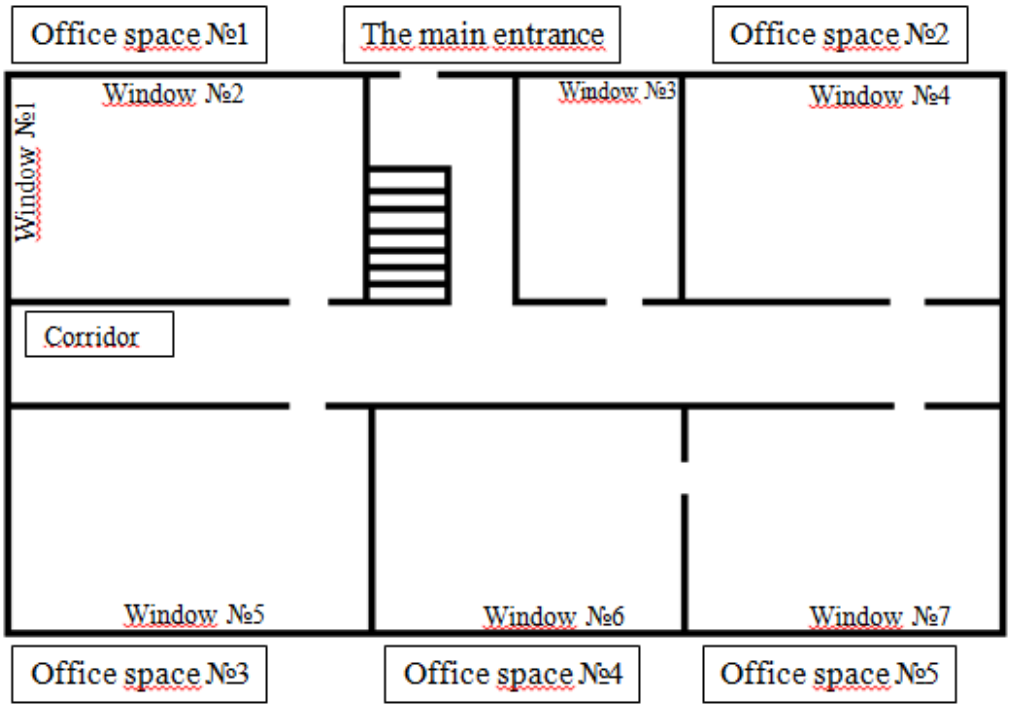

Fig. 5.3. Plan of office building - first floor

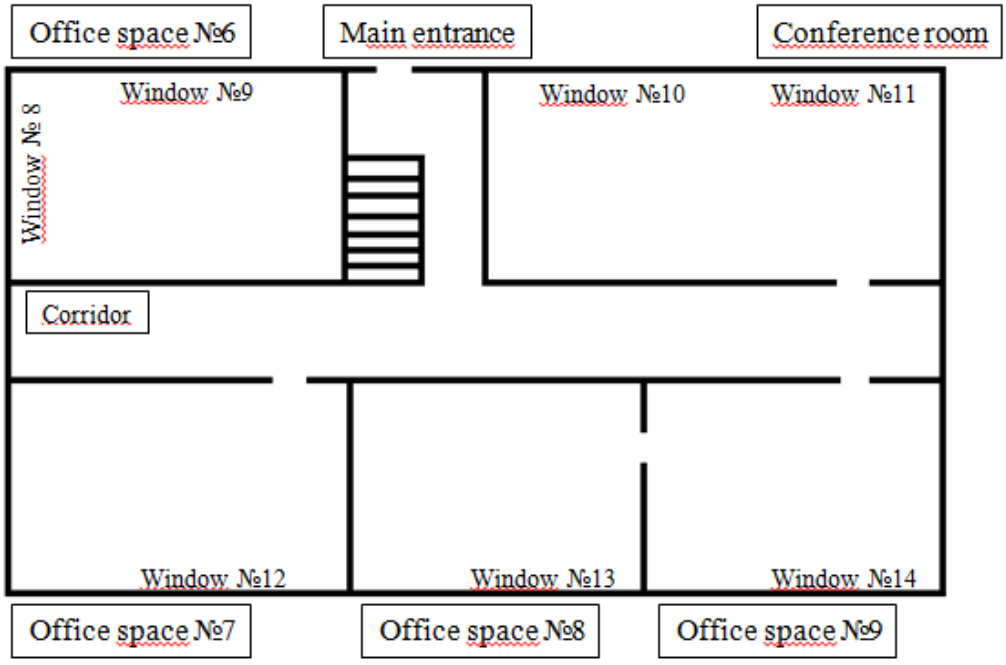

Fig.5.4. Plan of office building - second floor

5.1.2. List of harmful and dangerous production factors

According to State sanitary standards and regulations «Hygienic classification of labor by indicators of harmfulness and danger of factors of industrial environment, gravity and intensity of the labor process», approved by the Ministry of Health of Ukraine since 2014, to the main potentially harmful and dangerous factors, accompanying the professional activities of the office worker, in this case, environmentalist belong:

1) Microclimate of the working area;

2) Natural and artificial lighting;

3) Factors of gravity and intensity of work process;

4) Electromagnetic radiation of different frequency ranges;

5) Production noise and vibration, air ionization, static electricity [76].

5.1.3. Analysis of harmful and dangerous production factors

5.1.3.1. Microclimate of the working area

According to State sanitary rules and regulations «Hygienic classification of labor on indicators of harmfulness and danger of factors of industrial environment, gravity and intensity of the labor process» category of office worker's work by gravity – light -1a.

Offices for work with the PC are equipped with a heating system, and air conditioning. Optimal values of the microclimate parameters are not provided at the workplace: temperature, relative humidity and air mobility in accordance with the rules and regulations, and ДБН В.2.5-67:2013 «Heating, ventilation and air conditioning», approved by order of the Minregion from 25.01.2013 № 24 [3].

According to sanitary standards of the microclimate of industrial offices ДСН 3.3.6.042-99, depending on the time of year, for the category of works is light - 1a in an office space during the cold season:

- the air temperature is 20–22°C, the norm is 22–24°C;

- relative humidity - 40–50%, the norm is 40–60%;

- airspeed - not more 0,1 м/с.

And in the warm season:

- the air temperature is 20-22°C, the norm is 23–25°C;

- relative humidity — 35–50%, the norm is 40–60%;

- airspeed - not more 0,1 м/с [77].

Levels of positive and negative ions in the air meet the hygiene standards № 2152-80 (Annex 17 to State sanitary standards and regulations «Hygienic classification of labor by indicators of harmfulness and danger of factors of industrial environment, gravity and intensity of the labor process»).

Table 5.1

Levels of positive and negative ions in the air

№	Levels	The number of ions in 1 cm cube of air	
1	2	3	
1	Ions	n +	n -
2	The minimum required	400	600
3	Optimal	1500-3000	3000-5000
4	The maximum allowed	50000	50000

5.1.3.2. Natural and artificial lighting

Rooms, which have personal computers installed, should have natural and artificial lighting according to ДБН В.2.5-28:2018 «Natural and artificial lighting», approved by the order of the Minregion or PN-EN 12464-1:2011 Light and lighting - Lighting of work places - Part 1: Indoor work places.

For windows, workplaces are organized so that natural light is predominantly on the left (НПАОП 0.00-7.15-18 «Requirements for the safety and health of employees during working with screen devices»). The workplace is located as follows, to prevent direct light from entering the eyes. To protect and achieve normalized levels of computer radiation are used ways for individual eye protection, have been tested in accredited laboratories and

have an annual hygienic certificate (НПАОП 0.00-7.15-18 «Requirements for the safety and health of employees during working with screen devices»).

Artificial lighting of the room is provided by a system of general even lighting (НПАОП 0.00-7.15-18 «Requirements for the safety and health of employees during working with screen devices»).

According to НПАОП 0.00-7.15-18 «Requirements for the safety and health of employees during working with screen devices» the general lighting system is installed in the form of intermittent lines of lamps, located to the side of the workplaces parallel to the line of sight of workers.

The pulsation ratio does not exceed 5% (НПАОП 0.00-7.15-18 «Requirements for the safety and health of employees during working with screen devices»). The level of illumination on the desktop in the document placement area 280 lux. Local lighting fixtures are installed as follows, to prevent glare on the surface of the screen, and the screen brightness does not exceed 300 lux.

To ensure the normalized values of the ambient light in accordance with НПАОП 0.00-7.15-18 «Requirements for the safety and health of employees during working with screen devices» windows and lamps are washed at least twice a year, and replace the burned-out lamps in a timely manner [75].

5.1.3.3. Factors of gravity and intensity of work process

Among the most dangerous factors of the difficulty and intensity of the labor process is the slow motion of work.

For most of the office hours, office staff are sitting in the workplace, and doing the same job (monotony of labor).

Prolonged work with documents and a computer overloads the visual analyzer. And work with a high degree of responsibility, can lead to nervous and emotional exhaustion. Mind work involves solving many tasks, and therefore threatens mental overload.

5.2. Development of safety measures

5.2.1. Microclimate of the working area

To maintain acceptable microclimate values must be provided settings or humidification and air conditioning devices.

Ukraine has no legislatively approved maximum permissible standards for the carbon dioxide content of air for residential, office and public buildings. But, given its impact on employees, namely, a significant reduction in their performance, employers should pay attention to this issue and take preventive measures.

5.2.2. Factors of gravity and intensity of work process

When organizing work, related to the use of personal computers, to keep employees healthy, prevention of occupational disease and support for performance intermittent regulated rest breaks should be provided. Intra-shift modes of work and rest should provide for additional non-continuous breaks in periods, that precede the appearance of objective and subjective signs of fatigue and reduced performance. Main work with a personal computer should be considered to take at least 50% of the time during a work shift. They should be scheduled throughout the day:

- breaks for rest and eating (lunch breaks);
- breaks for rest and personal needs (according to labor standards);
- additional breaks, introduced for particular professions, taking into account the peculiarities of the work activity.
- for computer set operators should be assigned a regulated rest period of 10 minutes after each hour of work on a personal computer.

In order to reduce the negative impact of monotony, it is advisable to use alternating operations of conscious text and numerical data (change of content of work), alternating data entry and text editing. To reduce nervous and emotional stress, fatigue of the visual analyzer, improvement of cerebral circulation, overcoming the adverse effects of

hypodynamia, preventing fatigue, it is advisable to use some breaks to perform a series of exercises. In some cases — for chronic complaints of working on visual fatigue, despite the observance of sanitary and hygienic requirements to the modes of work and rest, as well as the application of local eye protection — individual approaches to limiting the hours of work with a personal computer are allowed, changes in the nature of work, alternation with other activities, not connected to a personal computer. Active rest should be performed in a complex of gymnastic exercises, aimed at relieving nervous tension, muscle relaxation, restoration of functions of physiological systems, violated during the labor process, relieve eye fatigue, improvement of cerebral circulation and performance. High intensity of work with a personal computer shows psychological unloading in specially equipped premises (in rooms of psychological unloading) during regular breaks or at the end of the business day.

5.3. Fire safety of office space

The office space houses wood and textiles, paper, extension cords, uninterruptible power systems, computers and office equipment.

The fire can be a result of:

- poor condition of electrical appliances and violation of the rules of their installation and operation;
- violation of the rules for use of electrical appliances;
- power congestion;
- careless handling of fire.

Class of possible fire – A (According to the international standard ISO 3941:2007 «Classification of fires») [78].

Category of office building by fire and fire hazard – B (According to ДСТУ Б В.1.1-36:2016 «Designation of categories of premises, houses, installations for explosion fire and fire danger» premises for explosive and fire hazard are divided into five categories A, B, C, D, E.

In case of fire protection a room with a PC, telephone stations, etc. Carbon dioxide extinguishers should be used or aerosol fire extinguishers. Such premises should be equipped with portable carbon dioxide extinguishers at the rate of one Carbon dioxide extinguisher (ВВК-1,4 or ВВК-2) or one ВВПА-400 (water aerosol fire extinguisher with a mass of charge of extinguishing agent 400 g) on three PCs, but not less than one fire extinguisher of the specified types per room [79].

Regarding fire alarm systems, then the fire sensors are divided into four main types (ДБН В.2.5-56:2014 Fire protection systems):

- thermal sensors;
- smoke sensors;
- flame sensors;
- combined sensors.

In most cases, the combined sensors combine the smoke sensor with the thermal sensor. This allows you to more accurately determine the presence of fire signs, to send an alarm to the remote control.

The following nuances must be considered for the sensor to perform its function:

- Detector sensors should be mounted on the ceiling of the room. If the ceiling design makes it difficult to install the sensors, it is permissible to install them on the walls, columns or tension cables, but no more than 30 cm from the stream.
- One loop (wiring diagram, transmits the signal of the detectors to the control device) no more than 5 appliances for industrial premises may be combined and no more than 10 for administrative premises and apartments. When using the address scheme of the connection, the number of devices in one loop can be increased to 20.
- If there are objects in the premises (office, apartment) - shelving, wardrobes, screens, the upper edge of which is less than 60 cm from the ceiling, obligatory placement of the detector in each of the zones formed by these objects.
- Area controlled by a single address or addressless detector, must match the values in the table, but should not exceed values, attributed to a specific model passport [80].

Requirements for evacuation routes in case of fire - НАПБ А.01.001-2014 Fire safety rules in Ukraine:

Evacuation means the routes, leading to evacuation exits outside the premises. Depending on the location of workers in the company, evacuation routes are laid in such a way that all employees can leave the dangerous place, taking advantage of the escape routes closest to them. The most common paths are passages, corridors, stairs, vestibules, foyer, halls, lobbies.

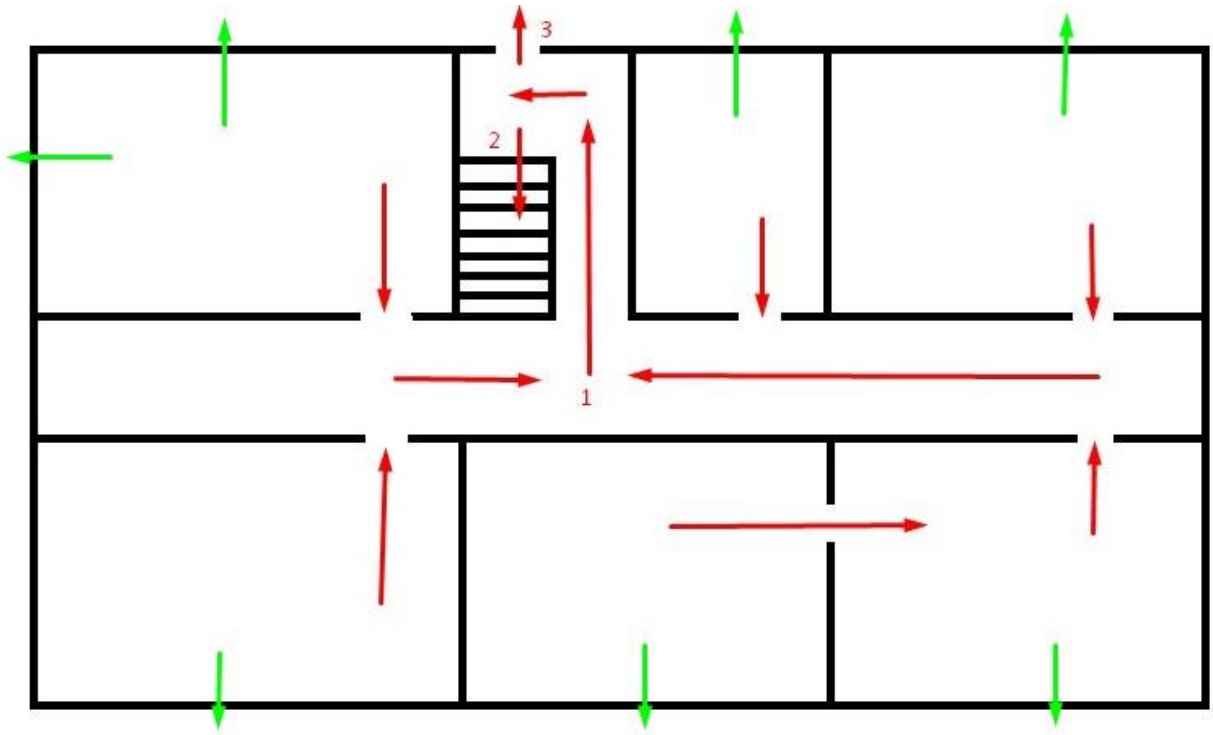

Fig. 5.5. Sketch of the evacuation plan

Legend:

- the main escape route;

- emergency evacuation route (subject to availability on the 1st floor of the building).

In case you are on the 2nd floor, get staircase 1 and use exit 3 or spare evacuation routes from the premises [81].

5.4. Typical calculation or labor protection issues before detailed elaboration (reasoning)

5.4.1. Checking calculation of artificial lighting of office space

For lighting office space with dimensions A = 6 m, B =4 m and height H = 3,5 m 4 ODR lamps are used with two fluorescent lamps type LB-40. The reflection coefficients of light from the ceiling, walls and floor are respectively equal $\rho_{ст}$ = 70%, $\rho_{с}$ = 50%, $\rho_{п}$ = 10%. There is no shading of jobs. The height of the slope of the lamp $h_{с}$ = 0, height of work surface above floor level $h_{Р}$ = 0,85 m. It is necessary to determine the actual illumination of the room under general uniform illumination and to compare with the standard value.

Normative value of illumination for office space $E_{н}$ = 500 lux (premises for work with displays, video terminals) - PN-EN 12464-1:2011 Light and lighting – Workplace lighting. Part 1: Indoor work places or ДБН В.2.5-28:2018 «Natural and artificial lighting».

When checking that the ambient light is at the regulatory level, when the number of lamps, illuminators, their type and power, the actual illumination in the room is determined by the formula:

$$E_{\phi} = \frac{N \cdot F \cdot n \cdot \eta}{S \cdot z \cdot k_{з}}, \text{ lux}, \quad (5.1)$$

where N = 2 - number of lamps, pcs; F = 3120 lm - light flux lamp; n = 2 - number of lamps in the illuminator; S = 24 - the area of the illuminated room; z = l,1 - coefficient of irregularity of illumination for fluorescent lamps (ratio $E_{сер}$ /$E_{мін}$); $k_{з}$ - reserve coefficient, which takes into account the decrease in illumination due to pollution and aging of the lamp, value $k_{з}$ = 1,5; η - the using coefficient of the lighting installation.

To determine η you need to know the type of lamp, the index of the room and the reflection coefficient of light flux from the ceiling walls and floor. Since the type of lamp and the reflection coefficients of light are known, then for finding η it is necessary to determine the value of the room index i.

The room index i is determined by the equation:

$$i = \frac{A \cdot B}{h_{\text{П}} \cdot (A+B)}, \quad (5.2)$$

where A and B - respectively the length and width of the room in m, $h_п$ - height from the work surface to the lamp, is determined by the height of the room (H, m) and the height of the conditional work surface ($h_р$ = 0,85 m) by the formula: $h_п = H - h_c - h_р = 3{,}5 - 0 - 0{,}85 = 2{,}65\ m$

Substitute the value obtained $h_п$ and find the room index: $i = \frac{6 \cdot 4}{2{,}65 \cdot (6+4)} = 0{,}90$.

By application we determine that the lamp has a curve of light power Г1 and the utilization ratio of the lighting installation, which is equal 89%. We substitute all found values for $E_Ф$: $E_ф = \frac{2 \cdot 3120 \cdot 2 \cdot 0{,}89}{24 \cdot 1{,}1 \cdot 1{,}5} = 280{,}5$ lux

Since the obtained value $E_Ф < E_н$, to achieve regulatory illumination, it is necessary to increase or increase the number of lamps, or increase the power of the lamps. We calculate the degree of increase W: $W = \frac{E_н}{E_ф} = \frac{500{,}0}{280{,}5} = 1{,}78$

Now you can calculate the required number of illuminators: $N_1 = N \cdot W = 2 * 1{,}78 = 3{,}56 \approx 4$

We will increase the number of lamps to 4 pcs. Then $E_ф = \frac{4 \cdot 3120 \cdot 2 \cdot 0{,}89}{24 \cdot 1{,}1 \cdot 1{,}5} = 561{,}0$ lux

Thus, by increasing the number of lamps by 2, the actual illumination of the $E_Ф$ corresponds to the normative value of illumination $E_н$ = 500 lux. The same effect can be obtained when replacing a lamp with a high luminous flux. Calculate the required light flux of the lamp: $F_1 = F \cdot W = 3120 \cdot 1{,}78 = 5553{,}6$ lm

So, if all LB-40 type lamps in office space are replaced by LB-80 type lamps with F = 5600 lm, then the $E_Ф$ will be equal to: $E_ф = \frac{2 \cdot 5600 \cdot 2 \cdot 0{,}89}{24 \cdot 1{,}1 \cdot 1{,}5} = 503{,}4$ lux

In this case, the actual illumination will also correspond to the normative value [82; 83].

5.5. Conclusion to Chapter 5

According to the Constitution of Ukraine establishes the right of everyone to adequate, safe and healthy working conditions. It is crucial that business owners (managers) of all levels understand this and do not approach this issue on a residual basis.

Selected workplace of the subject for analysis and development of labor precaution measures - office space № 9, workplace №1, namely the premises of an environmental firm ZWP Emitor (Olimpijska 6 Street, Opole city). The basic tasks of labor protection of selected workplace that must be followed by the standards are considered.

Microclimatic conditions are one of the leading factors in workplaces in modern office space. Despite the presence of air conditioning systems, in the cold period of the year, the air temperature of the office premises exceeded the permissible average by 1 °C with insufficient air humidity (20–39 %), in the warm period - average air temperatures exceeded permissible by 1,5–8 °C. If the cause of poor well-being in the workplace, and as a consequence, poor performance is a violation of the indoor climate, you should ask your employer to remedy the situation. For the fire safety of office space it is important to have fire extinguishers and fire protection systems. Also, in order to preserve the health of workers, prevent occupational disease and maintain working capacity, regular rest breaks should be provided.

CONCLUSIONS

1. A car has become an integral part of our lives by this time. On the one side automobiles improve living conditions, but on the other hand it has led to severe environmental pollution affecting human health, contributing to climate change and degrading living conditions in cities. Thus, big cities suffer from smog, greenhouse gases, and the urban heat island effect mostly due to traffic.

2. There is a wide range of methods to be applied for the assessment of cars impacts on the environment. For the purposes of the given research the methods of traffic intensity and related emissions and noise pollution levels and approaches to the assessment of environmental and economic efficiency were considered.

3. The phenomena "car-free city" was analyzed as a new solution to the problem of cars in cities and the examples of "car-free cities" in different countries are given. Based on the considered examples of cities with limitations of traffic, the project of the car-free city for Opole was proposed. It involves blocking 6 main city center roads for private car entry, removing car parking spaces in the center, development of cycling network and creation of underground parking instead of old buildings. The released roads are to be converted into bike lanes, bicycle parking, and areas for landscaping and recreation.

4. To characterize the intensity of environmental pressure the traffic on the environment of Opole the annual emissions of pollutants and noise levels were established. The results of economic costs of the given impacts, that were calculated in terms of Ukrainian and Polish regularities show, that banning traffic on the selected streets will give economic benefits of over 993.973.409,8 UAH/year or 993.105.481,5 UAH/year.

5. To evaluate the urgency of the problem and social acceptance of the proposed project the interviewing of Opole residents was conducted based on the specially developed list of questions. According to the survey results, even if people understand the deteriorating effects of cars on the environment and health, they are not ready to change their life style to improve the situation. To improve the situation the recommendations on the information campaign for the support of the project were developed.

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ANNEXES

Annex A

Table A.1

Mały Rynek – Muzealna

№	Data	Cars	Cars to 3,5 t	Cars from 3,5 t 12 t
1	2	3	4	5
1	Weekdays	972	90	2
2	Weekends	624	25	0
3	Length of road segment	97,58		

$\mathbf{M_{(CO\ w\text{-}day)}}$ = ((0,09758)*((1,5*972*0,75)+(8,4*90*0,75)+(6,8*2*0,75))) = 163,026906

$\mathbf{M_{(CO\ w\text{-}end)}}$ = ((0,09758)*((1,5*624*0,75)+(8,4*25*0,75))) = 83,87001

$\mathbf{M_{(NO2\ w\text{-}day)}}$ = ((0,09758)*((0,5*972*0,75)+(1,8*90*0,75)+(6,4*2*0,75)))= 48,360648

$\mathbf{M_{(NO2\ w\text{-}end)}}$ = ((0,09758)*((0,5*624*0,75)+(1,8*25*0,75))) = 26,127045

$\mathbf{M_{(CH\ w\text{-}day)}}$ = ((0,09758)*((0,3*972*0,75)+(2,1*90*0,75)+(4,8*2*0,75))) = 35,875287

$\mathbf{M_{(CH\ w\text{-}end)}}$ = ((0,09758)*((0,3*624*0,75)+(2,1*25*0,75))) = 17,5424445

$\mathbf{M_{(Soot\ w\text{-}day)}}$ = ((0,09758)*(((0,5*(10^(-2)))*972*0,75)+(((3,4*(10^(-2)))*90*0,75)+(0,38*2*0,75)))) = 0,6352458

$\mathbf{M_{(Soot\ w\text{-}end)}}$ = ((0,09758)*(((0,5*(10^(-2)))*624*0,75)+(((3,4*(10^(-2)))*25*0,75)))) = 0,29054445

$\mathbf{M_{(SO2\ w\text{-}day)}}$ = ((0,09758)*(((1,2*(10^(-2)))*972*0,75)+(((2,6*(10^(-2)))*90*0,75)+(4,8*(10^(-2)))*2*0,75))) = 1,0319085

$\mathbf{M_{(SO2\ w\text{-}end)}}$ = ((0,09758)*(((1,2*(10^(-2)))*624*0,75)+(((2,6*(10^(-2)))*25*0,75)))) = 0,59557953

$\mathbf{M_{(f/d\ w\text{-}day)}}$ = ((0,09758)*(((1,8*(10^(-3)))*972*0,75)+(((7,8*(10^(-3)))*90*0,75)+(2,1*(10^(-2)))*2*0,75))) = 0,18249412

$\mathbf{M_{(f/h\ w\text{-}end)}}$ = ((0,09758)*(((1,8*(10^(-3)))*624*0,75)+(((7,8*(10^(-3))) *25*0,75)))) = 0,09647247

$\mathbf{M_{(b/p\ w\text{-}day)}}$ = ((0,09758)*(((0,2*(10^(-6)))*972*0,75)+(((0,6*(10^(-6)))*90*0,75)+(1,8*(10^(-6)))*2*0,75))) = 0,000018443

$\mathbf{M_{(b/p\ w\text{-}end)}}$ = ((0,09758)*(((0,2*(10^(-6)))*624*0,75)+(((0,6*(10^(-6))) *25*0,75)))) = 0,000010231

Table A.2

Rynek

№	Data	Cars	Cars to 3,5 t	Cars from 3,5 to 12 t
1	**1**	**2**	**3**	**4**
2	Weekdays	780	36	2
3	Weekends	396	16	0
4	Length of road segment	75		

$\mathbf{M_{(CO\ w\text{-}day)}}$ = ((0,075)*((1,5*780*0,75)+(8,4*36*0,75)+(6,8*2*0,75))) = 83,5875

$\mathbf{M_{(CO\ w\text{-}end)}}$ = ((0,075)*((1,5*396*0,75)+(8,4*16*0,75))) = 40,9725

$\mathbf{M_{(NO2\ w\text{-}day)}}$ = ((0,075)*((0,5*780*0,75)+(1,8*36*0,75)+(6,4*2*0,75))) = 26,3025

$\mathbf{M_{(NO2\ w\text{-}end)}}$ = ((0,075)*((0,5*396*0,75)+(1,8*16*0,75))) = 12,7575

$\mathbf{M_{(CH\ w\text{-}day)}}$ = ((0,075)*((0,3*780*0,75)+(2,1*36*0,75)+(4,8*2*0,75))) = 17,955

$\mathbf{M_{(CH\ w\text{-}end)}}$ = ((0,075)*((0,3*396*0,75)+(2,1*16*0,75))) = 8,5725

$\mathbf{M_{(Soot\ w\text{-}day)}}$ = ((0,075)*(((0,5*(10^(-2)))*780*0,75)+(((3,4*(10^(-2)))*36*0,75)+(0,38*2*0,75)))) = 0,330975

$\mathbf{M_{(Soot\ w\text{-}end)}}$ = ((0,075)*(((0,5*(10^(-2)))*396*0,75)+(((3,4*(10^(-2)))*16*0,75)))) = 0,141975

$\mathbf{M_{(SO2\ w\text{-}day)}}$ = ((0,075)*(((1,2*(10^(-2)))*780*0,75)+(((2,6*(10^(-2)))*36*0,75)+(4,8*(10^(-2)))*2*0,75))) = 0,58455

$\mathbf{M_{(SO2\ w\text{-}end)}}$ = ((0,075)*(((1,2*(10^(-2)))*396*0,75)+(((2,6*(10^(-2)))*16*0,75)))) = 0,2907

$\mathbf{M_{(f/d\ w\text{-}day)}}$ = ((0,075)*(((1,8*(10^(-3)))*780*0,75)+(((7,8*(10^(-3)))*36*0,75)+(2,1*(10^(-2)))*2*0,75))) = 0,09713250

$\mathbf{M_{(f/h\ w\text{-}end)}}$ = ((0,075)*(((1,8*(10^(-3)))*396*0,75)+(((7,8*(10^(-3)))*16*0,75)))) = 0,04711500

$\mathbf{M_{(b/p\ w\text{-}day)}}$ = ((0,075)*(((0,2*(10^(-6)))*780*0,75)+(((0,6*(10^(-6)))*36*0,75)+(1,8*(10^(-6)))*2*0,75))) = 0,000010193

$\mathbf{M_{(b/p\ w\text{-}end)}}$ = ((0,075)*(((0,2*(10^(-6)))*396*0,75)+(((0,6*(10^(-6)))*16*0,75)))) = 0,000004995

Table A.3

Mały Rynek – Staromiejska

№	Data	Cars	Cars to 3,5 t	Cars from 3,5 to 12 t
1	**1**	**2**	**3**	**4**
2	Weekdays	1248	85	2
3	Weekends	928	28	0
4	Length of road segment	65,71		

$\mathbf{M_{(CO\ w\text{-}day)}}$ = ((0,06571)*((1,5*1248*0,75)+(8,4*85*0,75)+(6,8*2*0,75))) = 128,114787

$\mathbf{M_{(CO\ w\text{-}end)}}$ = ((0,06571)*((1,5*928*0,75)+(8,4*28*0,75))) = 80,192484

$\mathbf{M_{(NO2\ w\text{-}day)}}$ = ((0,06571)*((0,5*1248*0,75)+(1,8*85*0,75)+(6,4*2*0,75))) = 38,9233185

$\mathbf{M_{(NO2\ w\text{-}end)}}$ = ((0,06571)*((0,5*928*0,75)+(1,8*28*0,75))) = 25,350918

$\mathbf{M_{(CH\ w\text{-}day)}}$ = ((0,06571)*((0,3*1248*0,75)+(2,1*85*0,75)+(4,8*2*0,75))) = 27,72140625

$\mathbf{M_{(CH\ w\text{-}end)}}$ = ((0,06571)*((0,3*928*0,75)+(2,1*28*0,75))) = 16,618059

$\mathbf{M_{(Soot\ w\text{-}day)}}$ = ((0,06571)*(((0,5*(10^(-2)))*1248*0,75)+(((3,4*(10^(-2)))*85*0,75)+(0,38*2*0,75)))) = 0,487403925

$\mathbf{M_{(Soot\ w\text{-}end)}}$ = ((0,06571)*(((0,5*(10^(-2)))*928*0,75)+(((3,4*(10^(-2)))*28*0,75)))) = 0,27558774

$\mathbf{M_{(SO2\ w\text{-}day)}}$ = ((0,06571)*(((1,2*(10^(-2)))*1248*0,75)+(((2,6*(10^(-2)))*85*0,75)+(4,8*(10^(-2)))*2*0,75))) = 0,851700165

$\mathbf{M_{(SO2\ w\text{-}end)}}$ = ((0,06571)*(((1,2*(10^(-2)))*928*0,75)+(((2,6*(10^(-2)))*28*0,75)))) = 0,58468758

$\mathbf{M_{(f/d\ w\text{-}day)}}$ = ((0,06571)*(((1,8*(10^(-3)))*1248*0,75)+(((7,8*(10^(-3)))*85*0,75)+(2,1*(10^(-2)))*2*0,75))) = 0,14545237

$\mathbf{M_{(f/h\ w\text{-}end)}}$ = ((0,06571)*(((1,8*(10^(-3)))*928*0,75)+(((7,8*(10^(-3)))*28*0,75)))) = 0,09308479

$\mathbf{M_{(b/p\ w\text{-}day)}}$ = ((0,06571)*(((0,2*(10^(-6)))*1248*0,75)+(((0,6*(10^(-6)))*85*0,75)+(1,8*(10^(-6)))*2*0,75))) = 0,000014992

$\mathbf{M_{(b/p\ w\text{-}end)}}$ = ((0,06571)*(((0,2*(10^(-6)))*928*0,75)+(((0,6*(10^(-6)))*28*0,75)))) = 0,000009975

Table A. 4

ul. Edmunda Osmańczyka

№	Data	Cars	Cars to 3,5 t	Cars from 3,5 to 12 t
1	**1**	**2**	**3**	**4**
2	Weekdays	1008	67	2
3	Weekends	684	19	0
4	Length of road segment	81,04		

$\mathbf{M_{(CO\ w\text{-}day)}}$ = ((0,08104)*((1,5*1008*0,75)+(8,4*67*0,75)+(6,8*2*0,75))) = 126,932952

$\mathbf{M_{(CO\ w\text{-}end)}}$ = ((0,08104)*((1,5*684*0,75)+(8,4*19*0,75))) = 72,060768

$\mathbf{M_{(NO2\ w\text{-}day)}}$ = ((0,08104)*((0,5*1008*0,75)+(1,8*67*0,75)+(6,4*2*0,75))) = 38,741172

$\mathbf{M_{(NO2\ w\text{-}end)}}$ = ((0,08104)*((0,5*684*0,75)+(1,8*19*0,75))) = 22,865436

$\mathbf{M_{(CH\ w\text{-}day)}}$ = ((0,08104)*((0,3*1008*0,75)+(2,1*67*0,75)+(4,8*2*0,75))) = 27,515106

$\mathbf{M_{(CH\ w\text{-}end)}}$ = ((0,08104)*((0,3*684*0,75)+(2,1*19*0,75))) = 14,897178

$\mathbf{M_{(Soot\ w\text{-}day)}}$ = ((0,08104)*(((0,5*(10^(-2)))*1008*0,75)+(((3,4*(10^(-2)))*67*0,75)+(0,38*2*0,75)))) = 0,49098084

$\mathbf{M_{(Soot\ w\text{-}end)}}$ = ((0,08104)*(((0,5*(10^(-2)))*684*0,75)+(((3,4*(10^(-2)))*19*0,75)))) = 0,24713148

$\mathbf{M_{(SO2\ w\text{-}day)}}$ = ((0,08104)*(((1,2*(10^(-2)))*1008*0,75)+(((2,6*(10^(-2)))*67*0,75)+(4,8*(10^(-2)))*2*0,75))) = 0,84690852

$\mathbf{M_{(SO2\ w\text{-}end)}}$ = ((0,08104)*(((1,2*(10^(-2)))*684*0,75)+(((2,6*(10^(-2)))*19*0,75)))) = 0,52890756

$\mathbf{M_{(f/d\ w\text{-}day)}}$ = ((0,08104)*(((1,8*(10^(-3)))*1008*0,75)+(((7,8*(10^(-3)))*67*0,75)+(2,1*(10^(-2)))*2*0,75))) = 0,14459562

$\mathbf{M_{(f/h\ w\text{-}end)}}$ = ((0,08104)*(((1,8*(10^(-3)))*684*0,75)+(((7,8*(10^(-3)))*19*0,75)))) = 0,08383993

$\mathbf{M_{(b/p\ w\text{-}day)}}$ = ((0,08104)*(((0,2*(10^(-6)))*1008*0,75)+(((0,6*(10^(-6)))*67*0,75)+(1,8*(10^(-6)))*2*0,75))) = 0,000014915

$\mathbf{M_{(b/p\ w\text{-}end)}}$ = ((0,08104)*(((0,2*(10^(-6)))*684*0,75)+(((0,6*(10^(-6)))*19*0,75)))) = 0,000009008

Table A.5

plac Świetego Sebastiana

№	Data	Cars	Cars to 3,5 t	Cars from 3,5 to 12 t
1	**1**	**2**	**3**	**4**
2	Weekdays	1968	102	2
3	Weekends	1044	37	0
4	Length of road segment	82,39		

$\mathbf{M_{(CO\ w\text{-}day)}}$ = ((0,08239)*((1,5*1968*0,75)+(8,4*102*0,75)+(6,8*2*0,75))) = 236,195652

$\mathbf{M_{(CO\ w\text{-}end)}}$ = ((0,08239)*((1,5*1044*0,75)+(8,4*37*0,75))) = 115,972164

$\mathbf{M_{(NO2\ w\text{-}day)}}$ = ((0,08239)*((0,5*1968*0,75)+(1,8*102*0,75)+(6,4*2*0,75))) = 72,939867

$\mathbf{M_{(NO2\ w\text{-}end)}}$ = ((0,08239)*((0,5*1044*0,75)+(1,8*37*0,75))) = 36,3710655

$\mathbf{M_{(CH\ w\text{-}day)}}$ = ((0,08239)*((0,3*1968*0,75)+(2,1*102*0,75)+(4,8*2*0,75))) = 50,3114535

$\mathbf{M_{(CH\ w\text{-}end)}}$ = ((0,08239)*((0,3*1044*0,75)+(2,1*37*0,75))) = 24,15468825

$\mathbf{M_{(Soot\ w\text{-}day)}}$ = ((0,08239)*(((0,5*(10^(-2)))*1968*0,75)+(((3,4*(10^(-2)))*102*0,75)+(0,38*2*0,75)))) = 0,86929689

$\mathbf{M_{(Soot\ w\text{-}end)}}$ = ((0,08239)*(((0,5*(10^(-2)))*1044*0,75)+(((3,4*(10^(-2)))*37*0,75)))) = 0,400291815

$\mathbf{M_{(SO2\ w\text{-}day)}}$ = ((0,08239)*(((1,2*(10^(-2)))*1968*0,75)+(((2,6*(10^(-2)))*102*0,75)+(4,8*(10^(-2)))*2*0,75))) = 1,62909747

$\mathbf{M_{(SO2\ w\text{-}end)}}$ = ((0,08239)*(((1,2*(10^(-2)))*1044*0,75)+(((2,6*(10^(-2)))*37*0,75)))) = 0,833580825

$\mathbf{M_{(f/d\ w\text{-}day)}}$ = ((0,08239)*(((1,8*(10^(-3)))*1968*0,75)+(((7,8*(10^(-3)))*102*0,75)+(2,1*(10^(-2)))*2*0,75))) = 0,27065115

$\mathbf{M_{(f/h\ w\text{-}end)}}$ = ((0,08239)*(((1,8*(10^(-3)))*1044*0,75)+(((7,8*(10^(-3)))*37*0,75)))) = 0,13395378

$\mathbf{M_{(b/p\ w\text{-}day)}}$ = ((0,08239)*(((0,2*(10^(-6)))*1968*0,75)+(((0,6*(10^(-6)))*102*0,75)+(1,8*(10^(-6)))*2*0,75))) = 0,000028326

$\mathbf{M_{(b/p\ w\text{-}end)}}$ = ((0,08239)*(((0,2*(10^(-6)))*1044*0,75)+(((0,6*(10^(-6)))*37*0,75)))) = 0,000014274

Annex B

Calculation of noise pollution:

Y1wm = 46+11,8*LN(103)-3 = 97,69 dB

Y1wl = 46+11,8*LN(91)-3 = 96,23 dB

Y1we = 46+11,8*LN(72)-3 = 93,46 dB

Y1hm = 46+11,8*LN(70)-3 = 93,13 dB

Y1hl = 46+11,8*LN(54)-3 = 90,07 dB

Y1he = 46+11,8*LN(38)-3 = 85,92 dB

Y2wm = 46+11,8*LN(91)-3 = 96,23 dB

Y2wl = 46+11,8*LN(83)-3 = 95,14 dB

Y2we = 46+11,8*LN(31)-3 = 83,52 dB

Y2hm = 46+11,8*LN(54)-3 = 90,07 dB

Y2hl = 46+11,8*LN(32)-3 = 83,90 dB

Y2he = 46+11,8*LN(17)-3= 76,43 dB

Y3wm = 46+11,8*LN(115)-3 = 98,99 dB

Y3wl = 46+11,8*LN(92)-3 = 96,36 dB

Y3we = 46+11,8*LN(127)-3 = 100,16 dB

Y3hm = 46+11,8*LN(89)-3 = 95,97 dB

Y3hl = 46+11,8*LN(70)-3 = 93,13 dB

Y3he = 46+11,8*LN(98)-3 = 97,10 dB

Y4wm = 46+11,8*LN(93)-3 = 96,48 dB

Y4wl = 46+11,8*LN(54)-3 = 90,07 dB

Y4we = 46+11,8*LN(122)-3 = 99,69 dB

Y4hm = 46+11,8*LN(65)-3 = 92,26 dB

Y4hl = 46+11,8*LN(42)-3 = 87,10 dB

Y4he = 46+11,8*LN(69)-3 = 92,96 dB

Y5wm = 46+11,8*LN(216)-3 = 106,43 dB

Y5wl = 46+11,8*LN(168)-3 = 103,46 dB

Y5we = 46+11,8*LN(133)-3 = 100,71 dB

Y5hm = 46+11,8*LN(102)-3 = 97,57 dB

Y5hl = 46+11,8*LN(99)-3 = 97,22 dB

Y5he = 46+11,8*LN(67)-3 = 92,62 dB

Annex C

Number of drivers and passengers (N_1) affected by noise:

Mały Rynek – Muzealna:

$N_{1\ \text{weekday intensity morning}}$ = (40*0+1,5)*103(cars/hour)/(40km/hour) = 3,8625

$N_{1\ \text{weekday intensity lunch}}$ = (40*0+1,5)* 91/40 = 3,41

$N_{1\ \text{weekday intensity evening}}$ = (40*0+1,5)* 72/40 = 2,7

$N_{1\ \text{weekend intensity morning}}$ = (40*0+1,5)* 70/40 = 2,63

$N_{1\ \text{weekend intensity lunch}}$ = (40*0+1,5)* 54/40 = 2,025

$N_{1\ \text{weekend intensity evening}}$ = (40*0+1,5)* 38/40 =1,425

Rynek:

$N_{1\ \text{weekday intensity morning}}$ = (40*0+1,5)*91(cars/hour)/(40km/hour) = 3,41

$N_{1\ \text{weekday intensity lunch}}$ = (40*0+1,5)* 83/40 = 3,1125

$N_{1\ \text{weekday intensity evening}}$ = (40*0+1,5)* 31/40 = 1,1625

$N_{1\ \text{weekend intensity morning}}$ = (40*0+1,5)* 54/40 = 2,025

$N_{1\ \text{weekend intensity lunch}}$ = (40*0+1,5)* 32/40 = 1,2

$N_{1\ \text{weekend intensity evening}}$ = (40*0+1,5)* 17/40 = 0,6375

Mały Rynek – Staromejska:

$N_{1\ \text{weekday intensity morning}}$ = (40*0+1,5)*115(cars/hour)/(40km/hour) = 4,3125

$N_{1\ \text{weekday intensity lunch}}$ = (40*0+1,5)* 92/40 = 3,45

$N_{1\ \text{weekday intensity evening}}$ = (40*0+1,5)* 127/40 = 4,7625

$N_{1\ \text{weekend intensity morning}}$ = (40*0+1,5)* 89/40 = 3,3375

$N_{1\ \text{weekend intensity lunch}}$ = (40*0+1,5)* 70/40 = 2,625

$N_{1\ \text{weekend intensity evening}}$ = (40*0+1,5)* 98/40 = 3,675

Ul. Edmunda Osmańczyka:

$N_{1\ \text{weekday intensity morning}}$ = (40*0+1,5)*93(cars/hour)/(40km/hour) = 3,4875

$N_{1\ \text{weekday intensity lunch}}$ = (40*0+1,5)* 54/40 = 2,025

$N_{1\ \text{weekday intensity evening}}$ = (40*0+1,5)* 122/40 = 4,575

$N_{1\ \text{weekend intensity morning}}$ = (40*0+1,5)* 65/40 = 2,4375

$N_{1\ \text{weekend intensity lunch}}$ = (40*0+1,5)* 42/40 = 1,575

$N_{1\ \text{weekend intensity evening}}$ = (40*0+1,5)* 69/40 = 2,5875

Plac Świetego Sebastiana:

$N_{1\ \text{weekday intensity morning}}$ = (40*0+1,5)*216 (cars/hour)/(40km/hour) = 8,1

$N_{1\ \text{weekday intensity lunch}}$ = (40*0+1,5)* 168/40 = 6,3

$N_{1\ \text{weekday intensity evening}}$ = (40*0+1,5)* 133/40 = 4,9875

$N_{1\ \text{weekend intensity morning}}$ = (40*0+1,5)* 102/40 = 3,825

$N_{1\ \text{weekend intensity lunch}}$ = (40*0+1,5)* 99/40 = 3,7125

$N_{1\ \text{weekend intensity evening}}$ = (40*0+1,5)* 67/40 = 2,5125

Table C.1

Average values N_1

№	Street	Morning	Lunch	Evening	Average (N_1)
1	1	2	3	4	5
2	Mały Rynek –	3,25	2,72	2,06	2,68

	Muzealna				
3	Rynek	2,72	4,31	0,9	2,64
4	Mały Rynek – Staromejska	3,83	3,04	4,22	3,7
5	ul. Edmunda Osmańczyka	2,96	1,8	3,58	2,78
6	plac Świetego Sebastiana	5,96	5,01	3,8	4,93

Table C.2

Number of windows and N_3

№	Street	Number of windows	N_3
1	1	2	3
1	Mały Rynek – Muzealna	32	25,6
2	Rynek	93	74,4
3	Mały Rynek – Staromejska	58	46,4
4	ul. Edmunda Osmańczyka	69	55,2
5	plac Świetego Sebastiana	82	65,6

Table C.3

Pedestrians affected by noise

№	Street	Morning	Lunch	Evening	Together	Average	N_2
1	1	2	3	4	5	6	7
1	Mały Rynek – Muzealna	358	330	262	950	316,7	79,175
2	Rynek	418	462	386	1266	422	105,5
3	Mały Rynek – Staromejska	238	272	170	680	226,7	56,675

4	ul. Edmunda Osmańczyka	1296	1540	984	3820	1273,3	318,325
5	plac Świetego Sebastiana	218	242	118	578	192,7	48,175

$N_{3\ Mały\ Rynek\ –\ Muzealna} = 32*0,8 = 25,6$

$N_{3\ Rynek} = 93*0,8 = 74,4$

$N_{3\ Mały\ Rynek\ –\ Staromiejska} = 58*0,8 = 46,4$

$N_{3\ ul.\ Edmunda\ Osmańczyka} = 69*0,8 = 55,2$

$N_{3\ plac\ Świetego\ Sebastiana} = 82*0,8 = 65,6$

Annex D

Annual regulatory losses are determined:

$\Pi_{\text{Mały Rynek – Muzealna}}$ = (5,76* (2,68+ 79,175+25,6)) * 3600*0,09758*0,3*1,5= 890853 UAH/hour

Π_{Rynek} = (5,76* (2,64+ 105,5+74,4))* 3600*0,075*0,3*1,5 = 939913,11 UAH/hour

$\Pi_{\text{Mały Rynek – Staromejska}}$ = (5,76* (3,7+ 56,675+46,4))*3600*0,06571 *0,3*1,5 = 447724,43 UAH/hour

$\Pi_{\text{ul. Edmunda Osmańczyka}}$ = (5,76*(2,78+ 318,325+55,2))*3600*0,08104*0,3 *1,5 = 2932454,6 UAH/hour

$\Pi_{\text{plac Świetego Sebastiana}}$ = (5,76* (4,93+ 48,175+65,6))*3600*0,08239*0,3 *1,5 = 498665,17 UAH/hour