Landscape and Urban Planning 189 (2019) 372–381

Contents lists available at ScienceDirect

Landscape and Urban Planning

journal homepage: www.elsevier.com/locate/landurbplan

Research Paper

Safety evaluation methodology of urban public parks by multi-criteria decision making

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ARTICLE INFO

Keywords:
Urban Park
Safety
Socio-economical context
Multi-criteria decision making
WASPAS
Neutrosophic sets

ABSTRACT

Proximity to green areas makes a positive impact on citizens' life quality. Sustainability principles generally govern modern urban public park design. This paper proposes a novel Safety Evaluation Methodology of Urban Public Parks (SEMUPP) which includes a multi-criteria solution to rank a set of urban public parks according to their safety level. Eleven groups of Urban Public Park (UPP) safety factors and seventeen quantifiable criteria are proposed as the basis for UPP safety assessment. Modification of Weighted Aggregated Sum Product Assessment (WASPAS) technique is applied to solve the constructed multi-criteria decision-making problem (MCDM). Six urban public parks located in Vilnius (Lithuania) are estimated to test the effectiveness of the SEMUPP.

1. Introduction

1.1. Safe urban parks and the quality of life

Urban public parks provide nature in the urbanised territories, but they can be crime concentration points if they are insufficiently maintained, inadequately supervised or do not provide an environment for positive activities.

High-quality green spaces are especially important for parents with babies, children, seniors, citizens working adjacent to the park and residents living near the place (Wang & Zhao, 2017). Urban parks offer space to increase social interaction, activate residents' engagement in health-promoting processes (Blanck, Allen, & Bashir, 2012; Chawla, 2015; Roe, Aspinall, & Thompson Ward, 2016; Root, Silbernagel, & Litt, 2017). Time spent outside also cures mental fatigue, inattentiveness, irritability and impulsivity (Chiesura, 2004). Vacant lot greening and larger tree canopy cover can also be related with the reduced level of vandalism, robbery, burglary, theft, narcotics or shooting (Bogar & Beyer, 2016; Schusler, 2017; Troy, Grove, & O'Neil-Dunne, 2012).

Naturally, local community respects the neighbourhood of well-maintained urban parks, since proximity to green spaces (McCormack, Rock, Toohey, & Hignell, 2010), waterside (Jim & Chen, 2010) and various cultural or recreational objects (Henderson, Child, Moore, Moore, & Kaczynski, 2016; Iqbal & Ceccato, 2015; Smiley et al., 2016) increase life quality. Nevertheless, a neighbourhood of the urban park also has undesirable effects on the quality of life. For instance, urban public parks (UPP) as well as pedestrian crossings, public transport stops, industrial areas and empty commercial areas are defined as the surroundings where criminal activities have the highest possibility to occur (Wekerle & Whitzman, 1995). Burglaries, sexual offences, violence, vandalism, alcohol consumption and drug dealing are the most common criminal actions associated with UPP (Levald, Proosa, Sibul, Paaver, Lehtovuori, Soomeren, Klein, & Viikmaa, 2015). Increased crime rate can be noticed both in the UPP and within the buffer zones (Groff & McCord, 2011).

UPP safety is becoming a serious problem in modern societies (Kula, 2015). Municipalities and police departments are continually searching for novel UPP management strategies that help to prevent crime (Levald et al., 2015; Telep & Weisburd, 2012). Crime Prevention Through Environmental Design (CPTED) is a frequently used worldwide philosophy to prevent crime in various spaces (Cozens, Saville, & Hillier, 2005). Surveillance, Target hardening, Access control, Territoriality, Image of the place and Activity Support are six CPTED strategies dedicated to reduce the fear of crime and to prevent crime in public areas (Atlas, 2008). However, CPTED is not devoted to assessing UPP safety level, so it does not suggest clear guidelines on how to decide which of the several UPPs need urgent CPTED-based renovation. Moreover, CPTED does not take into consideration, that UPP safety level cannot be estimated separately from its spatial, socio-economical or criminality context (Sreetheran, 2015; Mak & Jim, 2018). The proper criminal situation, high-level of park maintenance and UPP location near the city centre (Cho, Poudyal, & Roberts, 2008; Dehring & Dunse,

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https://doi.org/10.1016/j.landurbplan.2019.05.014
Received 12 April 2018; Received in revised form 10 April 2019; Accepted 20 May 2019

2006; Morancho, 2003) increase positive bonds between green spaces and real-estate value. Lack of maintenance, hazardous equipment or UPP location near the transportation junction makes a negative impact on UPP safety (Groff & McCord, 2011).

The multicriteria solution that is suitable to estimate UPP safety considering UPP location and layout, landscaping and structures, design, activities, surveillance, maintenance, accessibility, target hardening and socio-economical context may be a valuable instrument to recognise which urban public parks need immediate safety-related decisions.

1.2. Evaluation of urban public park safety

Safety audit, checklists and indices are the most common tools that can be used to evaluate UPP safety.

A safety audit is an approach usually employed to identify UPP features that increase fear of crime. Respondents' insights collected by specific questionnaires (Malek & Mariapan, 2009; Sreetheran, 2017), allow researchers to recognise fear-evoking factors, to detect unsafe places and to extract additional information about the evaluated UPP. Since safety audit results vastly depend on participants' sex, age, health, culture, socio-economic factors and respondent's motivation to answer the questions (Kothencz & Blaschke, 2017; Mak & Jim, 2018), it can not be considered as the effective methodology to compare safety level in several UPPs.

Checklists and indices are the most structured form to collect objective data about UPP safety (Rigolon, 2016). In recent years, different tools were proposed to inspect UPP safety. For instance, Németh and Schmidt (2007) presented "*Security index for public places*" to estimate UPP security with the concern on public accessibility. Twenty estimates associated with hard and soft control methods were proposed. UPP physical design, maintenance and activity support were identified as passive control principles; surveillance cameras, private security guards and similar legal actions were understood as active control strategies. Final UPP security level was constructed applying the criteria indicating park accessibility and public place control. This index can be a useful tool for assessing UPP security, but it does not evaluate spatial, socio-economical or criminality context of these UPPs.

Another UPP safety inspection approach was proposed to investigate if CPTED principles can be used as the basis to assess UPP safety (Iqbal & Ceccato, 2016). Fifty-four criteria were offered in the "Park Inspection Checklist Based on CPTED Principles". Both UPP audit and UPP inspection methods were used to collect data about a high-crime UPP located in Stockholm, Sweden. Finally, the gathered information was mapped with crime data recorded by police. The results of this research verified that crime concentrations are directly related to the design and maintenance of the park. This research also proved that CPTED principles could be efficiently employed to evaluate UPP maintenance, pathways quality, clearance of sightlines, illumination level, signage quality, accessibility and activity support. However, the CPTED-based evaluation does not give tools to assess the impact of the criminal and socio-economical context of the UPP. Besides, CPTED principles overlap each other, and this overlapping does not affect UPP estimation results in the same way. For instance, installation of padlocks increases crime anticipation, but at the same time, it compromises the aesthetics of the park. Similarly, the number of attraction objects increase visitors' rate, but also grow the opportunity for misleading, theft and vandalism (Cozens et al., 2005).

1.3. Application of MCDM methods

Multi-criteria decision making (MCDM) methods are commonly applied when different, often contradictory, criteria should be assessed to solve complex urban sustainability problems like UPP safety. Different MCDM methods can be chosen to solve sustainability tasks.

For instance, Neema, Hossain, Haque, and Farhan (2014) applied Weighted sum model (WSM) to identify which of the six UPPs located in Dhaka city is lacking behind others and what are the key factors that influence UPP quality (environment, landscape, aesthetics and safety). Analytic Hierarchy Process (AHP) based MCDM method can be applied to make sustainable decisions about public space renovations (Saaty, 1987, 2008; Martinelli, Battisti, & Matzarakis, 2015). Weighted Aggregated Sum Product Assessment (WASPAS) method initially presented by Zavadskas, Turskis, Antucheviciene, and Zakarevicius (2012) is widely employed to solve urban development (Zavadskas, Bausys, & Lazauskas, 2015) and urban life quality related tasks (Bausys & Juodagalviene, 2017).

The evolution of WASPAS and its applications were analysed and systemized by Mardani et al. (2017). Recently WASPAS was extended by single-valued neutrosophic sets (WASPAS-SVNS), which makes it a suitable MCDM approach to rank alternatives under the uncertainty of the initial information (Bausys et al., 2015; Nie, Wang, & Zhang, 2017; Zavadskas, Bausys, Stanujkic, & Magdalinovic-Kalinovic, 2016). Since UPP safety evaluation problem can be identified as the urban sustainability problem where urban parks should be ranked considering their safety level, WASPAS method with neutrosophic sets are proposed to be applied to solve this task.

1.4. Aims and objectives

Challenges of previous UPP safety evaluation studies enlightened the necessity for the novel methodology that combines elements of Crime Prevention Through Environmental Design (CPTED) and socio-economic context to rank a set of urban public parks according to their safety level. Development of the original Safety Evaluation Methodology of Urban Public Parks (SEMUPP) is the main objective of this research. A wide range of factors that affect UPP safety will be studied to identify criteria that might be easily evaluated by decision makers or landscape planners. Since these criteria are going to be assessed based on expert opinions, UPP maps and statistical data analysis, haziness related to the data origin may occur. A multi-criteria decision-making approach WASPAS-SVNS that can deal with the uncertainties of the initial information will be integrated as the part of the SEMUPP framework. SEMUPP methodology is going to be tested in a real case study in Vilnius, Lithuania.

2. SEMUPP methodology

SEMUPP methodology is conducted in a series of sequential steps (Fig. 1) The workflow includes five main points described through this section.

An expert panel that included three landscape planners and two decision makers were asked to work in a single group to perform these tasks: (i) to distinguish essential UPP safety estimation factors; (ii) to define weights of the criteria proposed to evaluate UPP safety; (iii) to suggest minimal requirements for the safe UPP.

2.1. Factors that affect UPP safety

Determination of clearly measurable criteria is the crucial part of the proposed framework. Authors of this research examined questionnaires, checklists and indices (Iqbal & Ceccato, 2016; Levald et al., 2015; Mak & Jim, 2018; Malek & Mariapan, 2009; Németh & Schmidt, 2007) to inspect what socio-economical (SEC) context and CPTED related features can be used to make decisions about UPP safety level. Mappings between six CPTED strategies and associated factors are proposed in Table 1. The additional strategy called Socio-economical context was included in determining elements connected to the spatial, demographic, economic and criminal situation of the analysed UPPs.

Information clustering into the more significant groups allows a better understanding of the problematics. For this reason, experts were asked to study Table 1 to reach a concensus on which factors are the

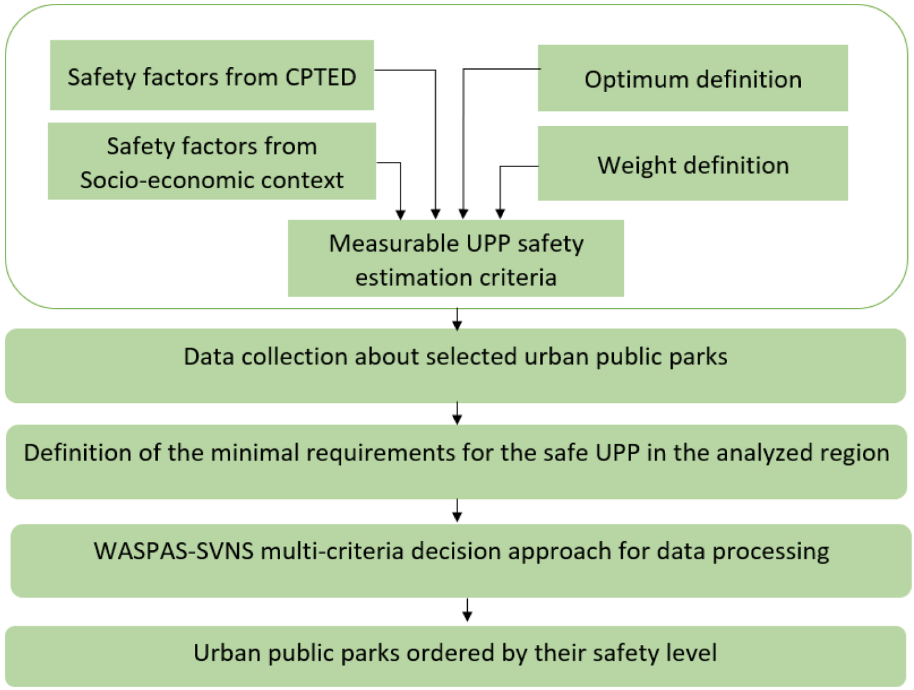


Fig. 1. Workflow of the SEMUPP methodology.

most important for UPP safety assessment process. The identified factors were clustered into eleven factor groups according to their functionality and similarity. The determined UPP safety factor groups are explained in the next sub-section.

2.2. Features of the safe UPP

Features of the “Safe Park” had been analysed to understand what are the requirements for UPP safety.

2.2.1. Surveillance

UPP guards together with park workers, managers and shop/café employees ensure UPP surveillance, increase park maintenance and prevent UPP from criminal activities like burglary, vandalism, violence, theft or arson. However, an optimal number of guardians and handlers should be defined separately for each country. For instance, it’s normal that at least one café/shop employee can be detected in UPP located in the USA, but it’s not an ordinary practice in Lithuania.

2.2.2. Sightlines

Path visibility forward, well-maintained trees and minimisation of heavy planted areas produce clear sightlines. Appropriate planting design and incorporation of thorny plants into planting mixes help to evade potential hiding places. Plants or shrubs that block the field of view should be avoided (including landscaping and fencing); dense planting of tall shrubs and big trees within 2 m of either side of pathways also should be prevented.

2.2.3. Lighting

Lighting is an essential feature that ensures UPP safety in the dark time of the day. Places with well-lit entryways and corners witness a smaller amount of criminal actions. CPTED recommends that for safety reasons nightly park usage should be discouraged and only paths that are essential designated routes should be illuminated.

2.2.4. Perimeter control

UPP visitors must be informed about restricted areas. Installation of low hedging or low open-type fencing around the periphery of the park or a particular space can be used to control park perimeter and to channel people to entrances. Large, easily read signage at the entranceways to parks, recreational areas and playgrounds also help to ensure legal usage of the UPP and increase the likelihood that people who witness a crime will respond by quickly reporting.

2.2.5. Entrances

A number of legible routes to and from the park areas should be maximised to provide users with a choice of physical access. In a small UPP the number of entrances should be at least two, but preferably more if the paths can all be connected to the urban network. Entries should be visible from the street; fences should be designed in a way that they would maximise natural surveillance from the street and minimise opportunities for intruders to hide.

2.2.6. Design of pathway routes

The network of UPP pathways should be connected to the surrounding environment in a clear way. At least one paved pathway route and additional smaller (not necessarily paved) paths that lead back to surrounding streets or parking areas should be provided to ensure UPP safety. Since secluded places and unexploited facilities may become hotspots of criminal activity, the number of dead-end paths should be minimised.

2.2.7. Flow of people

The people attraction objects installed in the UPP, ensure flow of people, strengthens social ties among UPP visitors, increase natural surveillance. Examples of positive activity support are family orientated and picnic suitable spaces, playgrounds, sports areas, gardens, plants, water fountains, kid play areas, age orientated equipment, cafés, art, cultural and visual enhancements, public events.

2.2.8. Maintenance

Regular maintenance is one of the most critical factors that affect UPP safety. Poor UPP care together with run-down buildings, graffiti, litter and public drunkenness give the impression that criminal activity (or vandalism) is tolerated in the UPP. Clean environment, aesthetics of the park, low-rise structures, upheld greenery and satisfactory

Table 1
UPP safety assessment factors associated with CPTED strategies and Socio-economical context.

Strategy	Factor	Studies
Surveillance	Guardians and handlers	Németh and Schmidt (2007), Malek and Mariapan (2009) Levald et al. (2015), Iqbal and Ceccato (2016), Mak and Jim (2018)
	Pathways through parks	Németh and Schmidt (2007), Matijošaitiene, Zaleckis, and Stankevičė (2013), Levald et al. (2015), Sreetheran and Bosh (2015), Iqbal and Ceccato (2016), Mak and Jim (2018)
	Clear sightlines	Németh and Schmidt (2007), Matijošaitiene et al. (2013), Levald et al. (2015), Sreetheran and Bosh (2015), Iqbal and Ceccato (2016), Mak and Jim (2018)
	Heavy planted areas	Malek and Mariapan (2009), Matijošaitiene et al. (2013), Sreetheran and Bosh (2015), Mak and Jim (2018)
	Buildings/window placement	Iqbal and Ceccato (2016), Mak and Jim (2018)
	Lighting	Németh and Schmidt (2007), Malek and Mariapan (2009), Matijošaitiene et al. (2013), Levald et al. (2015), Sreetheran and Bosh (2015), Iqbal and Ceccato (2016), Mak and Jim (2018)
Territoriality	Park boundary definition	Malek and Mariapan (2009), Matijošaitiene et al. (2013), Levald et al. (2015), Iqbal and Ceccato (2016)
	Signage and rules	Németh and Schmidt (2007), Levald et al. (2015), Iqbal and Ceccato (2016), Mak and Jim (2018)
	Separations between semi-private and public places	Németh and Schmidt (2007), Iqbal and Ceccato (2016)
Access control	Heavy planted areas	Malek and Mariapan (2009), Matijošaitiene et al. (2013), Sreetheran and Bosh (2015), Mak and Jim (2018)
	Number of access routes, entrances	Németh and Schmidt (2007), Malek and Mariapan (2009), Levald et al. (2015), Sreetheran and Bosh (2015), Iqbal and Ceccato (2016), Mak and Jim (2018)
	Natural barriers to create boundaries without gates	Németh and Schmidt (2007), Malek and Mariapan (2009), Sreetheran and Bosh (2015), Iqbal and Ceccato (2016)
	Constrained hours of operation	Németh and Schmidt (2007), Levald et al. (2015)
	Pathways through parks	Németh and Schmidt (2007), Levald et al. (2015), Iqbal and Ceccato (2016), Mak and Jim (2018)
	Dead end paths	Németh and Schmidt (2007), Levald et al. (2015), Iqbal and Ceccato (2016), Mak and Jim (2018)
Activity support	Family orientated areas	Iqbal and Ceccato (2016), Mak and Jim (2018)
	Playground/sport areas	Iqbal and Ceccato (2016), Mak and Jim (2018)
	Garden, plants, fountains	Iqbal and Ceccato (2016)
	Flow of people	Németh and Schmidt (2007), Malek and Mariapan (2009), Matijošaitiene et al. (2013), Iqbal and Ceccato (2016)
	Café	Németh and Schmidt (2007), Iqbal and Ceccato (2016)
	Teenagers orientated areas to control them	Levald et al. (2015), Iqbal and Ceccato (2016)
	Age orientated equipment	Levald et al. (2015)
	Art, cultural and visual enhancements, events	Németh and Schmidt (2007), Matijošaitiene et al. (2013), Levald et al. (2015), Mak and Jim (2018)
Image of the place	Park management	Németh and Schmidt (2007), Sreetheran and Bosh (2015)
	Regular maintenance	Malek and Mariapan (2009), Levald et al. (2015), Sreetheran and Bosh (2015), Iqbal and Ceccato (2016), Mak and Jim (2018)
	Aesthetics of the place	Matijošaitiene et al. (2013), Sreetheran and Bosh (2015), Iqbal and Ceccato (2016), Mak and Jim (2018)
	Public toilets	Németh and Schmidt (2007), Iqbal and Ceccato (2016), Mak and Jim (2018)
	Clean environment	Levald et al. (2015), Sreetheran and Bosh (2015), Mak and Jim (2018)
	Number of garbage cans	Levald et al. (2015), Iqbal and Ceccato (2016)
	Free walls for graffiti artists	Iqbal and Ceccato (2016)
	Maintenance of walking paths	Matijošaitiene et al. (2013), Levald et al. (2015), Sreetheran and Bosh (2015)
Target Hardening	CCTV cameras	Németh and Schmidt (2007), Matijošaitiene et al. (2013), Iqbal and Ceccato (2016), Mak and Jim (2018)
	Provision for alcoholics/drug users	Matijošaitiene et al. (2013), Levald et al. (2015), Iqbal and Ceccato (2016), Mak and Jim (2018)
	Provision for homeless	Matijošaitiene et al. (2013), Levald et al. (2015), Iqbal and Ceccato (2016), Mak and Jim (2018)
Socio-economical context	Crime number in the surrounding area	Malek and Mariapan (2009), Matijošaitiene et al. (2013), Levald et al. (2015), Sreetheran and Bosh (2015), Iqbal and Ceccato (2016), Mak and Jim (2018)
	Graffiti, vandalism level	Malek and Mariapan (2009), Matijošaitiene et al. (2013), Levald et al. (2015), Sreetheran and Bosh (2015), Iqbal and Ceccato (2016), Mak and Jim (2018)
	Neighbourhood characteristics	Németh and Schmidt (2007), Sreetheran and Bosh (2015), Iqbal and Ceccato (2016), Mak and Jim (2018)

condition of walking paths is visible signs indicating that public place is well-maintained, cared and controlled.

2.2.9. Surrounding neighbourhood

Socially connected communities are better organised and act as guardians that semi-formally supervises UPP or other public spaces. The absence of bonds between community members results in the low level of natural surveillance (Kohn, 2004). Nevertheless, it is tough to decide objectively if the local community is strong or weak. More objective parameters are needed to assess the impact of neighbourhood characteristics.

State of the art analysis shows that the density of the neighbourhood, real-estate costs and the quantity of youth concentration points in the surroundings of the UPP undirectly affect urban park safety (Iqbal & Ceccato, 2015; Karanikola, Panagopoulos, Tampakis, & Karipidou-Kanari, 2016; Kestens, Thériault, & Rosiers, 2004). Since UPP proximity to the city centre usually rises real estate prices and neighbourhood density (Cho et al., 2008), features of the safe UPP should be determined to analyse the socio-economic context near the UPPs located in the residential districts of the city. The number of residents living 400 m meters from the UPP centre (5 min by feet) can be used as a criterion that describes the density of the neighbourhood. Youth concentrations points (schools, youth centres etc.) may increase the disorderly behaviour in the surroundings (Iqbal & Ceccato, 2016); therefore their number near the UPP should be minimised.

2.2.10. Serious crimes and public law offences

UPP safety cannot be estimated separately from its criminality context. Increased crime rate can be noticed both in the UPP and within the buffer zones (Groff & McCord, 2011). However, UPP safety

Table 2
The mapping between UPP safety factor groups and UPP safety estimation criteria. Weights of UPP safety factor groups, criteria optimum and data source are also presented in this table.

UPP safety factor group	UPP safety estimation criteria	Weight	Optimum	Data Source
Surveillance		**0.075**		
	Guardians and handlers, number (S_1)	0.075	Max	Observations on site
Sightlines		**0.075**		
	Impenetrable barriers along the pathways/length of all pathways, % (S_2)	0.075	Min	Publicly available city maps
Lighting		**0.1**		
	Illuminated pathways, % (S_3)	0.1	Max	Observations on site
Perimeter control		**0.075**		
	Unprotected perimeter of the park/all perimeter of the park, % (S_4)	0.05	Min	Publicly available city maps
	Informative and clear signage, 10 points scales (S_5)	0.025	Max	Observations on site
Entrances		**0.075**		
	Formal entrances, number (S_6)	0.05	Max	Publicly available city maps
	Formal entrances visible from the street/all entrances (S_7)	0.025	Max	Publicly available city maps
Design of pathways routes		**0.1**		
	All pathway routes, number (S_8)	0.025	Max	Observations on site and publicly available city maps
	Paved pathway routes, number (S_9)	0.025	Max	Observations on site
	Dead end paths, number (S_{10})	0.05	Min	Observations on site and publicly available city maps
Flow of people		**0.1**		
	People attraction objects, number/ha (S_{11})	0.1	Max	Observations on site
Maintenance		**0.1**		
	Park maintenance, 10 points scales (S_{12})	0.1	Max	Observations on site
Surrounding neighbourhood		**0.125**		
	Residents living 400 m meters from the park centre, number (S_{13})	0.05	Max	Open data mapped with GIS data
	Real estate price in the surroundings, euro per square meter (S_{14})	0.05	Max	Open data mapped with GIS data
	Schools located 400 m. around the park, number (S_{15})	0.025	Min	Publicly available city maps
Serious crimes		**0.1**		
	Thefts and criminal offences in the surrounding area, number per year (S_{16})	0.1	Min	Publicly available police records mapped with GIS data
Public law offences		**0.075**		
	Public law offences, number per year (S_{17})	0.075	Min	Publicly available police records mapped with GIS data

evaluation based only on crime statistics can be misleading, since usually, people do not inform police about small offences like disorderly youth activities, graffiti, drug dealing or illicit sexual activities (Uittenbogaard, 2014). Low crime statistics may also be influenced by citizens' avoidance of areas perceived as unsafe (Hilborn, 2009). Extended UPP safety assessment should be performed to decide if UPP needs safety-related decisions. Nevertheless, both serious crimes and public law offences that occur near the UPP territory should be minimised to increase UPP safety.

2.3. UPP safety estimation criteria

Criteria identification is a crucial part of any multicriteria decision-making solution. Comprehensive analysis of CPTED and SEC strategies was done to explain how UPP safety factor groups can be associated with easy measurable criteria. Seventeen UPP safety estimation criteria were proposed by the authors of this research (Table 2).

Each of the proposed criteria can be measured by open data (police reports and real-estate databases) investigation, city map analysis or on-site observations. Optimum of each of the criteria is also presented since most of them should be maximised, and the rest of them should be minimised to ensure a high level of UPP safety.

2.4. Weights of UPP safety estimation criteria

The adapted AHP approach similar to the one proposed by Ristic, Maksin, Nenkovic-Riznic, and Basaric (2018) was applied to determine weights of the UPP safety estimation criteria. Weighting process was deconstructed into two steps: weighting of the UPP safety factors groups and the weighting of the UPP safety estimation criteria.

At the first step, the expert group was asked to determine the importance of the UPP safety estimation factor groups. Each of UPP safety estimation factor groups had to be defined as the highly important, very important or important. Expert groups decided that shadowing, sightlines, perimeter control, entrances and public law offences should be considered as important factor groups; lighting, design of pathways routes, flow of people, maintenance and serious crime level as very important. The surrounding neighbourhood was described as a highly important factor group. Since the total sum of the weights should be equal to 1.0, the surrounding neighbourhood was weighted as 0.125, lighting, design of pathways routes, flow of people, maintenance and serious crime level factor groups were weighted as 0.1 and finally the rest five-factor groups (shadowing, sightlines, perimeter control, entrances and public law offences) were weighted as 0.075.

At the second step, the expert group was asked to achieve consensus on the final weights of the 17 UPP safety estimation criteria according to their importance for the corresponding factor group. Weighting results are shown in Table 2.

2.5. WASPAS-SVNS for data processing

WASPAS-SVNS is going to be applied as the data processing approach for the SEMUPP methodology. WASPAS-SVNS can be deconstructed into eight steps (Zavadskas et al., 2015):

1. To identify if distinct UPP safety estimation criteria should be

maximised or minimised and to determine their weights (Table 2).

2. To construct a decision matrix X, where x_{ij}, $i = 1, \ldots m$; $j = 1, \ldots n$ is the aggregated value of the expert evaluations of j^{th} criterion for the i^{th} UPP (Table 4):

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \quad (1)$$

3. To normalise the decision matrix X by vector normalisation technique:

$$\tilde{x}_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} (x_{ij})^2}} \quad (2)$$

4. To do neutrosophication and to calculate the neutrosophic decision matrix $\tilde{X}^n$. Conversion between crisp normalised values $\tilde{x}_{ij}$ and single-valued neutrosophic numbers (SVNNs) is required to calculate $\tilde{X}^n$. Elements of the neutrosophic decision matrix are the single-valued neutrosophic numbers $\tilde{x}_{ij}^n = (t_{ij}, i_{ij}, f_{ij})$, where t corresponds to membership degree, i – to indeterminacy degree and f – to a non-membership degree. Standard crisp-to-neutrosophic mapping (Table 3) will be applied in this study. Nevertheless, decision makers are allowed to introduce additional mappings concerning the vagueness of the initial information.
5. To calculate the first decision component that is based on the sum of the total relative importance of the i^{th} *UPP*:

$$\tilde{Q}_i^{(1)} = \sum_{j=1}^{L_{\max}} \tilde{x}_{+ij}^n \cdot w_{+j} + \left(\sum_{j=1}^{L_{\min}} \tilde{x}_{-ij}^n \cdot w_{-j} \right)^c \quad (3)$$

The $\tilde{x}_{+ij}^n$ and w_{+j} are the values associated with the criteria which are maximised, consequently $\tilde{x}_{-ij}^n$ and w_{-j} are related to the criteria which are minimised. Criteria weight is an arbitrary positive real number, $L_{\max}$ is the amount of the maximised criteria, $L_{\min}$ is the amount of the minimised criteria. The following algebra operations should be applied for the single-valued neutrosophic numbers (SVNN):

$$\tilde{x}_1^n \oplus \tilde{x}_2^n = (t_1 + t_2 - t_1 t_2, i_1 i_2, f_1 f_2) \quad (4)$$

$$\tilde{x}_1^n \otimes \tilde{x}_2^n = (t_1 t_2, i_1 + i_2 - i_1 i_2, f_1 + f_2 - f_1 f_2) \quad (5)$$

$$w\tilde{x}_1^n = (1 - (1 - t_1)^w, i_1^w, f_1^w), \; w > 0 \quad (6)$$

$$\tilde{x}_1^{nw} = (t_1^w, 1 - (1 - i_1)^w, 1 - (1 - f_1)^w), \; w > 0 \quad (7)$$

$$\tilde{x}_1^{nc} = (f_1, 1 - i_1, t_1) \quad (8)$$

Here $\tilde{x}_1^n = (t_1, i_1, f_1)$ and $\tilde{x}_2^n = (t_2, i_2, f_2)$.

6. To calculate the second decision component, that is based on the product of total relative importance in the ith UPP:

Table 3
Standard crisp-to-neutrosophic mapping to rate the importance of the alternatives.

Crisp normalised terms	SVNNs in the form (t, i, f)
Extremely good (EG)/1.0	(1.00, 0.00, 0.00)
Very very good (VVG)/0.9	(0.90, 0.10, 0.10)
Very good (VG)/0.8	(0.80, 0.15, 0.20)
Good (G)/0.7	(0.70, 0.25, 0.30)
Medium good (MG)/0.6	(0.60, 0.35, 0.40)
Medium (M)/0.5	(0.50, 0.50, 0.50)
Medium bad (MB)/0.4	(0.40, 0.65, 0.60)
Bad (B)/0.3	(0.30, 0.75, 0.70)
Very bad (VB)/0.2	(0.20, 0.85, 0.80)
Very very bad (VVB)/0.1	(0.10, 0.90, 0.90)
Extremely bad (EB)/0.0	(0.00, 1.00, 1.00)

Table 4
Initial decision matrix for Urban park safety estimation in Vilnius, Lithuania.

Criteria ID	A0	A1	A2	A3	A4	A5	A6
S_1	1	0	1	0	0	0	0
S_2	25	30	5	30	75	75	5
S_3	80	70	95	10	10	30	95
S_4	40	50	5	75	80	85	30
S_5	6	0	10	4	0	3	8
S_6	2	11	3	2	4	9	8
S_7	2/2	5/11	2/3	2/2	1/4	5/9	8/8
S_8	2	4	10	4	2	4	5
S_9	1	2	10	0	0	3	5
S_{10}	0	0	0	2	1	4	0
S_{11}	3/3	3/3	13/9	3/4,5	2/5	5/11	6/8.5
S_{12}	7/10	6/10	10/10	6/10	4/10	3/10	8/10
S_{13}	2000	2743	2895	2851	998	4266	847
S_{14}	1350	2022	3009	2460	1187	1079	1504
S_{15}	0	1	2	1	0	2	0
S_{16}	50	57	118	95	128	493	21
S_{17}	150	183	266	199	706	1267	60

$$\tilde{Q}_i^{(2)} = \prod_{j=1}^{L_{\max}} (\tilde{x}_{+ij}^n)^{w_{+j}} \cdot \left(\prod_{j=1}^{L_{\min}} (\tilde{x}_{-ij}^n)^{w_{-j}} \right)^c \quad (9)$$

7. To compute joint generalised criteria:

$$\tilde{Q}_i = 0.5\tilde{Q}_i^{(1)} + 0.5\tilde{Q}_i^{(2)} \quad (10)$$

8. To calculate the score function $S(\tilde{Q}_i)$ for deneutrosophication of the joint generalised criteria:

$$S(\tilde{Q}_i) = \frac{3 + t_i - 2i_i - f_i}{4} \quad (11)$$

The final rankings of the UPPs are determined considering the descending order of the $S(\tilde{Q}_i)$. Values of the score function calculated for six urban public parks evaluated in the study case are presented in Table 5.

3. Safety estimation of urban public parks located in Vilnius

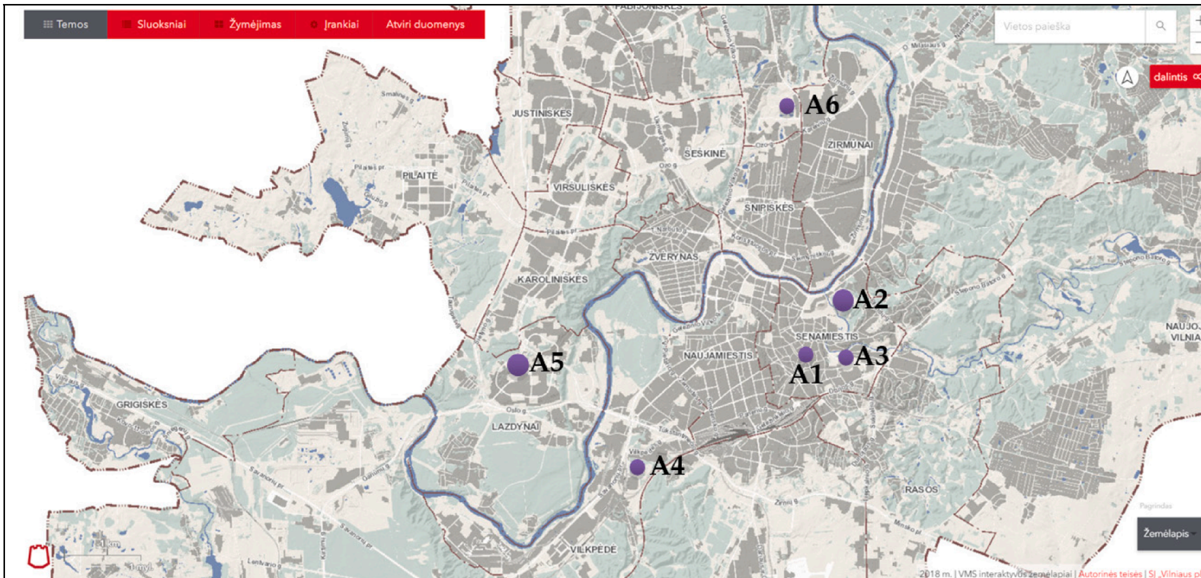
3.1. Case study description

Vilnius is one of the greenest capitals in Europe. The historic centre of Vilnius was inscribed into the UNESCO World Heritage Centre (1994). City area reaches 392 km^2. 43,9% of Vilnius territory is devoted to green zones and forests (*Vilnius municipality information*). Green zones in Lithuania are divided into three categories: a) Scientific, cultural and memorial landscapes; b) Protective and ecological areas; c) Town recreational areas (Law of the greenery in Lithuania).

Scientific, cultural and memorial landscapes are public places, governed by the governmental or private sector. Typically, the entrance fee should be paid to visit this type of green spaces (botanical gardens, zoos, ethnographic parks, art and exhibition parks, memorial parks, columbarium etc.). Protective and ecological areas like hill parks, forest parks, beaches, national or regional parks, reserves etc. are big open spaces that can be visited free of charge. Usually, these spaces are located further from the urbanised territories. Urban public parks as well as urban gardens and public squares, etc. are located in urbanised

Table 5
Results of safety estimation in 6 urban public parks located in Vilnius, Lithuania.

Alternative	A0	A1	A2	A3	A4	A5	A6
$S(\tilde{Q}_i)$	0.8203	0.7672	0.8307	0.6834	0.5180	0.3335	0.8723
RANK	3	4	2	5	6	7	1



Alternatives	A1	A2	A3	A4	A5	A6
UPP Name	Reformatai park	Bernardinai gardens	Kudru park	Vilkpedes park	Pasaku park	Ozas park
Size, ha	3	9	4.5	5	11	8.5
Location	Old Town	Old Town	Old Town	Residential districts	Residential districts	Residential districts

Fig. 2. Location of six UPPs that were selected for the case study (Vilnius, Lithuania). Parks are numbered and ordered according to their distance from the Vilnius Oldtown. Map source: open data maps proposed by Vilnius municipality (https://maps.vilnius.lt).

Fig. 3. The view of Ozas park map. Map source: open data maps proposed by Vilnius municipality (https://maps.vilnius.lt).

regions. They are classified as the town recreational areas dedicated to citizens and can be visited freely, without a charge.

Most of the UPPs in Vilnius can be identified as the small ones (from 1 ha – to 20 ha). The only UPP in Vilnius that can be identified as the big UPP is Vingis Park (162 ha). Size and complexity of Vingis park can distort safety comparison results for smaller UPPs, so we excluded it from further research.

Six small UPPs with different renovation histories were chosen as the research object. Half of the selected UPPs (alternatives A1, A2, A3) are established near the Old Town of Vilnius city, another half (alternatives A4, A5, A6) are located in the Residential districts further from the city centre. Positions of the chosen UPPs are visualised in Fig. 2.

3.2. Data collection

A mix of data collection methods was applied to accumulate data for 17 UPP safety estimation criteria proposed in Table 2. Observations on site were performed to obtain information about the number of guardians and handlers (S_1), illuminated pathways (S_3), quality of informative and clear signage (S_5), number of paved pathway routes (S_9), number of attraction objects (S_{11}) and the level of park maintenance (S_{12}).

Publicly available statistical data mapped with GIS data were used to evaluate criteria S_{13}, S_{14}, S_{16}, S_{17}:

- Crime data (S_{16}, S_{17}) were acquired from the police website (https://www.epolicija.lt/statistics)
- Real estate prices in the surroundings (S_{14}) were acquired from the open data proposed in by real estate value estimation company (https://kurgyvenu.lt)
- Data on residents living 400 m meters from the UPP (S_{13}) were gathered from Lithuania statistic department https://www.stat.gov.lt.

Analysis of publicly available city maps (https://maps.vilnius.lt) was completed to estimate criteria S_2, S_4, S_6, S_7, S_8, S_{10}, S_{15}. Like the illustration, the view of Ozas park map (A6) that was available to researchers is shown in Fig. 3. UPP inspection was additionally employed when map analysis was not enough to determine the values of these criteria.

3.3. Minimal requirements for the safe UPP in Lithuania

Minimal requirements for the safe UPP in Lithuania were proposed by the expert group considering features of the “Safe Park” analysed in Section 2.2. They were used to construct alternative A0 that works as the threshold to separate safe and unsafe UPPs. Alternative A0 can be considered as a small UPP (3 ha) which has three people attraction objects, two formal entrances visible from the street and two pathway routes. Experts agreed that 25% of impenetrable barriers are allowed in a safe park. Since UPP is an open space, it was decided that 40% of the unprotected perimeter and 80% of illuminated pathways is enough to ensure security and the accessibility of the safe UPP.

Values of the criteria that are related to a socio-economical context were proposed investigating the surroundings of the existing urban public parks located in Vilnius (Lithuania). Experts also stated that minimally acceptable values for criteria S_{13}, S_{14}, S_{15}, S_{16}, S_{17} should be determined separately for each city since socio-economical context should be described considering the features of the studied area. The characteristics of the alternative A0 and six urban public parks selected for the case study are presented in Table 4. All the data were collected in spring of 2017.

4. Results and discussion

Results of the SEMUPP framework applied to estimate the safety level of urban public parks located in Vilnius (Lithuania) are shown in Table 5. The highest rank represents UPP with the highest safety level, and the lowest rank embodies green space which has the most safety issues.

The safety level of the alternative A0 that works as the minimal requirements for the safe park located in Vilnius is 0.8203. It means that Ozas Park (A6) and Bernardinai gardens (A2) can be determined as safe. Since safety level in the rest four UPPs (Reformatai park, Kudru park, Vilkpedes park and Pasaku park) is lower than the threshold value, decision makers are recommended to pay attention to these public places. Exceptional attention should be drawn to Pasaku park (A5), which was determined as the UPP with the lowest safety level.

It is important to emphasise that SEMUPP methodology also provide complementary information about UPP safety. For instance, Reformatai park (A1) was determined as the third safest UPP in Vilnius; nevertheless, its safety level is lower than the threshold value 0.8203. Analysis of the data presented in Table 4 may arouse the assumptions that some relatively inexpensive and quickly implemented solutions may increase the safety level of the Reformatai park (A1) to the required level. We performed a small experiment to ascertain that the reduction of the impenetrable barriers together with the improved maintenance provided by a handler that regularly works in the Reformatai park is enough to pass the threshold line. The alteration of the decision matrix X was done to examine how the specific changes affect UPP evaluation results.

A completely different situation was noticed in Pasaku park (A5). Neither easy improvements like tree trimming, increased lighting or enhanced maintenance, nor more significant enhancements like pathways design and installation of people attraction objects might increase its safety level up to the minimal requirements. A high number of residents, low real-estate prices and exceptionally high crime rate in the surroundings of this park negatively affect safety situation in the UPP A5. Socio-economic context cannot be changed in a short period; therefore it can be presumed that a comprehensive safety improvement strategy is needed for this public place (Pasaku park was not renovated since 1986).

Since state-of-art analysis revealed that high crime rate should not be used as the decisive criterion that describes UPP safety, we also examined if the higher crime rates always mean a lower level of UPP safety. Our case study analysis demonstrated that a number of crimes (S_{16}, S_{17}) in the surroundings of Bernardinai Gardens (A2) is higher than the crime rate near Reformatai park (A1) or Kudru park (A3). Nevertheless, other safety-related decisions that were applied during the renovation of Bernardinai Gardens (completed in 2013) made it the second safest UPP in Vilnius. This example reveals that the number of criminal activities should not be used as the solitary criteria to estimate urban park safety.

4.1. Sensitivity analysis

The sensitivity analysis was performed to study the consistency of the obtained ranking. Since the hypothetical park A0 works as the threshold that assists decision makers in revealing unsafe public parks, an additional experiment was done to examine how ranking results are affected by the determination of A0. Eight park visitors who do not have experience in urban planning were asked to express their opinion about the minimal requirements of the safe park. Five criteria that are easy to understand and assess (S_2, S_3, S_4, S_5, S_{12}) were chosen as the basis for this sensitivity analysis. Criteria associated with the socio-economic context remained unchanged. Values that were proposed by the participants are presented in Table 6.

Results of the sensitivity analysis are presented in Fig. 4, where TEST 1 corresponds to the UPP ranking that was determined using the $A0(S_2)$, $A0(S_3)$, $A0(S_4)$, $A0(S_5)$, $A0(S_{12})$ values proposed by the expert group. TEST 2 – TEST 9 demonstrate ranking results when the subjective opinions of different citizens are used to characterise minimal requirements for the safe park.

Fig. 4 reveals that small adjustments of the A0 values might slightly affect the final ranking of urban public parks. However, since there are no drastic changes in the final list of the safe UPPs (green lines in Fig. 4), the consistency of the obtained ranking can be observed. A more systematic analysis that examines how the alteration of all the initial conditions may impact ranking results is going to be performed in the future researches.

Table 6
Values of the criteria S_2, S_3, S_4, S_5, S_{12} for the for-sensitivity analysis of UPP A0.

	$A0(S_2)$	$A0(S_3)$	$A0(S_4)$	$A0(S_5)$	$A0(S_{12})$
Test2 (park visitor 1)	30	85	45	5	8
Test3 (park visitor 2)	20	70	50	5	6
Test4 (park visitor 3)	15	85	30	7	8
Test5 (park visitor 4)	35	80	20	5	7
Test6 (park visitor 5)	15	60	20	5	6
Test7 (park visitor 6)	25	60	50	6	7
Test8 (park visitor 7)	20	60	30	5	8
Test9 (park visitor 8)	25	80	40	6	7

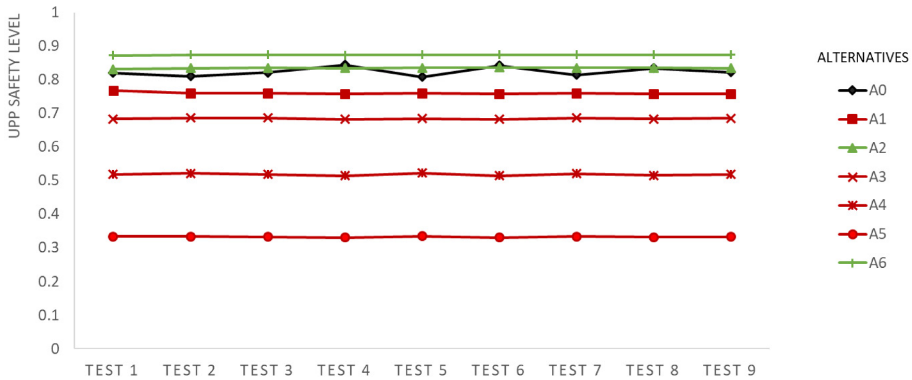


Fig. 4. Sensitivity analysis illustration.

5. Conclusions

Urban public parks can become crime generators if they are insufficiently maintained, inadequately supervised and does not provide an environment for positive activities. New Safety Evaluation Methodology of Urban Public Parks (SEMUPP) was proposed to measure safety level in small urban public parks. Multicriteria approach WASPAS-SVNS was applied to estimate safety level in several UPPs and to identify, which of them needs professional supervision, renovation or other safety-related solutions. Twelve UPP safety factor groups and 17 quantifiable UPP safety estimation criteria were determined to assess UPP safety level. Since the combination of criteria related to the environmental design and the socio-economical context is employed, the SEMUPP methodology allows decision makers to achieve valuable information about UPP safety.

SEMUPP methodology was tested in the capital of Lithuania. Six small urban public parks were evaluated. Three of them were located in the City Centre, the other three – in the suburbs. The safest alternative Ozas park (A6) and the alternative that needs urgent renovation Pasaku park (A5) were detected as the result of the proposed methodology. Case study analysis also revealed that the crime level should not be used as a single criterion to evaluate urban park safety.

Urban park renovation is an expensive project; therefore SEMUPP can become a valuable tool to assess if it meets the requirements of the safe UPP. Since characteristics like park size and geographical position effect UPP safety, we recommend to apply the proposed methodology separately for small and for big urban public parks. Additional studies that would analyse the safety level in big UPPs could be a valuable addition to this research. SEMUPP application in different countries also may give useful information about the relationship of UPP safety and the socio-economic context.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.landurbplan.2019.05.014.

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