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CLIMATE-ORIENTED ASSESSMENT OF MAIN STREET DESIGN AND DEVELOPMENT IN BUDAPEST

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Abstract. Main streets play pivotal role in urban areas in terms of economic, social, moreover environmental contexts. Such streets are generally situated in densely built-up areas, where the adverse effects of climate change, such as rising temperature and changing precipitation patterns occur emphatically. Increasing urban heat island effect or extreme amount of runoff water during severe storms and floods significantly decrease the adaptive capacity of a city, consequently its residents becoming more vulnerable. Therefore involving climate-oriented design principles into planning and construction phase contributes to reach more sustainable and climate-friendly open spaces what are strongly relevant especially in main streets which are designed for a great amount of people. Present study provides a criteria matrix for assessing the climate-friendly level of recently renewed main streets in Budapest. Due to this assessment tool the adaptation and mitigation performance of the selected projects can be evaluated. For identifying strengths and weaknesses of a given project, a rating scheme has been applied by selecting and using 42 indicators grouped into mitigation, adaptation and awareness raising categories. Thus planners, decision-makers and other stakeholders can easily define future opportunities and challenges, accordingly this study may contribute to take urban street design practices toward climate-friendliness by paying more attention on changing local weather patterns and related consequences.

Keywords: urban sustainability, adaptation, mitigation, assessment, main street, matrix, indicators.

Introduction

As cities becoming more densely populated (UN 2014) and the impacts of climate change are getting more severe (IPCC 2014), there is an urgent need for elaborating effective evaluation systems for assessing our cities' climate-oriented performance. Urban areas are crucial sites due to their concentrated economic, social, environmental and spatial features (Andersson-Sköld *et al.* 2015), consequently reliable assessment systems are inevitable for avoiding maladaptation and for inspiring innovative adaptation actions (Medved 2016). Extreme weather events may increase the losses in urban areas, therefore cities and their population are largely vulnerable regarding climate-related hazards and risks (Birkmann *et al.* 2014; Mitchell *et al.* 2015; Norton *et al.* 2015). It can be declared that urban population has to take adaptation efforts and being more resilient regarding adverse effects and risks caused by climate change (Norton *et al.* 2015; Voskamp, Van de Ven 2015), since economic and social consequences of above mentioned impacts may go beyond the administrative borders of urban zones (Zheng *et al.* 2014). Therefore, integration of sustainability principles into urban development actions is a prerequisite of effective resource management in a given urban area, thus reducing environmental degradation, consequently making cities climate-friendly (Gaitani *et al.* 2014). Nowadays a shift can be seen from mitigation to adaptation in current urban studies and such solutions and questions are raising, which are focusing on middle-, and long term impacts of climate change and paying significant attention to adaptive capacity (Costa *et al.* 2013). It shall be emphasised that uncertainties regarding the possible impacts of climate change are significant, therefore this challenge fundamentally determines the allocation of available resources and knowledge.

As one of the East-Central European metropolises of the former socialist block, the Hungarian capital Budapest has to face a number of challenges concerning urban regeneration, moreover changing climate patterns raising numerous questions about its adaptive capacity as well.

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Due to its unique and specific local weather features and predicted climate patterns in the future (Probáld 2014), urban heat island and extreme floods can be determined as the key climate-related challenges of Budapest (Buzási 2014).

The beginning of the years 2000 found the historic city centre including its public spaces in fairly run-down conditions, but the EU accession of Hungary in 2004 opened new ways for the regeneration of the city. After 2004, with the help of the available EU and national subsidies Budapest got a unique possibility for the regeneration of its run-down historic city centre. By offering fast and spectacular results, public space renewal became a popular tool for local decision-makers and during the last few years all the inner districts realised their main square or high street projects. Being co-financed by the EU these projects were obligated to apply European standards including different sustainability requirements as well. Nevertheless, projects diverge in achieved qualities and are often criticised for not serving effectively the harmonised social, economic and environmental development of the city. Regarding climate aspects there are some promising initiatives emerging recently originating from both public and private actors in order to gain more consciousness in climate friendly urban regeneration and public space renewal[1].

Present study has three different, but relating aims regarding climate-friendly main street design, moreover it can foster to define sustainable and climate-oriented measures and techniques on micro scale. The first aim is focusing on assessment methodology by developing a criteria matrix for evaluating climate-friendliness of main street renewal projects. The matrix is based on CH2MILL evaluation system elaborated by Bevan *et al.* (2007), however modified in climate-friendliness point of view, such as mitigation, adaptation and awareness raising aspects have been involved in it. The system and the evaluation methodology are detailed below. By applying the elaborated criteria matrix for specific sites, the second aim of the study seeks to evaluate recent main street renewal projects of the historic city centre of the Hungarian capital Budapest regarding climate related issues. The elaborated framework represents the different aspects of design, construction and maintenance phase in a given main street project by applying comprehensive indicators and by using an easily understandable three-coloured assessment system. The third aim is to identify present challenges and future opportunities by analysing the strengths and the weaknesses of main street reconstruction projects.

The simplified assessment method can be used not only in case of Budapest but also in other cities with continental climate and common climate risks. Apart from the objective of wider application of this method, it must be emphasised, that meteorological conditions emerging in cities are greatly varied especially with respect to microclimatic features. Underlying this statement, the paper seeking to draw up an assessment method, in which adaptation, mitigation and awareness raising aspects are involved, in addition climate-oriented criteria may take into consideration in renewal projects of urban spaces. This approach has remarkable significance because of the vulnerability of cities concerning predicted extreme weather events.

1. Literature review

1.1. Urban regeneration – macro level

As it was mentioned in the previous paragraphs, changing weather patterns affect more and more significantly the urban areas, whereas urban regeneration and the preparedness for climate hazards are on the focus in recent urban studies (Reckien *et al.* 2014). Urban areas shall pay increasing attention on present and future impacts and risks generated by climate change, since cities and their population are largely exposed to the future impacts. One of the most studied and analysed phenomenon is the urban heat island (UHI) effect, i.e. the larger surface and air temperature in city centres compared to non-urban surrounding areas (Lokoshchenko 2014; Brown *et al.* 2015; Tam *et al.* 2015; van Hove *et al.* 2015). There are several causes what are responsible for increasing the UHI, such as non-reflective and low-albedo materials, human generated heat sources, densely built-up areas and the lack of green spaces and water bodies (Maimaitiyiming *et al.* 2014; Zoras *et al.* 2014). Therefore urban greening, changing surface materials and other techniques in densely populated areas have significant and well-known role in urban regeneration projects for creating sustainable and climate-friendly cities (Csete, Horváth 2012; Jim 2013). Other weather risks which have impact on our cities are changing precipitation patterns: the more frequent storm surges, and regarding to this, the more serious fluvial and pluvial floods (Pathirana *et al.* 2014; Zhang *et al.* 2015).

Climate predictions play highly important role in urban design and regeneration, since according to Costa *et al.* (2013) urbanism may be influenced by them in two manner: firstly, there may be substantial impact in planning and construction phase; secondly the approaches with regards to infrastructure will be changed because of the need for adaptation to changing climate. Similar to these statements, Benkő (2011) in her study noted that one of the most significant debate concerning urban planning is the re-designing and the re-evaluating of urban spaces in order to reach a sustainable condition.

[1] It is worth to mention the Association of Climate Friendly Municipalities, the EU financed Urban Heat Island project or the Green City Hungary movement among others.

Since climate predictions and future climate hazards, moreover related risks are changing from place to place, there is no rigorous guidelines for improving cities' adaptive capacity. It is noted that every city need divergent actions to meet its demand with regards to achieve climate goals and improve the quality of life of its citizen. Nevertheless climate-related urban regeneration techniques can be grouped into three main categories, which are the followings:

- mitigation actions, such as: enhancing green-covered areas; preferring non-motorised ways; reusing of construction materials; using low-maintenance and low-energy devices; improving accessibility by promoting public transport; traffic calming (Csete, Török 2009; Kelemen-Erdős 2012; Juhász 2013; Wamsler *et al.* 2013; Bede, Török 2014; Brown *et al.* 2015; Gaál *et al.* 2015),
- adaptation actions, such as: passive cooling and shading techniques; tackling stormwater issues; promoting integrated water management; paying attention on biodiversity in urban green spaces; designing climate-resistant materials (Gersonius *et al.* 2012; Jim 2013; Gaitani *et al.* 2014; Takebayashi *et al.* 2014; Djukic *et al.* 2016),
- awareness raising actions, such as: collaborating with citizens; using public information about actions; promoting innovative solutions; sustainable designing in planning phase; early warning system regarding heatwaves (Gaitani *et al.* 2014; Takebayashi *et al.* 2014; Groot *et al.* 2015; Lee, Painter 2015).

Costa *et al.* (2013) well summarised the changed demand with respect to urban design what is stimulated by climate change. They determined five different changes in the topic, such as: re-evaluating of present urban infrastructure; investing in improvement of applicability of innovative urban design techniques; reassessing of urban plans with respect to climate resilience; reducing the importance of strategies focusing on short-term goals and objectives; re-evaluating of risk management and civil protection strategies based on newly acceptable climate data.

Present study may reflect to above mentioned challenges and needs in the field of climate-friendly street design by applying criteria matrix with qualitative indicators for assessing climate-related aspects of main street renewals.

1.2. Public spaces – micro level

As it can be seen in the previous sections, city level plays an important role in preparing to changing climate patterns. Since cities consist of public spaces, where regeneration projects are made, micro level has become one of the most relevant place for building cities' adaptive capacity and resilience. As Costa *et al.* (2013) stated, climate change can be understood on global scale, however its impacts have local features, thus demonstrating the obvious importance of micro level in climate-friendly street design. This increasing importance has been recognised in recent urban studies, proved by rising number of publication regarding appropriate street and other public space design from sustainable and climate-friendliness point of view.

Erell (2008) emphasised the importance of application of climatology in urban design processes by distinguishing the challenges and opportunities of design techniques and influencing factors regarding urban microclimate on city and micro level. Jim (2013) provided recommendations concerning urban forestry based on case studies of 100 cities from 25 countries. His recommendations contribute urban spaces to become climate-proof ones concerning ecological design, greenspace geometry, biodiversity, tree and soil issues etc. The statements can be applied not only in design but in construction phase as well.

Zoras *et al.* (2014) performed simulations regarding the use of cool materials in the centre of Florina, Greece. Their results obtained show that surface temperature could be reduced by using cool materials. Rehan (2013) in his comprehensive study conceptualised the sustainability of streetscape and street, as well as determined the main elements to achieve sustainable streetscape. Shashua-Bar *et al.* (2012) analysed the opportunities in amelioration of citizens' thermal comfort in summertime by using climate-oriented urban planning approaches and passive cooling techniques. According to the authors, greening and vegetation issues play more significant role in decrease of temperature compared to actions regarding modification of albedo of walls of buildings. Connecting with latter study, Takebayashi *et al.* (2014) studied technologies concerning decrease of UHI and provided the same consequences, completing this with a statement, that water retention has also important role in decreasing the surface temperature.

Gaitani *et al.* (2014) analysed microclimatic features for urban regeneration project in case of Acharnes. They suggested recommendations with regards to land coverage and building materials in order to ameliorate the thermal comfort in selected streets of Acharnes. Riera Pérez, Rey (2013) focused on neighbourhood scale, between building and city level which aspect provide opportunities to the evaluation of actions and complex urban renewal projects in a highly sensitive way. Beside, on neighbourhood scale both sustainable building and city level exist and can be analysed. Radulovic *et al.* (2015) focused on extreme heat waves and related impacts in case of Serbian cities. They studied compact urban structure, as an opportunity to mitigate urban heat in lights of urban planning whether it has an importance in creating climate-friendly cities.

Klemm *et al.* (2015) emphasised and numerically simulated the potential role of street greenery in moderate climates in case of nine streets of Utrecht, the Netherlands. It can be stated that green facilities in urban streets play significant role in increasing thermal comfort and mitigating heat discomfort. Through above mentioned mechanisms (evapotranspiration, shading, etc.) they contribute to create not only attractive but climate-resilient streets in cities with soft and hard measures. The results of their study pointed out that significant role of trees in urban streets can be observed, moreover taking green aspects into consideration in designing streets is required for achieving global sustainability- and climate-oriented goals.

Based on the reviewed literature it can be stated that street-level refurbishments and renewals plays significant role on city scale, because they are crucial elements of climate-friendliness in a given city.

1.3. Existing evaluation methods

However numerous set of indicators exists regarding urban renewal on international scale, there is no widely accepted method for assessing impacts and contributions of renewal projects in lights of climate-oriented challenges and opportunities.

Norton *et al.* (2015) elaborated a five-step approach for evaluating potential impacts of green infrastructure on micro scale, as a comprehensive urban development tool. The role and the importance of green infrastructure in light of present study is undoubted through both mitigation and adaptation efforts. Therefore green areas have to be treated in the centre of urban renewal projects in developing the most effective urban street renewal strategy. Andersson-Sköld *et al.* (2015) evaluated different scenarios in the field of urban renewal by applying individual rankings for taking environmental and social impacts into consideration, then using these information, recommendations have been drawn up. The main aim of the study was to reduce climate-related risks through a renewal project of Gothenburg with paying more attention on inhabitants' perceptions. A framework for assessing climate-.related risks in the field of extreme heat waves, floods and air pollution has been provided in order to be able to avoid latter incompetent urban development decisions. The potential impacts of the given actions are ranging from –2 (counter-productive effect) to +2 (very effective). Finally, the design alternatives of impact categories (such as flood risk mitigation; urban heat stress; energy and raw material consumption; wellbeing) have been scaling from –3 (very negative contribution) to +3 (very positive contribution). Madureira *et al.* (2015) focusing on social factors by surveying and evaluating urban residents' belief associated with urban green spaces in case of Paris, Angers, Lisbon and Porto. They stated that urban residents rated climate-related aspects at a lower level than well-being and recreation-based benefits provided by urban green spaces. Since urban residents and their needs are in the heart of a given regeneration project, understanding their opinion is crucial in the co-operation phase. Therefore present study provides indicators regarding co-operation between planners, constructers and residents. The Sustainable Pittsburgh released a sustainability assessment tool (Sustainable Pittsburgh 2008) as guidance for decision makers and residents. The brochure introduced different aspects of sustainable urban renewal projects, such as:

- site selection (brownfield or greenfield),
- site preparation (tree removal; water bodies; green areas),
- infrastructure (capacity issues; storm water runoff),
- site design (environmental aspects; bike lanes; accessibility; traffic calming),
- transportation (parking places; promoting non-motorised modes),
- housing (affordability; design),
- buildings (materials; orientation),
- and community character (street furniture; community spaces; public involvement).

Each subcategory have checklists (for example "preservation of flora and fauna habitat and migration corridors" in site preparation category), so the reporter can easily decide and mark in a cell whether a given statement is true or not in case of a given site renewal project.

In summary it can be stated that there are several studies regarding ex-post analysis of a given renewal project, they are mainly focusing on a few aspects of climate change. Involvement of broader scale of subsystems, such as evaluation of both mitigation and adaptation topics – completed by social factors, such as awareness raising – is lacking nowadays in the scientific field, therefore present study can be fill the gap existing in recent urban studies.

2. Methodology

2.1. Criteria matrix for evaluating climate-friendliness

Based on the sustainable urban street options of CH2MHILL (Bevan *et al.* 2007) a simplified criteria matrix for the evaluation of main street renewals' climate friendliness aspects have been elaborated. The evaluation matrix can be divided into three main categories, namely mitigation, adaptation and awareness raising. Each category includes the main aspects from urban regeneration and climate-oriented point of view, by covering the most frequently mentioned topics in present scientific are (see Table 1). Mainly qualitative indicators are involved into each topic which are rated in a three-scale scheme from plus to minus across neutral (minus sign refers to bad performance, zero signs moderate one, and plus ranks well-performed actions). This rating system contributes to straightforward results and can support the evaluation of strengths and weaknesses related to an examined urban main street regeneration projects, moreover it can support planners and decision makers for identifying consequences and future improvement opportunities. Each rating scheme is slightly different from others, in addition to this some indicators have a two-step approach, if an intermediate value could not be identified (see Appendix).

Selection of indicators is based on the set of indicators composed by Bevan *et al.* (2007), however restructured from a climate friendly perspective, modified for local features and data availability. As it was mentioned above, present set of indicators and assessment system are mainly referring to main street renewal projects and their consequences in Budapest, however with a slight modification considering local circumstances it can be applied for assessing other renewal projects in other cities. Mitigation topics reflect to reduction of GHG emissions through site preparation; promoting and preferring non-motorised transportation modes; material issues in maintenance and construction; and green areas. Adaptation ones are based on the improved preparation and adaptive capacity of a given main street for changing weather patterns, such as rising temperature and the risk of more severe floods and storms. As it was declared in the previous section, local climate features and the predicted changes of them largely endanger the adaptive capacity and the resilience of Budapest, moreover this statement is particularly true for densely built-up areas, such as main streets in the downtown. Consequently water management and shading issues are strongly emphasised within adaptation topics, however climate-resistance of materials and green areas have been taken into consideration as well.

Table 1. Evaluated subsystems regarding mitigation, adaptation and awareness raising

Mitigation
Bicycle facilities
Promoting non-motorised transport options
Maintenance
Construction
Public transport facilities
Green areas
Adaptation
Storm water issues
Material and construction elements
Usage of porous pavements
Shading
Water management
Biodiversity issues
Awareness raising
User-oriented solutions
Construction-oriented solutions

Awareness raising aspect acts a slightly different consideration in urban climate studies and often has less attention on it, however stakeholder involvement and information spreading are crucial in developing efficient strategies and creating climate-resilient and sustainable open spaces in urban areas. Therefore the aspects of user-, and construction-oriented solutions have been involved into present analysis by evaluating collaboration between users and planners, by analysing information spreading and the existence of sustainability issues in planning phase and off-site parking.

Data upload of this evaluation matrix is based on divergent methods, such as onsite analysis and planner interviews via phone and email. By performing onsite analysis mainly mitigation- and adaptation-oriented subsystems have been uploaded, however in case of tree removal, construction issues, storm water management actions and water-appropriate plantings there was a need for interviews. Similarly to mentioned subsystems, almost all of the them have been assessed by interviewing planners of the examined projects via phone or email.

2.2. Study area

For the on-site analysis five recently renewed main streets have been chosen, all of them located within the historic inner city districts of Budapest (Fig. 1). The sites correspond in many characteristics that with certain limitations facilitate the comparison of the survey results. These characteristics include:

- high streets: all of them function as the main street of their districts with attractive and intensive retail sector;

Fig. 1. Location of the examined main streets

– rehabilitation sites: all the streets have been totally refurbished during the last two decades, when sustainability and climate-based issues could been taken into consideration;
– many of them are co-financed by the EU;
– traffic calming was a basic objective of the renewal projects.

However, there are some important factors that differ between the sites:
– developers of all the projects are different, most of the projects were coordinated by the local district municipality of each site, except one project that has been realised by the city municipality;
– urban design solutions differ in lack of any kind of common design codes or other design requirements except of basic national regulations, district municipality building codes and utility requirements.

General data about studied projects and areas can be seen in Table 2, that summarises the locations, developers, the date of the given renewal and the length of the streets. It can be stated that the New Main Street project is the biggest action regarding the length of the street with almost 2 kilometres, however the renewed stage of Lövőház Street is only 300 metres. As it was mentioned before, the common primary aim of the projects was traffic calming, therefore mitigation-orientation can be anticipated. This statement shall enhanced by taking the dates of renewals into consideration, since worldwide in the late 90's and the early 2000's mitigation actions outweighed adaptation ones.

3. Results

Table 3 shows the mitigation-oriented features of the renewed streets, where each indicator and the rating scheme can be seen. As it was stated before, traffic calming was distinguished and primary aim of the examined main street projects, therefore transportation issues have

Table 2. General data of the studied areas

Name	(1) New Main Street of the Downtown	(2) Király Street	(3) Baross Street – Krúdy Street axis	(4) Ráday Street	(5) Lövőház Street
Location	District V	District VI and VII	District VIII	District IX	District II
Developer	Local Municipality of District V	Local Municipalities of District VI and VII	Municipality of Budapest	Local Municipality of District IX	Local Municipality of District II
Date of renewal	2010, 2014	2005, 2010	1997, 2002, 2004	1997–2002	2012
Length	1800 m	700 m	500 m	800 m	300 m

Table 3. Mitigation-oriented features of the renewed streets

		Ráday Street	Baross Street	New Main Street	Lövőház Street	Király Street
Bicycle facilities	Bike racks	0	0	+	0	–
	Bicycle route signage	0	+	+	+	–
	Bicycle priority at signals	–	–	–	–	–
Promoting non-motorised transport options	Traffic calming features	+	+	+	+	+
	Remove on-street parking	–	–	–	0	–
Maintenance	Low maintenance pavements	+	+	+	+	0
	Low energy lighting	0	0	0	0	0
	Solar power photovoltaic energy sources	–	0	0	–	–
Construction	Usage of recycled materials	0	+	0	–	–
	Minimal tree removal	NR	+	+	+	NR
	Use of locally obtained materials	0	0	0	N/A	0
Public transport facilities	Enhanced bus zones and shelters	NR	NR	+	NR	NR
	Accessibility by public transport	+	+	+	+	+
Green areas	Change of green-covered area	+	+	+	+	+
	Create pocket green spaces	0	0	+	+	0
	No. Of trees / 100 m	–	+	-	+	0

been emphasised in the set of indicators with five variables. Based on the results of the bicycle issues and of the non-motorised ways it can be stated that in case of Király Street there is a lack of efficient actions in this field, however traffic calming measures (speed humps, chicanes, and chokers) emerged in an appropriate way, similar to the other projects. Removing on-street parking is an other common weak point of the studied renewals by not banning parking places in the streets, though one half of the Lövőház Str. (from Fény Str. to Káplár Str.) is a completely no-traffic zone. The results of maintenance issues is unequal, since low maintenance payments have been applied in case of almost the total stage of the streets, however solar power photovoltaic energy sources emerged only in the Baross and the New Main Street in a small amount (mainly by supplying power to parking meters).

Usage of recycled materials was not a common part of the renewals, it can be seen on Baross Str., however on Lövőház Str. and Király Str. recycled materials have not been used for reducing the footprint of the projects. Minimal tree removal, or more likely additional planting can be observed in the renewed streets in all case, however the original aspect of tree removing was not relevant on Ráday Str. and Király Str. because of the lack of trees previously. The assessment of the accessibility issues is based on the public transport fatalities and stops. Since each of the streets are situated in downtown area, proximity of public transport stops are in 200 metres from the ends of the studied streets. Actions regarding bus stops and related zones are not relevant except in case of New Main Street, because of the lack of public transport route on the other streets.

Green areas are highly relevant actors in offsetting GHG emissions in urban areas, however they have adaptation features, based on the indicators this topic has been involved into the mitigation category. The first evaluated factor was the change of green-covered area, what was found as strength of the projects, since in case of each street, the ration of green-covered area was clearly increased. The fragmentation of green spaces was quite low on New Main Street and Lövőház Str., but moderate on the other three cases as well, what shall endanger ecological connectivity, therefore mitigation capacity shall be reduced in these sites because of the lack of well performed and connected green spaces. The no. of trees / 100 m is the only quantitative indicator in this study, so that the determination of effective value of it is based on literature review (McBride 2008; City of Vancouver 2011; City of Philadelphia 2014). The sustainable and liveable tree spacing is about 8–12 m between trees, so completed by the length of the streets, an effective tree density can be calculated. In case of Ráday Str. and New Main Street, slightly more than 3.5 trees can be observed in average, this value is approximately 7 trees / 100 m on Király Str., 10 for Baross Str. and almost 12 for Lövőház Str. However it must be emphasised that average size of tree canopies was the smallest on Király Str., therefore shading capacity was moderate on this street (see in the next paragraph).

In Table 4, adaptation-centred indicators and related results have been summarised and visualised by the applied three-scored approach. In case of Budapest, increasing temperature and more intense storms and flood risks are the most relevant predicted weather extremes in the future. Therefore water management and shading have been involved into the analysis in a highly emphasised way by using 13 indicators in these fields. It can be stated that storm water management is a totally weak point of the projects, since there is no reusing, treating or reducing actions regarding storm water runoffs on the analysed main streets. However in case of Ráday Str., New Main Street and Király Str., there is an opportunity for infiltrating run off water into a basin, but these technical solutions are out of service. The rating of material and construction elements is basically more positive, since typically modular elements and higher strength pavements have been applied (except on Király Str., where some damages can be observed on the pavement). Usage of climate-resistant design principles and street furniture could not been proved, although each of the furniture have been replaced, but climate-resistance was not a perspective in design and construction phase of the projects regarding street furniture. Opposite of the above mentioned perspectives, usage of porous pavements is widely and properly applied adaptation technique, since impermeable surfaces do not prevent storm water runoff, consequently the risk of storm floods shall increasing. One exception is Király Str., where impermeable surface has been used for the roads, and an other exception is Baross Str., where porous pavements have been partly used for traffic lanes and parking areas. Since intensive warming must be faced by Budapest in the near future, shading of main streets in densely built-up urban areas is crucial in terms of resilience.

In case of three of the studied streets, namely Ráday Str., New Main Street and Király Str., retailers' and restaurant owners' contribution is essential in effective shading, consequently tree canopy layers are not continuous on these streets. However on Ráday Str. there are some shelters when pedestrians can be protected from weather extremes. Existences of public drinking water equipment and water-appropriate plantings have been covered by water management issues in the analysis with moderate or bad results. Firstly, public drinking fountains can be found only on Baross Str. and New Main Street, however in a very small number (1 or 2 fountains per street). Furthermore water-appropriate planting can be applied for designing main streets in a moderate way, since local climate features and predicted changing precipitation patterns have not been into consideration in planning site, although urban-tolerant species have been selected for green spaces. Finally, biodiversity issues are emerging through tree planting and selecting practices and ecological connectivity. With few exceptions, it can be noted that every examined main street has a moderate performance in this field, because of the lack of climate-oriented designing approaches.

Based on Table 5 which represents the results regarding awareness raising aspects it can be stated that these directions of climate-conscious design is in its infancy. This assumption is based on the lack of information concerning collaboration with stakeholders and off-site worker parking. Moreover the streets' performance with regards to information spreading is relatively bad or at least moderate due to the lack of public information boards. Public information boards are crucial in awareness raising by informing broad scale of urban residents about divergent actions and used technology in a given project in terms of sustainability or climate-friendliness. In summary it can be stated that sustainability principles have been partly involved into planning phase by taking technical solutions and opportunities into consideration, however neither project can be seen as sustainable main street renewal one.

Table 4. Adaptation-centred indicators and results

		Ráday Street	Baross Street	New Main Street	Lövőház Street	Király Street
Storm water issues	Reuse of storm water for irrigation	–	–	–	–	–
	Surface conveyance for storm water	–	–	–	–	–
	Reduced storm water vaults through natural drainage systems	–	–	–	–	–
	Storm water infiltration basins in planters	0	–	0	N/A	0
	Rain gardens for storm water infiltration	–	–	–	–	–
	Storm water treatment vaults	–	–	–	–	–
Material and construction elements	Incorporation of recycled vegetative material	0	+	0	+	0
	Precast or modular construction elements	+	+	+	+	0
	Climate-resistant designs and materials	0	0	0	0	0
	Higher strength concrete pavements	+	+	+	+	0
Usage of porous pavements	Porous pavement for traffic lanes	+	0	+	+	–
	Porous pavement in parking areas	+	0	+	+	+
	Porous sidewalk pavements	+	+	+	+	+
Shading	Retention or introduction of tree cover to reduce heat gain on paved areas	0	+	0	+	0
	Shelters for protecting pedestrians from weather	+	+	0	+	0
Water management	Public drinking fountains	–	0	0	–	–
	Water-appropriate plantings	0	0	0	0	0
Biodiversity issues	Diverse plant/tree selections	0	0	0	0	0
	Local climate-oriented plant/tree selections	0	0	0	0	0
	Enable ecological connectivity	0	+	0	+	0

Table 5. Indicators and results regarding awareness raising

		Ráday Street	Baross Street	New Main Street	Lövőház Street	Király Street
User-oriented solutions	Trash and recycling receptacles	0	0	+	0	0
	Collaborate with property owners for mutual benefit	N/A	+	+	N/A	N/A
	Promotional information regarding sustainable elements in the project	–	–	0	–	–
	Public information about actions and used technology	–	–	0	0	–
Constructor-oriented solutions	Off-site construction worker parking	N/A	+	N/A	N/A	N/A
	Sustainable design in planning phase	0	0	0	0	0

4. Discussion

Based on the results of the assessment detailed above, strengths and weaknesses regarding climate-orientation in recent main street design can be defined. First of all it can be stated that there is no clear difference between overall adaptation and mitigation performance of the projects, however as it was mentioned above mitigation-oriented technical solutions was well known on date of the renewals. Traffic calming features, green area-related action can be clearly emphasised as strengths of the examined projects, so applied technologies and design practices shall be continued and spread. On the other hand, bicycle issues, removing on-street parking, using more amount of renewable energy sources and designing with existing and possibly reusable materials are the main opportunities what shall be taken into consideration in future climate-oriented urban main street designs. Involving these missing elements of present street design practices into future projects can enhance sustainability of main streets and contribute to reduce GHG emissions by using innovative and well performed infrastructure solutions, consequently the magnitude of negative effects of climate change shall be reduced.

From adaptation point of view, studied streets are extremely vulnerable to extreme precipitation and related floods because of the lack of effective storm water management. For improving the assessed main streets' adaptive capacity, storm water issues must be taken into consideration during planning and developing phase, since main streets are essentially situated in downtowns. Due to their economic role by attracting retail stores, restaurants and by providing great opportunities for urban residents to meet their recreational needs, enhancing resilience of main streets play pivotal role in the overall cities' adaptive capacity and related vulnerability. After the revision of adaptation-oriented indicators and results, it can be noted that the usage of porous pavements and the strength of used materials are properly performed from climatic point of view, however paying more attention on climate-resistant street furniture is needed. Shading, water management and biodiversity issues are such topics where relevant and greatly important opportunities can be observed by:

- installing public drinking fountains;
- taking water-appropriateness and local climate-orientation into consideration during plant and tree selection;
- paying more attention on enhancing ecological connectivity.

These recommendations completed by total improvement of storm water management and existing good practices contribute to provide more attractive, vibrant and viable open spaces in urban areas.

Based on the results of the awareness raising category, it can be stated that this aspect of climate-friendliness is in its infancy due to the inappropriate information spreading. However collaboration with property owners were effective and proper in case of Baross Str. and New Main Street projects by involving local residents into decision making processes, there is no information regarding this aspect from the other sites. This lack of information makes comprehensive analysis and recommendations more difficult, but the spread of existing good practices with ex-ante stakeholder involvement can be recommended.

Conclusions

Based on the results from the applied criteria matrix, it can be stated that the climate-friendly level of studied main streets in Budapest is moderate. It means that there are good practices observed during on-site analysis, however there are some weaknesses as well, such as bicycle issues, storm water management or information spreading. As improving adaptive capacity of each of cities' subsystem, such as infrastructure elements can contribute to increasing resilience on a larger scale, it can be noted that climate-oriented street design is a crucial part in reducing our cities' and their residents' vulnerability. Therefore adaptation, mitigation and awareness raising aspects must be involved into planning and construction phase of main street design. In terms of climate resilience, this previously mentioned planning approach may contribute to increase adaptive capacity of both infrastructure and urban residents by applying innovative and effective tools for involving climate aspects into street design principles. Since urban main streets have the ability to attract competitive enterprises, consequently they can increase the economic power of a given city. Therefore urban streets with climate-oriented design practices may influence climate resilience and vulnerability on larger scale mainly due to their economic-dependency, however taking climate aspects into urban planning processes may contribute to both economic prosperity and less vulnerability in a given city.

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