Application of the Threats Matrix in Procedure of Space Safety Development

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Abstract. Start Human Ensuring security belongs to the tasks of public administration. It consists in preventing crisis situations and planning actions in the case of their occurrence. In order to ensure space safety, great importance was focused on forecasting the possibility of occurrence of both natural and anthropogenic threats. This space, by characterizing the features present in specific places, generates or eliminates various threats. Appropriate early identification of endangered places, consisting in the identification, evaluation and assessment of the space features, gives the possibility of eliminating possible crisis situations.

The article presents a procedure for the construction and use of threats matrix in the process of safe space development (a safe planning space). The Authors show one of the method of forecasting the occurrence of natural and anthropogenic threats in a given area and method for determining the probability of their occurrence. The matrix developed by combining the features of space (assigned to individual object classes according to the Topographic Data Base) and natural and anthropogenic threats gives the possibility of their identification and location. The study was conducted on the area of University campus in Olsztyn (Kortowo), Poland.

1. Introduction

Space is associated with an infinite number of features. The accumulation of certain features in one place results in a variety of hazards. The identification of such areas will enable the selection of a place to which special attention should be paid and the preparation of action plans if a potential hazard becomes real. All hazards have their specific location, as all things happen at a specific time and within a specific space. Therefore, the features of a space are the main source of data on hazards that may emerge. Currently, such characteristics are considered equivalent to all images of features, properties of a space, its condition and to the attributes with specific coordinates and, frequently, an already specified time.

Hazards are manifestations of risks related to a specific place, time, function and resources of a space. They can be identified on an intuitive basis, as every person involved in the identification of risks will intuitively use their experience and associate it with the above-mentioned context [1]. The identification and analysis can be carried out using standard risk classifications or e.g. hazard lists. The aim of such a risk analysis is to develop a vision of the manner in which a hazard may occur. Will it be
a hazard likely to result in the loss of health or life, or will it only be an incident, a minor disruption, a conflict? The development of a hazard is affected by both the mechanism of its emergence and the local susceptibility to its emergence. On the other hand, a risk assessment involves the development of a measure for a risk, which enables a comparison of the possible consequences of the emergence of dangers. The analysis should separately refer to the causes and to the mechanism of risk emergence. The results of risk analyses are the core of decisions taken regarding crisis management and the design of safe planning space. The potential consequences of events and the probability of their occurrence provide the main information on the risk level and are used in taking significant decisions regarding the planning a safe space. In the process of spatial analysis, theories of network analyses, including the scale-free network theory, are employed [2,3,4], genetic algorithms, fuzzy sets and rough sets theory [5,6].

In space administration, the most important thing is to strive for an improvement in people’s living conditions and for ensuring order in each area of life. At the same time, space, as a limited good, must be subject to certain legal and administrative regulations. It must also be planned and used in accordance with the commonly recognized social, aesthetic and cultural values. The main aim of spatial planning is to create a living environment for people so that the spatial order is obtained. Secondary aims are defined by the division criteria, for example, protection against aggression, creating conditions for reasonable space administration and striving for a balanced standard of living [7]. These aims are achieved through defining the intended use and the manner of development of an area, resulting from the current socio-economic needs. Therefore, they should be as close as possible to optimum uses, with account taken of possible hazards and spatial conflicts.

2. Natural and anthropogenic hazards, spatial conflicts
One of the major needs in human life is a sense of security which is necessary for the proper functioning and development of a society. Security is a social, economic, legal, cultural, military and environmental phenomenon and a factor that is determined by individual lives. In each case, however, it is associated with a sense of permanence and stability of a certain state of affairs and with a sense of a lack of hazards. Many events that have occurred over several recent years in Poland and worldwide have affected the way in which people perceive security. Such events make us reflect on our security, on prevention and on the preparation for hazards.

In terms of the sources, events (hazards) can be divided into:

1. natural:
   - floods,
   - anomalies and adverse atmospheric phenomena: frosts and droughts, black ice, intense snowfalls, limited visibility and fogs, strong winds and hurricanes, landslides;

2. anthropogenic:
   - chemical and environmental hazards,
   - radiation hazards,
   - biological hazards,
   - fires,
   - power/ gas supply/ heat distribution/ water supply and sewage failures,
   - road, rail, and water disasters,
   - aviation accidents or incidents,
   - terrorist hazards,
   - hazards to public policy and public security.

A natural disaster is an event associated with the action of the forces of nature. Anthropogenic hazards are adverse and unexpected events emerging as a result of human activities, human error, equipment failure or long-term accumulation of factors contributing to the deterioration of the technical condition of objects.
A spatial conflict is an incompatibility in the intended use of neighboring areas, which is related to adverse external consequences, e.g. degradation of the natural environment and results in a decreased effectiveness in their functioning. The basic factor that can limit the emergence of spatial conflicts is an appropriate spatial policy. Spatial planning and development should help in the management of conflict situations. As regards space, the main factor causing conflicts is its limited nature, which is the subject of competition between economic operators. A conflict occurs when the balance of a system is disturbed, i.e. when one function is excessively extended. Due to the factor of time, conflicts in spatial development can be divided into historical, current and potential [8]. Conflicts within a space can be considered on at least three planes (reference points): conflicts occurring when new functions are developed, conflicts occurring (or caused) when using particular functions, conflicts caused by changing human needs and the mutual expansion of particular functions [9,10]. The development of these functions is determined by many natural and anthropogenic determinants which are, or can be, a source of conflicts between man and nature. The developed hazard matrix which, using geoinformation [11,12], predicts and locates potential hazards, can eliminate or limit the risk of possible events.

3. Development of a hazard matrix
A space is characterized by an infinite number of features which are conducive to various events. The accumulation of certain features results in an increased probability of the emergence of specific events. The accumulation can be a uniform hazard in nature (only one type of a hazard occurs) or a multiplied hazard in nature. Within a space, there are features which are conducive to the emergence of hazards and ones which eliminate them. A space itself is neutral but it changes with the occurrence of an anthropogenic factor. Sufficiency early determination of places or components of a space that attract attention can, to a large extent, help to develop appropriate action plans or scenarios in the event of hazards. The most important thing is the estimation of the value of probability of the emergence of these hazards. This can be estimated based on an analysis of events occurring in history, or by the method of experts based on their experience. The probability of the emergence of a hazard in a particular area can be estimated by the application of feature matrices referred to as hazard matrices. A hazard matrix is a table which, in the rows, contains features of the space that are important due to the hazard under analysis, and, in the columns, contains the hazards under analysis. The accumulation of several features in the same area is conducive to the occurrence of hazards to various degrees – the more features causing a hazard, the higher the possibility of its emergence [13].

Features are inventoried in various ways. To this end, a grid of basic fields of assessment is plotted onto a map of, e.g. the situation of the area. The shape of these fields and their size are selected depending on the subject of the analysis. Each of such fields presented in the map is numbered, which assigns a general location to the features occurring in a particular area. A map of hazards is thus compiled, i.e. a map presenting a geographic area covered by the range of a hazard, with an account taken of various event scenarios [14]. To develop the hazard matrix, selected features were used from the topographic object database BDOT which is one of the most important components of Poland’s spatial information infrastructure. The features were selected in relation to both natural and anthropogenic hazards and to the land under analysis. In order to determine whether a particular feature contributes to the emergence of a particular hazard, a survey was carried out. Drawing up an appropriate questionnaire enabled the collection of data from all respondents in the same form. Respondents provided answers in the binary system (the so-called classical method). “0” meant that a particular hazard was not determined by a selected feature of the area, while “1” meant that the hazard was determined by the selected feature. While developing hazard matrices with these methods, we can inter alia determine the features of the space which cause hazards, their mutual relations and correlations, the probability of the occurrence of a hazard and assess the significance of the hazard-causing attributes. During the analysis of the questionnaires, in the matrix developed using the classical method, the values for which over 50% respondents answered “1” were adopted as dependent responses, i.e. “1”. Table 1 shows the results of the survey in the form of a hazard matrix.
| Hazards | Code | Description |
|---------|------|-------------|
| Floods | 1    | long-term frosts and droughts |
|        | 11   | strong winds and hurricanes |
|        | 111  | landslides |
|        | 110  | hail, black ice |
|        | 10   | intense snowfalls |
| Chemical and environmental hazards | | |
| Radiation hazards | | |
| | epiphenotolics | |
| Biological hazards | | |
| Fires | | |
| | power | |
| Failures | | |
| | gas supply | |
| | heat distribution | |
| | water supply and sewage | |
| | road | |
| | rail | |
| | water | |
| Disasters | | |
| Hazards to life and health | | |
| Hazards to property | | |
| Hazards to public policy | | |
| Hazards to road safety | | |
| Juvenile delinquency | | |
| Hazards to family structure and functioning | | |
| Terrorist hazards | | |

Table 1. Hazard matrix

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| Location | industrial | cultural facilities | museums, libraries | hospitals | religious sites | historic assets | bridge | pedestrian tunnel | tunnel | outdoor swimming pool | stadium | smokestack | lighting mast | power pole | telecommunication tower | scenic viewpoint | sediment tank | tank for propellants or gas | breakwater | bank protection | flood control dyke | water intake | fuel dispensers | combined heat and power station | power station | gas-works | livestock farm | mine | wastewater treatment plant | landfill | materials recovery facility | marketplace | aerodrome | car park | fuel station | park | higher education facility | cemetery | military training area | bus stop | historic ruins | windmill | wetland |
|----------|------------|---------------------|--------------------|-----------|----------------|----------------|--------|------------------|--------|----------------------|---------|----------|------------------|------------|-----------------------|----------------|--------------|-------------------|------------|---------------------|----------------|----------------|-----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|--------------|--------------|---------|----------|-----------|----------|
Legend of table 1:
SW - water network; SK - transport network; SU - utilities network: (SULN - overhead power line: SULN02 - high voltage, SULN03 - medium voltage, SULN04 - low voltage, SULN05 – telecommunication), (SUPR – piping); PT - land cover: WN - multi-family housing, MN - single-family housing, H-U - commercial and service buildings; BU - building, structures, and equipment, KU - land use complexes, OI - other objects.

4. The application of the threats matrix in procedure of space safety development – case study
The case study was carried out for a district of the city of Olsztyn, namely Kortowo. A grid of hexagons with a side of 120 metres was plotted on an orthophotomap of Kortowo district. The district was divided into 97 fields numbered from 1 to 97 – Figure 1.

The process of designing a safe planning space using hazard matrices involves the inventory of features and spatial objects, and the development of a hazard matrix for each of the area under analysis. An example of such an inventory for Area No 21 is presented in Table 2.

For each of the 97 fields, the features of the area that are found within it, and hazards affected by these features were determined. On each of the fields into which the Kortowo district has been divided, potential hazards were plotted. A detailed analysis of the risk of emergence of particular hazards is presented in Figure 2 in the form of a hazard map.
Table 2. Hazard matrix developed for Area No 21

| Code | Area 21 | Hail, black ice | Chemical and environmental hazards | Epiphytotics | Fires | Failures power | Failures gas supply | Failures heat distribution | Failures water supply and sewage | Disasters road | Hazards to road safety |
|------|---------|-----------------|------------------------------------|--------------|------|---------------|---------------------|--------------------------|----------------------------|----------------|-----------------------|
| SK   | arterial road | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1
| SK   | low voltage | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0
| SK   | telecommunication | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0
| SK   | heat distribution | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0
| SK   | gas supply | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0
| SK   | sewage | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0
| SK   | water supply | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0
| PT   | grasses | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0
| PT   | a square | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0
| BU   | fuel dispensers | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0
| KU   | car park | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0
| KU   | fuel station | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0

Figure 2. Hazard map. Legend: Pw- Floods, Dms- long-term frosts and droughts, Sw- silne strong winds and hurricanes, O- landslides, Gg- hail, black ice, Ioś- intense snowfalls, Zce- Chemical and environmental hazards, Zr- Radiation hazards, Zbc- Biological hazards: epidemics, Zbz- Biological hazards: epizootics, Zbr- Biological hazards: epiphytotics, Pż- Fires, Ae- Failures power, Ag- gas supply, Ac- heat distribution, Aawk- water supply and sewage, Kd- Disasters road, Kk- Disasters rail, Kw- Disasters water, Wl- Aviation accidents or incidents, Zż- Hazards to life and health, Zm- Hazards to property, Zpp- hazards to public policy, Zbrd- hazards to road safety, Zpa- Juvenile delinquency, Zsfr- hazards to family structure and functioning, Zt- Terrorist hazards.
The classical method took into account the hazards for which a majority of respondents marked the dependence on a particular feature of the area. This results in the matrices only showing whether or not such a hazard may occur in a particular area. However, these matrices do not take into account the degree of membership of these disasters.

5. Conclusions
The referenced methods for identification and analysis of potential hazards and conflicts can help in the process of crisis management, in the minimization of the consequences of spatial conflicts, and in planning actions in the event of their emergence. As a result of the application of the cited methods, the possibility for generating hazards by specific spatial features is determined. The identification of such places is also important with respect of spatial planning and management through increasing the level of space security. Actions in this field would involve reducing the risk of the emergence of a hazard through, e.g. the elimination of features causing a hazard or their transfer. An analysis of the obtained geoinformation should be the first stage in the process of drawing up local area development plans, which, as regards space administration, will minimize the emergence of crisis situations [15,16].

As regards the district of Kortowo, many hazards, both natural and anthropogenic, occur there. The presence of standing waters and a river contribute to a flood hazard. Forests, woodlots, shrubs and grasses contribute, to a large extent, to a fire hazard, and to the emergence of epizootics and epiphytotics. Chemical and environmental hazards are also a frequently occurring hazard. It follows from the analysis that most disasters can occur in areas with single-family and multi-family development as well as higher education facility. The fewest disasters can occur in forested, wooded, and grassy areas, in which fires are the main problem.

References
[1] A. Kosieradzka, J. Zawiła- Niedźwiecki (red.), „Zaawansowana metodyka oceny ryzyka w publicznym zarządzaniu kryzysowym”. Edu-Libri, Kraków- Legionowo, 2016.
[2] A. Kowalczyk, “The use of scale-free networks theory in modeling landscape aesthetic value networks in urban areas”, GEODETSKI VESTNIK, Vol. 59, pp.135-152,2015. DOI: 10.15292, ISSN 0351-0271.
[3] A. Kowalczyk, “The analysis of networks space structures as important elements of sustainable space development”, 10th International Conference Vilnius Gediminas Technical University- "Environmental Engineering", 2017.
[4] T. Bajerowski, A. Kowalczyk, M. Ogrodniczak, “Network structures in developing uniformed service intervention maps”, 17th International Multidisciplinary Scientific Geoconference SGEM 2017, Conference Proceedings Volume 17, Issue 23, pp. 619-624, 2017.
[5] A. Biłozor, S. Czyża, K. Szuniewicz, „Wykorzystanie algorytmów genetycznych do prognozowania stanów przestrzeni miejskiej w procesie proaktywnego przeciwdziałania zagrożeniom”. Acta scientiarum polonorum Administratio Locorum, Wydawnictwo UWM, Olsztyn, 2013.
[6] M. Renigier-Biłozor, A. Biłozor, Opracowanie systemu wspomagania podejmowania decyzji z wykorzystaniem teorii zbiorów rozmytych oraz teorii zbiorów przylbliżonych w procesie kształtowania bezpieczeństwa przestrzeni. Acta scientiarum polonorum Administratio Locorum, Wydawnictwo UWM, Olsztyn, 2013.
[7] R. Cymerman (red.), „Postawy planowania przestrzennego i projektowania urbanistycznego”. Wydawnictwo UWM, Olsztyn,2009.
[8] M. Przewoźniak, „Konflikty w zagospodarowaniu przestrzennym obszaru przybrzeżnego województwa pomorskiego”, praca wykonana na zamówienie Wojewódzkiego Biura Planowania Przestrzennego w Słupsku w ramach realizacji projektu „PlanCoast” (Interreg IIIB CADSES), Gdańsk, 2007.
[9] A. Szczepańska, „Procesy decyzyjne w gospodarce przestrzennej”, Space-society-economy. Instytut Zagospodarowania Środowiska i Polityki Przestrzennej, WNG, UL, Łódź, 2009.
[10] A. Biłozor, “Urban land use changes forecasting”. 9th International Conference on “Environmental Engineering”. 22-23 May 2014. Vilnius, Lithuania, 2014. ISBN 978-609-457-4.

[11] A. Biłozor, M. Renigier-Biłozor, „The use of geoinformation in the process of optymalizing the use of land”. 9th International Conference on “Environmental Engineering”. 22-23 May 2014. Vilnius, Lithuania. ISBN 978-609-457-4

[12] M. Renigier-Biłozor, A. Biłozor, “The use of geoinformation in the process of shaping a safe space”. 16th International Multidisciplinary Scientific GeoConferences SGEM. Bulgaria ISBN 978-619-7105-60-5, B.2 Vol. 3, pp 549-556, 2016.

[13] T. Bajerowski, A. Kowalczyk, „Metody geoinformacyjnych analiz jawnoźródłowych w zwalczaniu terroryzmu. Wydawnictwo UWM, Olsztyn,2013.

[14] K. Kocur-Bera, „Uwarunkowania przestrzenne zarządzania kryzysowego”. Acta scientiarum polonorum Administratio Locorum, Wydawnictwo UWM, Olsztyn, 2012.

[15] A. Biłozor, M. Renigier-Biłozor, Optimization and polioptimization in the management of land. GeoConference on Informatics, GeoInformatics and remote sensing. SGEM2015 Conference Proceedings, ISBN 978-619-7105-35-3/ISSN 1314-2704, June 18-24, 2015, Book2 Vol. 2, pp 1011-1018, 2015.

[16] A. Biłozor, M. Renigier-Biłozor, “The procedure of assessing usefulness of the land in the process of optimal investment location for multi-family housing function”. Procedia Engineering. Volume 161, 2016, Pages 1868–1873, 2016. World Multidisciplinary Civil Engineering-Architecture-Urban Planning Symposium 2016, WMCAUS 2016. DOI: 10.1016/j.proeng.2016.08.720