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Article

Grey Relational Analysis (GRA) as an Effective Method of Research into Social Preferences in Urban Space Planning

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Abstract: The appearance of urban space is most often determined by planners, urbanists, and officials who fail to consider social preferences in the planning process. According to recent scientific research, spatial design should take into account people's preferences with regard to its shape, as it is they who are the target audience. Moreover, legal regulations in many countries require the public's inclusion into the space planning process. This paper outlines the legal status of the issue of social participation in spatial planning and provides an overview of the methods and techniques applied in the research into preferences. The aim of the article is to determine the strength of the relationship between the features adopted for the study using the grey system theory and to investigate the model's behaviour for varied input data. It also presents the results of a study into the effect of geospatial features on the perception of the sense of security within urban space. The features were extracted using a heuristic method for solving research problems (i.e., brainstorming) and the survey was conducted by the point-scoring method. The survey results were processed by the grey system method according to the grey system theory (GST) of the grey relational analysis (GRA) type to yield a sequence of the strength of dependence between the analysed features. The study was conducted five times, with the order of entering the survey results being changed. The conducted analyses indicated that a change in the order of data from particular surveys applied for calculations resulted in the order of the epsilon coefficients in the significance sequences being changed. The analysis process was modified in order to obtain a stable significance sequence irrespective of the order of entering survey results in the analysis process. The analysis results in the form of a geospatial feature significance sequence provide information as to which of them have the greatest impact on the phenomenon under consideration. The research method can be applied to solve practical problems related to social participation.

Keywords: space user preferences; social participation; safety in urban space; geospatial features; grey system theory (GST); grey relational analysis (GRA)

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1. Introduction

1.1. Spatial Planning Model Applied in Practice

Spatial policies and the arrangements of planning documents concern the vital interests of the local community and individual space users. It is planners, who are most often guided in the planning process by the rule of functionality in space and who fail to consider the expectations of the users of a space, who are responsible for the appearance of urban spaces. In spatial planning practice, the rationalistic model [1], also referred to as "technical approach planning", is most commonly applied worldwide [2]. Its basis for planning activities is the full comprehensiveness of operations, with the maximum possible amount of spatial data used and the required procedures followed. In the rationalistic model, public participation in planning work is only guaranteed pursuant to legal provisions. As Hanzl noted, the consultations held in this model are often regarded by decision-makers as an inconvenient element, and the use of knowledge of the community living in a particular area is often marginalised. A feature typical of the rationalistic model is also citizens' difficult access to the methods and source materials used by planners [3]. In this model, the lack of agreement between planners and the designed space users can be observed. As noted by Jeleński and Kosiński, designs are usually implemented for political reasons, business needs or at the developer's request. It is very rare that a design is the result of a public discussion concerning the creation of good spaces for the benefit of the local community. The spatial development concepts developed by the local community centre around their needs. In most cases, these are very realistic and practical but also contain innovative ideas. Such designs, co-created by space users, are valuable, as the vision included in them is considerably broader than what a single expert or agency can offer [4]. It is worth considering the idea of incorporating social preferences into the planning procedure by including citizens in the process of co-determining the surrounding reality, as it enables both a reduction in social conflicts and the optimisation of the decision-making process in spatial management.

1.2. The Need for Participation in Spatial Planning

Participation (from Latin participo—to participate) means taking part in an enterprise or belonging to a group. Currently, it is understood much more broadly as joint participation in making decisions, co-determination, and active participation in developing the surrounding reality [5]. Social participation in spatial planning refers to a process in which both the authorities and the inhabitants collaborate in the preparation of plans, the execution of a specified policy, and decision-making. This method prevents the emergence of conflicts that are inevitable in spatial planning [6].

Smith believes that the issue of social participation in public management is regarded in Western countries as one of the main political priorities and is very often reflected in the policies implemented at both national and local levels [7].

Many authors note that the dynamics of urban development are changing urban objectives that should be consistent with human needs and experience. The authors stress the need to move away from the paradigms that define idealised spaces, such as Ebenezer Howard's Garden City, Plan Voisin of Le Corbusier's geometric ideal city, or a city following the New Urbanism convention which has, according to the assumptions, a market square in the city centre, city block development in its area and a designed public transport network that marginalises individual means of transport [8,9]. The benefits of incorporating urban development dynamics into spatial planning will allow simplified economic or ecological models to be overcome [10] and initiate productive interactions with psychological tests that examine the individual's needs in the cities [11]. Urban development dynamics should be supported in decision-making with qualitative social research. Following Walmsley's opinion, officials, decision-makers, and planners should respect individuals' needs in the cities by incorporating local communities into the space design process.

There are a growing number of studies that call for a reduction in the role of planners, urbanists, and decision-makers in decisions concerning the design of urban space by incorporating spatial user expectations into the spatial planning process. The current variety of New Urbanism, promoted by the Congress for the New Urbanism Sign-In CNU (a non-profit organisation with its registered office in Washington), is an activity focused on urban planning design for humans. The principles for designing human-friendly public spaces are also presented in a book by Jeleński and Kosiński, who claim that the planning process requires discussion and collaboration with the community at the outset. This approach assumes that professionals extract ideas that are thought up by community members as they track their point of view, actual problems, and even more importantly, local ideas on how to change local public spaces. The role of professionals is then to implement the vision created by the local community [4]. According to Schafran, it is necessary to consider, in the urban environment, that each design is good and should be accepted by the authorities and to think of how to select any concept, including creativity, entrepreneurship, sustainable development, resilience, and freedom, in which all ideas and aspirations can be very useful [12].

1.3. Legal Status of Participation

The currently observed crisis of representative democracy, and the decrease in citizens' involvement in this area, has prompted local authority representatives to prevent these negative trends and to search for new methods for engaging inhabitants in their local government communities [13].

The incorporation of social preferences into spatial policy can be regarded as a standard whose significance is stressed at the international level in guidelines from individual Earth Summits (Stockholm, 1972; Rio de Janeiro, 1992, 2012; Johannesburg, 2002) or in other supranational agreements, e.g., the Business Charter for Sustainable Development, the UN "Global Compact" system, the UN Declaration "Banking and the Environment", and the Habitat Agenda [14].

Participation has become a standard feature of municipality management, particularly in West European countries and in both Americas. It was in South American countries that both the principles of "social urban planning" based on the inhabitants' participation in the design process and the idea of participatory budgeting were first introduced [15].

In Europe, social participation became a popular issue, resulting from, among others, progressive social and political changes as late as the 1990s [13].

Social participation in spatial planning is well established in Germany, where its protection extends to the very process of considering the planning direction (Abwägungsvorrang) and its effect (Abwägungsergebniß) [16]. Firstly, the planning procedure takes into account the obligation to prevent conflicts (Gebot der Konfliktbeseitiegung) in order to foresee and pre-emptively solve future conflicts and, secondly, an obligation to consider individual interests (Gebot der Rucksichtsnahme). In this case, the municipality is required to protect individual interests because a specific development of a plot affects neighbouring plots, which may infringe the legal and factual interests of other property owners (holders) [17]. Errors in the assessment of interests can, consequently, result in the annulment of the validity of plans, both through inspections and in administrative court proceedings [16].

Protection of private interests under the English system is of a different nature than that under the German system, as it is primarily based on supervisory activities of the state Planning Inspectorate [18,19]. The basic tool is an examination of the draft planning document submitted by the planning authority, in order to compile written comments to the document, collected during the presentation of the initial form of the draft, along with the recorded planning authority's response to the comments made. The collected material, along with the entire planning document, is subject to the Inspector's assessment as to its reliability. Substantive consideration of these comments is an integral part of the draft document [18].

In Poland, participation in the creation of space is strengthened by law and implemented at the local level in the spatial planning process. Nevertheless, the established catalogue of forms in which citizens can become involved in spatial planning is not extensive. Under the current legal structure, the authority is required to consider the comments and has the right to take them into account by introducing changes to the draft plan. However, the authority is not required to justify its decisions on whether or not to take the comments into account [14]. The consultations are limited to providing information and an opportunity for stakeholders to submit proposals and comments and to participate in a public discussion. Their implementation is not part of the idea of including the public in the consultation process but serves to meet the statutory requirement. Most comments are collected at a later stage of the planning procedure when the initial draft is prepared and subject to public access. Moreover, most municipalities do not apply additional forms of consultation [5]. As Buczek argues, these regulations actually specify certain minimum deadlines and requirements for activities related to social participation, as they allow all stakeholders to take the activities described by these regulations, while being so "imprecise that allow them to be treated pro forma, or even circumvented" [17].

Moreover, as Niewiadomski points out, the incorporation of participation into the spatial planning process is hindered by the NIMBY (Not In My Back Yard) syndrome concerning the behaviour of persons who do not give their consent to the implementation of investments in the vicinity of their place of residence [20].

As follows from the above, the inclusion of social participation in the planning of space is legally empowered in many countries.

Many studies have indicated the problems and limitations related to the implementation of the social preference incorporation process into urban management in the context of social co-decision-making. Participation is most commonly implemented in the form of providing information and consultation but without specific implementation of public expectations. The actual extent of social participation is still very limited, usually to the forms required by law, which are very often implemented by municipalities and designers in order not to actually communicate but to meet legal requirements [21].

The enrichment of planning work with additional studies or predesign analyses, in particular, are in regards to the space users' preferences, can increase the quality and improve the work of the design team, and will enable the application of law in this regard.

1.4. Forms and Techniques of Research on Participation in Spatial Planning

In the decision-making processes, participation comprises three essential elements:

- information exchange—providing information;
- interactions—consultation;
- exercising influence—co–decision–making [22,23].

The state where citizens and social organisations that represent them are given the opportunity to negotiate and co-determine decisions should be regarded as the highest level of participation. This stage, referred to as co-decision-making or authorisation, is a situation in which the administration divests itself of some of its decision-making authority and transfers it to the citizens.

Forms of participation can be implemented using a number of techniques, for example, advisory committees and commissions, task groups, citizens' juries, or public voting. Consultations usually take the form of public discussions, workshops, local referendums, complaints, applications, petitions, opinion polls, qualitative interviews, public hearings, and open meetings [14,23]. Open meetings are held as a series of meetings with designers, thematic workshops, urban planning picnics, debates with experts, neighbourhood consultation points, thematic forums, seminars, questionnaires, and other forms of contact carried out using a variety of techniques (methodologies) and tools [14].

Considering the function of participatory actions, the social participation techniques can be divided into four groups:

1. research: questionnaire survey, qualitative interview, walking survey, and urban prototyping;
2. debates: an open meeting, citizens' café;
3. workshops: Future City Game, Planning for Real®, participatory planning;
4. mixed: citizens' panel, deliberative poll®, World Café, research in action, discussion game, citizens' jury, Charette™ workshop, sentimental map and working group [24].

In the age of the Internet, it is advisable to use, besides the above-mentioned techniques for obtaining social preferences, technologies based on GIS spatial information systems such as geo-survey and geo-discussion.

The aim of the consultation is often to obtain information on the preferences concerning the future development of space with account taken of the aspects addressed during the study (e.g., built-up area density, the nature of public spaces, the presence of service facilities, transport solutions, safety in space, etc.). The data obtained for analysis from research into preferences or during meetings or debates with citizens will not always be satisfactory. The data quality will be determined by the public interest in the planning process, meeting attendance, public commitment, etc.

1.5. Outline of Data Processing Methods in Participation

The first step of research into preferences is the collection of information during organised meetings, debates, and other methods described in Section 1.4. This step yields the research problem subject to analysis. There are numerous methods of research into social preferences. The data obtained at the first stage of research into preferences, such as the features that have an effect on safety disturbance in space, the features that affect the choice of location of the place of residence in the city, and the features that determine the need for renovation, etc., are the subject of research at a later stage. The obtained information can be elaborated by various methods.

The first group of methods includes statistical techniques that enable the evaluation of features and the determination of the tie relationship between its individual elements accepted for the study. These include correlation methods, variance analysis, quotient transformation in relation to a reference point [25–29], direct comparisons [30], and status value models [31].

The second group involves ranking methods used in research aimed at discovering and measuring a respondent's preferences. They also enable the analysis of data expressed on an ordinal scale. These include, for example, Gerbier's technique, the 0–10 technique, 100 rank point distribution, and multi-criteria evaluations that are applied when the ranking process is based on a few criteria with different ranks [32,33].

Yet another group comprises point-scoring methods (weighted scoring, indicator and scoring method), whose advantage is that they express all the features of the phenomenon under study, being separately assessed as a single number. Point-scoring assessments are one of the scaling method groups. These methods enable the assessment of a few or even several separate qualitative features of the issue under study. They are constructed in such a manner that, for specific qualitative characteristics, individual points on the scale are attributed verbal terms and corresponding conventional numbers/points [34,35].

An alternative to the above-mentioned methods for spatial data analysis, especially point-scoring methods, is the grey system theory developed by Juo-Long Deng. The theory has been developed specifically for the analysis of current systems, while taking into account scarce, uncertain, and incomplete information [36–39].

1.6. Grey Systems in Comparison with Preference Research Methods

Grey systems are an effective method for modelling and forecasting short-term time series that can be applied in all areas based on models with limited, incomplete or uncertain data ranging from social sciences, through economy and economics, to technical sciences [40,41]. The grey system theory has proved itself in economic forecasting [42], agriculture [43], medicine [44,45], tourism enterprise development [46], and noise source location [47]. In practice, the grey relational analysis (GRA) is most commonly used. It uses information on the similarity and differences between series of data describing the objects under consideration that can be ranked [39]. GRA is a method that enables data analysis resulting in the determination of the significance of the features under study. For the studied features with specified ranks or attributed points, the method enables the determination of a significance sequence which indicates those features that have the greatest influence on the phenomenon under study.

Thanks to the application of appropriate procedures, the grey system theory allows, based on information only partially known, additional, previously non-disclosed, useful information to be generated, searched for, found, and extracted. This facilitates both the modelling and monitoring of the behaviour of real systems and a description of the rules that govern their changes [39]. Hence, a GRA-type grey system was applied in order to learn about opinions as to which geospatial features result in the loss of the sense of safety in space. The analysis was conducted based on a small and incomplete group of arbitrarily selected respondents. The advantage of the grey system method over ranking and point-scoring methods is that a small number of necessary data can be taken for analysis. The minimum number of observations that enables the construction of a grey system model, regardless of the number of features taken for analysis, amounts to four ($n \geq 4$) [48]. It was demonstrated that a stable sequence of tie strength for five features was achieved for 20 observations [49]. The aim of this article is to determine the strength of the relationship between the features adopted for the study using the grey system theory and to investigate the model's behaviour for varied input data. The aim of the present analysis was to examine the relationships between multiple independent variables (geospatial attributes) and the dependent variable (perceptions of safety in urban space). Geospatial attributes that are most likely to contribute to the feeling of insecurity were identified based on the strength of the analysed relationships.

2. Materials and Methods

2.1. Characteristics of the Grey Relational Analysis Method

According to the general system theory, it is rare to have systems that we know everything about, i.e., white box systems. Generally, there are situations where our information is limited, i.e., grey boxes, or where it is only possible to observe the inputs and/or outputs of the system, i.e., black boxes. The basic idea of applying this theory involves obtaining, from accessible, uncertain, and incomplete information, additional information of a "white" and "grey" nature at the expense of "grey" and "black" information, respectively. This is equivalent to a reduction in the proportion of "black", i.e., uncertain information. For discovering information, "whitening" operators are used. "Grey" systems are used to take account of the imperfections of the available information [39].

Having observed and considered the functioning of systems, it can be concluded that, in most cases, a grey system is involved, where information is incomplete (e.g., it is not possible to examine the entire population) and uncertain (e.g., not all behaviours and interactions can be foreseen, i.e., the butterfly effect in forecasting) [50]. Moreover, in the information collecting process (measurements, market research results, opinions, etc.), the problem of scarce data often emerges, with the obtained information on the system behaviour incomplete as well. In addition, based on such incomplete and uncertain information, the system functioning often needs to be assessed, its behaviour needs to be forecast, and various functional, operational, and strategic decisions of great technical and social significance need to be taken [37,48,51–53].

The grey system theory enables the determination of the tie relationship between the variables of the grey relational analysis (GRA) [39,54]. Using the method of grey incidence (relation) analysis, it is possible to determine the absolute degree of grey incidence of the observed system factors and characteristics. The research procedure for GRA is described in [48,54,55].

The starting point of the analysis is the definition of the system observation vector containing information on the system characteristics (X_0) in the following form: $X_0 = (x_0(1), x_0(2), \ldots, x_0(n))$, and of the system behaviour factor vector ($X_1, X_2, \ldots, X_k$) in the following form: $X_k = (x_k(1), x_k(2), \ldots, x_k(n))$. The number of system behaviour factors is determined by the assumed number of observed variables (k). Each vector contains information on a particular variable, obtained from a specified number of respondents (n), for example. The essence of grey modelling is to describe the behaviour of the system observed in reality, in the form of a forecast/endogenous variable: $X_{(0)(k)}$, where $k = 1, 2, \ldots, n$ is a set of explanatory variables that are determinants of the forecast variable condition. Therefore, an endogenous process observable in reality, given as $X_{(0)(k)}$, is explained over time by the number N of independent (explanatory) variables [56,57].

An important step is to calculate the so-called reflection of the observation vectors by zeroing the initial vector values. This operation enables the smoothing of incidental disturbances and highlights the evolutionary tendency of the grey system behaviour [48]. This operation is performed according to the following formula:

$$X_i^0 = \left(x_i^0(1),\ x_i^0(2), \ldots, x_i^0(n)\right) \quad x_i^0 = x_i(k) - x_i(1) \tag{1}$$

where: k = the number of observed variables (system behaviour factors); n = the number of respondents.

The next step is to calculate the behaviour measures s_0 and s_i by means of summing and subtracting the values of reflected vectors [48,49,55].

The essence of the method is the calculation of the absolute degree of grey incidence, i.e., the similarity coefficient ε between the observation vectors X_0 and $X_1, X_2, \ldots, X_n$ [55]:

$$\varepsilon_{0i} = \frac{1 + |s_0| + |s_i|}{1 + |s_0| + |s_i| + |s_0 - s_i|} \tag{2}$$

Using this measure, one can assess the similarity of behaviour of a pair of vectors and also assess their degree of interrelation if it is known that one of them represents a factor affecting the grey system and the other represents the responses of the system. The properties of the similarity coefficient ε are useful to evaluate the obtained results:

1. $0 < \varepsilon \leq 1$;
2. ε is only related to the geometrical shape of vectors X_0 and X_k, while having no relationship to their spatial arrangement;
3. the more the observation vectors are related (similar), the higher the ε value [48].

2.2. Research into Social Preferences in Terms of the Sense of Safety Disturbance in Space

The data obtained in the social participation process are mostly incomplete and often scarce. The methodology of research using grey systems addresses the analysis of data of such quality. The method enables an analysis that yields reliable results in the form of an ε similarity coefficient significance sequence, even though the data is incomplete—the data is obtained from a small study sample (e.g., when the attendance rate of questionnaire surveys or the public debate is low).

Research into social preferences using the methods described above (Section 1.4) is mostly carried out through organised public debates or questionnaire surveys. In order to collect information, the following research methods are employed: interviews, observations, documentation analysis, and data collection analysis (e.g., interview questionnaires or survey questionnaires). The GRA method allows the data from heuristic methods to be easily applied in the spatial planning process, from the state of cognitive character to the state of knowledge application in practice. The study examined selected geospatial features which, according to the respondents, caused a disturbance in security within urban space.

The features for research into safety disturbance in space were extracted using the brainstorming method [58,59], on an incidental sample of an arbitrarily selected group of students with basic knowledge of safety within urban space [60,61]. The respondents were university students who attended classes and lectures addressing the research problem. During the study program, the students enrolled in a course on designing safe public spaces became familiar with geospatial factors that influence perceptions of security/insecurity in space. The study was conducted on a sample of 60 respondents.

For the research into the preferences for the sense of safety within urban space, the following variables were adopted:

X_1—vacant buildings, ruins;
X_2—uncontrolled greenery;
X_3—narrow passages between buildings;
X_4—protruding staircase entrances without door intercoms;
X_5—pedestrian tunnels, bridges, etc.

After determining the features for the research, a questionnaire survey was conducted on the same group of respondents. In order to grade the features, a point-scoring method was applied [35], using a seven-point scale including quality levels for the assessment of each of the safety disturbance features that the respondents identified. For each feature for perceptions of insecurity in space, on a scale of 1 to 7, a score of 1 denoted an attribute that was least important and a score of 7 denoted an attributes that was most important. The results of the survey were implemented in a GRA-type research procedure:

- very high safety disturbance = 7 points;
- medium-high safety disturbance = 6 points;
- high safety disturbance = 5 points;
- medium safety disturbance = 4 points;
- low safety disturbance = 3 points;
- very low safety disturbance = 2 points;
- no safety disturbance = 1 point.

The data obtained from the survey on a sample of 60 respondents, in the form of a certain number of points assigned to each variable, was applied to the procedure described in Section 2.1. Based on the data, general system observation vectors (formula 1) were created. The number of the system's behaviour factors is determined by the adopted number of the variables observed. Each vector contains information on a particular variable, obtained from a specified number of respondents: $X_{(0)(k)}$, for $k = 1, 2, \ldots, n$, where k = the number of variables observed and n = the number of respondents.

3. Results

The results obtained from the survey were analysed by the GRA-type grey system method. The calculations were made for 4, 10, 20, 30, 40, 50, and 60 input data. The data was calculated five times, with the order of entering the survey results being changed each time. The similarity coefficient values were presented for the observed system characteristics: (X_0)—the sense of safety in space with the system behaviour factors and (X_1, X_2, X_3, X_4, X_5)—the features adopted for the study. The conducted analyses yielded the epsilon similarity coefficient values shown in Table 1.

Table 1. ε similarity coefficient values depending on the number of observations included in the model.

Number of Analysis	Number of Observations							
	Epsilon Values	**4**	**10**	**20**	**30**	**40**	**50**	**60**
Analysis 1	ε_1	0.611111	0.646154	0.575472	0.592050	0.593558	0.593824	0.596000
	ε_2	0.527778	0.576923	0.540881	0.550209	0.547546	0.551069	0.552000
	ε_3	0.526316	0.507143	0.531447	0.543933	0.538344	0.532067	0.548000
	ε_4	0.520833	0.506098	0.502404	0.501656	0.501202	0.500947	0.500792
	ε_5	0.518519	0.505495	0.502370	0.501587	0.501188	0.500924	0.500761
Analysis 2	ε_1	0.692308	0.638462	0.575472	0.589796	0.593558	0.614458	0.596000
	ε_2	0.653846	0.546154	0.540881	0.548980	0.547546	0.539759	0.552000
	ε_3	0.653846	0.507143	0.531447	0.536735	0.538344	0.518072	0.548000
	ε_4	0.525000	0.506024	0.502404	0.501623	0.501202	0.500951	0.500792
	ε_5	0.520833	0.505435	0.502370	0.501558	0.501188	0.500949	0.500761
Analysis 3	ε_1	0.954545	0.884615	0.928105	0.888446	0.892537	0.899761	0.909182
	ε_2	0.909091	0.820513	0.816993	0.792829	0.774627	0.778043	0.781437
	ε_3	0.750000	0.634615	0.705882	0.685259	0.702985	0.713604	0.710579
	ε_4	0.613636	0.615385	0.640523	0.629482	0.614925	0.606205	0.609780
	ε_5	0.521739	0.505952	0.503106	0.501859	0.501433	0.501139	0.500928

Table 1. *Cont.*

Number of Analysis	Number of Observations							
	Epsilon Values	4	10	20	30	40	50	60
Analysis 4	ε_1	0.620690	0.574324	0.565359	0.593617	0.593168	0.607053	0.608081
	ε_2	0.603448	0.574324	0.562092	0.574468	0.557453	0.560453	0.552525
	ε_3	0.534483	0.540541	0.526144	0.508511	0.501488	0.501222	0.500967
	ε_4	0.514286	0.505747	0.502717	0.501812	0.501351	0.501092	0.500883
	ε_5	0.513889	0.505435	0.502604	0.501618	0.501171	0.500954	0.500767
Analysis 5	ε_1	0.766667	0.645833	0.566038	0.593617	0.591195	0.947072	0.610548
	ε_2	0.533333	0.534722	0.556604	0.574468	0.556604	0.607053	0.556795
	ε_3	0.516129	0.506173	0.525157	0.508511	0.501511	0.501176	0.500967
	ε_4	0.514286	0.505814	0.502674	0.501812	0.501381	0.501092	0.500887
	ε_5	0.513158	0.505814	0.502500	0.501618	0.501182	0.500984	0.500769

4. Discussion

The obtained values were sorted in descending order to obtain an ε similarity coefficient significance sequence. The obtained results of the epsilon coefficient values in individual analyses are provided in Table 2.

Table 2. The order of ε similarity coefficient relationships depending on the number of observations included in the model.

Order of Strength of Relationships	Number of Observations						
	4	10	20	30	40	50	60
Analysis 1	$\varepsilon_2 > \varepsilon_3 > \varepsilon_1 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_2 > \varepsilon_3 > \varepsilon_1 > \varepsilon_4 > \varepsilon_5$	$\varepsilon_2 > \varepsilon_3 > \varepsilon_1 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_2 > \varepsilon_1 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_2 > \varepsilon_1 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_2 > \varepsilon_1 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_2 > \varepsilon_1 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$
Analysis 2	$\varepsilon_3 > \varepsilon_1 > \varepsilon_2 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_2 > \varepsilon_3 > \varepsilon_1 > \varepsilon_4 > \varepsilon_5$	$\varepsilon_2 > \varepsilon_3 > \varepsilon_1 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_2 > \varepsilon_1 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_2 > \varepsilon_1 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_2 > \varepsilon_1 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_2 > \varepsilon_1 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$
Analysis 3	$\varepsilon_1 > \varepsilon_3 > \varepsilon_2 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_3 > \varepsilon_2 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_3 > \varepsilon_2 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_3 > \varepsilon_2 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_3 > \varepsilon_2 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_3 > \varepsilon_2 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_3 > \varepsilon_2 > \varepsilon_5 > \varepsilon_4$
Analysis 4	$\varepsilon_5 > \varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_5 > \varepsilon_2 > \varepsilon_4 > \varepsilon_3$	$\varepsilon_5 > \varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4$	$\varepsilon_5 > \varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4$	$\varepsilon_5 > \varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4$	$\varepsilon_5 > \varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4$	$\varepsilon_5 > \varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4$
Analysis 5	$\varepsilon_3 > \varepsilon_4 > \varepsilon_1 > \varepsilon_2 > \varepsilon_5$	$\varepsilon_3 > \varepsilon_4 > \varepsilon_5 > \varepsilon_1 > \varepsilon_2$	$\varepsilon_5 > \varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4$	$\varepsilon_5 > \varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4$	$\varepsilon_5 > \varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4$	$\varepsilon_5 > \varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4$	$\varepsilon_5 > \varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4$

In the third analysis, the sequence is stable for all observations. In the fourth and fifth analysis, sequence stability is achieved with 20 observations, while in the first and second analysis, stability is achieved with 30 observations. The results indicate that stable sequences are obtained for all analyses with 30 observations, but the order of ε similarity coefficient is different when the order of input data is changed. For the first and second analyses with 30 observations, the order of ε in the significance sequence is $\varepsilon_2 > \varepsilon_1 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$; for the third analysis, it is the sequence $\varepsilon_1 > \varepsilon_3 > \varepsilon_2 > \varepsilon_5 > \varepsilon_4$; and for the fourth and fifth analyses, it is the sequence $\varepsilon_5 > \varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4$. Therefore, it is difficult to determine, based on the obtained results, which features have the greatest effect on the disturbance of the sense of safety in space.

In the next step, the research procedure was modified at the stage of calculating the reflection of the observation vectors by zeroing the initial vector values. In formula 1, in each case, a maximum number of points to be scored for each feature (seven points) was assumed to be $x_i(1)$. Again, the analysis was conducted five times while maintaining the order of entering data from previous analyses to obtain the epsilon coefficient values shown in Table 3.

Table 3. ε similarity coefficient values depending on the number of observations included in the model at $x_i(1)$ equal to 7.

Number of Analysis	Number of Observations							
	Epsilon Values	4	10	20	30	40	50	60
Analysis 1	ε_1	0.512500	0.504854	0.502463	0.501730	0.501285	0.501016	0.500859
	ε_2	0.510000	0.504237	0.501873	0.501292	0.500967	0.500765	0.500644
	ε_3	0.509615	0.503937	0.501799	0.501220	0.500904	0.500708	0.500607
	ε_4	0.509434	0.503731	0.501667	0.501152	0.50085	0.500676	0.500566
	ε_5	0.509091	0.503497	0.501650	0.501119	0.500843	0.500664	0.500550
Analysis 2	ε_1	0.516129	0.504854	0.502463	0.501695	0.501285	0.500973	0.500859
	ε_2	0.511364	0.504202	0.501873	0.501272	0.500967	0.500791	0.500644
	ε_3	0.511111	0.503817	0.501799	0.501193	0.500904	0.500720	0.500607
	ε_4	0.510417	0.503704	0.501667	0.501136	0.500850	0.500678	0.500566
	ε_5	0.509615	0.503472	0.501650	0.501104	0.500843	0.500677	0.500550
Analysis 3	ε_1	0.511111	0.504587	0.502591	0.501629	0.501241	0.501010	0.500859
	ε_2	0.509259	0.503623	0.501916	0.501222	0.500943	0.500768	0.500640
	ε_3	0.509259	0.503378	0.501880	0.501208	0.500891	0.500718	0.500603
	ε_4	0.508621	0.503311	0.501779	0.501144	0.500849	0.500675	0.500567
	ε_5	0.508333	0.503226	0.501712	0.501087	0.500833	0.500667	0.500549
Analysis 4	ε_1	0.511111	0.505155	0.502660	0.501825	0.501319	0.501080	0.500867
	ε_2	0.508929	0.504132	0.502101	0.501374	0.500984	0.500805	0.500650
	ε_3	0.507937	0.503597	0.501812	0.501225	0.500923	0.500746	0.500611
	ε_4	0.507813	0.503472	0.501761	0.501134	0.500843	0.500692	0.500569
	ε_5	0.507692	0.503247	0.501645	0.501131	0.500835	0.500679	0.500553
Analysis 5	ε_1	0.511111	0.505556	0.502564	0.501825	0.501330	0.501080	0.500876
	ε_2	0.508929	0.504587	0.502049	0.501374	0.500994	0.500805	0.500650
	ε_3	0.507813	0.503876	0.501792	0.501225	0.500936	0.500746	0.500613
	ε_4	0.507813	0.503788	0.501712	0.501134	0.500846	0.500692	0.500571
	ε_5	0.507576	0.503623	0.501618	0.501131	0.500840	0.500679	0.500554

The epsilon coefficients were sorted again in descending order to obtain tie strength sequences. The obtained results show that a rather stable sequence is obtained for all analyses at 20 observations. For the fourth and fifth analyses, complete sequence stability occurs for 40 observations ($\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$), but starting from the 20th observation, the differences are only noticeable for the two last epsilons ($\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4 > \varepsilon_5$). In all conducted analyses, the ε coefficient order is maintained in the significance sequences (Table 4).

Table 4. The order of the ε similarity coefficient relationship depending on the number of observations included in the model at $x_i(1)$ equal to 7.

Order of Strength of Relationships	Number of Observations						
	4	10	20	30	40	50	60
Analysis 1	$\varepsilon_1 > \varepsilon_2 > \varepsilon_5 > \varepsilon_3 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4 > \varepsilon_5$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$
Analysis 2	$\varepsilon_1 > \varepsilon_3 > \varepsilon_2 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4 > \varepsilon_5$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$
Analysis 3	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4 > \varepsilon_5$	$\varepsilon_1 > \varepsilon_3 > \varepsilon_2 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$
Analysis 4	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4 > \varepsilon_5$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_4 > \varepsilon_3 > \varepsilon_5$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4 > \varepsilon_5$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4 > \varepsilon_5$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$
Analysis 5	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4 > \varepsilon_5$	$\varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4 > \varepsilon_1$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4 > \varepsilon_5$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4 > \varepsilon_5$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$

The conducted analysis result is a tie strength sequence that enables the determination of which features adopted for analysis have the greatest effect on the disturbance of the sense of safety in space. As indicated by a tie strength sequence that is stable due to the epsilon order for all analyses performed after the modification of the calculation process, the disturbance of safety in space is most contributed to, according to respondents, by features X_1 (vacant buildings, ruins), followed by X_2 (uncontrolled greenery), and X_3 (narrow passages between buildings). According to respondents, the sense of safety in space is affected the least by features X_4 (protruding staircase entrances without door intercoms) and X_5 (pedestrian tunnels, bridges, etc.).

The GRA-type grey system method applied for the analysis is an alternative to point-scoring methods, as it enables information on the most significant features in the aspect under study to be obtained in a simple manner based on an incomplete and scarce sample.

5. Conclusions

Many authors point out that there is a need to implement the results of social preferences surveys in the space design process. The literature review outlined the problem of participation that is legally empowered in many countries. Moreover, the limitations and problems related to the implementation of participation were described. This leads one to reflect on the need for a more in-depth look at this issue.

This study presented the advantage of the GRA-type grey system methods over the methods commonly applied to assess social preferences. The GRA method is more effective than other methods of research into social preferences (e.g., point scoring or ranking), as it enables an analysis based on incomplete and scarce data while maintaining the reliability of the obtained results. As a result of the analysis, knowledge is gained as to which features under study are most important in terms of the phenomenon being analysed.

The study into the sense of safety within urban space demonstrated that the feature of vacant buildings, ruins, and uncontrolled greenery was most significant, while pedestrian tunnels and bridges had the smallest effect.

The described methodology can be applied to other urban areas. The required information relates to a given place and time. An evaluation of social preferences in any area of research is a costly and time-consuming process. This study proposes a simple method for acquiring information that can be used in any area of research. The criteria selected for a research study should be validated in a survey with the use of a points method and the results inputted into a GRA-type grey system.

The method presented can be applied in research into social preferences in a variety of areas. The method is effective in all cases where points or specified ranks are attributed to the characteristics under study. The performance of a GRA-type analysis based on such points or specified ranks will provide knowledge on which features are the most relevant for the phenomenon under study. The application of the GRA-type grey system method will streamline the application of the results obtained from research into preferences in urban space planning and does not require great effort to yield reliable results. The analysis is conducted based on scarce and incomplete data, with the knowledge gained in the form of a similarity coefficient tie strength sequence streamlining the process of social participation implementation in urban spatial planning and management.

The aim of the analysis was to construct a reliable model of the grey system to predict its behaviour and make decisions concerning the present or future based on the obtained order of the similarity coefficient ε relationship strength. The analyses conducted determined the strength of the relationships between the features adopted for the study and indicated the model's behaviour for various numbers of input data. The application of the grey system-based method is supported by the fact that it requires no quantitative limitations on representative data samples, with no need to comply with the formal requirements imposed by statistical samples. Potential users of space have different perceptions of safety. Urban structures and spaces also differ in terms of management and maintenance. Analyses of public perceptions of safety require information that pertains to a given location and point in time but surveys of social preferences are expensive and laborious. This study proposes a simple method for generating data that can be used in numerous fields of research. The GRA approach facilitates the determination of the relationships between various factors and their influence on the examined system. The processed data can be used to evaluate the interdependencies between observation vectors, to predict the system's responses to various situations, and make optimal decisions without the need for complex statistical analyses. With the GRA approach, analyses of scarce, incomplete, and uncertain data produce reliable results.

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