

## REVIEW ARTICLES

**Magdalena FRONCZEK-WOJCIECHOWSKA\*, Karolina KOPACZ\*,  
Gianluca PADULA\*, Szymon WIŚNIEWSKI\*\*, Anna WOJNAROWSKA\*\***

### PROPOSAL FOR A METHOD OF CONSTRUCTING INCLUSIVE URBAN GREEN INFRASTRUCTURE

**Abstract:** Population ageing and growing awareness of the need for physical activity is one of the most important topics in Europe nowadays. But it should be noted that there is still no interdisciplinary and integrated approach to urban environment planning concerning physical activity of elderly people which would take into account special needs and possibilities of this particular group. Elderly people represent one of the groups which are threatened with social exclusion for different reasons. This article presents a proposal for a method of constructing a spatial system consisting of natural and anthropogenic elements of urban environment which can be interpreted as Inclusive Urban Green Infrastructure, enabling active and healthy ways of recreation, including the needs of elderly persons. It is based on the existing elements of the environment, but to create a well-functioning system in urban space it is necessary to introduce additional elements, both natural and man-created. The method refers to the spatial definition of areas for active recreation which meet the adopted, specific for elderly people, pro-health and functional requirements. Creation of such a system in cities would contribute to inclusion of this group into social life, thus boosting social coherence and integration across generations, and would also bring beneficial health results. Such infrastructure would also be of considerable importance for sustainable urban growth and improvement of the quality of urban space. The paper is based on source materials from the fields of science investigating health in connection with physiology of the process of ageing, influence of physical activity on this process, impact of negative features of the environment on the health of elderly people as well as urban space planning and development. The proposed methodology of constructing Inclusive Urban Green Infrastructure is presented

---

\* Magdalena FRONCZEK-WOJCIECHOWSKA, Karolina KOPACZ, Gianluca PADULA, 'DynamoLab' Academic Laboratory of Movement and Human Physical Performance, Medical University of Łódź, 92-216 Łódź, ul. Pomorska 251, e-mails: Magdalena.fronczek-wojciechowska@umed.lodz.pl; karolina.kopacz@umed.lodz.pl; gianluca.padula@umed.lodz.pl

\*\* Szymon WIŚNIEWSKI, Anna WOJNAROWSKA, Institute of the Built Environment and Spatial Policy, University of Łódź, 90-142 Łódź, ul. Kopcińskiego 31, Poland, e-mails: szymon.wisniewski@geo.uni.lodz.pl; annawojnarowska365@gmail.com

on the example of Łódź, using data from the Geographic Information System (Topographic Objects Database) and population database for cities.

**Key words:** healthy ageing, inclusive urban green infrastructure, quality of urban space.

## 1. INTRODUCTION

The aim of this article is to present a proposal for a method to construct Inclusive Urban Green Infrastructure. In principle, this infrastructure would serve to improve the quality of inhabitants' life through including in urban space development a possibility of active and healthy recreation, with a particular focus on the needs of elderly people (65+).<sup>1</sup> This paper is treated as the first step to further research on including in urban planning the topic of active recreation of elderly people.

Nowadays Europe is facing a growing problem of ageing societies. There is ongoing research and activities aimed at analyzing this issue and extending the period of life in good health. There is also a growing interest in the needs of elderly people as far as the use of urban space is concerned. Forecasts show now that population aged 65+ in the EU countries is going to double in the forthcoming decades from 85 million in 2008 to 151 million in 2060,<sup>2</sup> which justifies taking up the topic of quality of urban environment and urban space with a particular focus on the needs of elderly people. The quality of urban space may be defined as a degree to which it meets the requirements of the society. These are, in turn, conditioned by values to which the society aspires in its development, and in the case of quality of space, in its spatial development. These values are expressed as general developmental aspirations as well as detailed space shaping principles (models, formulas) (Goethals, 2007). The quality of space may be characterized by its functional, perceptive and forecast qualities. The forecast quality of space includes such features as sustainability, biodiversity, richness and flexibility in respect of both sustainability of new forms of use and adjustment to new cultural and economic needs. This contemporary definition of the notion of space quality encompasses the concept of sustainable development, taking it into account in the forecast value of space (Assink and Groenendijk, 2009). The proposed Inclusive Urban Green Infrastructure would meet the requirements of the functional and forecast quality of urban space, leading to sustainability as well as flexibility in respect of adjustment to the needs of elderly people.

---

<sup>1</sup> *WHO Strategy and Action Plan for Healthy Ageing in Europe, 2012–2020.*

<sup>2</sup> *The Ageing Report 2012, European Commission.*

In order to create an integrated platform for activities aimed at solving the problem of population ageing, the European Commission launched the *European Innovation Partnership on Active and Healthy Ageing* (EIP-AHA) in 2010 as part of *Europe 2020 Flagship Initiative Innovation Union*,<sup>3</sup> which represents one of the essential elements to accomplish the aims of the strategy of Europe 2020<sup>4</sup>: smart, sustainable and inclusive growth. The initiative sets a target consisting in co-operation of 27 EU nations and 6 countries from outside the EU to lift barriers in the physical and social environment which restrict participation of elderly people in physical activity and to enable them to stay independent in their best physical and mental health as well as to maintain good quality of life for as long as possible.

There is also an increase in the level of social awareness of benefits arising from different forms of physical activity used as a means of staying healthy and living longer as more and more people pursue a more active lifestyle. Urban space, however, is not properly developed to meet these expectations. Considering both appreciably larger groups of users and specific needs of some social groups such as the elderly there is no integrated approach to urban environment planning concerning physical activity of elderly people which would take into account special needs and possibilities of this particular group.<sup>5</sup> This results in taking up active recreation of different kinds in unsuitable urban environment often characterized by negative health features, which is counterproductive and contributes to deterioration of health, or even different kinds of injuries instead of health improvement. Elderly people are among the groups which are threatened with social exclusion for different reasons: deteriorated physical condition, health problems, exclusion on the social, financial and digital level. Creation of the Inclusive Urban Green Infrastructure in cities would contribute to inclusion of this group into social life, thus boosting social coherence and integration across generations, and it would also bring about beneficial health results. All city inhabitants would be able to use inclusive green infrastructure, which would lead to improved quality of life and health and, with regard to younger generations, to a reduction in problems faced by adult population, especially elderly people, in the future. This infrastructure would also be of considerable importance for sustainable urban growth, contributing to an increase in environmental attributes on urbanized areas and a more integrated approach to effective use of urban space in a diversified way.<sup>6</sup>

---

<sup>3</sup> *Europe 2020 Flagship Initiative Innovation Union*, COM (2010) 546 Final.

<sup>4</sup> *Europe 2020 A Strategy for smart, sustainable and inclusive growth*, COM (2010) 2020 Final.

<sup>5</sup> *European Innovation Partnership on Active and Healthy Ageing. Action Plan on 'Innovation for Age-friendly buildings, cities and environments'*, 6 November 2012, Conference of Interested Partners, Brussels.

<sup>6</sup> European Commission, *Building a Green Infrastructure for Europe*, 2013.

### **1.1. Scope of Study**

This article presents a proposal for a method of constructing the Inclusive Urban Green Infrastructure in the spatial sphere on a city-wide scale on the basis of data from the Geographic Information System (Topographic Objects Database) and population database for cities. The method, to be more legible and provide visualizations of the outcomes on maps, is tested using available data – in this case taking Łódź as an example. It is necessary to use an interdisciplinary and integrated approach leading to creation of Urban Green Infrastructure forming an environment which is easy to adapt to changing conditions and friendly to all inhabitants, including elderly people.<sup>7</sup> It must be stressed that this publication is only concerned with the methodology for spatial definition of areas for active recreation which meet the adopted pro-health and functional requirements, without discussing the social, economic, legal or institutional issues.

### **1.2. State of Research**

Although population ageing is a very topical issue and there is a growing awareness of the benefits of physical activity, it should be noted that there is still no interdisciplinary and integrated view of urban space in respect of its adjustment to this type of use. Medical research applicable to urban space development does not yet translate into practical solutions in this field. While over the last few decades urban space is gradually being adjusted to the needs of the disabled, there are still no principles connected with planning and designing urban areas so as to meet the specific needs of elderly people, including active recreation. Specialists in the field of medicine and urban space planning formed an independent team and decided to join their knowledge and efforts in order to develop a method of creating the Inclusive Urban Green Infrastructure.

## **2. SOURCE MATERIALS AND RESEARCH METHODS**

This work uses source materials from the fields of science concerned with physiology of the process of ageing, influence of physical activity on this process, impact of negative features of the environment on health, and urban space planning and development. The authors make use of Polish and foreign literature of the subject as well as legal regulations and research relating to permissible noise and pollution levels. An important source of data for the model trial research was the

---

<sup>7</sup> European Commission, *Building a Green Infrastructure for Europe*, 2013.

Topographic Objects Database and the demographic database. The first one was available from the Provincial Geodetic and Cartographic Documentation Centre in Łódź. It is a spatial database of accuracy corresponding to a topographic map in scale of 1:10 000. The database was elaborated between 2012 and 2013 (and is periodically updated) on the basis of technical guidelines included in the Regulation of the Minister of Internal Affairs and Administration as of November 17, 2011 on topographical databases and databases of general geographical objects as well as standard cartographic works. The database gathers information about topographic objects in the relevant national spatial reference system, object characteristics, cartographic codes and metadata of objects. Demographic information, in turn, was obtained from the Strategy Office of Łódź City Hall. The database was elaborated on the basis of registration data and PESEL identification numbers, which is why it also contains the place of residence of every registered inhabitant of Łódź together with information about his or her age and sex.

In the spatial dimension the Inclusive Urban Green Infrastructure will consist of new elements of urban environment as well as the existing elements which encourage spending free time in the city in an active and healthy way. This infrastructure will be available for all inhabitants, and by taking care of the special needs of the elderly it will enable this social group to participate actively in the city's social life.

### **3. INCLUSIVE URBAN GREEN INFRASTRUCTURE – DEMOGRAPHIC, MEDICAL AND URBAN PLANNING CONDITIONS**

The physical and social environment is a key factor for staying healthy and leading an independent and satisfying life until old age; the so-called *supportive environment* is one of the four priority areas within the WHO Europe strategy.<sup>8</sup> The necessity to adapt urban environment to the needs of elderly people is gaining particular importance as over 75% of Europe's population lives in cities. In order to extend the time of staying healthy it is necessary to adapt urban environment to the needs of the elderly in the best possible manner to promote physically and mentally active lifestyles and create safe areas, easily accessible and ensuring dignity and respect<sup>9</sup>. It is therefore necessary to adapt the existing city spaces as well as create some new elements for the purposes of active recreation of elderly people and other groups of city dwellers. Implementation of the elaborated solutions

---

<sup>8</sup> *Strategy and action plan on healthy ageing for Europe.2012–2020*, WHO Europe.

<sup>9</sup> *European Innovation Partnership on Active and Healthy Ageing. Action Plan on 'Innovation for Age-friendly buildings, cities and environments'*, 6 November 2012, Conference of Interested Partners, Brussels.

will contribute to the long-term improvement of social, environmental and spatial cohesion of cities and to creating an attractive high-quality urban environment available to all city dwellers on equal basis, and, consequently, to improvement in the quality of life and health of the inhabitants.

In Poland, too, population ageing is becoming an increasingly serious problem with significant social and economic consequences, which has an impact on the country's current policy. The growing average life span shows that the period of old age is also extended: until recently there were two stages of old age: the first phase, so-called third age of 'young old people' aged from 65 to 79 and the phase of the fourth age – 'old old people' after 80 years of age. Yet there are voices in the literature of the subject about the necessity to single out longevity as the third stage of old age. Demographic forecasts for Poland predict that by 2035 the process of population ageing will be more intensive than so far: the percentage of people aged over 65 will grow together with the percentage of people aged over 80. According to forecasts by Poland's Central Statistical Office (2009), the percentage of population over 65 will be systematically growing to reach 23.2% in 2035, while in cities it will reach a slightly higher level (24.3) than in the country (21.7) (Błędowski *et al.*, 2012).

Most elderly people (65+) suffer from or are prone to a number of diseases in which physical activity is an extremely important preventive factor or a factor easing some symptoms of these diseases. Weight training causes changes in the nervous system of elderly people: there is an increase in the frequency of discharges in motor neurons and the activity of motor units in muscles is improved (Moritani and de Vrieś, 1979). Resistance training tends to cause muscle hypertrophy in people over 60 years of age (Frontera *et al.*, 1988), brings about beneficial changes in bone structure, reduces the risk of osteoporosis and prevents bone breaking. Endurance training taken up even in old age quickly leads to an improvement in the mental state of those who work out, increases self-esteem, reduces fear levels and improves cognitive abilities. It should be noted that an increase in muscle strength, particularly resulting from weight training, can be observed much earlier than an increase in muscle weight. There is more and more evidence that regular training also reduces the risk of civilization diseases, especially metabolic ones (including type 2 diabetes) and cardiovascular diseases (Żołądź *et al.*, 2011). Runners at the average age of 60 had an almost 50% higher level of the desirable protective HDL cholesterol (Seals *et al.*, 1984). Low-intensity 9-month training of people between 60 and 70 years of age suffering from hypertension reduces blood pressure by 20 and 12 mm Hg in men and women respectively (Hagberg *et al.*, 1989).

One in three people after their 65th birthday is prone to fall down at least once a year. These falls end up in over 50% of cases in injuries which lead to hospitalization and reduced fitness which prevents them from leading their previous lifestyle and may even cause death. Mortality among elderly women

resulting from falls is estimated at 10–20%. Consequences of falls tend to be more serious in the case of elderly people than young people or children, which is conditioned by the fact that the skeletal system is usually weakened by osteoporosis, and defensive reflexes (such as assuming a protective body position) are slower since reaction time gets longer as people become older. Regular physical activity is recommended for all patients and it includes walking, jogging, Tai-Chi, dancing or climbing stairs (Czerwiński *et al.*, 2006).

There are many health benefits resulting from creation of the Inclusive Urban Green Infrastructure enabling elderly people to undertake active recreation, such as:

1. Prevention of premature death.
2. Reducing the risk of or delaying progress of cardiovascular diseases (e.g. stroke, myocardial infarction, arterial hypertension), metabolic diseases (e.g. diabetes, osteoporosis, obesity), mental (e.g. depression, dementia) and neurological diseases (e.g. Parkinson disease), renal failure, sleep disorders or certain cancers (e.g. breast cancer, colorectal cancer, prostate cancer).
3. Smaller doses of medicines consumed.
4. Improvement in the population's quality of life.
5. Improvement in motor skills (capacity, strength, endurance and motor coordination) as well as cognitive skills.
6. Lower stress levels.
7. Reduced risk of a fall in the case of elderly people.
8. Increase in social awareness of beneficial effects of physical activity on health.
9. Better moods and social relations.
10. Increase in self-evaluation of active people.

The increased awareness of healthy lifestyles among adult and elderly people will result in reduced need for painkillers, antihypertensive cardiac and neurological medication, and medicines regulating disorders of lipid and carbohydrate metabolism in the population of elderly people.

In recent years there has been a tendency to draw more and more attention to active use of urban space by the inhabitants, an aspect which is connected with the quality of urban space. The environment (built, natural and social) as well as sex, age, amount of time available, motivation, and physical possibilities all have an impact on the participation of inhabitants in different forms of physical activity. Active life contributes to social cohesion in cities, creation of a network of connections and strengthening cultural identity. Consequently, as for shaping the quality of urban space more and more importance is attached to the role of adjusting this space to the needs of spending leisure time in an active way in the open space (Edwards and Tsouros, 2006). The possibility of pursuing different forms of physical activity depends on street planning, land use, transport system



and location of recreational equipment, parks and public utility facilities. Social groups which tend to be less active in the city space are those on a lower income due to lack of possibilities of spending financial means on paid forms of leisure and often living in degraded urban areas characterized by poor quality of land development and problems connected with crime. Opportunities for physical activity should be created as close to places of residence as possible through going green on such areas, improvement in cleanliness, security and environment fostering activities (Edwards and Tsouros, 2006).

Currently there is a growing trend to appreciate the advantages of foot traffic and the so-called *walkability* is considered to be a fundament of sustainable city: without good foot traffic accessibility it is not possible to save resources in a meaningful fashion. Walking also has a direct positive influence on both mental and physical health, reducing stress levels, helping fight obesity and fostering mental agility. As research shows, living in more intensively built-up city zones promotes foot traffic, whereas those living in suburban areas tend to travel by car more often, which restricts their physical activity and contributes to overweight and hypertension (Ewing *et al.*, 2003, after: Southworth, 2007: 6).

Research also points to differences in the relation between the environment and physical activity depending on the age group. Elderly adult people are more sensitive to the influence of environmental factors in relation to taking up physical activity than younger adult people. Research was conducted on a group of 1,623 adults between 20 and 97 years of age (divided into the following age groups: 20–39, 40–49, 50–65, 66–75, 75+) from King County, Seattle and WA, from housing estates selected in terms of differentiation of land use and level of income. Survey research with the use of nine attributes<sup>10</sup> was used to assess the state of environment development within 15–20 minutes of access on foot from the place of residence to public transport stops or recreation places. It was shown that it is of primary importance for the elderly to have access on foot to non-residential (service) areas and recreation facilities. For the last two age groups (65+) these features of the residential environment were of paramount importance for taking up physical activity. This is why it was assumed that areas and elements of their development within walking distance from the place of residence are most beneficial for fostering physical activity of elderly people. This assumption is also based on the research indicating that walking on foot is the preferred way of moving of elderly people considering both fitness and the issue of cost (Gell *et al.*, 2015).

---

<sup>10</sup> The nine attributes of environment development included in the research comprise: density of population in the place of residence, proximity to non-residential forms of land use (e.g. commerce, services, recreation), easy access to these forms of land use, street connections, facilities for foot and bicycle traffic, aesthetics, road safety of pedestrians, public security (level of crime), closeness to recreation equipment.



There are many elements of urban infrastructure which have an impact on physical activity of elderly people, such as:

- open-air gyms;
- exercise stations located in different places in parks;
- running tracks;
- bicycle tracks,
- Nordic walking tracks;
- toilets;
- benches;
- points of blood pressure and pulse measurement;

as well as:

- adjustment of urban public transport and rail to the needs of elderly people;
- special mini-buses for elderly people coming close to their place of residence;
- appropriate lighting on the streets: a 65-year-old person needs 4 times more light than a 20-year-old person (Błaszczuk and Czerwosz, 2005).

Elements which should be avoided in the urban space by elderly people include:

- too hard surface;
- protruding tree roots;
- protruding flagstones;
- advertisements and signboards on pavements or at the head height of passers-by;
- too high volume of noise causing acoustic nuisance;
- insufficient intensity of light.

Places of active recreation should be ultimately combined into a system of Inclusive Urban Green Infrastructure leading from residential areas to already existing parks and sports or recreation areas, which would additionally have an important environmental dimension and increase the possibility of using this infrastructure in a diversified way. The marked areas fostering physical activity will enable everyday active recreation in the open space of the city, often in the closest vicinity to the place of residence, which is important for both less fit people and the elderly ones as this offers an opportunity for convenient and independent active recreation. There are possibilities of locating new elements of Inclusive Urban Green Infrastructure to complement the existing system of green and recreation areas e.g. in ill-developed and open areas of housing estates waiting for humanization (in Poland mostly housing estates with blocks of flats dating back to the period of socialist economy, often characterized by vast and undeveloped green areas), unused sections of waterside areas near watercourses, including those which have already been re-naturalized. Another important opportunity for many cities is a possibility of developing an area for a proposed purpose (or taking them into consideration as an accompanying function) of degraded urban and postindustrial areas as part of revitalization processes.

#### 4. METHODOLOGY

The basis for the method of construction of Inclusive Urban Green infrastructure is exclusion of areas with unfavourable health features from use as places of active recreation and indication of those areas which are predestined for this kind of use. These premises were adopted as a starting point for delineating areas in the urban space which enable city inhabitants to spend free time in an active and healthy way, bearing in mind both functional and health needs of elderly people. Another important assumption of the model is identification of places of concentration of the already existing urban space development elements which foster physical activity of the group in question. Topographic data provide a source of information on the location of these elements on the area of the city.

Elements of development which already exist in the area as well as those which may be used in the future to create Inclusive Urban Green Infrastructure were divided into three groups according to the hierarchy of importance as well as needs and possibilities of including them in the Inclusive Urban Green Infrastructure system:

1. Basic elements – fundamental elements which condition accomplishment of active recreation in the urban space and consequent health or physiological needs: buildings whose function is connected with recreation and health protection as a way of increasing the sense of security of elderly people doing recreation activities in the open urban space, recreation areas, facilities for foot and bicycle traffic, noise protection elements, functional landscaping elements. Consequently, the Topographic Objects Database includes the following elements in this group: hospital and health care buildings, hospital or sanatorium complexes, health centres, hospitals, chemists, physical education buildings, running tracks, tennis courts, playgrounds, sport and recreation centres, swimming pools, drinking water tapping points, street lighting, lanes, passages, paths, overpasses, bridges, subways for pedestrians, bicycle stands, acoustic barriers, toilets and benches.<sup>11</sup> These elements are of fundamental importance for accomplishment of Inclusive Urban Green Infrastructure also due to economic reasons as they may be used in the present form or after adaptation for the needs of elderly people, which considerably reduces the necessary capital expenditures for Inclusive Urban Green Infrastructure. The economic issue is of primary importance, especially in the aftermath of the economic crisis after 2008 but also in the situation when these are investments financed mostly from public funds (Manley 2015) and are city-wide rather than located in one point.

---

<sup>11</sup> Topographic Objects Database.

2. Complementary elements – elements indirectly supporting physical activity, increasing aesthetics of the surroundings and encouraging to go to the open urban space, also providing an opportunity of spending free time in an additional way while going out, such as: cultural facilities, tourist attractions, monuments, landscaping elements including sculpture elements, objects of religious cult and certain services. These elements may represent an additional facility for the elderly and increase the attractiveness of going out in order to take up active recreation. They are not indispensable to take it up, therefore they do not belong to the group of investment projects necessary for accomplishment of Inclusive Urban Green Infrastructure, with the assumption that its use is based on movement on foot. This group comprises the following elements in the Topographic Objects Database listing: bus or tram stops, public transport stops, stages, botanical gardens, zoos, tourist attractions, antique ruins, historical walls, piers or quays, fountains, monuments, statues, shrines, roadside crosses, churches, chapels, cash dispensers and post offices.<sup>12</sup>

3. Potential elements – areas or objects which are wasteland or remain undeveloped but which may potentially be used for creation of new elements of Inclusive Urban Green Infrastructure, such as: green uncultivated land on residential areas or in their vicinity, post-industrial or post-railroad land as well as other undeveloped parcels which used to be occupied by some vanishing functions.

The Inclusive Urban Green Infrastructure system was referred to the present and future demographic situation – spatial location of population aged 65+ in the city. Łódź was selected for testing the model due to availability of population data and the Topographic Objects Database.

The following methodology of proceedings was adopted:

1. Identification of places in the city characterized by negative features for healthy and active recreation (*destimulant*) on the basis of information on exceeding the permissible values of air pollution, noise and extreme delevelling (over 10%). As for the quality of air, this work refers to a report on the state of environment elaborated by the Provincial Inspectorate of Environmental Protection in Łódź in 2014. According to it, of all chemical substances including SO<sub>2</sub>, CO, NO<sub>2</sub> and particulates, only PM 2.5 suspended particulates are detrimental to human health. Information on exceeding permissible levels of road, rail, tram and industrial noise was taken from the Acoustic Map of Łódź website run by the City Hall. Data on the city's landscape features were obtained on the basis of the Numeric Terrain Map made available by the Central Geodetic and Cartographic Documentation Centre.

2. Identifying areas in the city that have positive characteristics for healthy and active recreation (*stimulants*) on the basis of the Topographic Objects Database and data from the resources of the OpenStreetMap website after prior field verification.

---

<sup>12</sup> Topographic Objects Database.

3. Delineating areas characterized by presence of *stimulants* and lack of *destimulants* as predestined for use in active recreation.

4. Delineating areas of concentration of population aged 65+ on the city's area in 2015 and forecast for 2035.

5. Identifying spatial differentiation of population density of elderly people in Łódź in 2015 and 2035 in areas indicated in step 3.

6. Identifying places, objects and elements of development in the city which foster active recreation (classified as basic and complementary) in areas predestined to creating Inclusive Urban Green Infrastructure.

7. Delineating areas of concentration of elements mentioned in step 5.

8. Superimposing spatial differentiation of population density of elderly people (present and forecast) on the distribution of analysis units diversified in terms of being equipped with basic and complementary elements;

9. Proposal for a system of Inclusive Urban Green Infrastructure in the city space.

It should be noted that the model concerns the city-wide scale. On the local scale it would be advisable to analyze the existing land development elements and elaborate detailed proposals addressed to individual areas of Inclusive Urban Green Infrastructure with respect to complementing it with elements necessary for physical activity (predominantly the basic and potential ones described in this text).

## 5. RESULTS OF TESTING THE MODEL

The city of Łódź was selected for conducting research for testing the model. Łódź is the third largest city in Poland considering the number of inhabitants registered for permanent residence (703,186) and the fourth in terms of space (293.25 km<sup>2</sup>), a major academic (6 public and 22 private universities), cultural and industrial centre. Before the political and economic transformations of 1989 it used to be a centre of textile and film industries. It is an important road transport node.

In order to mark out areas in the city which foster active recreation of elderly people, the authors used the method of creating Inclusive Urban Green Infrastructure. It was assumed that it is necessary to take into account protection against air pollution and other potential environmental nuisances such as noise during increased effort accompanying physical activity. Research shows that exposure to long-term noise nuisance (e.g. from transport sources) brings about lower levels of physical activity directly or through sleep disorders, and it also represents a factor which affects formation

of cardiometabolic diseases (Foraster *et al.*, 2016). Air pollution in Łódź was taken into consideration in accordance with the report on the state of the environment elaborated by the Provincial Environmental Protection Inspectorate in Łódź in 2014. The level of noise exceeding levels permissible for health was adopted on the basis of domestic regulations in this respect.<sup>13</sup> It should be stressed, however, that elderly people are considered to belong to groups more sensitive to noise nuisances,<sup>14</sup> which is why better protection against noise should be implemented. Besides, attention should be drawn to the fact that recreation and leisure areas are described as particularly noise sensitive. Excessive noise levels generated by the surroundings result there in disturbance of basic functions, which brings about their smaller attractiveness (Szopińska, 2015). Research also shows that those who are exposed to loud noise are more likely to go down with cardiovascular and upper respiratory diseases, more often have problems with the balance organ, hypertension, stomach ulcers and many other diseases (Pawlas, 2012). Using acoustic barriers and interweaving them in the urban public space can reduce noise as much as by 9–10 dB (Gołąb-Korzeniowska, 2001). Data concerning noise levels in Łódź were obtained from the Łódź Acoustic Map internet service run by the City Hall. Also areas with an excessive inclination of land were excluded due to the possibility of increased risk of injuries as medical research points to a greater possibility of injuries and falling when the inclination of land exceeds 10% (Dixon *et al.*, 2011).

The above-mentioned negative features of the environment such as: (1) exceeded values of air pollution and noise levels or (2) excessive inclinations of land were classified as *destimulants*. Areas in which there is at least one of the aforementioned negative factors were, as a result, marked on the city map as unsuitable for creation of Inclusive Urban Green Infrastructure with the present level of inconvenience due to its negative influence on health during physical effort. Positive factors (*stimulants*) were defined as green areas of different type as well as flowing and standing waters. Consequently, in the Topographic Objects Database listing this group comprises the following elements: parks, Nature 2000 areas, landscape parks, national parks, trees or groups of trees, clumps of bushes, small forests, lines of bushes or hedge, grass, flowing waters, standing waters, forest, grove, tree stand, bushes, grass vegetation.<sup>15</sup> Distribution of these areas against the background of Łódź is illustrated by Fig. 1.

---

<sup>13</sup> *Announcement of the Minister of the Environment...* (2014).

<sup>14</sup> Ministry of Health, Department of Public Health, *Wpływ hałasu na zdrowie człowieka* [Impact of noise on human health], Seminar on protection against noise, 11 December 2012.

<sup>15</sup> Topographic Objects Database.

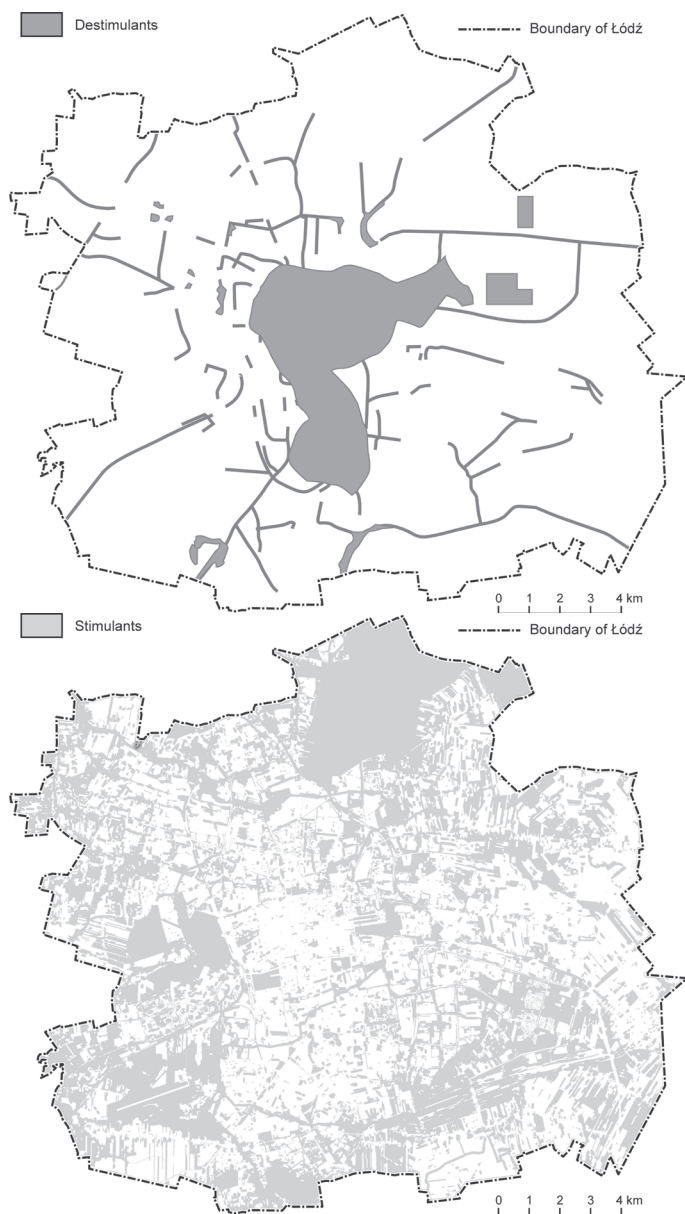


Fig. 1. Distribution of destimulants and stimulants in the space of the city of Łódź  
Source: own work

Conducting further research required introduction of the basic field of analysis. It allowed the city space to be differentiated in an objective way, taking into account all considered research variables. It was decided to introduce an artificial

basic field, the shape and size of which were determined by the functional and spatial structure of the analyzed area and the adopted methodology of examining accessibility on foot in the urban space.

In Poland it is customary to assume that the impact zone of pedestrian transportation covers an area with radius ranging from 500 metres to 1 kilometre. This means that inhabitants are willing to reach, for instance, a local transport stop, shop or basic health care centre on foot in the time between 6 to 12 minutes assuming that their average speed is 5 kph (Majewski and Beim, 2008). Such a model, naturally, does not reflect the possibility of generating all the demand for different kinds of services even if these were realized in all possible directions and with maximum accessibility, which results from the fact that every inhabitant may have a different border distance beyond which he or she will give up using the given service. In addition, the hypothetical public transport user may consider other factors, beside the distance, such as possible facilities which facilitate the access to the given location in the city space or barriers hindering access to it. The power of influence of these factors is different for every inhabitant and tends to be heavily determined by individual features of each user, such as age, health condition, sex, place of residence etc. Taking this into account it must be noted that specifying accessibility of urban space is extremely difficult and naturally it is necessary to use certain generalizations, which will allow to have a synthetic outlook on this issue. The research therefore uses the distance (equidistance) of 500 m, adopting at the same time the analysis basic field of  $500 \times 500$  metres. Generally speaking, in the literature there are methodological problems connected with the border walking distance. In Great Britain, for instance, the equidistance of 640 metres is considered the maximum distance of access to the bus stop in town whereas in the case of regional rail or underground it is 960 metres (Majewski and Beim, 2008). German urbanists, in turn, assume that the maximum way of accessing the bus stop is 300 metres, the tram stop – 400 m and the regional rail – 500 metres (Loose, 2001).

According to Mazurek (1965), the use of means of transport, or an objective necessity to use them to cover a distance measured in time wasted by inhabitants on transport, usually takes place when trip distances exceed 2 kilometres. This means that inhabitants are able to cover shorter distances on foot if there are no alternative means of transport. It is important to remember at the same time that analysis concerns elderly people, which is why this border distance was arbitrarily shortened to 1 kilometre. It would also be largely erroneous to delineate the catchment area of pedestrians on the basis of the method used by Litman (2012), i.e. a circle with centre in the place of his or her place of residence. This is why the authors decided to use the variant of artificial basic fields in the form of a network of squares. One unquestionable advantage of this approach is its universality of use for settlement units in extremely different spatial and functional structures.



Once the network of basic fields had been superimposed on the city space, it was possible to delineate areas for further analysis in accordance with the model (Fig. 2.).

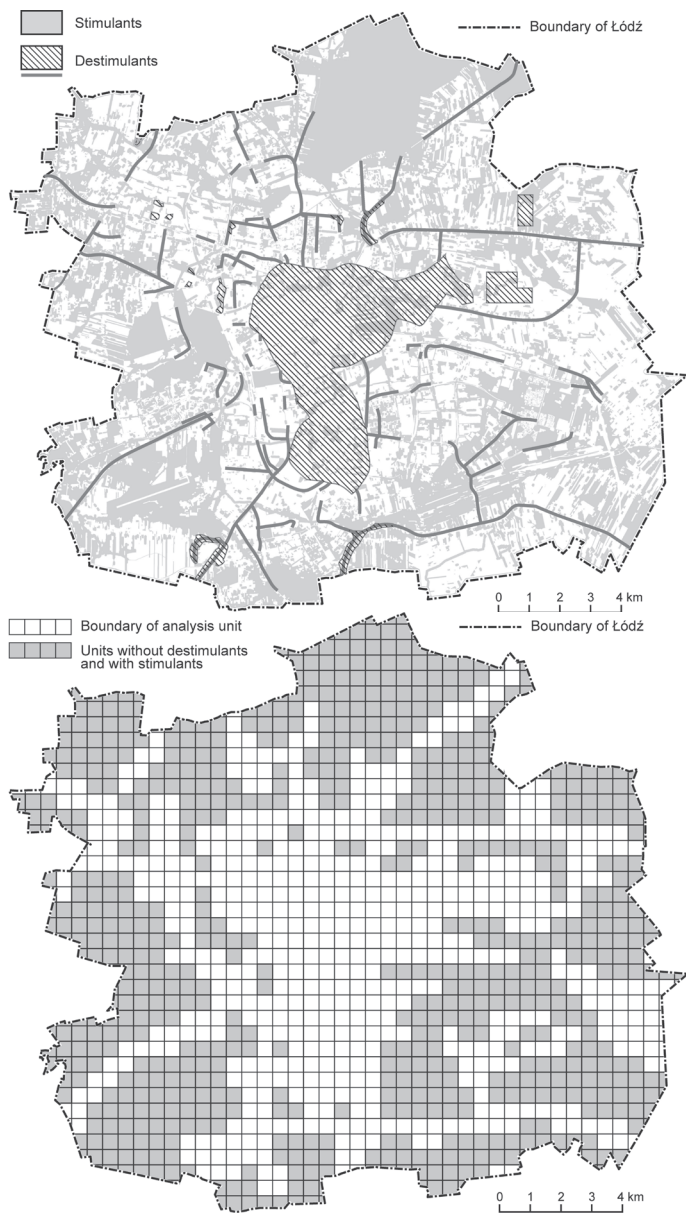


Fig. 2. Areas marked for further analysis after taking into account stimulants and destimulants  
Source: own work

The next step consisted in delineating places of concentration of population aged 65+ at the present moment (data from 2015) and predicted data for 2035 on the basis of forecast demographic tendencies (Błędowski *et al.*, 2012) (Fig. 3). It was assumed that places of residence in this period remained unchanged due to low mobility of this group of inhabitants with regard to changing the permanent place of residence.

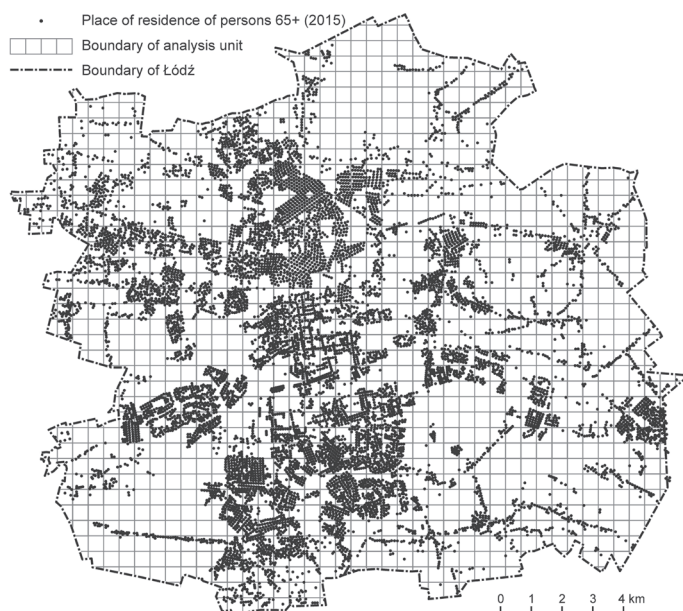


Fig. 3. Distribution of elderly people in 2015 in Łódź  
Source: own work

Next, the number of elderly people was calculated for every square of the network of basic fields of the analysis. In this way spatial differentiation of elderly population density in Łódź was obtained (for squares of  $0.25 \text{ km}^2$ ). Subsequently, the authors specified the average level of density and calculated standard deviation of the variable for areas marked earlier for further analysis (Fig. 4).

The next step in the model was the choice of basic and supplementary elements important for creation of Inclusive Urban Green Infrastructure. Beside the choice of elements to be considered while seeking a synthetic gauge of equipping the area in places and objects fostering activity of elderly people, the second problem which should be solved was finding its calculation method. The main difficulty was that the considered elements were of point, linear and surface character, which is why their size/number was expressed in different units. Consequently, it was necessary to use a variable standardization method which allows to bring different measures

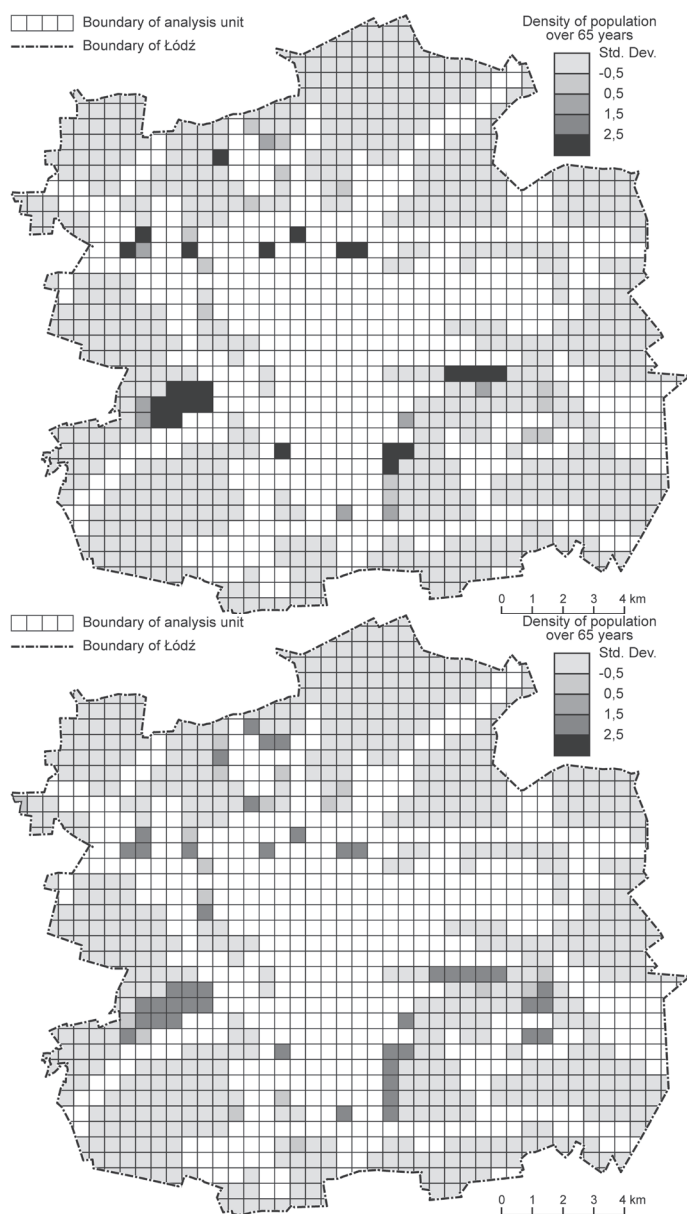


Fig. 4. Spatial differentiation of elderly population density in 2015 and 2035 in Łódź  
Source: own work

of gauges to a common denominator. The results for every basic field represent sizes differentiating the units which enable a comparative analysis of the current “attractiveness” of an area for the researched function. In this work the following

procedure formed a basis for calculating the synthetic gauge. The authors specified the distance being the number of standard deviations of the given result from the mean for the given variable. In other words, it was pointed out to what extent the given result, the given value of the feature for the specific square of the network is different from the average result. For standardizing results the following formula was adopted:

$$Z = \frac{x - \mu}{\sigma},$$

where:  $Z$  –  $Z$  test results;  $x$  – observed value of variable;  $\mu$  – anticipated value, mean;  $\sigma$  – standard deviation.

Converting every result obtained in the measurement using the standardization formula, normalized measure is obtained and its anticipated value (mean) equals 0 whereas the variance equals 1. This allows to determine to what extent the given result ( $x$ ) differs from the mean value.

The units researched were ordered in descending order of the size of the synthetic gauge. Figure 5 illustrates the distribution of concentration fields of basic and supplementary elements in the city space.

The final step was ‘superimposing’ spatial differentiation of elderly population density in 2015 on the distribution of analysis units diversified in terms of being equipped in basic and complementary elements (Fig. 6).

Following the analysis of current distribution of the city’s population concentration and clusters of basic and complementary elements which could be used to create Inclusive UGI it is possible to delineate areas of priority in creation of Inclusive Urban Green Infrastructure. These are areas:

- populated by the biggest number of elderly people (65+) in areas marked as suitable for Inclusive Urban Green Infrastructure;
- already equipped to the largest degree with basic and complementary elements of Inclusive Urban Green Infrastructure;
- also located in parts of the city characterized by a lack of negative health factors, such as air pollution, noise and excessive downslopes and existence of positive features of the environment fostering active recreation (greenery, water).

It seems obvious that one cannot exclude population living in areas with environmental nuisances and without positive features of urban environment from using Inclusive Urban Green Infrastructure for active physical recreation. Areas delineated using the proposed method are those that would enable creation of Inclusive Urban Green Infrastructure in the quickest and most cost-effective manner. As for other areas, it is necessary to undertake activities aimed at reducing nuisances, increasing the share of positive environmental features (stimulants) as well as ensuring facilitations regarding accessibility of

Inclusive Urban Green Infrastructure elements located in areas predestined for their accomplishment, e.g. through special forms of public transport adapted to the needs of elderly people.

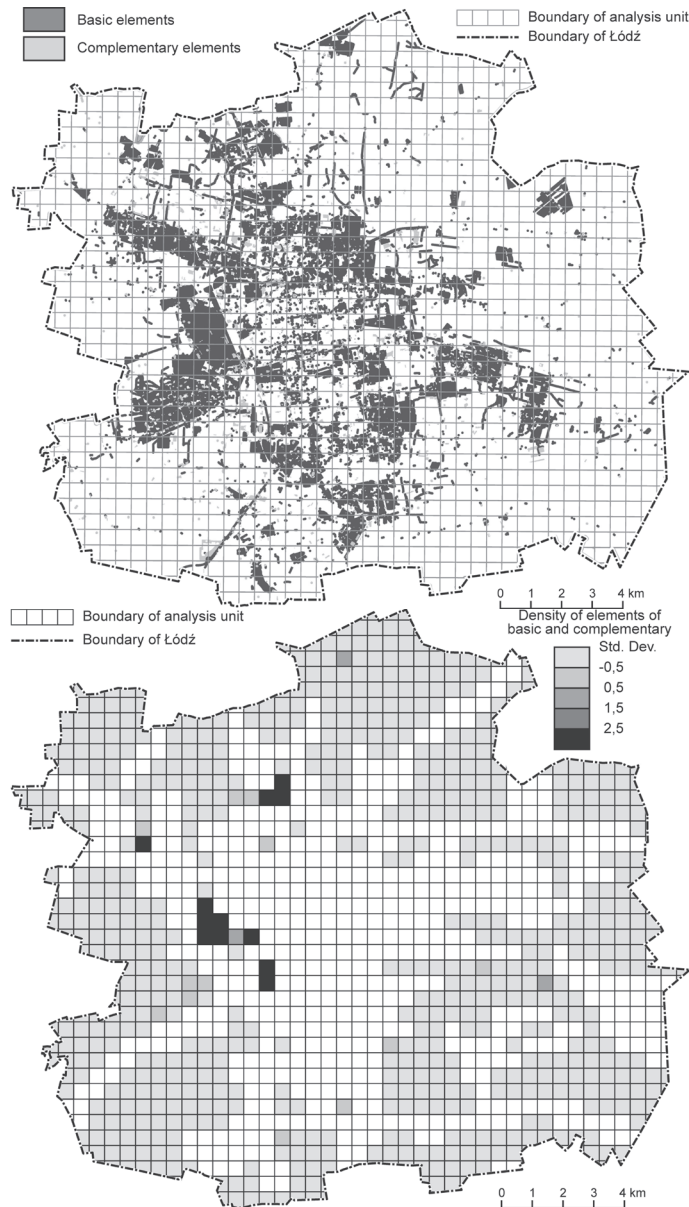


Fig. 5. Distribution of basic and complementary elements in the space of Łódź  
Source: own work

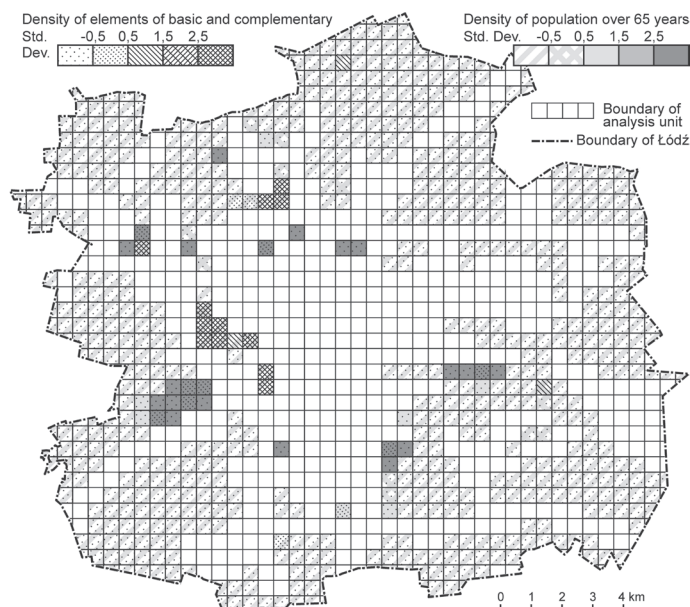


Fig. 6. Spatial differentiation of basic fields of analysis in respect of possibility of and need for introducing Inclusive Urban Green Infrastructure

Source: own work

## 6. CONCLUSIONS

The distribution of *destimulants* (in the case of Łódź) in the city points to nuisances in the form of exceeded noise and pollution levels (PM 2.5 suspended particulates) in the downtown densely built-up area, in the industrial zone in the eastern part of the city and along transport arteries. These parts of the city are, at the same time, densely populated also by elderly people since as many as 22% of Łódź inhabitants over 65 years of age live there.

The spatial distribution of *stimulants* in the city is mostly conditioned by the layout of green areas and other natural elements of the environment. As a result, these areas are naturally unpopulated and therefore on the city plan form, together with places of high population density, areas which complement one another. Bearing in mind the need for locating places of active recreation within walking distance (up to 500 metres) from the concentration of places of elderly people's residence for creation of Inclusive Urban Green Infrastructure, one should consider, in the first place, border zones of green areas neighbouring with these places.



Undeveloped green areas in the places of residence should be another potential element of Inclusive Urban Green Infrastructure. In the scale of the city these are impossible to single out as it requires a far more detailed analysis. Below, however, there is a fragment of the area of Łódź which was indicated in the model as predestined for accomplishment of Inclusive Urban Green Infrastructure due to health values and concentration of population aged 65+. In this area there are destimulants covering only its small fragments, which does not exclude introduction of Inclusive Urban Green Infrastructure. Also stimulants in the form of green areas, including housing estate green areas, can be seen, which may be adjusted to the needs of Inclusive Urban Green Infrastructure.



Fig. 7. Spatial differentiation of basic fields of analysis in respect of possibility of introducing Inclusive Urban Green Infrastructure  
Source: own work

As it may be observed in Fig. 7, spatial differentiation of basic elements, which were considered vital for construction of Inclusive Urban Green Infrastructure, in general overlaps with spatial differentiation of population aged 65+. Supplementary



elements are also evenly distributed in the residential area. Therefore, it may be assumed that in the case of Łódź creating the system of Inclusive Urban Green Infrastructure in areas of high concentration of elderly population will be facilitated as in this area there are already elements of land development denoted as basic and supplementary for creation of Inclusive Urban Green Infrastructure. They may require adjusting to the needs of elderly people through supplementing the equipment.

Due to the fact that *destimulants* may be found mainly on populated areas not only in Łódź but also in other cities (city centres, areas along transport arteries and those adjacent to industrial areas) it is worth considering how to tackle the issue of ensuring the possibility of healthy and active recreation in these places. It must be remembered that due to the preference of elderly people, who for different reasons are less mobile, for moving within walking distance in the proximity of the place of residence, this role will not be played solely by facilities of this type located away from places of residence in areas characterized by beneficial health qualities (on the city plan these are areas without destimulants and with stimulants – Fig. 2). Introduction of Inclusive Urban Green Infrastructure elements should take place in areas excluded as a result of existence of destimulants through implementing different forms of protection against pollution and its reduction, creating new biologically active areas, particularly on densely built-up areas such as city centres. These activities could contribute, at the same time, to reduction of pollution, which in turn would translate into reducing the scope of influence of destimulants.

There is a need to consider in future the practical application of Inclusive UGI in urban planning strategies and documents, of general (city-wide) and local scale. It should be also noticed that there are still no normative regulations for planners concerning the specific needs of elderly people in urban environment. Further research on this topic should be carried out on the interdisciplinary basis, which could produce material for generalizations and setting standards in urban planning and design regarding required features of urban environment adapted for the needs of elderly.

## REFERENCES

- Announcement of the Minister of the Environment as of 15 October 2013 on announcing the consolidated text of the Minister of the Environment regulation on permissible noise levels in the environment*, Dz. U., 22 January 2014, Item 112.
- ASSINK, M. and GROENENDIJK, N. (2009), 'Spatial quality, location theory and spatial planning', Paper presented at Regional Studies Association Annual Conference *Understanding*

- and Shaping Regions: *Spatial, Social and Economic Futures*, Leuven, Belgium, April 6–8, 2009.
- BŁASZCZYK, J. W. and CZERWOSZ, L. (2005), 'Stabilność posturalna w procesie starzenia', *Gerontologia Polska*, 13, pp. 25–36.
- BŁĘDOWSKI, P., SZATUR-JAWORSKA, B., SZWEDA-LEWANDOWSKA, Z. and KUBICKI, P. (2012), *Raport na temat sytuacji osób starszych w Polsce*, Warszawa: Instytut Pracy i Spraw Socjalnych.
- Building a Green Infrastructure for Europe* (2013), European Commission.
- CZERWIŃSKI, E., BOROWY, P. and JASIAK, B. (2006), 'Współczesne zasady zapobiegania upadkom z wykorzystaniem rehabilitacji', *Ortopedia Traumatologia Rehabilitacja*, 4, pp. 380–387.
- DAMAVANDI, M., DIXON, P. C. and PEARSALL, D. J. (2012), 'Ground reaction force adaptations during cross-slope walking and running', *Human Movement Science*, 31, pp. 182–189.
- DIXON, P. C., TISSEYRE, M., DAMAVANDI, M. and PEARSALL, D. J. (2011), 'Inter-segment foot kinematics during cross-slope running', *Gait and Posture*, 33, pp. 640–644.
- EDWARDS, P. and TSOUROS, A. (2006), *Promoting physical activity and active living in Urban Environments. The Role of Local Governments*, WHO Europe.
- Europe 2020. *A Strategy for smart, sustainable and inclusive growth*, COM(2010) 2020 Final.
- Europe 2020. *Flagship Initiative Innovation Union*, COM(2010) 546 Final.
- European Innovation Partnership on Active and Healthy Ageing. *Action Plan on 'Innovation for Age-friendly buildings, cities and environments'*, 6 November 2012, Conference of Interested Partners, Brussels.
- FORASTER, M., EZE, I. C., VIENNEAU, D., BRINK, M., CAJOCHEN, CH., CAVIEZEL, S., HÉRITIER, H., SCHAFFNER, E., SCHINDLER, C., WANNER, M., WUNDERLI, J.-M., RÖÖSLI, M. and PROBST-HENSCH, N. (2016), 'Long-term transportation noise annoyance is associated with subsequent lower levels of physical activity', *Environment International*, 91, pp. 341–349.
- FRONTERA, W., MEREDITH, C., O'REILLY, K., KNUTTGEN, H. and EVANS, W. (1988), 'Strength conditioning in older men: skeletal muscle hypertrophy and improved function', *Journal of Applied Physiology*, 64, pp. 1038–1044.
- GADZIŃSKI, J. (2010), *Ocena dostępności komunikacyjnej przestrzeni miejskiej na przykładzie Poznania*, Biuletyn IGSE i GP UWAM, Seria Rozwój Regionalny i Polityka Regionalna, Vol. 13, Poznań: Bogucki Wydawnictwo Naukowe.
- GELL, N. M., ROSENBERG, D. E., CARLSON, J., KERR, J. and BELZA, B. (2015), 'Built environment attributes related to GPS measured active trips in mid-life and older adults with mobility disabilities', Brief Report, *Disability and Health Journal*, 8, pp. 290–295.
- GOETHALS, M. (2007), *Shared terms for spatial quality of strategic projects*, 43<sup>rd</sup> ISOCARP Congress, Antwerp, Belgium.
- GOŁĄB-KORZENIOWSKA, M. (2001), 'Przekształcenia miasta w warunkach zagrożenia hałasem', *Czasopismo Techniczne. Architektura*, 108, pp. 51–56.
- HAGBERG, J. M., LIMACHER, M., WOODS, D. R., LEGGETT, S. H., CONONIE, C., GRUBER, J. J. and POLLOCK, M. L. (1989), 'Cardiovascular responses of 70–79-yr-olds men and women to exercise training', *Journal of Applied Physiology*, 66, pp. 2589–2594.
- KŁOS, G., ŚWIĄTCZAK, B. and WACHOWIEC, A. (2015), *Roczna ocena jakości powietrza w województwie łódzkim w 2014 r.*, Łódź: Wojewódzki Inspektorat Ochrony Środowiska.
- LITMAN, T. (2012), *Evaluating Accessibility for Transportation Planning. Measuring People's Ability to Reach Desired Goods and Activities*, Victoria: Victoria Transport Policy Institute.

- Łódź Acoustic Map Internet Service, Łódź City Hall, <http://akustyczna.mapa.lodz.pl/mapa/> [27.04.2016]
- LOOSE, W. (2001), *Flächennutzungsplan 2010 'Freiburg – Stellungnahme zu den verkehrlichen Auswirkungen'*, Freiburg: Öko-Institut e.V.
- MAJEWSKI, B., BEIM, M. (2008), 'Dostępność komunikacji publicznej w Poznaniu', [in:] CZYŻ, T., STRYJAKIEWICZ, T., CHURSKI, P. (eds.), *Nowe kierunki i metody w analizie regionalnej*, Biuletyn IGSE i GP UAM, Seria Rozwój Regionalny i Polityka Regionalna, Vol. 3, Poznań: Bogucki Wydawnictwo Naukowe.
- MANLEY, S. (2015), 'Inclusive Green Infrastructure', [in:] SINNETT, D., SMITH, N., BURGESS, S. (eds.), *Handbook on Green Infrastructure: Planning, Design and Implementation*, Cheltenham: Edward Elgar Publishing, pp. 242–250.
- MAZUREK, T. (1965), *Komunikacja miejska, cz. 1: Planowanie tras komunikacyjnych w miastach oraz eksploatacja komunikacji miejskich*, Łódź: PAN.
- Ministerstwo Zdrowia, Department Zdrowia Publicznego (2012), *Wpływ hałasu na zdrowie człowieka*, Seminarium poświęcone ochronie przed hałasem, 11 grudnia 2012.
- MORITANI, T., DE VRIES, H. A. (1979), 'Neural factors versus hypertrophy in the time course of muscle strength gain', *American Journal of Physical Medicine*, 58, pp. 115–130.
- Numeric Terrain Map, the Central Geodetic and Cartographic Documentation Centre, Warsaw, <http://www.codgik.gov.pl/index.php/darmowe-dane/nmt-100.html> (27.04.2016).
- OpenStreetMap Internet service, <https://www.openstreetmap.org> (27.04.2016).
- PAWLAS, K. (2012), *Hałas w środowisku komunalnym*, Sosnowiec: Instytut Medycyny Pracy I Zdrowia Środowiskowego.
- Regulation by the Minister of Internal Affairs and Administration as of 17 November 2011 on the database of topographic objects and the database of general geographic objects as well as standard cartographic works*, Dz. U. 2011, No. 279, Item 1642.
- SEALS, D. R., ALLEN, W. K., HURLEY, B. F., DALSKY, G. P., ESHANI, A. A., HAGBERG, J. M. (1984), 'Elevated high-density lipoprotein cholesterol levels in older endurance athletes', *American Journal of Cardiology*, 54, pp. 390–393.
- SHIGEMATSU, R., SALLIS, J. F., CONWAY, T. L., SAELENS, B. E., FRANK, L. D., CAI, K. L., CHAPMAN, J. E., KING, A. C. (2009), 'Age Differences in the Relation of Perceived Neighborhood Environment to Walking', *Medicine and Science in Sports and Exercise*, 41 (2), pp. 314–321.
- SOUTHWORTH, M. (2007), 'Morphology of the liveable city', *Urban Forms and Metropolitan Spaces*, Berkeley: University of California.
- Strategy and action plan on healthy ageing for Europe 2012–2020*, WHO Europe.
- SZOPİŃSKA, K. (2015), 'Hałas drogowy jako czynnik wpływający na atrakcyjność miejskich terenów rekreacyjno-wypoczynkowych', *Logistyka*, 3, pp. 4740–4749.
- The Ageing Report 2012*, European Commission.
- ŻOŁĄDŹ, J. A., MAJERCZAK, J., DUDA, K. (2011), 'Starzenie się a wydolność fizyczna człowieka', [in:] GÓRSKI, J. (ed.), *Fizjologia wysiłku i treningu fizycznego*, Warszawa: Wydawnictwo PZW, pp. 157–165.