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Integrating water, waste, energy, transport and ICT aspects into the smart city concept

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Abstract

The paper presents the partial results of the EU BlueSCities project [1]. The project is developing the methodology for the integration of the water and waste sectors within the 'Smart Cities and Communities' concept to compliment other priority areas such as energy, transport and Information and Communication Technologies (ICT). The project has developed the City Blueprint Framework for water and waste and the City Amberprint Framework for energy, transport and ICT.

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1. Introduction

The BlueSCities Project was designed to bridge the gap between those stakeholders involved in the Water and Waste sectors on the one hand and their counterparts in the ICT, Transport and Energy sectors on the other. To date, these sectors have proved to be notoriously inefficient with regards to collaboration and transversal knowledge sharing in a subject which demands just such an approach. The creation of a BlueSCities package consisting of the City Blueprint, the City Amberprint and the BlueSCities Self-Assessment Software offers a practical mechanism which will permit the integration of water and waste within long-term Smart City policies [1]. The resulting combination is an effective, dynamic and accessible methodology which will ensure a more global attitude to the planning and implementation of sustainable urban roadmaps with a strong emphasis on the bottom-up approach. It has been observed that such a philosophy is becoming more widely acceptable both to supranational administrations and their regional and municipal counterparts thus ensuring the utility and necessity of what is described in this paper.

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Nomenclature

ACI	Amber City Index
BCI	Blue City Index
CAF	City Amberprint Framework
CBF	City Blueprint Framework
IWRM	Integrated Water Resources Management
TPF	Trends and Pressures Framework
TPI	Trends and Pressure Index
UHI	Urban Heat Island
WWT	Waste Water Treatment

The City Blueprint Framework is used to perform a baseline assessment of Integrated Water Resources Management in cities (Table 1) [2], and has been applied on 47 municipalities and regions in 30 countries, predominantly in Europe [3,4]. The City Blueprint® provides a snapshot of the actual state of a city's IWRM (Fig. 1 and Fig. 2). This is a key first step in the transformation towards sustainable urban water management [5]. The City Blueprint is designed to enable comparison between cities, and as such promotes city-to-city learning by exchange of experiences, implementing knowledge and best practices [4]. It forms the basis for strategic understanding and long-term planning of urban IWRM. The City Blueprint consists of two separate frameworks, i.e., Trends and Pressure Framework and City Blueprint performance-oriented Framework.

The City Amberprint Framework is a complement to the CBF. The main goal of the City Amberprint is a baseline assessment of the sustainability of Energy, Transport and ICT in cities. The indicators in the City Amberprint™ are introduced in order to: (i) evaluate current state of the sustainability in the cities; (ii) identify the best practices and share them with other municipalities; (iii) find direct links between the City Amberprint™ indicators and five aspects of a smart city: water, waste, energy, transport and ICT; (iv) inform citizens and stakeholders about the current situation in the city.

All thee frameworks were applied to the City of Leicester in the UK. The paper is structured as follows: in Section 2 the Trends and Pressures Framework is described. Section 3 follows with a short description of the City Blueprint Framework. In Section 4 the methodology for the City Amberprint is summarized. The results from the City of Leicester are presented in Section 5. The paper concludes in Section 6.

2. Trends and Pressures Framework

The urban water cycle management performance is strongly influenced by a social, environmental and financial setting that is unique for each city. These general trends and pressures can hardly be influenced by urban water management. Therefore, a separate Trends and Pressures Framework has been developed in order to provide a wider context. The TPF consists of 12 descriptive indicators (Fig. 1) that are equally distributed according to the triple bottom line approach [6,7]. Through the TPF awareness is raised of the most relevant aspects that hinder, or conversely, reveal opportunities for IWRM [8].

3. City Blueprint Framework

The City Blueprint Framework consists of 25 performance-oriented indicators, divided into 7 broad categories representing the entire urban water cycle (Table 1). The overall score is called the Blue City Index and is obtained through the geometric mean of the 25 indicators. Both the CBF and TPF are implemented through a questionnaire which is available on-line [1].

[1] For the CBF and TPF questionnaire and related information see http://www.eip-water.eu/sites/default/files/City%20Blueprint%20questionaire_.pdf

Table 1: Basic method and features of the improved City Blueprint Framework

Goal	Baseline performance assessment of the state of IWRM	
Framework	Twenty-five indicators divided over seven broad categories:	
		1. Secondary WWT
	I Water quality	2. Tertiary WWT
		3. Groundwater quality
		4. Solid waste collected
	II Solid waste treatment	5. Solid waste recycled
		6. Solid waste energy recovered
		7. Access to drinking water
	III Basic water services	8. Access to sanitation
		9. Drinking water quality
	IV Wastewater treatment	10. Nutrient recovery
		11. Energy recovery
		12. Sewage sludge recycling
		13. WWT Energy efficiency
	V Infrastructure	14. Average age sewer
		15. Operation cost recovery
		16. Water system leakages
		17. Stormwater separation
	VI Climate robustness	18. Green space
		19. Climate adaptation
		20. Drinking water consumption
		21. Climate robust buildings
	VII Governance	22. Management and action plans
		23. Public participation
		24. Water efficiency measures
		25. Attractiveness
Data	Public data or data provided by the (waste)water utilities and cities based on a questionnaire	
Scores	0 (bad performance) to 10 (excellent performance)	
Overall score	Blue City Index® , the geometric mean of 25 indicators varying from 0 to 10	

4. City Amberprint Framework

The 22 indicators have been developed in three categories: energy, transport and ICT (Table 2). Each of the indicators has a score between 0 (there is a concern) to 10 (no concern). The quantitative indicators were "normalised" on a scale from 0 to 10, where 10 points were assigned to cities that met or exceeded certain criteria on environmental sustainability. The visual representation of the City Amberprint is a radar chart similar to the one presented in Fig. 3. The overall score of sustainability is expressed as Amber City Index . The ACI is the geometric mean of the 22 indicators for energy, transport and ICT and is calculated similarly to BCI.

The indicators are constructed in such a way to represent: 1) environmental impact of the city, 2) quality of life, 3) risks, for instance interruption of the services provision, 4) actions of the city to improve all three. The higher value of an indicator corresponds to the low environmental impact of the city, high quality of life, low risks and proactive actions undertaken by the city. The methodology was inspired by ideas developed in the City Blueprint and existing indicators from literature, such as Green City Index [9], ISO indicators [10], PLEEC Planning for Energy Efficient Cities project [11], The Digital Economy and Society Index (DESI) [12], International Telecommunication Union (ITU) [13] and others.

Table 2: City Amberprint Indicators

No.	Indicator	Definition
1	Carbon footprint	The carbon footprint per person in the city is compared with the international range [9]
2	Fuel poverty	The indicator presents the proportion of households in the city that are considered to be fuel poor [14].
3	Energy consumption	This indicator presents how does total energy consumption (domestic, industrial and commercial, and transport) per capita in the city compares with the international range (kgoe/cap/yr) [9]
4	Energy self-sufficiency	Measure of the proportion of a city's demand that could be met through indigenous production including renewable resources, waste, and traditional but generated locally in the city. The indicator shows how resilient city is in case of a sudden loss of connection with the power grid
5	Renewable energy ratio	Measure of proportion of total energy derived from renewable sources in the city, as a share of the city's total energy consumption compared to the international range [9,10]
6	Energy efficiency plans	Measure of the application of energy efficiency measures by the range of energy users across the city[9,13]
7	Energy infrastructure investment	Measure of the investment in the infrastructure for energy distribution compared to the international range. Investment can be in: (i) a new infrastructure (ii) maintaining (iii) and refurbishing the existing one
8	Commuting time	Measure of the proportion of time spent on commuting (minutes per day). Commuting time is calculated as average time spent on commuting in one day (in minutes) compared to the international range [15,16]
9	Use of public transport	Kilometres travelled by public transport and bicycles compared to overall kilometres travel by all means of transport [10]
10	Bicycle network	Length of bicycle network per inhabitant compared to the international range [9,11]
11	Transportation fatalities	Measure of transportation fatalities per 100 000 population in the city per year [10]
12	Clean energy transport	Clean energy transport and clean energy sharing transport. It should consider plans, measures and their implementation to improve the transport efficiency [9,13]
13	Transport-related pollutions	Air pollutant emissions from transport (kgoe/cap/yr). A lower indicator score is given where the pollutant emissions are greater [9]
14	Transport infrastructure investment	Measure of the investment in the transport infrastructure compared to the international range. Investment can be in: (i) a new infrastructure (ii) maintaining (iii) and refurbishing the existing one
15	ICT access	The ICT access is Measure of access to ICT in the city. This indicator is based on indicators in [13]
16	ICT use households	The ICT use in households is Measure of use of I CT in the city. A lower indicator score is given where the ICT use is lower. This indicator is based on indicators in [13]
17	ICT use water utilities	Measure of ICT implementation at the city-utility level. It includes: (i) Operation (ii) Maintenance (iii) Planning and design (iv) Customer service. A lower indicator score is given where there are less ICT tools implemented
18	ICT use energy utilities	Measure of ICT implementation at the city-utility level. It includes: (i) Operation. (ii) Maintenance. (iii) Planning and design. (iv) Customer service. A lower indicator score is given where there are less ICT tools implemented
19	ICT use transport	Measure of ICT implementation at the city-utility level. It includes: (i) Operation. (ii) Maintenance. (iii) Planning and design. (iv) Customer service [13]
20	ICT use waste management	Measure of ICT implementation at the city-utility level. It includes: (i) Operation. (ii) Maintenance. (iii) Planning and design. (iv) Customer service.
21	Digital public service	Measure of ICT implementation within public administration (percentage of Internet users that have engaged with the public administration and exchanged filled forms online) and health system. This indicator is based on indicators in [12]
22	ICT infrastructure investment	Measure of the investment in the ICT infrastructure compared to the international range. Investment can be in: (i) a new infrastructure (ii) maintaining (iii) and refurbishing the existing one

5. A case-study: Leicester

Leicester is the tenth largest city in the UK with a population of 330,000. The Principal Urban Area is the eleventh largest with a population of 509,000. The city is situated toward the upper catchment area of the River Soar which flows through the City [17].

5.1. The Trends and Pressures Framework

Leicester does not have many challenges of concern or great concern compared to other (European) cities as is reflected in the low Trends and Pressure Index of 0.97 points (1). However, Leicester is vulnerable for flooding as 20.7% of the city centre would be flooded if flood protection failed to protect against a 1 meter increase in river level [18]. Moreover, the green/blue space coverage is 22.5% which is relatively low [19]. At the same time, soil sealing is high with almost half (49.6%) of the urban surface being impermeable for rainwater infiltration [20]. Moreover, Leicester is vulnerable to the Urban Heat Island effect due to the low share of green (and blue) area. The urban temperature is often about 4 degrees higher than the surrounding area during heat waves.

The city of Leicester has suffered from flooding incidents and accidents. Leicestershire City Council has developed a Local Flood risk management Strategy [21]. This strategy document explains the Council's duties and responsibilities, together with those of other risk management authorities such as the Environment Agency and Water Company, and sets out objectives and an action plan covering the short term (1-2 years), the medium term (2-5 years) and long term (5 or more years). Actions include prevention, protection and preparedness. The extensive mapping of flood incidents and outcome of the detailed flood risk modelling provided the required evidence for cost-benefit analysis and justification for national investment [22].

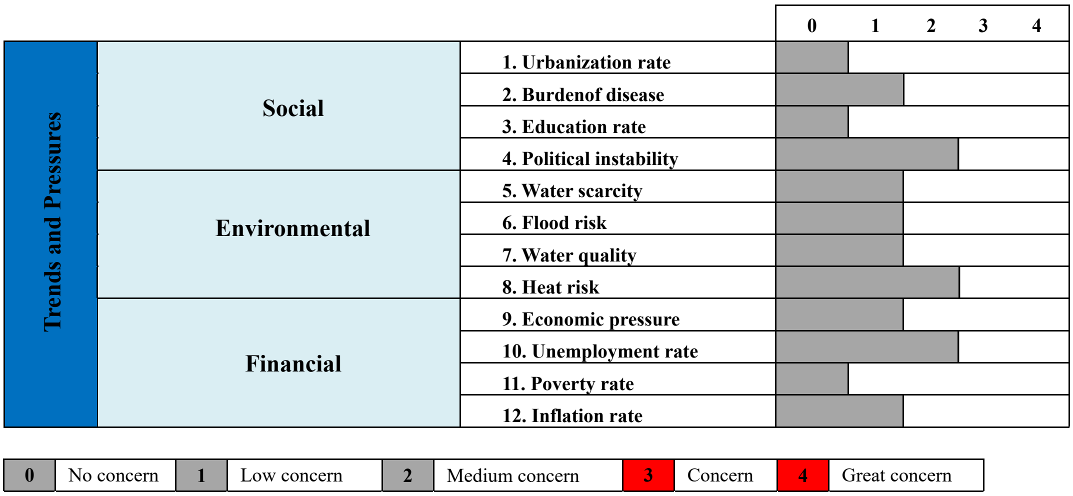

Fig. 1: Trends and Pressure scores for Leicester. The Trends and Pressure Index, the arithmetic mean of all 12 descriptive indicators, is 0.97 points

5.2. The City Blueprint Framework

The Blue City Index of Leicester is 5.3 points, which is below average, compared to other European cities. The TPF revealed that the city is vulnerable for flooding and UHI that are both amplified by climate change. Furthermore, low scores for performance indicators for "average age sewer" and "storm water separation" emphasize the current climate vulnerability. The CBF (Fig. 1) shows that the city is well aware of their vulnerability and has developed action plans and implements both climate adaptive and mitigation measures [23–26]. The City Blueprint assessment shows that the city has large opportunities to improve their water management especially with respect to the water infrastructure, increase of green and blue areas, and energy and nutrient recovery in both their solid waste and waste water treatment. At the same time Leicester is already doing very well with respect to drinking water conservation and the city has initiated many examples to reduce vulnerabilities for flooding and drought events [27].

Nutrient recovery from waste water is only partially done whereas nutrients such as phosphate are on the EU list of critical raw materials [28]. These nutrients become increasingly scarce and are valuable resources. Also for solid waste treatment the potential to recover renewable energy is not fully exploited as a third of the solid waste is neither recycled nor used for energy recovery [29,30]. It is of importance that Leicester addresses these issues.

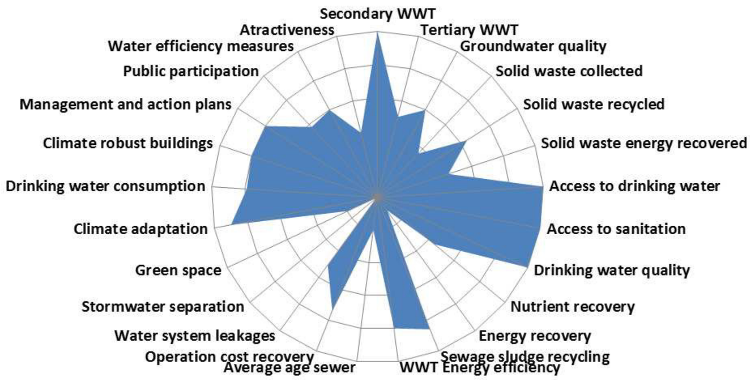

Fig. 2: The City Blueprint Performance assessment of Leicester. The overall score, the BCI of Leicester is 5.3 points

As the average age of the sewer system is relatively high [27], replacement of this sewer by separated systems poses opportunities to make the city more prepared for the effects of climate change. STW aims to reduce the CSO's and sewer flooding by more frequent cleansing and maintenance of the existing system on the short-term (2015-2020) [27], where replacement by a separated system is the ambition for the long term (i.e. 2010-2035) [31]. Leicester is actively increasing their green and blue area in order to combat droughts and flooding.

5.3. The City Amberprint Framework

The spider chart for Leicester is presented in Fig. 3. High scores on indicator "energy consumption" are contributing to relatively high score on "carbon footprint" indicator. However, the latter indicator is also affected by the City Blueprint indicator "energy recovery". It is estimated that energy recovery from waste water is done for only 10% of the total volume of waste water [32,33]. This is a missed opportunity to reduce the environmental impact as it is a source of renewable energy and reduces the emission of GHGs. However, there not much energy is derived from renewable sources in the city which contributes to a low score on "energy self-sufficiency" indicator and is also connected with the City Blueprint indicator "solid waste energy recovery". For solid waste treatment the potential to recover renewable energy is not fully exploited as a third of the solid waste is neither recycled nor used for energy recovery [29,30].

Compared with the international range, Leicester could improve investment in all three infrastructures. ICT tool are widely used in Leicester and Leicestershire as all indicators related to these issues are scoring around 8 points. Public transport is not widely used. The majority of trips to and from work are done by car. There is a car sharing scheme and park and ride that should encourage people to use public transport. There are three private bus companies operating in the area that provide good quality service. However, the city scores low when it comes to "bicycle network" indicator.

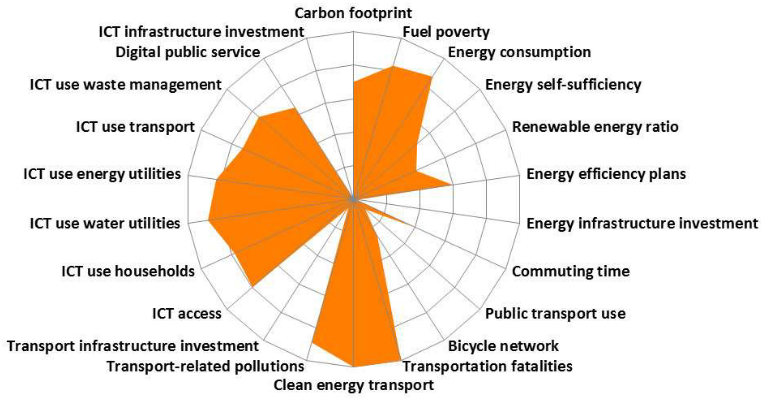

Fig. 3: City Amberprint for Leicester. The centre of the circle corresponds to 0 and its periphery to 10. The ACI for Leicester is 4.7 points

6. Conclusions

Both the City Amberprint and City Blueprint provide valuable, integrated, communicative and much needed empirical information that can help cities plan and continuously evaluate their current policies. Both methods have the potential to strongly contribute to the European urban agenda by providing city-to-city comparisons, quick identification of pitfalls and opportunities, and providing useful heuristic tools to support integrated policy and decision making in cities. The City Amberprint and City Blueprint also show the large learning potential of exchanging best practices, experiences and knowledge between cities [1]. One of the objectives of BlueSCities project was to facilitate sharing the best practices on urban water and waste treatment and utilisation. The following approach could be adopted. For each City Blueprint/City Amberprint indicator with high score relevant best practices from all assessed cities should be available. Under-performing cities should be able to access these best practices and consider whether it is possible to transfer them to their specific situation. In this process the Trends and pressures context in both cities should be considered. For example, Leicester has no stormwater separation [26,34–36] the city is particularly vulnerable to Combined Sewer Overflows [37] that could lead to pollution and degradation of the receiving water bodies. However, it could learn from the best practices in Melbourne, Jerusalem and Ankara which have quite high score for this indicator. Although City Blueprint and City Amberprint provide two different assessments, with the former focusing on water and waste aspects, and the latter on energy, transport and ICT aspects in the city, they are linked together. Some of the indicators from the City Blueprint, such as "solid waste energy recovered", "energy recovery", or "WWT energy efficiency" have a direct connection to the City Amberprint indicators, such as "carbon footprint" or "energy self sufficiency". This shows that water and waste aspects are very interdependent in the smart city concept and they should be considered together.

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