GEOINFORMATION ANALYSIS AND MARKET VALUE OF SAFE SPATIAL – SAFE PLACE

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Abstract

The marked value of spatial identified with the market value of real estate, in addition to many other factors, is also determined by the safety status of the spatial (place), and the safety of place is determined by the state of its features. The analysis of the status of spatial features that determine its safety lies in their geoinformation inventory and subsequent evaluation and valorisation allowing for the development of, inter alia, hazard maps and comparative analysis, as a result of which we can determine the share of space safety in the market value of real estate located in it. The article presents theoretical considerations on space safety leading to proposals for the practical use of known methods for estimating the value of non-market goods to assess the market value of a safe space based on data obtained from geoinformation analysis.

Key words: market value, spatial safety, value of spatial safety

Introduction

Determining the state of spatial safety, which provides the basis for rational, optimal development of the planning space, is similar (from a methodological point of view) to assessment and valuation of any qualitative good.

For this reason, it would be worthwhile to try to adapt for this purpose some already established methods for evaluating such goods - for instance, an evaluation of landscape value or assessment of the environmental condition (BAJEROWSKI et al., 2007; BIŁOZOR et al., 2018; KOWALCZYK, 2015, 2016, 2017).

The useful value of a safe space is generally unquestionable - it is obvious. People want to live in and be surrounded by an environment with high safety status.

Undoubtedly, space, demonstrating a high useful value, also has a high market value from the perspective of its safety, which is expressed, in its simplest dimension, in high real estate prices.

Therefore, apart from the problems of assessment and valuation of spatial safety, it is also necessary to carry out (not less important) an evaluation of spatial safety, the useful value of which must have a market value. It becomes important to evaluate how much it can cost to plan and then to implement a spatial design project that would be considered safe, although in the general meaning safety is "priceless", since it is one of the basic conditions of human existence.

Definition: Spatial safety is the characteristics of a specific place and time which, with a specific likelihood, which favour the occurrence (emergence) of specific crisis events (phenomena) or, with a specific likelihood, relatively continuously keeps this space in a condition of unacceptable perception of specific risks.

With safety thus defined, its condition in space is the function of the configuration (or a group) of characteristics (geo-information), as a set of features occurring in a given area in correlation with the perception of safety in the general meaning of this term (BAJEROWSKI, 2003).

However, spatial safety does not result directly from the state of its characteristics - it results from the competence and experience of a human being being in this space. Isolated, dehumanised space is neutral - it is neither safe nor dangerous. Two people with different history can perceive the same space in a quite a different manner. This is an intuitive assessment, but it gives rise to expert evaluation. This means that experts on the entire range of specific risks resulting from the configuration of spatial characteristics should participate in the evaluation of safety status and that there is no general notion for spatial safety – it can be considered only in the context of specific risks.

Identification of specific risks resulting from a specific configuration of spatial features can be conducted by experts, since "common" people do not perceive important correlations that can be observed by experts as a result of their knowledge and, above all, experience. Expert opinions also contain an intuitive load, but expert knowledge often replaces still imperfect, although objectivised knowledge gathered through analytical software.

Is safety a feature and characteristic of space or is it a psychological and sociological category independent of the safety status of space?

It cannot be a category separated from spatial conditions, although the state of safety felt in a specific place directly depends on those spatial conditions. However, as it was emphasized above, the same characteristics of space cause fear and anxiety in some people, while in others they do not, or do, but to a much lower degree. In other words, it is also the result of life experience and knowledge of people evaluating this status. The same situation concerns quality criteria. For example, the esthetical value of a landscape is something that is absolutely determined by the features of space, but also, and on equal basis, by the perception of aesthetic values by specific persons, and each person has his or her own history, knowledge and aesthetic experience. Consequently, there is nothing unusual or difficult in the evaluation of landscapes, and likewise, there should not be any major problems in evaluating the condition of spatial safety (or perhaps the status of human safety in space). Approaches of this type must be useful.

Therefore, the monetary evaluation of the spatial safety status, e.g. using the replacement cost method, willingness to pay, etc. also must have useful application for evaluation of spatial safety status.

Value of spatial safety

A claim could be made that safety has a value, which can be expressed in two dimensions - a useful value and a market value, with the latter obviously resulting from the former.

Spatial safety clearly has a value. In caring about its status, we are willing to bear both the direct and indirect costs of restoring the expected condition of space and costs of maintaining it in this state. However, since safety cannot be bought, it does not have a market measure of value, i.e. a price.

Spatial safety is a feature of space which, like other quality features, is not directly traded in the market - nobody sells a landscape value or spatial safety – but those values directly contribute to the value of a real estate demonstrating specific landscape condition or spatial safety state. However, since properties are traded, they have a market value and prices. People are willing to pay more for high values of such features while buying real estates with such characteristics, and they are ready to make regular payments to keep those features in a higher value state.

Therefore, for spatial safety, as one of its key features, market transactions do not exist. Consequently, pursuant to the theory of economics, it is a public good. The spatial safety in a given area is used by anybody who lives or stays there. For this reason, it is possible to attempt to evaluate spatial safety, applying methods corresponding to those applied to determine the value of other spatial characteristics operating as non-market goods.

Safety, and its state in a specific location, is therefore a non-market good, which does imply that it is not an economic good. Its economic value results from the fact that people are ready to pay for this good indirectly, paying for purchased properties or for the right to stay in a specific place.

Four systems (formats) for evaluating non-market resources (WOŚ, 1995), which undoubtedly include the value of spatial safety (just like, for example, the aesthetic value of this space, identified with landscape quality and, consequently, its value) can be distinguished:

1. The format of individual preferences - if people have any preferences with regard to any resources, this means that in attributing any importance to them, they value them. The more important are given resources for satisfying our needs and higher preferences are assigned to them, which directly translates into an increase in its value. Such an evaluation is of a subjective nature, but in relation to the fact that preferences of individuals are revealed in their choices, which become mass choices, the evaluation of such resources is objectivised. Consequently, it can be claimed that such resources have prices because people give prices to them according to their own preferences. The main principle of this format - a resource is worth as much as somebody is willing to pay for it, i.e. the safety of a specified fragment of space has a market value equal to how much people living or using this space are willing to pay for the state of characteristics describing this space that guarantees to them safety at the expected level.
2. The hedonistic format – results from the hedonism theory, according to which pleasure is the only aim of the human being and the motive of his behaviour. Man strives for consumption of all available pleasures. Spatial safety is strictly related to quality of life, and achieving pleasure requires being in a safe environment. Using appropriate statistical techniques, the hedonistic approach aims at:
   a) determining what part of the variance in the safety state depends on differences in the characteristics of this space,
   b) determining how much people are able to pay to improve spatial safety and to live in better conditions.

3. Format of conditional valuations - based on sociological studies on human behaviour in hypothetical situations. The question can be posed: how much are people ready to pay for a given benefit or good and is there anything to compensate for the expenses (costs) they bear? This method is based on the personal (unit) assessments of respondents and their reaction to an increase or decrease in the quality of a certain good in the condition of a hypothetical market. This method assumes that the respondent knows what is a benefit and what is a cost. The value is determined in an iterative process. Gradually increasing prices, the respondent stops at the price level he is ready to pay. Similarly, a readiness to pay the minimum price is established.
4. The form of the alternative cost assumes that each choice involves resignation from something else. The most precious unit that we are ready to abandon in order to acquire another good determines its alternative cost.

If the values of spatial safety cannot be directly determined, or such determination is very difficult, the methods applying intermediate pricing can be used for this purpose. Some of them can be useful.

The first of them is the Hedonic Pricing Method - HPM. The Hedonic Pricing Method is also referred to as a method for determining the price of pleasure. The main assumption underlying hedonic prices is the claim that the price for a specific market good - real estate, related to a non-market good - spatial safety, can be split into the sum of attributes making up this good. For real estate, the attributes could also include the state of spatial safety (FOLMER et al., 1996; WINNPENNY, 1995).

The concept of hedonic prices is the result of observations, which show that the price for some goods depends on their non-market characteristics that can be isolated, including those related to space. Based on the transactions made, the value of the features of our interest is indirectly established. Non-market prices are evaluated on the basis of observed market transactions concerning properties characterized by various intensity levels of those features. The value of a non-market good (e.g. spatial safety) is determined through the application of statistical methods. Using econometric techniques, the function of the hedonic price is determined, explaining property prices resulting from various features of space occurring in various places. As a result of applying the statistical analysis method, the coefficients determining how, with the highest probability, the market value of the property will change if the quality or level of one of the factors included in the model is changed (e.g. the spatial safety state). The coefficient corresponding to the "quality" of spatial safety determines the amount of an additional payment that the purchasers are willing to make for the property situated in the area characterized with higher safety values in comparison to the price of a comparable property located in an area of lower spatial safety values. Consequently, this is the value attributed by potential purchasers to the value of spatial safety in the context of a real estate market.

The Contingent Valuation Method – CVM is a method based on survey questionnaires developed for the purposes of analysing the demand for goods (opportunities) and services that are not present in the market, in cases when direct observations are not possible (FOLMER et al., 1996; WINNPENNY, 1995).

The respondents are asked to specify the maximum amount they would be willing to pay for a given good - including spatial safety, as if they were to purchase this good in an imaginary market. Two formulas of this method are used, describing:

- How much the consumers are willing to pay for a given good - Willingness To Pay (WTP). It is assumed that spatial safety is worth as much as much people are ready to pay to use a safe space.
- How much consumers are willing to accept in order to maintain a given good at the specified level of quality - Willingness To Accept (WTA). The readiness of the consumer to accept a certain amount in exchange for maintaining the space in a specific state of safety.

Geo-information analysis of spatial features.

Risk matrix (BAJEROWSKI et al., 2015) combines the characteristics of space identified as significant from the perspective of spatial safety and the likelihood of specific risks in a given area. The lower the likelihood of those risks, the safer is the space, for obvious reasons.

Estimating the probabilities requires:

- creating *risk matrix* M_z, created according to the idea of probabilistic causality - a preceding event contributes to a later event since it belongs to its history, but it is not certain whether it causes this later event (BAJEROWSKI, 2003);
- identification of those places and taking an inventory of features generating risks - creating an inventory matrix I ;
- multiplication of matrix I by matrix M_z to obtain the resulting matrix, directly coinciding with the digital elevation map.

Estimating the values of the above-mentioned likelihoods is the most important issue. This can be achieved by analysing historically observed events or using the expert method.

The cell located at the intersection of the row with the column shows the numerical representation of the likelihood that describes "to what extent" a given feature of space in a specific state favours a given type of risk. There are many features in space, and many types of risks can be taken into account. Therefore, the accumulation of various features also favours various risks to a various degree - the likelihood of risk depends on the accumulation of those features in a given place (in a given area) and, of course, increases along with an increase in the number of those features. The inventory of those features in real space will therefore allow the use of a *matrix of risks* to identify the areas (places) characterized by an increased (and varied) likelihood of various risks affecting the state of spatial safety.

A sample form of a *risk matrix* is presented below (Table 1). The sample matrix does not include, for obvious reasons, either a full or a real list of characteristics, or all possible risks - it is of an illustrative nature only.

Table 1. Risk matrix.

Item	**Features of space** / **Risk type**	K	R	P	W	S	**(...)**	Σ
1.	Multi-family housing	0.10	0.33	0.09	0.10	0.05	0.33	**1**
2.	Single-family housing	0.05	0.08	0.07	0.07	0.01	0.72	**1**
3.	Administrative buildings	0.33	0.33	0.20	0.07	0.05	0.02	**1**
4.	Underground station	0.50	0.08	0.15	0.20	0.03	0.04	**1**
5.	Shopping centre	0,25	0,58	0.03	0.03	0.03	0.08	**1**
6.	Railway station	0.30	0.10	0.08	0.10	0.10	0.32	**1**
7.	Bus stop	0.33	0.09	0.07	0.05	0.01	0.45	**1**
8.	Tram stop	0.33	0.08	0.08	0.05	0.01	0.45	**1**
9.	One-level intersection (three roads)	0,62	0.10	0.11	0.13	0.01	0,03	**1**
10.	One-level intersection (four roads)	0,62	0.10	0.11	0.13	0.01	0,03	**1**
11.	Multi-level intersection	0.45	0.05	0.11	0.13	0.01	0.25	**1**
12.	Petrol station	0.03	0.10	0,60	0.15	0.01	0,11	**1**
13.	Open area	0,45	0,05	0.22	0.11	0.01	0.16	**1**
n.	(...)	...	...	...	...	...	**...**	**1**
LIKELIHOOD P(Z) (for *n* characteristics)		**1/(...)**	**1/(...)**	**1/(...)**	**1/(...)**	**1/(...)**	**1/(...)**	**1**

Key: Denotations: K – communication risk R – criminal risks, P – fire risks, W – flood risks, S – weather risks, n – number of space characteristics, (...) – other characteristics, other types of attacks. P(Z) – likelihood of a specific type of attack in a given place.

Source: (BAJEROWSKI, KOWALCZYK, 2013).

Therefore, if, for example, one place accumulates such characteristics as administrative buildings, an underground station and a multi-level intersection (which is not something unique in a large city) then the likelihood of specific types of terroristic attacks, calculated as a sum of likelihoods in individual columns and weighted by a number of surveyed features amounts to (Table 2):

Table 2. Risk matrix.

Item	**Features of space** / **Type of attack (risk)**	K	R	P	W	S	**(...)**	Σ
3.	Administrative buildings	0.33	0.33	0.20	0.07	0.05	0.02	**1**
4.	Underground station	0.50	0.08	0.15	0.20	0.03	0.04	**1**
11.	Multi-level intersection	0.45	0.05	0.11	0.13	0.01	0.25	**1**
PROBABILITY P(Z) (for *3* features)		**0.42**	**0.16**	**0.16**	**0.13**	**0.03**	**0.10**	**1**

Key: Denotations: K – communication risk R – criminal risks, P – fire risks, W – flood risks, S – weather risks, n – number of space characteristics, (...) – other characteristics, other types of attacks. P(Z) – likelihood of a specific type of attack in a given place.

Source: (BAJEROWSKI, KOWALCZYK, 2013).

The analysed place is characterized by the lowest likelihood of communication risks (accidents) (**0.42**).

Inventory matrix *I* – an inventory of characteristics can be prepared in many ways. An inventory matrix combines the basic field of the analysis with the presence (1) or absence (0) of the analysed space characteristics.

A sample inventory matrix can take the form presented below (Table 3).

Table 3. Example of inventory matrix.

Item	**Basic field numbers** / **Features of space**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	**(...)**
1.	Multi-family housing	1	0	1	0	1	1	1	0	0	0	0	0	0	0	0	...
2.	Single-family housing	0	1	1	1	1	1	1	1	0	0	1	0	1	0	1	...
3.	Administrative buildings	1	0	1	0	1	0	1	0	0	0	0	1	1	0	1	...
4.	Underground station	1	0	0	0	1	1	1	0	0	1	1	1	0	0	0	...
5.	Shopping centre	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	...
6.	Railway station	1	0	1	0	1	0	0	1	1	0	0	1	1	0	0	...
7.	Bus stop	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	...
8.	Tram stop	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	...
9.	One-level intersection (three roads)	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	...
10.	One-level intersection (four roads)	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	...
11.	Multi-level intersection	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	...
12.	Petrol station	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	...
	Open area	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	...
n.	**(...)**	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	**(...)**

Source: (BAJEROWSKI, KOWALCZYK, 2013).

The analysis of this simple example of inventory matrix (Table 3) shows that there are basic fields with an accumulation of characteristics that we considered significant from the perspective of generating specific risks in space. At the sites corresponding to those areas in reality (in the physical location), such risks are more probable than in other places. Finding out how high this probability is requires taking into account the information contained in the risk matrix, which assigns a specific unit likelihood to each spatial characteristic (geo-information). The real value of likelihoods, taking into account the occurrence of all features in a given basic field, can be obtained only as a result of multiplying matrix *I* by matrix M_z, which will give us, in effect, the resulting matrix assigning the value of likelihoods to specific sites within the limits of individual basic fields.

As the final step of this analysis, we can develop an isarithmic or zone map of risks to help identify areas of a similar spatial safety state (Fig. 1).

Information on market transactions concerning the sale of property drawn on such a map will help to carry out an evaluation which will result in estimating the market value of space in categories in specific safety state levels – therefore, determining the market value of spatial safety.

The analysis conducted pursuant to the *ceteris paribus* principle will produce the values of comparative properties, resulting from adjusting their prices as a result of comparing other characteristics of importance for the local market of properties. The differences in values will result only from the location within specific spatial safety zones - i.e. they will directly indicate the market value of the space where those properties are located.

Consequently, by comparing prices obtained in the market in transactions concerning properties that differ only in the value of safety, we can obtain the market value of the spatial safety status.

Finally, after application of statistical methods, we will also be able to determine proper coefficients adjusting the market value of properties resulting from their location in areas with specific safety states.

Conclusions

The state of safety, as the spatial characteristics resulting from a specific set of characteristics of a given space, make specific places more attractive than other locations, and is of significant importance for the market value of real estate located there. Since safe areas are more desired, the demand for properties situated in such areas can be observed in the market.

This can be determined using geo-information analysis of the above-mentioned spatial characteristics and, especially, a risk matrix producing a risk map or a map of spatial safety.

It is very important, for practical reasons, that the analysis of spatial characteristics which are significant for generating specific safety states can be carried out as desk studies, using information provided in regularly updated geoportals, both specialist and public.

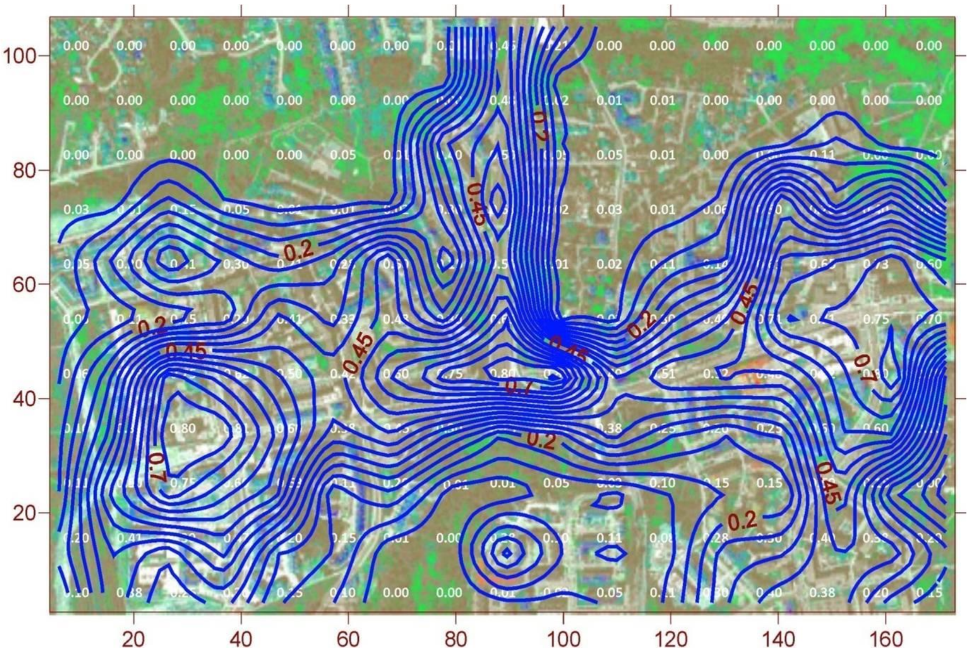

Fig. 1. Fragment of a sample isarithmic map of criminal risk (robberies).
The status of safety is determined within the 0.00 – 1.00 range, where 0.00 stands for a safe area, while 1.00 – the most dangerous area (probability of assault close to certain).
Source: Own work.

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