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Supporting urban decision-making processes through supply-side technologies characterisation

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Abstract. The MAtchUP project (Maximizing the Upscaling and replication potential of high level urban transformation strategies) developed an urban transformation methodology for sustainable city planning, based on demand-side and supply-side characterisations. The supply-side characterisation is based on the Smart City Technology Packages (SCTP), which are groups of solutions from those demonstrated in the Lighthouse cities of the Project, selected based on their replication potential and with the aim to maximise the impact of MAtchUP actions. The SCTPs are organised in the three main pillars of energy, mobility and ICT (information and communication technologies), and its characterisation includes three main fields: a general description (including reasons for implementing the technologies, barriers and benefits), operational model (analysing business models' archetype, cost structure and financial model), and impact assessment (in the fields of environment, economy and social). Such characterisation is done under common criteria, which allows comparisons among SCTPs. The supply-side methodology included also a PESTEL (political, economic, social, technological, environmental, legal) analysis done by each city in order to evaluate the viability of each SCTP under those circumstances of the city, to finally obtain the most suitable set of solutions to implement.

1. Introduction

In urban planning, it is important to understand how the needs of a city are met with the existing technologies, and with this end, their main features need to be explored. Additionally, in urban decision-making processes, it is required ensuring the bankability of solutions to attract private financing as well as to creating public value for society.

Advanced urban-planning processes methods are needed to guide cities towards sustainable urban planning. The EU H2020 smart city project MAtchUP, where seven cities participated, three lighthouses (demonstrating innovative solutions): Valencia (Spain), Dresden (Germany) and Antalya (Turkey); and four as followers learning from them: Herzliya (Israel), Skopje (North Macedonia), Ostend (Belgium) and Kerava (Finland), applied a same-name supply-side characterisation methodology.

This methodology merges existing methods used for the characterization of the demand- and supply-sides of the cities and allows the prioritization of the most suitable and viable technologies at the same time that a maximization of impacts is reached. Smart city technologies play a key role in the urban



transformation process towards a sustainable development, delivering relevant energy demand and greenhouse gas emissions reduction, as well as socio-economic benefits.

The supply-side characterisation is done through the so-called SCTPs (Smart City Technology Packages), which are groups of technological solutions of higher expected impact when implemented together from those demonstrated in the lighthouse cities of the project. Unlike other supply-characterisation methods, the MAtchUP one analyses as key factors the impacts evaluation and the bankability of the solutions, to ensure replicability, by defining business models for these smart city solutions within the city context and to highlight not only their private value, but also the overall public value (economic, social and environmental) for the society.

The Paper is structured as follows: in section 2, the MAtchUP methodology for the characterisation of the SCTPs is presented (supply-side analysis); in section 3, a comparative analysis of the SCTPs characterised is presented; section 4 informs on how the cities in the project have evaluated and selected the SCTPs for their Action Plans. Finally, section 5 provides the main conclusions from this work.

2. The MAtchUP methodology: Smart City Technology Packages characterisation

The MAtchUP project developed a methodology for urban sustainable transformation, based on demand-side and supply-side characterisation of both city context and needs and technologies, to obtain in this way a suitable set of solutions to include in the city Action Plans, for their planning and development.

In the supply-side, the characterisation is based on the concept of the SCTPs, which are groups of technological solutions in the pillars of energy, mobility and ICT that have been demonstrated in the cities of the project and have a high replication potential [1].

The methodological approach for the characterization and analysis of each SCTP included the following aspects detailed in Table 1.

Table 1. MAtchUP SCTP characterisation fields.

Field	Sub-fields	Description
IDENTIFICATION	SCTP name	Name to identify the Smart City Technology Package
	LH Cities	Lighthouse cities (Valencia, Dresden, Antalya) in which actions within the SCTP have been deployed and demonstrated in the project.
GENERAL DESCRIPTION	SCTP description	General description of the SCTP as an integral solution formed up by different concrete solutions. It includes the technical specifications from implementation in the cities.
	Socio-Technical Units	List and description of the actions included in the SCTP, as Socio-Technical Units implemented in the cities.
	Reasons for implementing	The reasons for implementing the SCTP were analysed under three fields: technical-environmental, economic and social. The answers were harmonised through pre-defined lists, so it can be compared afterwards.
	Barriers	The main barriers that can restrain the implementation of the SCTP were also analysed through pre-defined lists under the fields of a PESTEL analysis (political, economic, social, technology, environmental, legal).
	Benefits	In the same manner as the barriers, potential benefits were also analysed through pre-defined lists under the fields of a PESTEL analysis.
OPERATIONAL MODEL	Business models	It was analysed through the assignment of archetypes, which were defined based on the different actors involved in three main dimensions: funding source, asset ownership and responsible of operations.
	Cost structure	It provides an assessment of the investment required and the operation cost, both assessed through value ranges.
	Financial Model	It includes the description of the revenue streams, the main funding source and the financing scheme, with the share of public/external funds.

	Actors involved	It describes the actors involved in the implementation.
	Social acceptance	It assesses on whether the technology is usually well accepted by citizens.
	Market acceptance	It evaluates the technology readiness levels (TRLs) and if the technology is widely used.
IMPACT	Scale of impact	The scale of the SCTP intervention is assessed with a number from 1 to 5, where 1 represents the smallest scale (e.g. a solution in part of a building), and 5 represents the largest scale (city level significant impact). The impact is then assessed through indicators in the categories of environmental, economic and social impact. A score is provided to each from 1 to 5, according to a homogenised scoring scale (agreed criteria), and differently defined for each of the three SCTPs' pillars.
	Environmental impact	Indicators related to the reduction of the energy demand and CO ₂ emissions; increase in the renewables share; reduction in local air pollutants; and change in modal split, from traditional to clean vehicles.
	Economic impact	Indicators related to the economic viability, assessed through the payback time, the affordability, financial benefit for the end-user (operational); the business generation, job creation (new jobs) or new business opportunities created; the improvement in efficiency of service provision.
	Social impact	Indicators related to wellbeing (improvement in quality of life); end-user engagement; improvement in access and quality to services; accessibility of open data; improvement in quality of services through open APIs.

These fields were analysed for each SCTPs, considering the expected results and performance of the solutions implemented in the lighthouse cities. It was done by partners in the project with concrete knowledge on smart city solutions technologies, on their business and financial models, impacts assessments and main city planning processes.

3. Technologies characterisation analysis: insights from comparative analyses

Besides the catalogue itself, the main features of the SCTPs were analysed in a comparative way, facilitated by the pre-defined lists of answers from which to select in some fields, allowing to extract later common analyses and conclusions in the three main groups of the characterisation.

In the general description, SCTPs are analysed and compared in terms of the reasons for implementing, the barriers and benefits. In the figure 1, the reasons for implementing the energy SCTPs (as example) are compared in a table. The SCTPs are identified with a number in the first row, and its name is related to the number under the table. In the row below the SCTP number, the city for which it is analysed is included, noting that *Val* is for Valencia, *Dre* for Dresden and *Ant* for Antalya.

As overall assessment, the most common reasons to implement energy SCTPs (figure 1) are the reduction of GHG emissions, the enhancement of citizens' quality of life, the reduction of energy bills and acting as example to encourage citizens to invest in energy efficiency. The assessment can also be done by the SCTPs with a higher number of reasons to be implemented, which in this case are: construction of private residential buildings, retrofitting of private residential buildings, and retrofitting of public residential buildings, the three of them in Valencia.

For the mobility SCTPs, the most repeated reasons for implementing them are the reduction of GHG emissions, the increase of local air quality, the enhancement of citizens' quality of life and to boost local economy through the investment in solutions. While the solutions with more reasons to be implemented are: expansion of the charging infrastructure of Dresden and EV public bike or scooter in Antalya and ITS (intelligent transport system) for parking management in Dresden.

In the ICT SCTPs, the main reasons for implementing were related to boost local economies through investment in smart solutions and the enhancement of citizens' quality of life.

Energy SCTP ID ¹⁰		1	2	3	4	5	6	7	8	9	10	11	12	17								
Reasons for implementing		Val	Dre	Ant	Val	Val	Ant	Val	Val	Val	Val	Val	Dre	Val	Ant	Val	Dre	Ant	Val	Dre	Dre	
Technical-Environmental	Reduce the energy demand of residential and tertiary buildings																					
	Reduce the energy consumption of city infrastructures																					
	Maximize the use of RES to cover the energy needs of buildings located in the district																					
	Reduce GHG emissions to atmosphere																					
	Increase local air quality																					
	Increase local RES production																					
Economic	Reduce the energy bills and operational costs of citizens and companies																					
	Reduce societal costs due to climate change, air pollution and other externalities																					
	Boost local economies through investment in smart solutions																					
Social	To face energy poverty with cost-effective solutions																					
	Improvement of the neighbourhood																					
	Enhance citizens' quality of life																					
	Increase visibility and awareness of RES solutions																					
	Act as example to encourage citizens to invest in energy efficiency																					
	To trigger new jobs																					

¹⁰ 1 Construction of (private) residential building; 2 Construction of (public) residential building; 3 Construction of public tertiary building; 4 Retrofitting of private residential buildings; 5 Retrofitting of public residential buildings; 6 Retrofitting of public tertiary buildings; 7 Building integrated RES in a residential building; 8 Building integrated RES in a tertiary building; 9 Urban scale RES; 10 Smart public lighting; 11 Humble lampposts; 12 Smart controls and domotics in residential building; 17 District heating and cooling.

Figure 1. Comparison of the assessment of reasons for implementing the Energy Efficiency SCTPs

With respect to the barriers for implementation, in the energy SCTPs the most repeated ones are the high initial investment needed, the length and difficulty of administration procedures, as well as the high cost differential between new and existing technologies. For the mobility SCTPs, the main barriers are quite similar to the energy ones, with the addition of the limited access to capital and lack of interest due to long-term benefits. As per the ICT SCTPs barriers, remarkable ones are more related to that a part of the population does not use ICT tools and the few cases of proven technology.

The main benefits reported for the energy SCTPs are related to meet the local sustainability targets, the reduction of carbon emissions, the reduction of energy bills, and the increase of energy efficiency. In the mobility SCTPs benefits, the most common ones are to comply with existing policy and legislation, to improve air quality, and to meet the local sustainability targets. In the case of ICT benefits, the most highlighted ones are related to technology aspects: increase of the efficiency of public services, improve data availability and achieve a better use of data.

The operational model in the three pillars of the SCTPs was also analysed and compared, mainly in terms of their business models' archetypes, the types of stakeholder involved, and the target users. For the main aspect of the business model archetype, in the case of energy SCTPs the most frequent one is the city-centred (in which the funding source, asset ownership and responsible of operations are under municipal charge), while for the mobility SCTPs is the mix-funded, public-owned and operated. The type of stakeholder involved across the three SCTPs pillars is mainly the municipality, followed by ICT companies, university/research institutions/specialized bodies, and city services companies.

The impact assessment comparison provides a view of the impact that the implementation of SCTPs can reach, with the reference of the scale in the first row, to get an idea of the size of such impact at city level. Figure 2 shows, in the same way as previously shown, the impacts of the energy SCTPs. In this case, the analysis is colourful, with impacts assessed through a 1 to 5 scale. The assigned impacts are initial estimations done considering the technical descriptions of the demo interventions (i.e. building surface, amount of PV installed, etc.).

In the case of energy pillar, the SCTPs that have a greater impact, which can be easily scanned in a very visual way (column-wise), are the retrofitting of private residential buildings in Valencia, and the

retrofitting of public tertiary buildings in Valencia; for which considering the scale of such impacts, is much greater in the first case. For the mobility SCTPs, the ones with a higher impact are the multimodality in the three cities, followed by ITS for parking management and expansion of charging infrastructure, both in Dresden. The few ICT SCTPs are similar in terms of impacts, and worth mention that the higher impact through ICT is on the improvement in the quality of services through APIs.

		Energy SCTP ID ¹³																																						
		1			2			3			4			5			6			7			8			9			10			11			12			17		
IMPACT	Indicator (scales description in Table 3.16)	Val	Dre	Ant	Val	Val	Ant	Val	Val	Dre	Val	Val	Val	Val	Val	Dre	Val	Ant	Val	Val	Ant	Val	Val	Ant	Val	Val	Dre	Ant	Val	Dre	Dre									
		Scale of impact	1 = small (e.g. building level) to 5 = big (e.g. city level)	3	3	5	2	3	5	5	4	5	3	4	2	4	3	2	4	2	5	3	2	3	2	2	4													
Environmental impact	Increasing energy efficiency	3	3	3	3	4	4	4	3	3	4	3	5	3	3	3	3	2	1	2	3	3	3	2	2															
	Reduction in CO ₂ emissions	3	3	3	3	4	4	4	3	3	4	3	5	3	3	3	4	2	2	2	3	3	3	3	4															
	Share of RES	4	3	4	4	5	3	5	2	1	5	4	5	4	3	3	4	2	2	1	1	1	1	2	2															
Economic impact	Profitability & Financial performance	2	2	2	2	2	2	3	3	3	3	4	2	4	4	3	4	2	3	4	3	3	3	3	3															
	Affordability	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	1	3	5	5	5	5	5	3															
	Business generation	3	2	4	2	3	4	3	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2															
Social impact	Wellbeing	4	3	3	4	3	3	5	3	3	5	3	3	2	2	2	2	2	1	1	1	2	2	2	3	1														
	End-user engagement	5	3	2	5	3	3	5	2	2	5	2	3	3	4	1	2	1	2	1	2	3	2	2	1															

¹³ 1 Construction of (private) residential building; 2 Construction of (public) residential building; 3 Construction of public tertiary building; 4 Retrofitting of private residential buildings; 5 Retrofitting of public residential buildings; 6 Retrofitting of public tertiary buildings; 7 Building integrated RES in a residential building; 8 Building integrated RES in a tertiary building; 9 Urban scale RES; 10 Smart public lighting; 11 Humble lampposts; 12 Smart controls and domotics in residential building; 17 District heating and cooling.

Figure 2. Comparison of the impact assessment for the Energy SCTPs

The most repeated impacts in the energy SCTPs, they are those of affordability, reduction in CO₂ emissions, reduction in energy demand and increasing of renewables share. For the mobility impacts, the better rated ones are improvement in quality of services, affordability, and profitability improvement.

4. Cities evaluation of most suitable solutions

The urban transformation in MAtchUP included the development of smart city strategic plans and replication plans in the seven cities of the project; and the methodology for the supply-side characterisation, besides the characterisation of the SCTPs by the cities who implemented those technologies, included as well the analysis of such SCTPs in each city context.

This analysis of the SCTPs in the cities’ context was evaluated through a PESTEL analysis, in which the feasibility of each bundle of solutions considering the different Political, Economic, Social, Technological, Environmental and Legal implications for each was assessed. It was posed as a series of questions around each aspect, which cities answered for each SCTP based on their situation and circumstances, while generating discussion and debate around each. Then, each topic is evaluated from 1 to 5, where 1 is exemplary and 5 is sub-standard, according to their different cities’ circumstances in a subjective manner for each question formulated around each PESTEL aspect. Thus, an overall score for each SCTP is obtained, deriving in a list of the most suitable SCTPs to implement in the city, from the supply-side perspective. PESTEL analysis is done by staff involved in the project solutions implementation.

This analysis allows also a wider vision in the city for the suitability of solutions of high interest, and to others that may have not been considered so far. This identification of high-interest solutions was also relevant for the Project when planning and organising the learning and capacity building activities.

Besides the supply-side analysis and characterisation, there are many other considerations needed to finally select the best solutions to implement. These are mainly related with the demand-side

characterisation, which is the other component of the MAtchUP urban transformation methodology, based on the analysis and assessment the city needs and targets, as well as priorities (considered as well through the city level evaluation [2]). Thus, both demand-side and supply-side characterisation are matched, as can be seen in figure 3, obtaining an optimum pack of solutions to implement in the cities, while considering also the lessons learnt during the project from the Lighthouses' implementations.

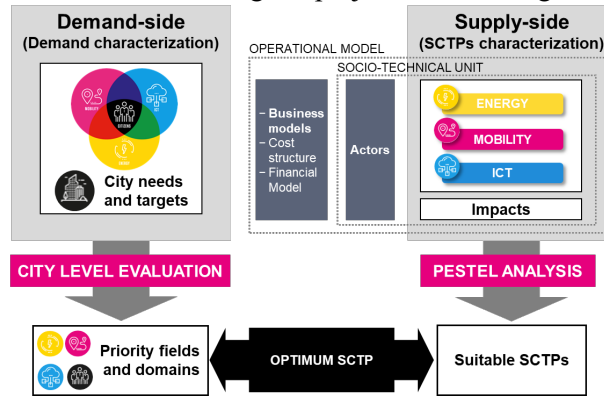


Figure 3. MAtchUP urban transformation methodology

5. Conclusions

The biggest advantage of demonstration projects is the validation of benefits and the potential of implementation of integrated solutions to improve key parameters that affect global quality of life in the city, ranging from the pure environmental ones, passing through those related with citizens' quality of life and housing affordability, and leading to those that allow a progress in the socio-economic conditions, as the promotion and attraction of talent, or new businesses yielding to an intensive job creation, or lower energy bills and reduction of energy poverty.

In this context, the MAtchUP urban transformation methodology proposes an integrated and comprehensive process, merging existing methods for the characterisation of both demand and supply sides, and matching them to obtain the best packages of solutions to be implemented in the city.

The characterisation of the SCTPs makes up a catalogue of solutions under demonstration in MAtchUP but with a high expected replication potential. This catalogue includes a large diversity of aspects, which cover reasoning, economic viability, social and environmental benefits and bottlenecks in their deployment related. Thus, this catalogue can help cities to take decisions on which solutions to deploy beyond project. However, the method has as limitation that the Sctp characterization is made with estimated values and expected assumptions. Once these outputs are known at the end of project, the reliability of this method will be known.

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