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Article

Assessment of the Exposure of Urban Areas the Pluvial Flood Risk Using the Method of Analytic Hierarchy Process

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Abstract: The report [1] shows that in many European cities the sewer system is older than 40 years, potentially reducing their ability to cope with more intense pluvial flooding [2] addition to climate change, urbanization is an important factor increasing the flooding risk, as it increases of impervious surfaces. Flash floods are particularly troublesome, causing not only the overloading of drainage systems [3], but also urban transport disruption, affecting human health, and contributing to pollution due to untreated sewage discharges [4]. Pluvial floods in urban areas are caused by short-duration precipitation, high intensity and on small scale. Such rainfall is difficult to predict and does not always apply to catchment areas. In Poland, heavy rainfall lasts relatively short, from a few minutes to a few, at most, several hours [5]. The method of the Analytic Hierarchy Process (AHP) was used to rank the importance of criteria characterizing exposure in urban areas. The ranking is based on expert judgements. The article focuses on exposure which is one of the components of risk. Geographical Information System (GIS) is integrated with Multicriteria Decision Analysis (MCDA) to evaluate exposure of urban area on pluvial floods.

Keywords: flood risk; urban areas; vulnerability; exposure; pluvial floods; Analytic Hierarchy Process

1. Introduction

The observed climate change is causing an increase in the frequency and intensity of extreme meteorological and hydrological events (e.g. storms, floods, heat waves, or heavy rainfall) all over the world. The resulting risk depends not only on climate change but also significantly on changes in land use. Urbanization and the associated land sealing are leading to increasing risks, especially in urban areas. „Climate change is expected to lead to an increase in precipitation in many areas. Increased rainfall over extended periods will mainly lead to fluvial (river) flooding, while short, intense cloudbursts can cause pluvial floods, where extreme rainfall causes flooding without any body of water overflowing” [6]. Studies [7] show that the average annual losses caused by multiple flash floods are almost equal to large river floods, that occur once in a century.

However, the future costs of climate-related hazards depend not only on the frequency and severity of events but also on several other factors such as the size of the population and the value of assets at risk. [8]. Spatial development and urbanisation processes in the European Union (EU) countries are subject to regulations, thus creating a framework for integrated urban development. Many European Union policies and laws promote sustainable development, land use, and urban safety. Identifying the locations of rainfall flooding areas and developing accurate maps based on them are crucial for spatial planning and flood management at the local scale [9]. It is equally important to conduct susceptibility and exposure studies. The issue of pluvial floods was taken up at the Institute of Meteorology and Water Management - National Research Institute (IMWM-NRI) as part of the research work. Currently, research focuses on the vulnerability of urban areas determined by a set of physical, economic, social and environmental factors (variables) that increase the vulnerability of areas to flood risk, and the capacity determined by a set of factors characterizing the

potential existing in these areas to reduce the risk. **The article focuses on exposure which is one of the components of risk.**

2. Materials and Methods

2.1. Risk assessment model

In the model of pluvial flood risk assessment in urban areas, a more specific definition of risk as a function of hazard (H), vulnerability (P), and exposure (E) was adopted. This qualitative approach to risk assessment provides an opportunity to explore the interactions between the last three elements.

$$R=f(H, P, E) \text{ [10]}$$

Potential negative consequences related to the flood were assessed in four categories: the impact of the flood on human life and health, economic activity, transport, and telecommunications infrastructure, as well as on cultural heritage. This approach is a modification of the definition from the Floods Directive [11], which also assesses the negative impact of flooding on the environment.

The risk assessment model used in the research includes the key elements of the urban area. The model does not include the cascading risk, and thus the reaction of environmental elements such as water, soil, and air to the negative consequences resulting from infrastructure failures that may contaminate them. Nevertheless, the model includes the importance of endangered objects in the context of potential losses. The risk assessment model adopted in the study shows the figure below.

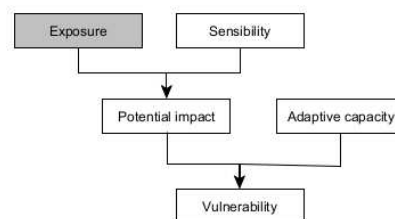


Figure 1. Key elements of vulnerability.

The following definition of exposure was adopted in the risk assessment model “Exposure: The presence of people; livelihoods; environmental services and resources; infrastructure; or economic, social, or cultural assets in places that could be adversely affected” [12]. In the flood risk assessment model, to examine the exposure of urban areas to pluvial floods, the above definition of exposure to four main criteria was adopted: “Human life and health”, “Economic activity”, “Transport and telecommunications infrastructure” and “Cultural heritage”.

2.2. Study Area

The meridional extent of the Krakow commune is 18 km, and the latitudinal length is 31 km [13]. The area is about 327 km². In geographical terms, Krakow is located at the junction of eleven physical-geographical mesoregions developed by J. Kondracki. [14]. The average altitude calculated based on DMT is 221 m a.s.l.

2.2.1. Climate

Krakow's climate, apart from radiation and atmospheric circulation factors, is influenced by local factors, mainly orographic and anthropogenic [15]. The most common is the western circulation, both cyclonic and anticyclonic (a total of over 20% of days in a year). The type of atmospheric circulation largely determines weather conditions. Convective rainfall is common in the warm half of the year.

Cyclonic circulation types are most often associated with cloudy weather, high wind speeds, and frontal rainfall. Krakow's location in a valley as well as atmospheric circulation result in

favourable precipitation conditions in the city, resulting in higher precipitation volumes than in non-urban areas. [16–18]. The analysis of meteorological data from the period 1991-2020 showed that on average in one year 171.7 days of precipitation per year, including 41.5 days with precipitation of at least 5 mm. The average annual number of days with precipitation of at least 10 mm is 17.1, and over 50 mm is only 0.3 days. The average annual rainfall is 673 mm. In the year, the maximum precipitation is marked in July, when the average monthly precipitation is 98.2 mm. The amount of precipitation from June to August is 3.5 times higher than in winter. The three main hazards to Krakow resulting from climate change are [19]:

- heat waves,
- long-term periods without rainfall combined with a maximum temperature above 25°C,
- heavy rains causing local flooding (e.g., urban floods),
- fluvial flooding.

2.2.2. Land cover

The percentage share of individual types of land use/land cover was developed based on the second BDOT10k level. The largest area is covered by green urban areas and arable land - 145.3 km² (44.5%). The total area of artificial surfaces is 94.1 km² (28.8%), of which single- and multi-family housing is 64.6 km², industrial units 10.3 km², commercial units 4.6 km², which is 19.8%, 3.2%, and 1.4% accordingly. The remaining buildings, not classified as any of the above are 14.6 km² (4.5%). A relatively large area is covered by forest and seminatural areas - 40.0 km² (12.3%). The share of other types of land cover is small and ranges from 0.1% for dump sites to 4.4% in the case of areas under roads, railroads, and airports.

2.2.3. Surface water

Krakow is located in the Upper Vistula basin. The Vistula River flows through the city from west to east over about 40 km and is the axis of the hydrographic network. River network layer for the study area presents Figure 2.

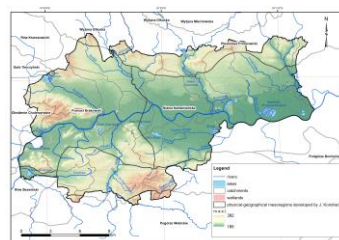


Figure 2. River network layer for the study area.

The most important left-bank tributaries are the following rivers: Sanka, Rudawa, Prądnik, Dłubnia, Suchy Jar, Kościelnicki Brook, and right-bank tributaries include: Sidzinka, Kostrzecki Brook, Pychowicki Brook, Wilga, Serafa and Podłęzanka. The most important water reservoirs include Mydlniki Ponds, Zakrzówek, Płaszowski Pond, Bagry Reservoir, Zesławice Reservoir, Nowohucki Reservoir, Brzegi and Przylasek Rusiecki.

2.3. Method of analysis

Flood risk assessment in the context of the sensibility and exposure of urban areas to pluvial floods requires not only knowledge about the risk itself, which is precipitation but also knowledge about the terrain, the degree of its sealing, the type of development, as well as the measures used to reduce this risk. The method of the Analytic Hierarchy Process (AHP) was used to rank the importance of criteria characterizing exposure in urban areas as a tool to support the identification of areas at risk of pluvial flooding. The ranking is based on expert opinion. Experts, by definition, should be specialists in the field covered by the analysis.

2.3.1. Main criteria and sub-criteria used in the AHP analysis

AHP is used as a Multi-Criteria Decision Analysis in the multi-criteria decision-making process. The problem was decomposed into goals, objectives/main criteria and sub-criteria. Based on the pairwise comparison of the main criteria and sub-criteria that was obtained from the Experts, matrices were formed. The experts were asked to select which sub-criteria is more important than the other with respect to a given main criterion and to state how much important. The table of pairwise comparison was constructed for each main criterion. This was done to compare each sub-criterion against the other with respect to the given main criterion. Another matrix was again constructed to obtain the relative weights for each main criterion with respect to the goal. Sub-criteria define areas that are characteristic from the point of view of the main criterion. Figure 3 presents the main criteria and sub-criteria for exposure assessment.

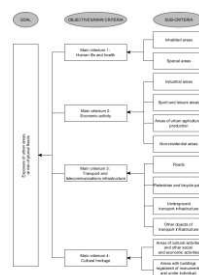


Figure 3. A three-level hierarchical structure of the characteristics of the parameters that represent urban flood exposure.

Main criterium 1: Human life and health

The criterion includes areas in which there are buildings where people stay for more than a few hours (e.g. single- and multi-family buildings, collective housing buildings, hotels, office buildings, commercial and service buildings, schools and research institutions buildings, detention centres shelters for underaged, prisons, penitentiary or correctional institution). From the point of view of the potential loss of life or health, this category also includes homeless homes, orphanages, social care homes, care and education facilities, hospices, sanatoriums, kindergartens, nurseries, hospitals, and medical care facilities. These are facilities where people are particularly sensitive to flood risk due to their age and possible mobility limitations. However, the issue of social sensitivity is much more complex and as Działek emphasizes [23] "it can no longer be treated as a static disposition of representatives of sensitive groups" but should consider its time volatility. In this respect, the issue of social sensitivity was not analysed in the studies. The studies used a classic approach to assessing the social loss, which involves taxonomically evaluating older people as more sensitive.

Main criterium 2: Economic activity

This criterion includes urban and economic activity areas where people stay for a limited time. These are industrial areas like buildings and industrial and storage areas, forests areas: forests, copse, agricultural areas: plantations, orchards, crops on arable land, and others including mountain pine, shrubs, allotment gardens, nurseries forest, decorative plants nurseries, grassy vegetation, screes, heap or rock rubble, rocky terrain, sandy or gravel terrain, remaining unused land, squares, landfills, industrial waste storage area, dump areas, the area under technical equipment or buildings.

Main criterium 3: Transport and telecommunications infrastructure

The criterion includes areas with buildings important from the point of view of urban mobility, in which the time of stay of people is short. However, hot spots, such as underground passages may pose a direct threat to human life and health. These buildings include national roads, regional roads, district roads and communal roads (e.g. trackways, pedestrian and bicycle paths, avenues and paths, tunnels, including underground passages, as well as bus and railway stations, hangars, bus and tram stations, garages, and terminal buildings). The consequences of flooding transport infrastructures mainly concern indirect losses, such as interruption of access roads from/to flooded areas, interruptions in the provision of services, interruptions in traffic and urban mobility, organizational dysfunctions, interruption of railway transport, metro, etc. This category also includes areas where there is telecommunications infrastructure.

Main criterium 4: Cultural heritage

This criterion includes areas with commonly available cultural buildings such as houses of culture, theatres, cinemas, philharmonics, zoos, animal shelters, and museums and libraries, for example, art galleries, and archives. There are also buildings entered in the register of monuments and under individual conservation protection, excluding immovable, archaeological cultural assets beyond immovable archaeological cultural goods.

2.3.2. A survey using the AHP method

A group of experts took part in the survey. The survey aimed to examine the exposure of urban areas to pluvial floods. The experts had to answer two questions. The first was regarding the main criteria, and the second was concerned with sub-criteria.

First question: In your opinion, what is more, important in the context of protection against pluvial floods from the point of view of potential losses?

Second question: What do you think is more important in terms of potential losses?

The survey consisted of the assessment of the main criteria and sub-criteria. Sub-criteria define the areas relevant to the main criteria. Workshops were organized for experts professionally involved in water management. During the workshop authors of a survey presented the concept of the study, and its purpose and discussed the project of the questionnaire along with the instructions for its completion. The AHP method and the principles of conducting the assessment are also presented.

This paper aims to determine the most important criteria for exposure evaluation of urban areas of the pluvial flood. The task of the experts is evaluation criteria using the scale shown in Table 1.

Table 1. The fundamental scale of absolute numbers [24].

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgement slightly favour one activity over another
5	Strong importance	Experience and judgement strongly favour one activity over another
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation

2.3.3. Obtain of the function of a synthetic variable

The value of the integrated exposure index is presented in an unit size of 500 m x 500 m. The formula aggregating normalized diagnostic features is the arithmetic mean:

$$s_i = \frac{1}{m} \sum_{j=1}^m z_{ij} \cdot w_j$$

1

where:
s_i – value of the synthetic feature in the i-th object, *i* = 1, 2, ..., n
w_j– weight of j-th feature, j=1,2, ..., m.

3. Results

The first part of the chapter presents the results of the analysis done on experts’ opinions on the most important criterion to protect against pluvial floods from the point of view of potential losses (Table 2–Table 11). The second part of the chapter presents the results of the integrated exposure index (IEI).

3.1. Ranking of main criteria and sub-criteria

The following pairwise comparison matrices were obtained based on experts’ judgments of the main criteria and the sub-criteria.

Table 2. Pairwise comparison matrix for the main criteria.

Pairwise comparison matrix	KG1	KG2	KG3	KG4
KG1	1,000	8,002	7,348	7,393
KG2	0,125	1,000	1,260	1,070
KG3	0,136	0,794	1,000	0,742
KG4	0,135	0,935	1,348	1,000
Sum	1,396	10,731	10,956	10,205

Table 3. Normalization matrix for the main criteria.

Normalization matrix	KG1	KG2	KG3	KG4	Priority vectors
KG1	0,716	0,746	0,671	0,724	0,7143
KG2	0,090	0,093	0,115	0,105	0,1008
KG3	0,097	0,074	0,091	0,073	0,0838
KG4	0,097	0,087	0,123	0,098	0,1013

C.R. = 0,06 %.

Table 4. Pairwise comparison matrix for the sub-criteria with respect to the main criterion – KG1.

Pairwise comparison matrix	KC1-1	KC1-2
KC1-1	1,000	0,553
KC1-2	1,809	1,000
Sum	2,809	1,553

Table 5. Normalisation matrix for the sub-criteria with respect to main criterion – KG1.

Normalization matrix	KC1-1	KC1-2	Priority vectors
KC1-1	0,356	0,356	0,356
KC1-2	0,644	0,644	0,644

C.R. = 0.0.

Table 6. Pairwise comparison matrix for the sub-criteria with respect to the main criterion – KG2.

Pairwise comparison matrix	KC2-1	KC2-2	KC2-3	KC2-4
KC2-1	1,000	5,357	4,718	4,333
KC2-2	0,187	1,000	0,804	1,070
KC2-3	0,212	1,244	1,000	1,619
KC2-4	0,231	0,858	0,618	1,000
Sum	1,630	8,459	7,140	8,022

Table 7. Normalisation matrix for the sub-criteria with respect to main criterion – KG2.

Normalization matrix	KC2-1	KC2-2	KC2-3	KC2-4	Priority vectors
KC2-1	0,613	0,633	0,661	0,540	0,612
KC2-2	0,115	0,118	0,113	0,133	0,120
KC2-3	0,130	0,147	0,140	0,202	0,155
KC2-4	0,142	0,101	0,087	0,125	0,114

C.R. = 0,3%.

Table 8. Pairwise comparison matrix for the sub-criteria with respect to the main criterion – KG3.

Pairwise comparison matrix	KC3-1	KC3-2	KC3-3	KC3-4
KC3-1	1,000	5,593	1,293	0,971
KC3-2	0,179	1,000	0,215	0,187
KC3-3	0,774	4,651	1,000	0,733
KC3-4	1,029	5,357	1,364	1,000
Sum	2,982	16,601	3,872	2,891

Table 9. Normalisation matrix for the sub-criteria with respect to main criterion – KG3.

Normalization matrix	KC3-1	KC3-2	KC3-3	KC3-4	Priority vectors
KC3-1	0,335	0,337	0,334	0,336	0,336
KC3-2	0,060	0,060	0,056	0,065	0,060
KC3-3	0,260	0,280	0,258	0,254	0,263
KC3-4	0,345	0,323	0,352	0,346	0,342
C.R. = 0,2%.					

Table 10. Pairwise comparison matrix for the sub-criteria with respect to the main criterion – KG4.

Pairwise comparison matrix	KC4-1	KC4-2
KC4-1	1,000	0,417
KC4-2	2,268	1,000
Sum	3,268	1,417

Table 11. Normalisation matrix for the sub-criteria with respect to main criterion – KG4.

Normalization matrix	KC4-1	KC4-2	Priority vectors
KC4-1	0,306	0,294	0,300
KC4-2	0,694	0,706	0,700
C.R. = 0.0.			

In Table 12 the priorities and the rank for each main criterion has been calculated.

Table 12. Final priority vector for the main criteria.

Main criteria	Priorities	Rank
Human life and health, KG1	0,7143	1
Economic activity, KG2	0,1008	3
Transport and telecommunications infrastructure, KG3	0,0838	4
Cultural heritage, KG4	0,1013	2

The global priority vector was obtained by multiplying the priority vectors of the main criteria by the priorities for each sub-criteria for each objective. In Table 13 the priorities and the rank for each sub-criteria with respect to each criterion have been calculated.

Table 13. Priority vectors and ranking of the sub-criteria given each main criterion.

Main criteria	Sub-criteria		Local weights	Global weights	Local ranking	Global ranking
KG1	KC1-1	Inhabited areas	0,356 (36%)	0,254 (25%)	2	2
	KC1-2	Special areas	0,644 (64%)	0,460 (46%)	1	1
KG2	KC2-1	Industrial areas	0,612 (61%)	0,062 (6%)	1	4
	KC2-2	Sports and leisure areas	0,120 (12%)	0,012 (1%)	3	10

KG3	KC2-3	Areas of urban agricultural production	0,155 (16%)	0,016 (2%)	2	9
	KC2-4	Non-residential areas	0,114 (11%)	0,011 (1%)	4	11
	KC3-1	Roads	0,336 (34%)	0,028 (3%)	2	7
	KC3-2	Pedestrian and bicycle paths	0,060 (6%)	0,005 (1%)	4	12
	KC3-3	Underground transport infrastructure	0,263 (26%)	0,022 (2%)	3	8
KG4	KC3-4	Other objects of transport infrastructure	0,342 (34%)	0,029 (3%)	1	6
	KC4-1	Areas of cultural activities and other social and economic activities	0,300 (30%)	0,030 (3%)	1	5
	KC4-2	Areas with buildings registered of monuments and under individual conservation protect	0,700 (70%)	0,071 (7%)	2	3

It can be observed in Table 14 that the value of the consistency ratio (C.R.) is less than 0.10, which means all the matrices are within an acceptable range.

Table 14. The value of the consistency ratio (C.R.) for aggregated experts' judgments of the main criteria (KG1-4) and sub-criteria (KG1, KG2, KG3, KG4).






Main criterion symbol/ Sub-criterion symbol	Consistency ratio [%]
KG1-4	0,6
KG1	0,0
KG2	0,3
KG3	0,2
KG4	0,0

3.2. Integrated exposure index

To determine the importance of the main and sub-criteria characterising the exposure of urban areas to pluvial floods, the method of hierarchical problem analysis was used. Indicators of area exposure to pluvial floods were obtained for each of the main criteria. The synthetic measure of the integrated exposure index (IEI) is the arithmetic weighted mean of standardized values of diagnostic features (from KC1-1 to KC4-2) characterising exposure and their weights. Obtained values of the

synthetic variable were classified using the method of natural breaks. The classes determine the level of exposure of a multidimensional object in Krakow to a pluvial floods. The formula for determining the synthetic variable characterising IEI and indicators for the main criteria is presented in Formula 1. The values of the sub-criteria indicators characterising the main criteria were obtained by summing up their standardized values. The partial criteria are shown in Figure 3. The graphical interpretation of the exposure level is presented in Table 15.

Table 15. The graphical interpretation of the exposure level.

Colour	Exposure level
	None or very small
	Small
	Medium
	High
	Very high

The spatial distribution of the exposure index characterizing "Human life and health" shows that the areas with the highest exposure in Krakow are in the central part of the city, mainly in the districts of Stare Miasto, Grzegorzki, Krowodrza, and Bieńczyce. The districts where the indicator has average or area), Bronowice (eastern area), Zwierzyniec (north-eastern area), Debniki (north-eastern area), Swoszowice (northern area), Bieżanów – Prokocim (western part), Pradnik Czerwony and Pradnik Biały (southern area). The spatial distribution of the E_KG1 index is shown in Figure 4.

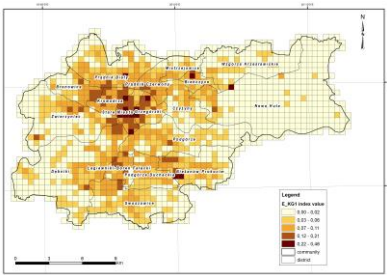


Figure 4. The spatial distribution of the E_KG1 index (“Human life and health”) in Krakow.

Very high and high values of the E_KG2 index characterising "Economic activity" (Industrial areas, “Sports and leisure areas”, “Areas of urban agricultural production”) can be distinguished in four main hot spots in the Krakow districts of Nowa Huta, Czyżyny, Podgórze, Bieżanów - Prokocim (northern – eastern) and locally in Bronowice, Krowodrza, Swoszowice. The spatial distribution of the indicator is shown in Figure 5.

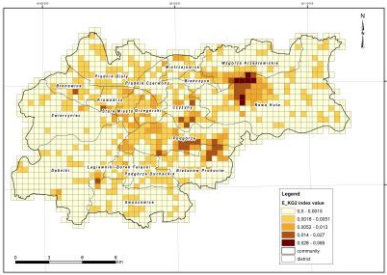
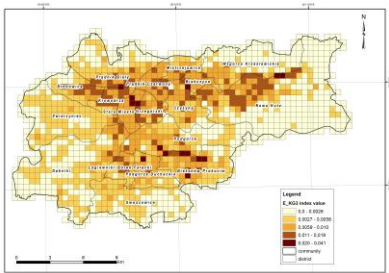


Figure 5. The spatial distribution of the E_KG2 index (“Economic activity”) in Krakow.

The spatial distribution of the exposure index characterising the “Transport and telecommunications infrastructure” in Krakow is presented in Figure 6. The main hot spots of areas with very high and high index values are in the northern and central parts of Krakow and locally in

the districts of Lagiewniki - Borek Falecki, Podgorze Duchackie, Biezanow - Prokocim, Podgorze and Debniki (north-eastern area).



— 0,1013. The average consistency ratio (C.R.) value is 0.6%, which means a high degree of agreement between the assessments. The results show that the main criterion of “Human life and health” is the most important in the context of protection against pluvial floods because of potential losses. The importance of the other main criteria is at the same level, ranging from 8.3% to 10.1%. Such a distribution of expert judgements greatly impacts the weights of sub-criteria in the global ranking, as presented in Table 13. The second place was awarded to the “Cultural heritage”, but with a very slight advantage over the “Economic activity's” criterion. The experts indicated “Transport and telecommunications infrastructure” as the least important. The results of AHP show that the most important criterion in the assessment of exposure in urbanised areas are “Special areas”, i.e. areas where people who are particularly sensitive to flood risk due to their age and possible mobility restrictions reside. These are the areas where homeless homes, orphanages, social care homes, care and education facilities, hospices, sanatoriums, kindergartens, nurseries, hospitals, and medical care facilities are. Sub-criteria such as “Pedestrian and bicycle paths”, “Non-residential areas” and “Sports and leisure areas” had little importance to the experts (weight 1%), considering the protection of these areas against potential losses. In addition, the low weight of the sub-criterion “Sport and leisure areas” may result from the fact that some of these areas may additionally perform a retention function and thus may reduce the risk, although this function was not researched in the survey. Distant places in the general ranking were given to "Areas of urban agricultural production" and "Underground transport infrastructure" (2% weight). A slightly higher weight (3%) was given to such sub-criteria as "Roads", "Other objects of transport infrastructure" and "Areas of cultural activities and other social and economic activities". As many as three out of four sub-criteria characterizing "Economic activity" were ranked low in the general ranking (weight from 1% to 2%). The exception is the main criterion "Industrial areas", which in the global ranking received a weight of 6%, thus receiving an average position in the ranking, like "Areas with buildings registered of monuments and under individual conservation protect" (7%). Although among the sub-criteria characterizing “Economic activity”, “Industrial areas” rank highest with a weight of 61%. In the general ranking, the sub-criteria characterising the main criterion “Human life and health” are in the leading positions, these are “Special areas” and “Inhabited areas”. They received priorities of 46% and 25%, respectively. Thus, confirming that human life is the highest priority of protection against pluvial floods (total weight 71%). Standard deviations of experts' assessments for partial criteria under individual main criteria are “Human life and health” - 14.6%, “Economic activity” - 2.5%, “Transport, and telecommunications infrastructure” - 1.1%, and “Cultural heritage” - 2.9 %. This proves that individual experts' assessments are slightly differentiated, the main criterion of “Human life and health”, which is presented in table 15.

Table 15. Assessment of the dispersion of experts' judgements.

	Human life and health	Economic activity	Transport and telecommunications infrastructure	Cultural heritage
standard deviation [%]	0,6	2,5	1,1	2,9
arithmetic average [%]	0,0	2,5	2,1	5,1

5. Conclusions

With the help of GIS and multicriterion techniques, useful information for pluvial flood risk analysis can be acquired. The method of the Analytic Hierarchy Process was used to rank the importance of criteria characterizing exposure in urban areas as a tool to support the identification of areas at risk of pluvial flooding. The ranking is based on experts’ judgements. Experts, by definition, should be specialists in the field covered by the analysis. The article focuses on exposure which is one of the components of risk. Mapping of integrated exposure index mapping follows a multi-parametric approach and integrates of the flooding losses for a specific area. Exposure of urban area

assessment on pluvial flood for four criteria "Human life and health", "Economic activity", "Transport and telecommunications infrastructure", and "Cultural heritage" was evaluated. According to the methodology used in the article, the most important criterion for assessing the exposure of urban areas to pluvial floods is "Human life and health" while the other main criteria are less important in that field.

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