Urban Decision-making and Expert Integration

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D2.2 URBAN DECISION-MAKING AND EXPERT INTEGRATION REPORT

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1 INTRODUCTION

1.1 Scope

The UrbanData2Decide project aims to extract and process information from two rich sources, namely public social media and open data libraries. This information, combined with advice from online expert panels, should support holistic, sustainable and well-founded decision-making processes in local governments on specific urban challenges such as urban renewal, urban safety and security.

The aim of this Deliverable 2.2 on **Urban Decision-making and Expert Integration** is to provide an overview of existing approaches, processes, tools and techniques to urban decision-making, and the usage of expert knowledge as well as data and more and more 'big data' to support decisions.

The report on urban decision-making starts out with an overview of urban decision-making approaches relevant for the project in section 2. The focus is on operational and expert-driven decision-making. Section 3 provides an overview of recent developments and experiences with data-driven decision-making both in commercial and public contexts. Section 4 presents a broad overview of existing decision support tools, as well as an analysis of the state of the art in the fields of public safety and urban renewal in section 5. Section 6 provides a summary of the findings and relates them to the overall objectives of the project.

References to other deliverables: This report complements D2.1 Social and open data visualization methods and data sources report, and provides the basis for D2.5 Integrated urban data visualizing and decision-making framework, and the concept design in WP3, especially D3.2 UrbanDecisionMaker Report including methods, specifications and approaches.

1.2 Methods

Literature on data driven decision-making is mainly based on what was collected through web search engines such as Google Scholar. Given that the concept of data driven decision-making in relation to big data is a fairly new concept, only a few journals with a specific focus on the subject could be found. However, within the private sector some important reports have been published on the subject by organisations such as McKinsey and the Data Warehouse Institute. Along with the journals, the reports constitute a literature research on data driven decision-making. Existing tools and techniques for urban decision-making were collected using intensive online research, especially through databases and platforms such as CORDIS by the European Union[1], or blogs such as Business News Daily[2]. Tools and techniques were collected according to one defined template specifying each tools name, key words and short description, year, main organization, location, purpose such as analysis, monitoring, stakeholder participation etc., access information such as free access or access for a fee, available features, used visuals such as graphs, maps, etc. We also looked into the usability of the tool, evaluating if it is easy to use, i.e. no background knowledge is required and the tool is intuitive, or if it is more sophisticated and can be used only by more experienced users. In total a number of 90 tools and techniques were collected and analysed.

The case specific discussion on decision-making tools represents a subsection of more comprehensive literature review done by the partners working with the Security Respective Urban Renewal case study. The presented approaches and tools were selected to provide relevant examples for the decision-making in the respective area.

2 URBAN DECISION-MAKING APPROACHES

> ***"Decision-making is usually based on a series of qualitative and quantitative data related to physical conditions and trends. Cities invest a great deal of time and resources in the collection of information […]. However, very little is known about how decisions are made and the processes that lead to them."***[3]

The following chapters stress urban decision-making today while attempting to disentangle some of the related complexities. Urban decision-making occurs at the interface of varying **topics** (urban planning, transport planning or urban safety) different **spatial scales**, **administrative structures** and **local traditions of urban decision-making** (e.g. more plan-led or consensus-led decision-making or practices of consultation with public/private entities).

The first part discusses main theories on urban governance and citizen participation in order to understand prevalent trends and changes of urban decision-making approaches. The second part elaborates on different stages of decision-making processes as well as the most prevalent factors influencing approaches taken by cities and governments.

[1] http://cordis.europa.eu/projects/home_de.html
[2] http://www.businessnewsdaily.com
[3] http://www.gdrc.org/decision/Participatory-Decision-Making-Indicators.pdf

2.1 Towards urban governance and collaborative models of planning

Urban decision-making today, both in terms of key actors and decision-making processes have most significantly been influenced by the increasing shift 'from government to governance'. While concepts of **urban governance** as 'softening borders of government and the governed' are not new they are certainly gaining more and more public attention. Manifold definitions and discussions about the concept of governance have entered current academic debates. The notion of government is broadened by concepts of governance, "*the former understood as vertical, monocentric, and unilateral steering, and the latter horizontal, pluricentric, and multilateral*" (Hendriks 2014, 555 cit. after Bevir 2010; Pierre 2000). Despite the widespread use of 'governance' and proclaimed shifts of governing systems, Hendrik (2014) warns to not fall into traps of dichotomizing A (government) or B (governance) since elements of governance can be found as long ago as in the 17th century in the Netherlands (or even ancient Rome) (see Hendriks 2014, 557).

"Collaborative or participatory approaches to planning and decision-making can deal with stakeholders' different, and perhaps competing, perceptions and are therefore often used to ensure that all perceptions are represented in decision-making." (Mayer et al. 2005, 404)

Urban governance stresses the role and political power of local organizations, NGOs and lastly the citizens themselves, referring to a more open decision-making process which **-** at its best **-** results in a transparent decision-making process. Transparency may be added to the five identified core values of good urban governance: responsiveness, effectiveness, procedural justice, resilience and counterbalance (see Hendriks 2014, 565). Transitions from the more classical urban decision-making approaches, namely top-down towards more collaborative and multi-stakeholder models, can be observed in recent urban renewal or community development projects. Citizen participation and more collaborative forms of urban planning (despite widespread debates and renowned advantages) often remain more of an exception "*as opposed to the rule in the everyday politics of most western societies*" (van Beckhoven et al. 2005, 231). Debates and criticism around the goals, implementation and facets of citizen participation within the realm of urban planning could easily fill an entire paper.

Nevertheless, in order to better understand the overall impact of these shifts in urban decision-making, main theories and cited work on citizen participation and collaborative planning will be briefly outlined below.

Perhaps the most well-known and frequently cited work in the body of literature on **citizen participation**, is the '*Ladder of Citizen Participation'* developed by Sherry Arnstein (1969) in which she outlines eight stages of participation ranging from a low level of citizen power to the highest level which is 'citizen control' (see Fig.1).

Whereas Arnstein's contribution to the debate on meanings and practices of participation remain of great value, much criticism has been aimed at the limitations of the ladder as a metaphor for achieving participation. Citizen participation in nature proves to be much more complicated than the hierarchical model presented by Arnstein's ladder. Furthermore identifying 'citizen control' as the ultimate goal of participation is problematic since citizen power does not always give the expected results if it is not accompanied by the essential resources. Van Beckhoven referred to different (formal vs. informal) opportunities of participation and the importance of neighborhood characteristics (e.g. socio-economic composition, neighborhood associations) when it comes to the amount of residents and who participates in the decision-making. (Van Beckhoven et al., 2005, 218)

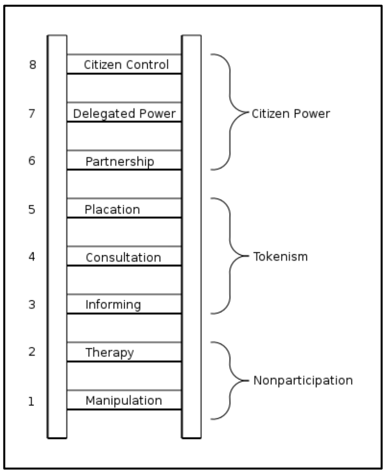

Figure 1: Ladder of Citizen Participation by S. Arnstein (1969)

There is however not one approach or practice of citizen participation, but a variety of approaches on how decisions are being taken, by whom and when. One of "*the most active territory for planning theorizing today is 'communicative planning' associated closely*" (Seltzer & Mahmoudi 2012, 4) with Patsy Healey (2003) and what she referred to as the 'communicative turn' in urban planning. **Collaborative planning**, as made explicit by Healey (2003) is inspired by the perception of planning as an interactive process. Some of the main components are to understand planning as an interactive and interpretative process, which requires respectful interpersonal and inter-cultural discussion within the public realm (Healey 1996, 221ff.) Collaborative planning challenges the long-standing components of rational planning processes (*survey*, *analysis*, *evaluation*, *choice of strategy*, and *monitoring*) in order to introduce a robust interactive approach whereby technical language is not the dominant language. Further the reasoning process moves beyond instrumental rationality (often financial discussions), allowing the discussion to develop more in moral and emotive terms (Ahmadi, 2014). This asks for a discourse facilitated by the planner (rather than being completely under taken by them) and favors the principles of *participatory democracy* over the hierarchical forms of *representative democracy* (Healey, 1996).

Citizen participation as well as participation by other key stakeholders is a key element of urban governance, which bears potential to make the decision-making process more inclusive and sustainable. The manifold characteristics and realities of participation: e.g. the political power and temporal dimension of *when, who and how* people are being involved in the decision-making process, points towards a great variety of approaches in the realm of urban governance. Whereas benefits and potentials of collaborative planning and involvement of citizens should not be disregarded, but, be treated with caution, as in fact, policy and decision-making processes are often significantly influenced by existing power dynamics at play in a specific institutional context (Albrechts, 2003).

There are many different methods of citizen participation, ranging from online petitions, interviews, focus groups[4] and workshops to open houses[5]. Often a mix of methods is applied to engage citizens depending on the timespan and scope of the project (e.g. redesign of a small neighborhood park or redevelopment of an entire urban area). Citizen participation, as discussed above, can involve various forms of participation, from once off signing of an online petition to personal consultation (e.g. participation in workshops or discussion groups) over a longer period of time. Whereas some methods focus more on discussing perspectives regarding current situations, others, like the CIVISTI method[6] are approaches used in foresight studies, i.e. developing future perspectives with citizens (and/or other experts, e.g. architects, urban safety experts).

The CIVISTI method consists of three steps: In the first step citizens ('lay people') work out future visions which are then, in a second step, analyzed by experts and formulated as policy recommendations. In a third stage the policy recommendation are validated by the citizens and prioritized before they are finally presented to policy makers.

Additionally, citizen participation refers to not only engaging citizens in terms of e.g. residents of an area, but also professionals and experts. Frequently, citizen participation processes aim at bridging these two groups: (1) people living in the neighborhood having 'local expertise' and are the ones directly affected by certain activities, as well as (2) professionals and experts in the fields of architecture, engineering, urban safety who bring thematic expertise to the table. For the 'UrbanData2Decide' project both groups are of interest.

[4] http://www.sagepub.com/upm-data/39360_978_1_84787_909_7.pdf

[5] Open house is "*a community or consultant sponsored event in which the public is invited to review alternative development scenarios or other products of the planning process. It is generally used to get citizen response to the development and/or planning alternatives. It is inexpensive but not as interactive as other approaches*." (Ohm 1999, 8)

[6] http://epub.oeaw.ac.at/ita/ita-manuscript/ita_11_03.pdf

2.2 Implications for the urban decision-making process

Urban decision-making processes vary greatly between countries and their respective cities. Often cities within the same country do not necessarily follow the same decision-making approach. Furthermore, there is no one-size fits all approach in urban decision-making. One has to pay attention to the local context in regards to political and institutional trajectories, which greatly influence predominant decision-making approaches. For instance, a city with a strong history of citizen involvement and participation will showcase a different decision-making approach than a city with a more traditional top down planning approach[7].

Moreover depending on the issues and topics, a city is confronted with, whether it is transport planning or urban safety, different decision-making processes take place, which require specific tools and involve different stakeholders and decision-makers. In this case operational decision-making processes are concerned and demand different procedures (e.g. fast decision-making in case of crisis management).

Operational decision-making processes in cities are highly complex and depend on the issue, its duration and urgency as well as the institutional context and histories of decision-making processes in cities.

Operation decisions can take place over a long period of time, or can occur quickly (for instance in the case of a fire hazard). Nevertheless decisions regarding operational procedures to follow in urgent cases (like fires) are usually based on crisis management procedures set up (over a longer time frame) by local authorities, including local councils, external stakeholders (fire brigade or rescue services). As Beroggi and Wallace (1994) state "*these procedures (also called courses of action) are designed to ensure that the operations are as safe and as cost-effective as possible*." (Beroggi and Wallace 1994: 1450) Not only decision-making processes in regards to crisis management[8] involve risk analysis - 'at which point does the police need to be involved?'- but also strategic decisions about future housing developments - 'where should a tower be placed depending on the statics under certain weather conditions?'

Further, operational decisions are often distinguished between decisions that are part of an automated process and those that need human intervention – both processes to varying extents include and rely on data. Decisions always reflect certain strategic and political directions of cities, with decision-makers who come with specific roles, decision-making power and agendas to the table.

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[7] See country specific findings from EU project ‚PROSPECTS'
http://www.its.leeds.ac.uk/projects/konsult/public/level1/sec04/

[8] See more on 'emergency response systems' Uhr, C. Johansson, H., Fredholm, L. (2008): Analysing Emergency Response Systems. Journal of Contingencies and Crisis Management, (16/2), p. 80-90

Two concepts in operational decision-making literature are: *Command and Control* and *Coordination*.

The concept of command and control originates from the military, which has a distinct top-down organization where orders and instructions are centralized and explicit. Within this context the concept of command and control is implemented as a "… *vertical information flow with information flowing up the chain of command and orders and instructions flowing down" (*Uhr, 2009, 59). In this approach, the concept of command and control can therefore be described as a formal bureaucracy with a central authority who has the power to adapt measures based on the operational goal set by the authority (Uhr, 2009, 60). However, command and control can also be approached as a "*complex system as a system with reciprocal action and feedback"* (Uhr, 2009, 59). This approach to command and control differs in several ways from the first description, but most importantly it does not consider the decision maker to be outside the system, exerting authority from the outside, instead the decision maker is seen as a part of the system, exerting authority in relation to it (Uhr, 2009, 59-60).

According to Uhr (2009), the first approach described above can be described as a way *"…to defeat the chaos often associated with multiorganizational response management …"* (Uhr, 2009, 60), and the second approach as a way "*… to ride on the edge of chaos, exploiting the leverage that this might allow"* (Uhr, 2009, 60). This makes the concept of command and control appropriate to use as an influence on how to make operational decisions, and it has also influenced models on how to prepare and handle civil crises. This concept is however referred to as *Civilian Command and Control*, and although the concept resembles the structure of military's equivalent, it has some obvious differences. Civilian command and control might, for instance, include several stakeholders with different organizational and structures and cultures, something that will not be found in a military organization (Uhr, 2009, 58).

The concept of coordination has a different approach to decision-making. Mainly the concept of coordination can be described as way of organizing available resources in order to respond properly to an incident or crisis, which means that a consensus among the stakeholders is needed on what to achieve (Uhr, 2009, 65). A consensus might however be hard to achieve, especially on an operational level since each stakeholders might have different operational goals. The fire brigade might, for instance, be interested in controlling a fire, while the police might be more interested in evacuating a certain block affected by a fire. The operational goals of the two stakeholders might therefore not be compatible, but an overall goal could be compatible; to return to a functional society (Uhr, 2009, 66). This implies that goals on an operational level might complement each other to achieve goals on other system levels in an efficient way. This does not, however, mean that the process has to be top-down driven where one stakeholder sets the overall goal, it can be developed for each stakeholders perspective and decisions.

When it comes to **decision-making related to planning**, the 'Decision Makers Guidebook' by the 'PROSPECTS'[9] project emphasizes three prevalent approaches (referring to urban transport planning as the domain) that have been identified based on the case study cities (e.g. Vienna, Stockholm). The three approaches are: vision-led, plan-led and consensus-led approaches, whereas the latter appeared as most common among the cities.

*"**Vision-led**: an individual or committee has a clear vision of the measures needed to improve transport and land use in the city, and focuses all action on implementing them*

***Plan-led**: objectives are specified, and the measures which best satisfy these objectives are determined, usually by analysis; the resulting plan is then implemented*

***Consensus-led**: discussions take place between the stakeholders involved in transport and land" (May et al. 2001, 14)*

Some efforts to break down the complexities of decision-making processes (see Figure 2 below) focus on different steps or phases. Within their guide "Tools to Support Participatory Urban Decision-making" the UN Habitat discusses four **phases of participatory decision-making processes** (see UNCHS Habitat Report, 2001).

The scheme in figure 2 describes steps within each of the four decision-making phases – this is not to be understood as a linear process, but rather as different tasks which take place simultaneously. Within all of the tasks (e.g. mobilizing stakeholders, identifying key issues or agreeing on action plans) the participation process as well as use of data to make informed decisions can vary. Decisions in an urban renewal project with regards to the identification of key issues or the mobilization of stakeholders can entail different types of information and methods, including the analysis of social media data, spatial data, press releases, policy briefs and conducting interviews. The scheme does not explicitly assign a role to the use and types of data used within each task or phase (more on the use of data in urban decision-making from section 3 and 4). Additionally, the implementation of the different decision-making phases also needs to take the specific (national/local) context, i.e. local and institutional traditions of urban decision-making, into account.

[9] 'Prospects' (**P**rocedures for **R**ecommending **O**ptimal **S**ustainable **P**lanning of **E**uropean **C**ity **T**ransport **S**ystems), an EU-funded project from 2000 – 2003. For more information, please see: http://www.ivv.tuwien.ac.at/forschung/projekte/international-projects/prospects-2000.html

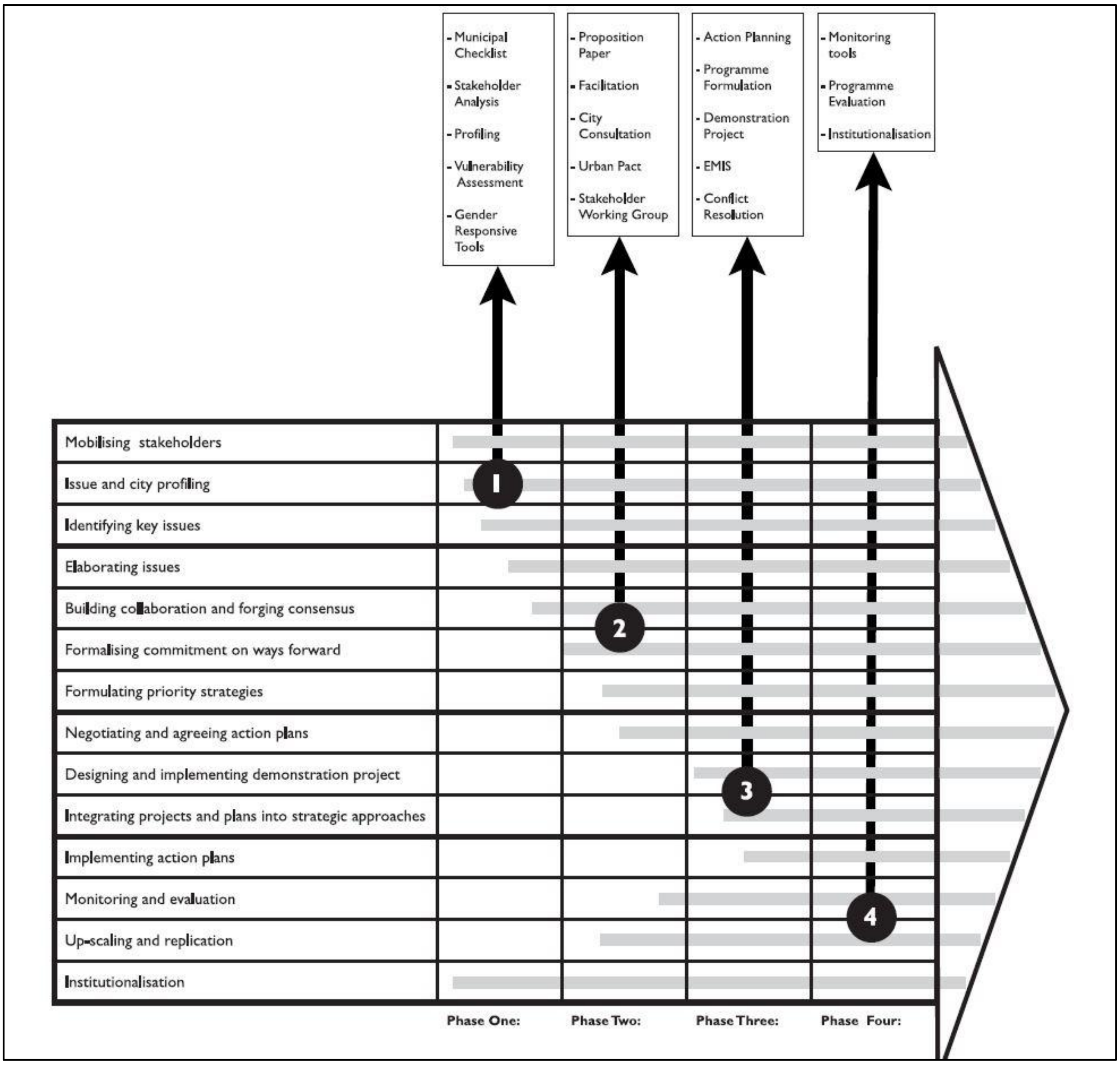

Figure 2: Participatory Decision-Making Process: Application by Phase (UNCHS Habitat Toolkit, 2001)

Phase 1: Preparatory and Stakeholder Mobilization
Phase 2: Issue Prioritization and Stakeholder Commitment
Phase 3: Strategy Formulation and Implementation
Phase 4: Follow-up and Consolidation

Factors influencing urban decision-making approaches

Seven main factors that influence the decision-making approach are outlined below (figure 3). These factors are institutional embedded-ness, administrative structure, funding, spatial scale, duration of the project, the stakeholders and data.

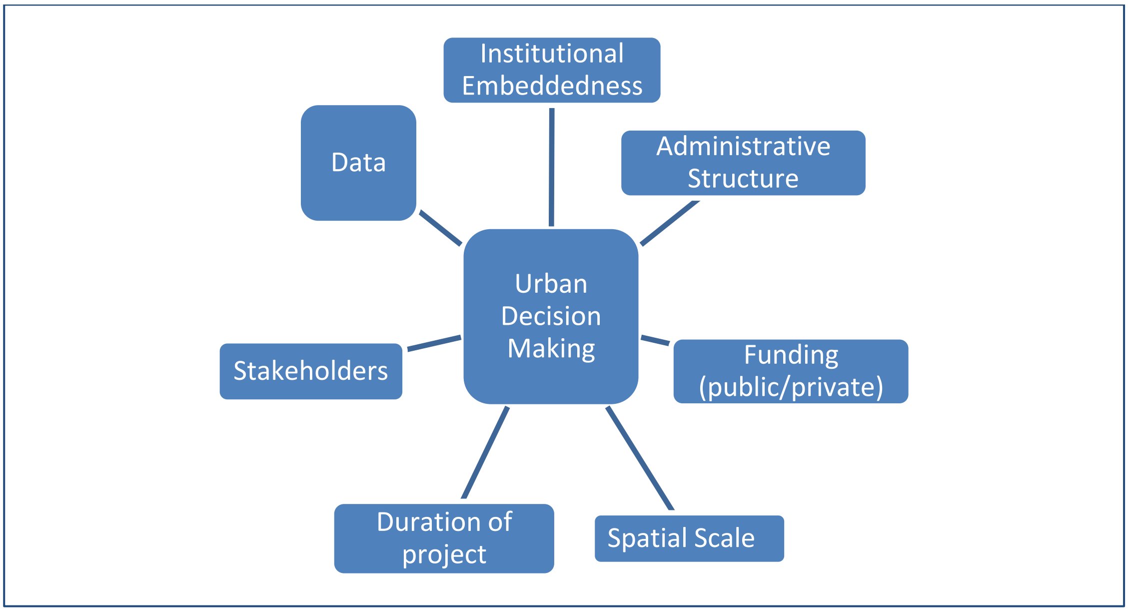

Figure 3: Factors influencing Urban Decision-making Approaches[10]

Data

The use of data in urban decision-making processes is not new, however the quantity and diversity of data available to cities today is. The diversity of data can influence the tasks that were outlined above, for instance an active twitter account (and separate hashtags for the city boroughs) of the city of Manchester[11] (UK) used as a channel by citizens to communicate demands and worries regarding new urban development projects and so forth. Besides local traditions of decision-making (for instance a city government that has been more oriented towards citizen participation) also other interdependent factors influence urban decision-making approaches.

Institutional embeddedness

Urban decision-making in cities has been developed for centuries and is sensitive to political and institutional trajectories of local governments. Hence in most cases decision-making approaches are not directly compatible to other cities or countries (especially considering that decision-making practices also vary nationally). Different decision-making practices further illustrate different availability, use and (internal) knowledge of data to be considered by decision-makers. The EU Project ‘Prospects’ concluded that character of decision-making approaches (e.g. whether they are more plan-led or more consensus-led) also depends on the size of a city alongside its geographical

[10] This figure has been compiled from findings of the European research project ‚PROSPECTS‘ and a UN Habitat report on ‘Tools to Support Participatory Urban Decision-making’.
[11] https://twitter.com/mancitycouncil

location (northern European cities tend to showcase higher levels of urban governance, i.e. citizen participation)[12].

Spatial scale and duration of project

Depending on the projects spatial scale and duration – whether it refers to national transport infrastructure implementation or a smaller local community development project – decision-making approaches can vary. Further, different approaches may even be found within the same project: decisions made about land use regulations on a national level can be more plan-led, using 'traditional sources' of data, whereas their local implementation integrates plan-led as well as participatory decision-making processes and 'new' forms of data (e.g. social media data). In Vienna, Austria, for instance the decision to build a new metro line 'U5'[13] was taken without the involvement of citizens beforehand (more of a plan-led approach) whereas the actual implementation on a local level did - so far - ask citizens to vote for a new color of the metro. Furthermore, local authorities have varying autonomies in decision-making.

Administrative structures

Each city government is embedded in an administrative structure, depending on the administrative divisions of the respective federal state into e.g. provinces, boroughs, municipalities, local councils and so forth. Moreover the divisions of administrative structures on international, EU, national and local levels stress different decision-making levels, institutional autonomy and power. In Austria for instance where spatial planning is regulated on the level of the nine Austrian federal states (Bundesländer), spatial planning regulations that are relevant for the local level (cities and municipalities) are done on a regional level. There are nine in – in some ways different – spatial planning laws in Austria. Zoning and land use plans are in the responsibility of the local level – but have to be in line with higher level regulations. The city of Vienna is a special case because the city is not only a municipality but a federal state at the same time.

Funding (private/public)

Funding resources greatly impact upon the time planning of a project, available resources which also affect forms of citizen participation (e.g. duration of engagement, methodology) and ultimately the decision-making approach (e.g. fast decision-making without consultation of experts or preceding analysis of current situation) taken by cities.

[12] See PROSPECTS, Deliverable 1 (2001) "Cities' Decision-Making Requirements" http://www.ivv.tuwien.ac.at/fileadmin/mediapool-verkehrsplanung/Diverse/Forschung/International/PROSPECTS/pr_del_1.pdf
[13] http://www.wien.gv.at/verkehr-stadtentwicklung/fahrplan/u5-plan.html

Stakeholders

The number and constitution of (key) stakeholders in urban decision-making processes depend on the projects topic and scale as well as institutional traditions of local (citizen) participation. Some of the (key) stakeholder and actors are[14]:

- National/Regional/Local Government and Institutions: City Council, Policy Advisors, District Level Representatives, Public Administration
- Developers, Architects
- Urban and Regional Planners and Technical Experts, External Advisors
- Private sector
- Research sector
- Citizens, Local Community
- NGOs, interest groups
- Media

Summing up this chapter has shown the complexity and multifaceted-ness of urban decision-making approaches. Urban decision-making has experienced major shifts in the past decades from more top-down to bottom-up approaches, given the increasing trends of urban governance (as opposed to government). However, there are many forms and types of citizen participation and engagement, ranging from low-level participation (e.g. online petition) to high-level participation (e.g. participating in workshops throughout a project) of citizens and experts. Depending on the scope (e.g. spatial scale, financing) and timespan of a project as well as a cities approach towards decision-making, various forms of citizen participation can be found. In addition, further findings from the theoretical discussions and analysis of previous research projects has found a lack of discussion and no transparency in regards to expert integration within decision-making (e.g. what are experts and at which points of the decision-making process are they involved). Besides citizen and expert engagement, other factors impacting upon urban decision-making approaches have been discussed, including: data, funding, duration of project, spatial scale, administrative structure, institutional embedded-ness and stakeholders.

[14] For a more elaborated discussion on stakeholder analysis regarding the different cities, please see our Deliverable 2.3.

3 DATA DRIVEN DECISION-MAKING

This section focuses on the factor "data" that influences urban decision-making. It outlines the role of data in the decision-making process and provides examples for data-driven decision-making.

3.1 The information hierarchy

Cities are complex systems – an interplay of different stakeholders with different interests and intentions such as policy makers, public administration, industry sector, researcher, real estate, service providers, citizens, etc., and an interaction of various thematic fields and domains such as society, economy and environment. In order to make sound decisions for a city, decision makers need to cross thematic borders as well administrative ones, which is why urban decision-making requires cooperation between different departments and organisations.

An example that highlights the impacts that urban decision-making can have: "if plans require towns and cities to grow in compact ways and there is a bias against permitting single family houses to be built in the countryside for urban people, the commuting distances will be reduced with associated reductions in greenhouse gas emissions; biodiversity will be less threatened; water quality in countryside streams will be protected from inadequately maintained sanitation systems; and last but by no means least, significant cost savings will be made in the provision of essential services" (McCormack et al. 2011, 21).

The example highlights facets of urban decision-making, namely, its role in the avoidance or reduction of negative effects such as environmental stress, waste of resources, inequalities, and its role in the support of quality of life, sustainability, and resilience of cities and regions. Sound decision-making "which avoids the negatives and reaps the positives requires a strong, solid evidence base, which is itself built on good, relevant and up to date information" (McCormack et al. 2011, 21) and useful tools which help to collect, analyse, model and monitor diverse (spatial) data and information in a rapid and efficient manner (Salvemini et al. 2011). The challenge for urban decision-making is "to use and to connect data [i.e. discrete objective facts about an event] in a way that information [a message] and then knowledge [experience, values, context that is applied to a message] can be generated, to finally reach better and more justified decisions ["wisdom"]" (Schrenk et al. 2012, 10) (Figure 4).

Reporting, definition of goals and measures, review of measures, and decisions must be based on well-founded facts that are of utmost importance for economic activities of private and public enterprises, politics, administration, citizens, media, and planners (Schrenk 2001).

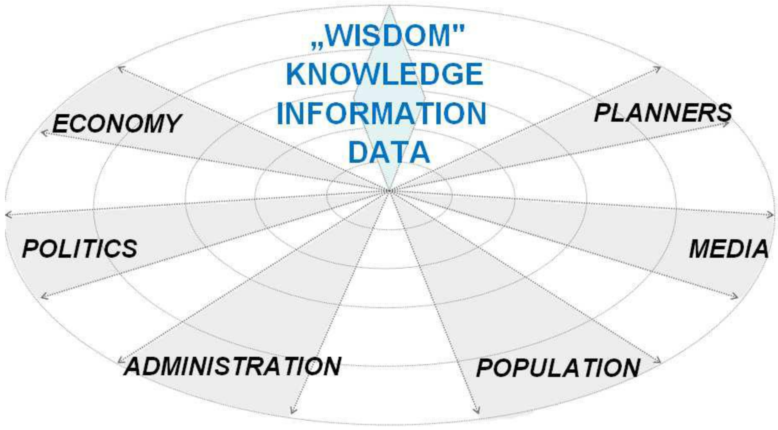

Figure 4: From Data to Information, Knowledge and Wisdom for better decision-making (based on Schrenk 2001)

Data sources have been discussed in UrbanData2Decide Deliverable 2.1, especially social media data and open (government) data. The following section looks deeper into the potential of big data for the urban decision-making process.

3.2 Big Data

The vast amount of data available today is the result of an increasingly bigger part of our lives that have become digitized. Computers, internet and smartphones are all generating huge amounts of data, and as technology continues to advance, the variety and volume of this data will continue to grow (Dumbill, 2013). The social and economic value captured in this data has given rise to the recognition of personal data as one of the most valuable resources of the 21th century (WEM, 2011). But in order to reap the benefits of this data, one must be able to manage, analyse, visualise and extract it from large datasets. The techniques developed to do this are referred to as big data analytics (Chen, Chiang and Storey, 2012).

The concept of big data is relatively new, but it is growing in importance and attention (Provost and Fawcett, 2013). Known that the concept is fairly new, a precise definition of it is hard to come across. In an article by Edd Dumbill big data is referred to as:

"[..] data that exceeds the processing capacity of conventional database systems. The data is too big, moves too fast, or doesn't fit the strictures of your database architectures. To gain value from this data, you must choose an alternative way to process it."(Dumbill, 2013, p. 1)

This definition is more or less consistent with how other authors define the term in articles and reports. However, an important point is that the emphasis should not only be on the volume of the data. By limiting the concept to only volume, other important attributes such as data variety and data velocity will be overlooked. Volume will, however, still be the primary attribute of big data.

In 2012, about 2,5 exabytes[15] of data was created each day.[16] These huge volumes of data are a result of the technological advances made in the last decades. Data generated in these domains includes messages, logs from the web, readings from sensors, GPS signals from mobile phones and updates and images posted on social networks (McAfee and Brynjolfsson, 2012). The wide variety of sources is referred to as data variety (Rossum, 2011). Given that data are generated in different digitals domains they can also be generated faster. This attribute is referred to as data velocity, or the speed at which data can be generated. The velocity of big data also allows us to analyze and interpret the data faster, in real-time or nearly real-time (Rossum, 2011). And it allows for identifying change patterns in the data produced as an indication of current or upcoming problematic developments.

As a summary, the three V's of big data (volume, variety, velocity) could be seen as a comprehensive definition of the term big data since each V is essential to understand the concept. More importantly, the three V's also tend to fuel each other; the data volume is dependent on data variety and velocity, and vice versa (Ibid, 2011).

3.3 The spatial dimension of big data

Even though big data is generated from a wide variety of sources, most of these sources share similar attributes and can broadly be divided into three different categories based on how they are generated: directed, automated and volunteered data (Kitchin, 2013).

Directed data: Is mainly generated from digital forms of surveillance, which means that it is generated from technologies (such as surveillance cameras) monitoring a specific person, place or activity.

[15] 1 exabyte = 1 million terabytes = 1 billion gigabytes

[16] A comparison can be made to the amount of data that Walmart collects each hour from its customers: 2,5 petabytes. 1 petabyte is equivalent to about 20 million filing cabinets worth of text, and one Exabyte is 1 000 petabytes (McAfee, A. and Brynjolfsson, E., 2012)

Automated data: Is generated automatically from devices or systems recording how users interact with them. Examples of automated data could be transactions made by credit cards, travel passes registering passenger's itinerary, smartphone recording the history of their own use, or various sensors measuring levels of humidity, temperature, movement or speed.

Volunteered data: Volunteered data is generated completely voluntarily by users. Volunteered data includes interactions made on social media such as Facebook, Twitter or Instagram, but also crowd sourced data collected by users and shared via a common platform such as OpenStreetMap or Wikipedia (Ibid, 2013).

Even though data deriving from these sources will differ in structure and form, most of the data will still share a common denominator, namely spatial attributes. The spatial attributes make it possible to link the data to a specific place or location, adding a location-based context to it. This will not only create a comprehensive source of data for geographical analysis, it will also make it possible to study how businesses, institutions, populations, and entire nations are changing, or being changed by, the physical world in real-time (Kitchin, 2013; Tucker, 2013). However, the spatial attributes of big data also incorporate a number of challenges.

Firstly, a number of ethical and legal challenges need to be addressed before processing and analyzing data with spatial attributes. This especially applies to data on a local level where it might be possible to draw conclusions about specific persons (Kitchin, 2013). This type of data needs to be handled with great care since the consequences can be fatal.

Secondly, the scale of accuracy in the spatial attributes will vary and might therefore not be reliable. For instance, if a user decides to disable his WiFi and GPS sensors on a mobile device, the device will not be able to collect as accurate information about the user's location as if they were enabled. Furthermore, the feature to add a location to data is usually optional in mobile and social applications, meaning that the user decides whether to include it or not (Gorman, 2013). It might therefore be hard to add a location based context to some volunteered data unless the user agrees to it. In some studies the location of the user has been used instead of the location of the data to create a place-based context, but this is not entirely accurate either (Crampton et al., 2013). When collecting data from the Twitter API for example, the spatial location can either be accessed by the location of the tweet or the location of the user. This means that even if the user chooses not to use his or her location as a feature when posting the tweet, the tweet can still be associated with a physical location based on information about the user, e.g. his residential address. But if a user lists his or hers location as X, and then tweets from location Y, the spatial information which the tweet is associated with will not be correct (Ibid, 2013).

In spite of the fact that big data and spatial attributes incorporate some challenges, the possible applications of big data within the context of geographical analysis are still numerous (Tucker, 2013). In section 3.4 some of these applications will be presented.

3.4 Data and decision-making

Given the difficulty to find a precise definition of big data, the general idea of the purpose is surprisingly coherent; to compute our way towards better decisions (Dumbill, 2013). By leveraging the vast amount of data available, governments and organizations will be able to make better decisions simply because they will know more, and therefore also will be able to make decisions based on the analysis of data rather than purely on intuition (Provost and Fawcett, 2013).

The ability to compute our way towards better decisions through the use of data is referred to as data-driven decision-making. To base decisions on data is not a new concept. Modern theories of the value of information began to take shape in the 1950s and tried to explain how decision makers could improve performance by acting on information, or more precisely; how they could identify the best possible outcomes from a set of all possible outcomes (Brynjolfsson, Hitt and Kim, 2011). Theoretically, this means that better information will lead to better decisions. Complementary theories argued that in order to identify the best possible outcome, organizations needs to be able to process a large amount of information. Processing large amounts of information would allow the organizations to minimize the risk for poor outcomes, and therefore also allow them to make better decisions (Brynjolfsson et al. 2011). Considering this, technologies that could collect and analyze a large amount of data would be beneficial to organizations, something that has been shown to be true.

In a study conducted by Eric Brynjolfsson et al. (2011), a way to measure the use of data-driven decision-making in publicly traded firms was developed. In the study, data-driven decision-making is related to productivity, financial performance and market value. The results show that companies that consider themselves as data-driven experience as much as a 5-6 % increase in their output and productivity (Ibid, 2011). Given these results, economic growth could be seen as one of the major drivers for big data and data-driven decision-making. There are, however, sectors where performance cannot be measured in just economic growth, such as the public sector (Misurac, Mureddu and Osimo, 2014). In this sector, the potential of big data is still largely unexploited, but there is a growing interest in how to utilize it. E-government initiatives undertaken during the past 15 years have also ensured that much of the data within the sector already is digital, the possible applications of big data and data-driven decision-making should therefore be numerous (MGI, 2013). But as mentioned above, few examples of how to exploit this data can be found.

Governments and the public sector do, however, regularly collect a large amount of data on individuals and business through various regulatory procedures and other filings. The problem is that much of this data is not compatible with other data collected from the public sector. Data collected from the tax agency might not be compatible with data collected from the labor agency because they were collected in different formats, and data from the labor agency might not be compatible with data from the environmental agency. The inconsistent data formats, which the data is collected in, make it difficult for the public sector to fully understand the potential of big data (Ibid, 2013). In view of the above issues, there are still several initiatives aiming towards the harmonization of public sector data across several thematic fields. To highlight in this context is the INSPIRE Directive – the European Directive for the establishment of a European Spatial Data Infrastructure across Europe. INSPIRE provides standards and specifications to harmonise public data so that it becomes accessible, comparable and exchangeable between departments and organisations (European Commission, 2007). Based on INSPIRE there has been a variety of activities and projects supporting compatibility of data[17] as part of a longer process on a technical as well as on a strategic level. Furthermore, legal constraints might also affect how data is used and shared between the agencies. Agencies might not be allowed to share the data they have because of secrecy policies, or they might not be allowed to access data from another agency because of security reasons (Ibid, 2013).

This data inaccessibility makes it difficult for agencies within the public sector to collaborate around mutual problems. But if the public sector were to overcome some of these difficulties, it could benefit hugely from big data according to McKinsey Global Institute (MGI). Most of the cost savings would be made through operational efficiency such as a reduction in the cost of errors and fraud in administration, and an increase in tax receipts by narrowing the tax gap (Ibid, 2013). But MGI also claims that the public sector could benefit in areas such as public services and public sector accountability. Big data would allow them to gain a greater understanding about how public services are used, and consequently inform them how to optimize them based on the vast information collected. Public trust could be enhanced by presenting collected data to the citizens, giving them the possibility to measure the effects of programs and policies (Ibid, 2013).

Given the examples above, the potential areas where big data could be beneficial within the public sector are wide. But there is still a growing interest in how to leverage big data for other applications such as making policy-making more 'intelligent' and increase public service (Misurac, Mureddu and

[17] For example the eContentplus project Plan4all (www.plan4all.eu) for the harmonisation, accessibility and comparability of spatial planning data, the ICT PSP project HLANDATA (www.hlandata.eu) for the harmonisation of Land Use and Land Cover data, FP7 project Plan4Business focusing on urban and regional planning data (http://www.plan4business.eu), FP7 project HELM for harmonised European land monitoring (http://www.fp7helm.eu/), HUMBOLDT (http://www.esdi-humboldt.eu/home.html) towards the harmonisation of spatial information in Europe, and many more.

Osimo, 2014). This would allow the public sector to address crime, public safety and quality of life issues in an even more effective way.

3.5 Examples of data-driven decision-making

As mentioned before, the possible applications of big data within the context of geographical analyses are numerous. In this section some examples of how big data have been leveraged for data-driven decision-making will be presented. The examples have been categorized into five different topics: Public Governance, Healthcare, Retail, Movements and Safety.

Public governance

Utilizing big data would not only allow the public sector to address crime, public safety and quality of life issues in a more effective way, it would also allow governmental authorities to work more predictively; to address issues before they happen by making data-driven decisions. One of the cities that have adapted techniques to do this is New York City (Goldsmith, 2011). By exploiting the large amount of data, which the city collects each year, New York City has been able to come up with a methodology to address issues in some of the areas mentioned above.

The methodology basically derives from the possibility to combine data-sets from different agencies to find out what information is missing. For instance, to run a coffee shop, a number of different permits need to be in order – permit to serve food, permit on how many people are allowed in the premises, permit on tax obligation etc. By combining this data, it is possible to identify places that should have data, but do not have, and investigate it further (Howard, 2012). But this methodology can also be used for more preventative work by looking at places where data conforms instead of places where data is missing. An example of this is how New York City works with fire prevention. By creating a file containing all of the 900 000 buildings existing in New York City and populate it with data from 19 different agencies, including data about the owner of the property and information about the property, it was possible to cross-tabulate it with 5 years of historical fire data to find out which attributes that were highly correlated to fires. The results were then passed on to the Department of Fire or the Department of Buildings to go out and inspect the areas and properties at risk (Howard, 2012).

According to Howard (2012), the introduction of data predictive analysis and data-driven decision-making in New York City has resulted among others in:

"[..] an increase in the rate of detection for dangerous buildings that are highly likely to result in firefighter injury or death, a five-fold return on the time of building inspectors looking for illegal

apartment [and] more than doubling the hit rate for discovering stores selling bootlegged cigarettes" (Howard, 2012)

These results indicate that data-driven decision-making will allow the public sector to work more proactive and benefit from it.

Healthcare

The benefits of big data and data-driven decision-making within healthcare are numerous. One application, that has received a lot of attention, is the possibility to predict seasonal influenza outbreaks in specific regions based on data from Google. By monitoring local search queries on Google, researchers have managed to predict where and when the seasonal influenza breaks out. Being able to identify and locate a possible disease outbreak might not stop it from spreading, but an early detection might reduce the impact since healthcare providers could take necessary measures (Ginsberg, Mohebbi, Patel, Brammer, Smolinski and Brilliant, 2009).

A similar example is the possibility to map areas with epidemiological issues to improve patient care. In Louisiana, USA, the department of health leveraged big data and GIS to find areas with poor birth outcomes, such as babies with a low birth weights. By collecting data about every live birth in Louisiana and combining it with the mother's residential information, the researchers were able to identify clusters in certain areas where babies are most likely to be born with a low birth weight. The results made it possible for the department of health to take preventative healthcare measures to lower the risk of poor birth outcomes in these areas (Waxer, 2014).

Retail

Data-driven predictions within the context of retail business can result in huge advantage compared to other competitors. One retailer, that has utilized these possibilities, is Wal-Mart. When hurricane Frances hit the coast of US in 2004, Wal-Mart used their shopper's history data from the previous hurricane to forecast which products that they would experience an increased demand for. By doing this, they were not only able to predict which products they would experience an increased demand for, but they could also project the amount of increase in sale due to the hurricane (Provost and Fawcett, 2013).

The huge amount of data collected by Wal-Mart is also utilized to make their own organization more effective. For instance, the data collected by checkout scanners is used to optimize the working hours for the personal by analyzing sales history at certain hours at a particular store (Hayes, 2004). In this way Wal-Mart can make sure that they will have enough personal on duty during the peak-hours.

Movements

Mobile devices are probably the single most important source for user generated data. Mobile devices today are location aware and contain multiple sensors including cameras, microphones, GPS and Wi-Fi, generating huge amount of data whether the user knows it or not (Tene and Polonetsky, 2013). Since much of the data generated from mobile devices will contain spatial attributes, this data is ideal to process in GIS.

One example of how the spatial attributes of mobile devices data is leveraged is the real-time traffic monitoring in Google Maps. A user who has his or hers GPS transmitter enabled on their mobile device and utilize Google Maps automatically sends anonymous data to Google describing how fast they are moving. This data is then combined with data sent from other users (also utilizing Google Maps) and allows Google to calculate the live traffic conditions. These calculations can then be sent out to other users, allowing them to get an idea about how long it will take to travel from point A to point B and take the live traffic conditions into account (Barth, 2009).

Another example is research group who used mobile phone data to track peoples movement and discovered how it seemed to follow a mathematical pattern, allowing them to forecast a person's future movement with 93,6 % accuracy (Hotz, 2011).

Safety

Much user generated data derives from social media networks such as Facebook, Twitter and Instagram. The data generated from these networks is usually unstructured, sometimes making it hard to analyze further. However, in recent years a lot of research has focused on how to extract and interpret this type of data. One outcome spawning from this research is the ability to identify earthquakes and send out warnings to affected persons merely by monitoring tweets on Twitter.

By scanning Twitter for geocoded tweets with specific keywords such as *"Earthquake"* or *"Now it is shaking"* and applying a semantic analysis on the tweet (making sure that tweets such as *"I am shaking hands with X"* gets sorted out), researches have been able to develop a system which identifies earthquakes in specific regions. The system has proven to be successful, identifying 96 % of the detected earthquakes in Japan with a seismic intensity on the Richter scale of 3 or more. The built in warning system, which sends out an e-mail to registered users notifying them about the event, has also been proven to warn users faster than the warning system used by the Japan Meteorological Agency (Sakaki, Okazaki, and Matsuo, 2010).

Social media data can also be combined with other data to map out points of interest or other information concerning safety. ESRI, the world's biggest supplier of GIS software, have recently begun to exploit possible applications within this area. To demonstrate one possible application, they use a scenario where a hiker is lost in a national park and the search leader has to narrow down the search areas with GIS as a tool (Tucker, 2013). In the scenario, the search leader has access to a database with records from 30,000 lost hiker search-and-rescue missions. From querying the database, the search leader finds out that a majority of the lost hikers are found downhill, two miles from the last spot seen. To find areas fitting these facts, a two mile buffer is added in GIS to the areas where the hike was last seen, and an elevation layer is also added, pointing out the areas where it slopes downhill or uphill (Ibid, 2013). From the database, the search leader also finds out that most lost hiker stops walking after three hours. From this information, the search leader can create a predictive model based on elevation data and land cover data to map out place that needs to be prioritized. To further improve the analysis, the map is also shared with the public. People who mentioned on social media that they would be hiking in the same national park that day are targeted specifically, allowing them to add information of interest to the map (Ibid, 2013). This will narrow the search area even more, and will probably allow the search-and-rescue team to predict where the lost hiker might be.

4 EXISTING TOOLS AND TECHNIQUES FOR DECISION SUPPORT

4.1 General overview

Computerized decision-making support already exists for over 40 years and is assisted by an overwhelming collection of regular tools and techniques that have the same intention. In this part an overview is constructed of the good practices and useful tools and techniques within the process of urban decision support. In order to construct such an overview, research was done online, and there has been research on tools that support different purposes in the urban decision-making process. The purposes that have been identified are: Analysis, Knowledge Exchange, Monitoring, Question & Answer, Simulation, Stakeholder Participation and Visualization. Based on these purpose categories a collection of over 90 tools and techniques was conducted and analysed. Some features of the tools and techniques which were added to the list during this research are highlighted below. Detailed examples and descriptions of selected tools are given in the following chapter.

Figure 5 presents different purposes of the collected decision-support tools and techniques. It shows that there was found a relatively balanced amount of tools and techniques serving each purpose. In some cases tools would fit more than one purpose, e.g. analysis tools often also include visualization functionalities. In such a case the main purpose of the tool was identified so that in the chart each tool belongs to only one category.

The results show that almost a third of the tools investigated are intended for **data analysis**. These are tools suitable for the analysis of statistics, stakeholder mapping and analysis, market research, multi-criteria analysis, pros & cons, rating and voting, economic analysis, decision matrixes, T-charts, decision trees, cost-benefit analysis, or effect measuring. Examples are tools and techniques such as SPSS[18], Geographic Information Systems, etc.

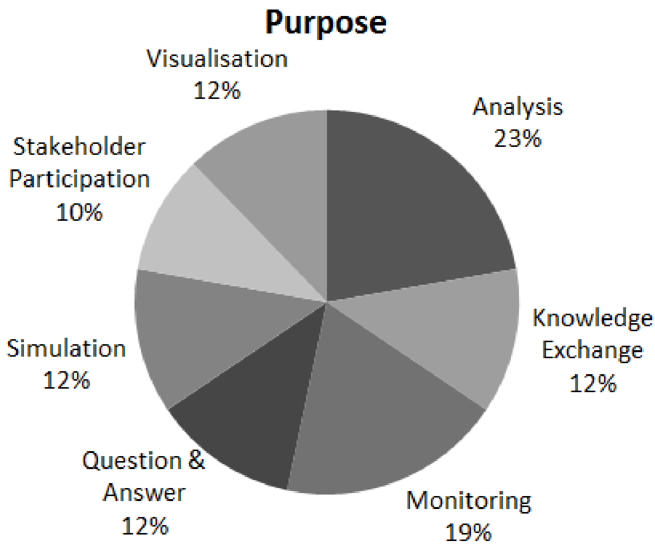

Figure 5: Main purpose of the collected decision-support tools and techniques

Common tools for **knowledge exchange** are information hubs or web platforms including a discussion forum, city profiles, a news section, functions such as comment, applaud, vote, blog, share ideas, include databases such as best practice catalogues, case studies, events calendar, etc. They are for example the Market Place of the European Innovation Partnership on Smart Cities and Communities[19], Open Ideo[20], or the Nordic Urban Platform[21]. A specific form of knowledge exchange is **question & answer sites** that where observed separately as they are for specific interest for the UrbanData2Decide expert-driven UrbanDecisionMaker. Examples are Quora[22], the location-based tool Askalo[23] or Thumb[24]. With the help of **monitoring tools** users can observe developments over a certain period of time to identify changes. These tools also support statistical analysis, social media monitoring or the creation of statistical timelines. They are for example iMonitoring[25] or Tracebuzz[26]. **Simulation tools** and techniques can be used for scenario planning, financial forecast, modeling, and system dynamics. Examples are CUBE for transportation modeling[27], UrbanSim[28], and NetLogo[29].

[18] http://www-01.ibm.com/software/analytics/spss/
[19] http://eu-smartcities.eu/
[20] https://openideo.com/
[21] http://www.ifhp.org/news/new-open-platform-showcases-nordic-urban-development
[22] www.quora.com
[23] http://www.askalo.info/
[24] http://thumb.it/
25 www.internetmonitoring.nl
[26] www.tracebuzz.com
[27] http://citilabs.com
[28] http://www.urbansim.org

Tools that support **stakeholder participation**, community outreach and civic engagement in urban decision-making processes include functionalities such as comment, blog, post, tag locations and attributes in a map, news, voting and rating, reporting etc. Examples are Bürgerbaustadt[30], Love Clean Streets[31] or MachMit![32]. Specific **visualization tools** provide all kinds of data and information visualisations like charts, infographics, maps, etc. Examples are visualizing.org, Quadrigram[33], Stack[34] or CityServer3D[35].

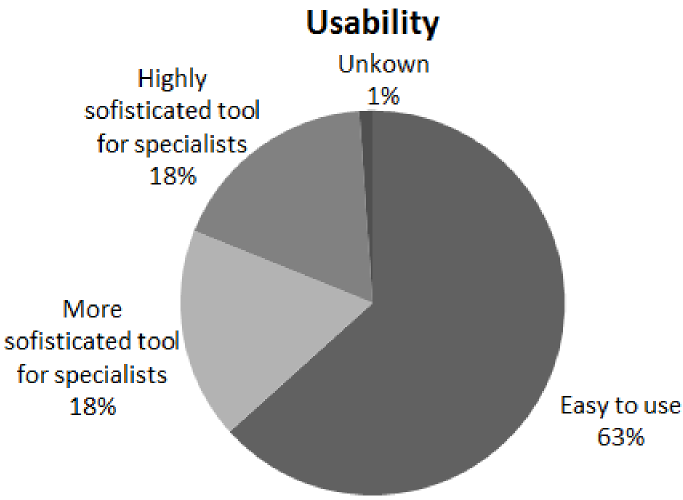

Figure 6: Usability of the collected decision-support tools and techniques

Concerning the usability of these tools, figure 6 shows that two third of all found tools and techniques are easy to use. They can be used by users without much or any background on specific technologies and methods and are intuitive. This amount can be partly explained by the high number of easy to use question and answer based websites and partly by the high number of fully commercial tools, where no additional actions by the user are needed. The more sophisticated and highly sophisticated tools and techniques include some more advanced simulation and analysis software such as ArcGIS, SPSS and as well as some open source software and tools that require some additional technical skills. The unknown group is formed by tools that are currently not used anymore and therefore could not be tested.

Figure 7 illustrates the amount of tools and techniques that were developed in co-financed research projects or industry projects. It shows that while most tools and techniques have not been funded,

[29] ccl.northwestern.edu/netlogo/
[30] http://buergerbautstadt.de
[31] https://www.cityoflondon.gov.uk/about-the-city/what-we-do/Pages/social-media.aspx
[32] https://open.wien.gv.at/site/mach-mit/
[33] http://www.quadrigram.com/
[34] http://www.webdesignerdepot.com/2009/06/50-great-examples-of-data-visualization/
[35] Cityserver3D

15% actually have. Among this 15% almost three quarters (62%) have been funded by the European FP7 program. Other funders are other research programs by the European Union and the U.S.A.

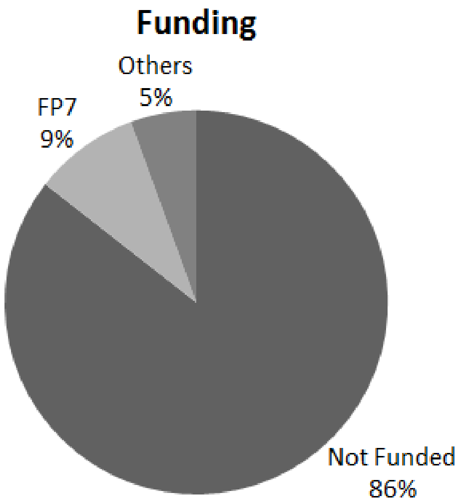

Figure 7: Funding of the collected decision-support tools and techniques

Another interesting feature is the accessibility of the tools and techniques concerning the costs of usage (figure 8). Almost two third (64%) of all found tools can be used free of charge. This category mainly consists out of free to use question and answer websites and commonly used stakeholder participation- and decision-making techniques. The 'fully commercial' category is mainly formed by social media monitoring tools and some highly sophisticated simulation and analysis software provided by commercial companies. This type of software is also found in the third group, but in this case they also offer some free features, like trials or limited software packages. The unknown group partly consists of tools that are not on the market anymore.

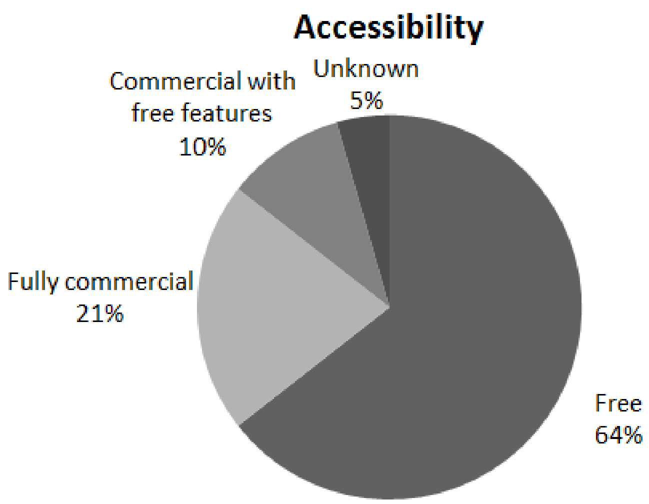

Figure 8: Accessibility of collected decision-support tools and techniques

Within a conducted shortlist of good practice tools, some additional features were described as well, such as the amount and types of visualisations the tool or technique offers, the data that it uses and the main organization that is behind it.

4.2 Example tools and techniques for decision-support

This part will describe some of the collected good practices in detail. Examples are provided for the following categories: Analysis, Knowledge Exchange, Monitoring, Question & Answer, Simulation, Stakeholder Participation and Visualization.

4.2.1 Analysis

Analyzing can be of great support when it comes to decision-making. By analyzing the context, problems, alternative solutions etc. one can make an informed decision based on one's findings.

Multiple Criteria Decision Analysis (MCDA)[36]

MCDA is a worldwide used technology in the field of complex decision-making. MCDA explicitly considers multi criteria in a complex decision-making environment. The analysis is based on the belief that most decisions we make are not simply based on one criterion, such as for example costs. This especially applies for complex environments with multiple stakeholders as is often the case in urban challenges. As in such cases a best solution often is not available, the decision maker's preferences are used to differentiate between alternatives. In the process the first step is to identify and define all alternatives and criteria that are important in the process. Then the criteria are given a number based on their relative importance and all alternatives are being scored on the different criteria. By combining the importance of the criteria and the scores of the alternatives a hierarchy arises among the alternatives. Based on this hierarchy one can make a deliberate decision on which alternative to implement.

It is free to use but we consider it highly sophisticated as it cannot be used without any pre knowledge. The results of a MCDA can be visualized in several ways depending on one's preferences.

Basic Information	
Name	Multiple Criteria Decision Analysis
Year established	1979
Organisation	Unknown
Funding	No
Location	Worldwide

[36] http://en.wikipedia.org/wiki/Multiple-criteria_decision_analysis

Access	Free
Features	Personal preferences are involved
Visuals	Mainly tables, based on users preferences
Usability	Highly sophisticated tool for specialists
Reference (URL)	http://en.wikipedia.org/wiki/Multiple-criteria_decision_analysis

Decision Tree[37]

The decision tree is just like the MCDA a tool that supports decision-making. It maps out the consequences concerning costs of all the alternatives and in that way supports a decision based on costs, utility and chance event outcomes. All alternatives are visualized as branches from a tree. When there is a choice to be made or a chance event, the branch splits. This ongoing process produces a set of outcomes on the different branches, forming a tree all together.

In a decision tree, nodes that represented by squares indicate decisions that need to be made, while nodes represented by circles indicate chance events and are annotated with the probability distribution. End nodes are represented by a triangle and are annotated with the cost that is associated with that particular branch.

Like the MCDA, the decision tree is open source and can be used freely without any costs for the user but it is a bit less sophisticated.

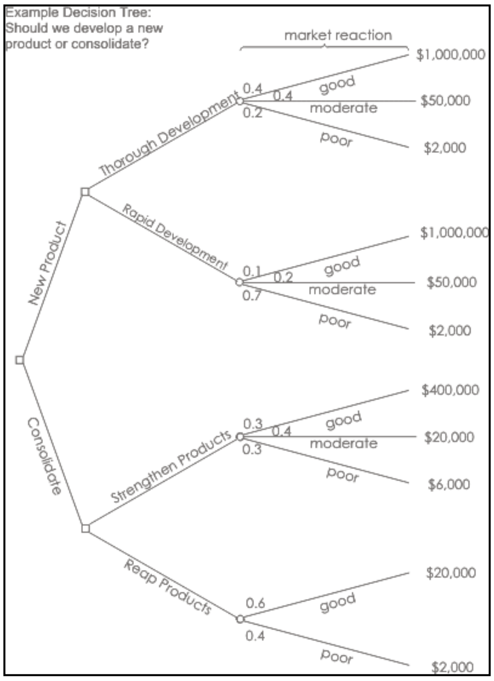

Figure 9: Example of a decision tree, about the possibility to develop a new product

[37] http://www.businessnewsdaily.com/6147-decision-tree.html

Basic Information	
Name	Decision Tree
Year established	Unknown
Organisation	Unknown
Funding	No
Location	Worldwide
Access	Free
Features	Chance events are taken into account
Visuals	Clear, tree-like, overview on the consequences of different decisions
Usability	More sophisticated tool for specialists
Reference (URL)	http://www.businessnewsdaily.com/6147-decision-tree.html

4.2.2 Knowledge platform

Knowledge platforms can be of great help in the decision-making process. It mainly functions as an information database or knowledge hub. All knowledge and information could be used to make a structured and deliberately decision.

Market Place of the European Innovation Partnership on Smart Cities and Communities[38]

The market place is a common platform for cities, industry and citizens to improve the life in cities through innovative solutions. These are for example applied innovation, optimised planning processes, stakeholder engagement, energy efficiency, transport solutions, intelligent use of Information and Communication Technologies (ICT), etc. This platform functions as an information sharing hub and was funded by the European Commission. The aim is to provide information on innovative solutions in various thematic fields such as energy, transport or ICT by cities for cities. It is based on user generated content and is free and easy to use, and holds a variety of visualizations like maps and charts concerning many topics.

[38] http://eu-smartcities.eu/

Figure 10: Interactive map provided by the market place of the EIP-SCC

Basic Information	
Name	Market Place of the European Innovation Partnership on Smart Cities and Communities
Year established	2011
Organisation	EC (DG Energy)
Funding	Yes, European Commission
Location	Europe
Access	Free
Features	Forum, project selector, city profiles, news, action clusters, post good practices, comments
Visuals	Interactive maps, charts, mind maps
Usability	Easy to use
Reference (URL)	http://eu-smartcities.eu/

Eltis[39]

Eltis is an urban mobility observatory. It is a platform that facilitates the exchange of information, knowledge and experiences in the field of sustainable urban mobility in Europe. It is aimed at

[39] http://www.eltis.org/mobility-plans/european-platform

individuals working in transport as well as in related disciplines, including urban and regional development, health, energy and environmental sciences.

The platform was founded in 2014 and funded by the Intelligent Energy Europe Programme of the European Union. Besides knowledge, information and experience Eltis also provides networks, events and forums. And the website holds a wide range of photos and videos concerning case studies and projects.

Figure 11: Website interface of Eltis

Basic Information	
Name	Eltis
Year established	2014
Organisation	European commission
Funding	Yes, Intelligent Energy Europe Programme of the European Union
Location	Europe
Access	Free
Features	Information hub with tools, best practices, networks, events, and case studies, forum
Visuals	Photos and videos
Usability	Easy to use
Reference (URL)	http://www.eltis.org/mobility-plans/european-platform

4.2.3 Monitoring

Monitoring is another approach to support the decision-making process. Social media monitoring for example tracks opinions of a greater audience concerning new projects, plans, trends etc. With tools to monitor social media, data can be generated to support the decision-making process. Online there is a great variety of free to use, fully commercial and partly commercial social media trackers. Regular monitoring can signal a trend or problem in the field in which the decision maker operates. An example of a monitoring tool is added below.

Cision[40]

Cision does not only track all desired information about a topic on social media, but also monitors classic media worldwide such as newspapers, television and magazines. It gives an overview over what is happening on the web related to your specific topic or company. This service is fully commercial but easy to use. It provides a personal dashboard with a clear overview on a specific topic.

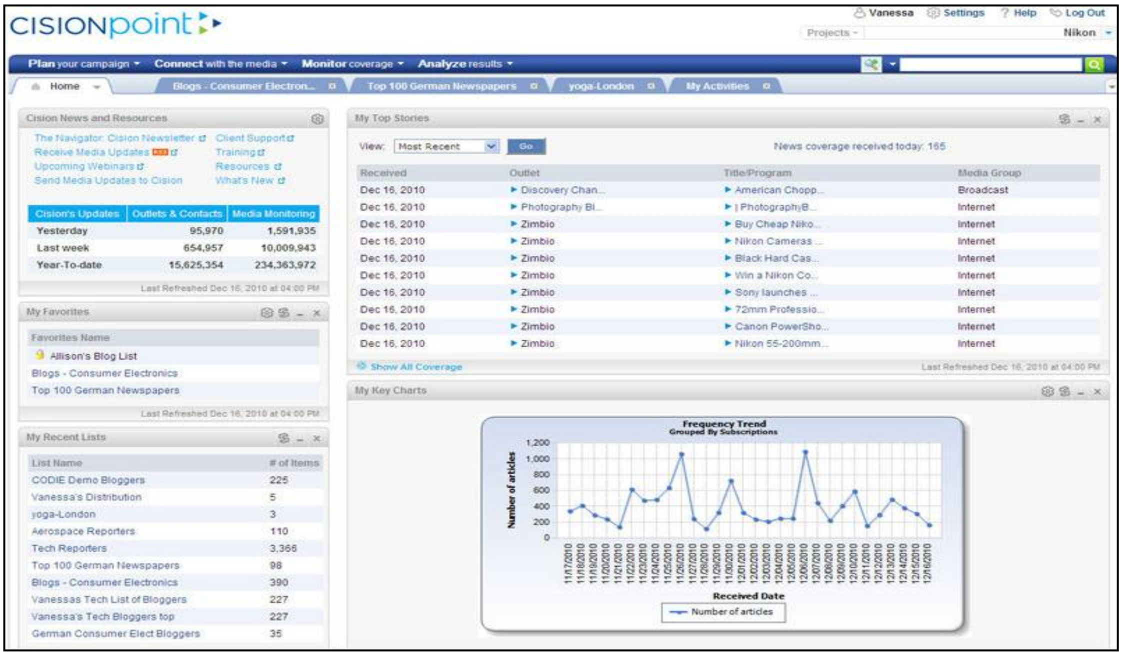

Figure 12: Overview of some features in Cision

[40] http://www.cision.com/us/pr-software/

Basic Information	
Name	Cision PR software
Year established	Unknown
Organisation	Cision
Funding	No
Location	Worldwide
Access	Fully Commercial
Features	Looks at online and offline media, media database
Visuals	Graphs, personalized dashboard
Usability	Easy to use
Reference (URL)	http://www.cision.com/us/pr-software/

Land Information System Austria (LISA)[41]

The goal of the Land Information System Austria is to provide existing spatial data on land cover and land use in Austria to public authorities and the private sector. LISA aims to contribute with this new information to thematic fields such as urban and regional planning, forestry, agriculture, water, natural hazard management as well as environmental protection and conservation. Reflecting the work of the European GMES Land Monitoring System (Land Monitoring Core Service, LMCS) LISA is defined as a two-stage project, namely the LISA mapping service and the LISA subject application (see corresponding menu item): The LISA mapping based on the LISA data model has been developed by a complex process chain for a automate evaluation of orthophotos and satellite data. The downstream services of LISA integrate the results of the LISA mapping services in order to create additional products.

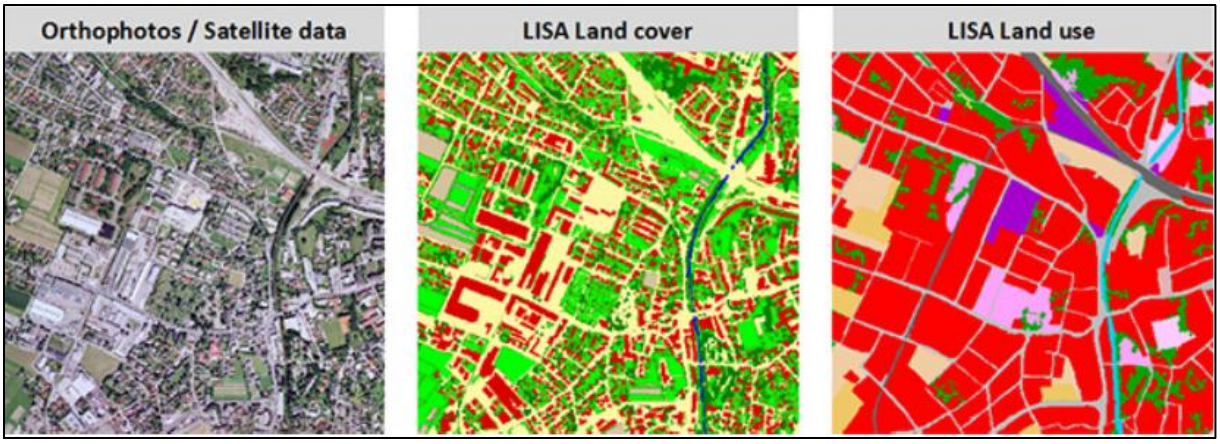

Figure 13: Land Information System Austria – monitoring Land Use and Land Cover data

[41] http://www.landinformationsystem.at

Basic Information	
Name	LISA - Land Information System Austria
Year established	2009
Organisation	Geoville
Funding	EESA, BMVIT
Location	Austria
Access	Free access for public organisations
Features	Add layers, overlay, data visualization, mapping, analysis of land cover change
Visuals	Maps
Usability	More sophisticated, background knowledge required
Reference (URL)	http://www.landinformationsystem.at

4.2.4 Question & Answered Sites

Question and answered based websites can be very useful in the decision-making process. On one hand they operate as opinion trackers that offer the possibility to track sentiments within the direct surroundings of a project. On the other hand they are a source of knowledge and questions can be asked to experts in different fields.

Askalo[42]

Askalo is a location based Question & Answer website, which operates worldwide. Its content is user generated and it focuses on local communities where citizens can post a question or comment about their region. It is a free and easy to use service by Yalwa and the clear maps that are attached make it rather easy to find the region of your interest. In a decision-making process such a question and answer website could be used to track opinions about, for example, new urban development projects.

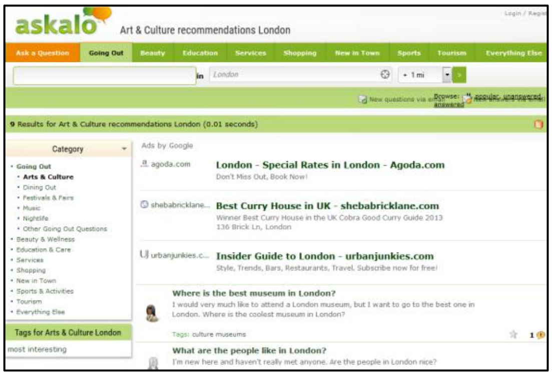

Figure 14: Overview of some features on Askalo

[42] http://www.askalo.info/

Basic Information	
Name	Askalo
Year established	2010
Organisation	Yalwa
Funding	No
Location	Worldwide
Access	Free
Features	Chose a city, post and answer questions, like and dislike
Visuals	Tags & Maps
Usability	Easy to use
Reference (URL)	http://www.askalo.info/

Thumb[43]

Thumb is a real-time Question & Answered based website, which also comes in a mobile app version and in a pro version for business. The website allows users to get feedback in real-time and the feedback can be rated by giving thumbs up or down. Besides asking questions, users can also upload pictures and ask for opinions.

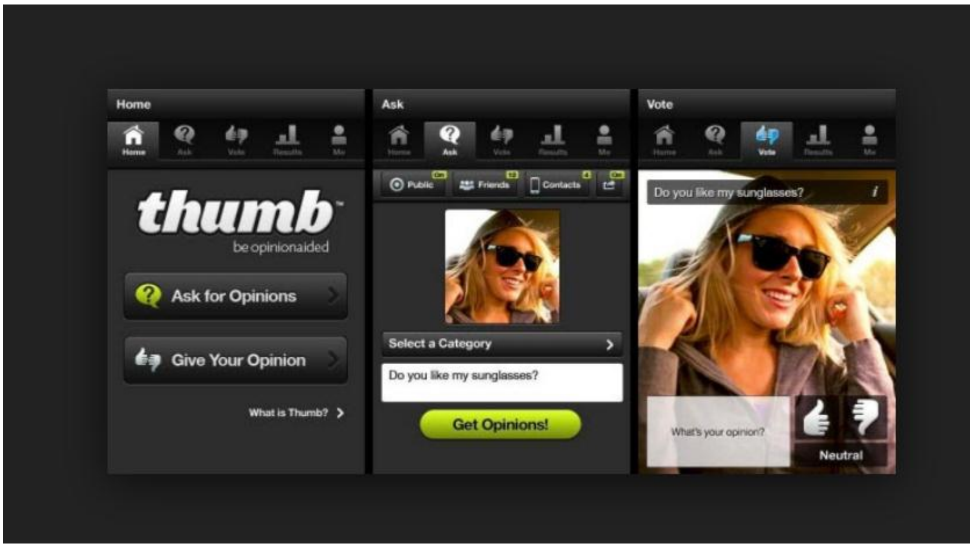

Figure 15: Interface on the thumb.it website

[43] http://thumb.it/

Basic Information	
Name	Thumb
Year established	2010
Organisation	Ypulse, Inc.
Funding	No
Location	Worldwide
Access	Free
Features	Ask questions, get opinions, voting (thumbs up or down)
Visuals	Pictures
Usability	Easy to use
Reference (URL)	http://thumb.it/

4.2.5 Simulation

When a complex decision needs to be made, simulations can be used to map all possible outcomes and consequences of a particular decision. Whether it is a discrete event or a continuous process, with the variety of simulation software that is on the market nowadays, any decision-making process could benefit from a certain type of simulation. Simulation systems might also be part of early warning systems e.g. predicting future behavior of water levels in case of heavy rainfall.

Vensim[44]

Vensim provides software to model system dynamics and helps to fully understand complex systems, including non-linearity. The software cannot be used without prior expertise in mathematical modelling. It needs both relevant data and domain expertise to define the relationships within the system. Vensim is a commercial company but offers free packages (mainly for students).

The biggest plus of Vensim and system dynamics is the possibility to simulate different alternatives and decisions and see the effect they have on the rest of the system over time. When all consequences of all possible decisions are calculated and mapped, it is slightly easier to make a well-founded decision.

[44] www.vensim.com

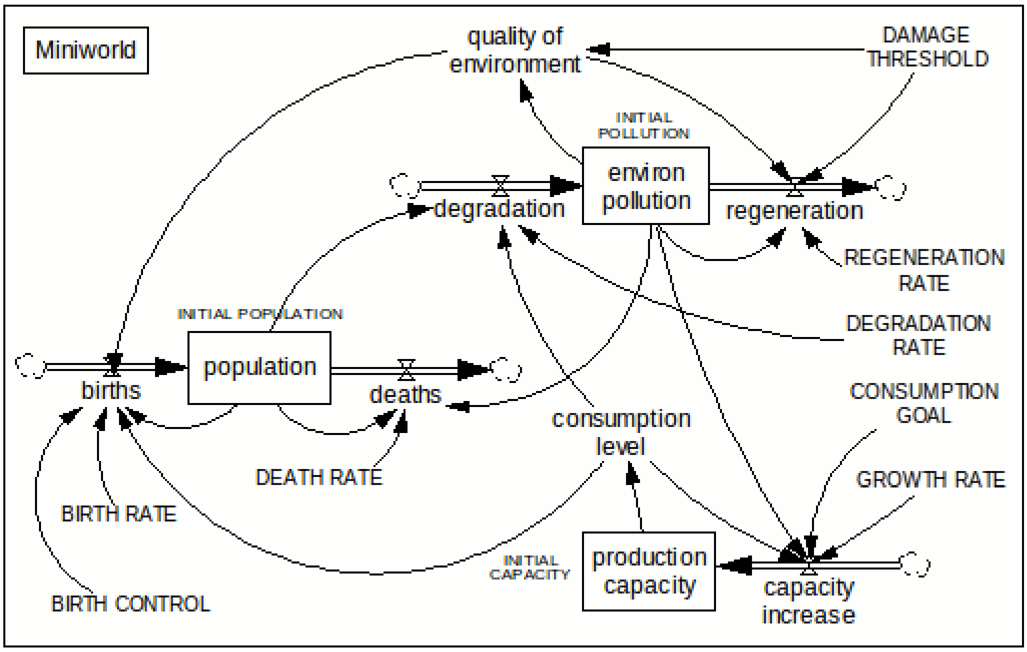

Figure 16: Example of System Dynamics in Vensim software

Basic Information	
Name	Vensim various software packages
Year established	Unknown
Organisation	Vensim
Funding	No
Location	Worldwide
Access	Commercial with free features
Features	Simulation, policy/decision testing
Visuals	Graphs and Relations within a system
Usability	Highly sophisticated tool for specialists
Reference (URL)	www.vensim.com

NetLogo[45]

NetLogo provides a type of simulation and models primarily agent based situations. The NetLogo environment enables exploration of emergent phenomena. It comes with an extensive model library including models for a variety of domains, such as economics, biology, physics, chemistry, psychology, and system dynamics. NetLogo allows exploration by modifying switches, sliders,

[45] ccl.northwestern.edu/netlogo/

choosers, inputs, and other interface elements. Beyond exploration, NetLogo allows authoring of new models and modification of existing models.

NetLogo and agent based modeling is less sophisticated compared to system dynamics and can be used for free. It could be of support in the decision-making process when a decision in an agent based environment adjusts the input, conditions or boundaries.

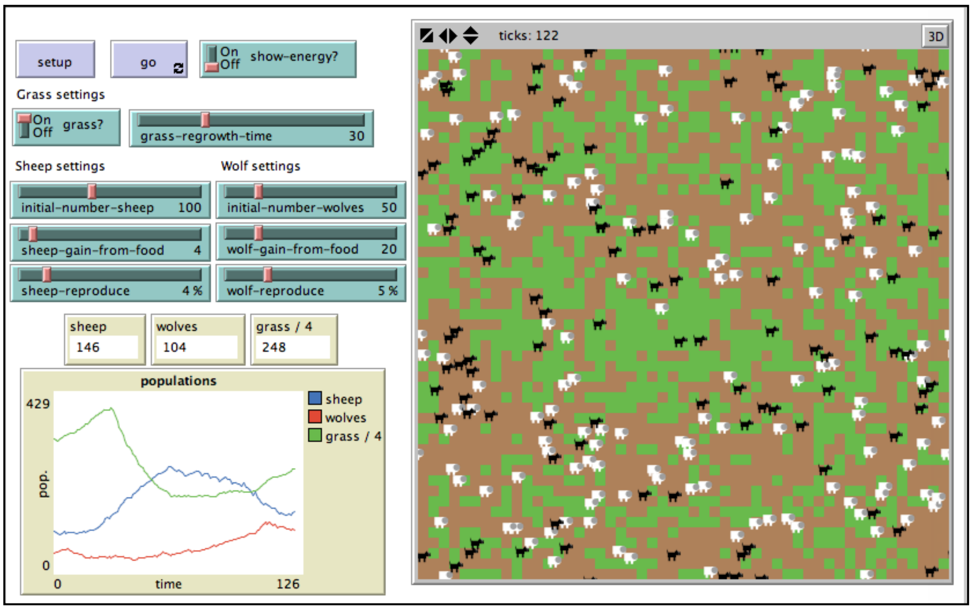

Figure 17: Example of agent based modeling in NetLogo

Basic Information	
Name	NetLogo
Year established	1999
Organisation	Northwestern
Funding	No
Location	Worldwide
Access	Free
Features	Simulations, environmental adjustments
Visuals	Graphs, Statistics, Basic simulation overview
Usability	More sophisticated tool for specialists
Reference (URL)	ccl.northwestern.edu/netlogo/

4.2.6 Stakeholder Participation

In the process of decision-making, stakeholder participation can be of great influence. Stakeholders could help in developing ideas, alternatives or solutions for problems that address them. Also in the implementation phase they could be very useful or be experienced as an obstacle. Active engagement of stakeholders initiated by city municipalities also strengthens the commitment of citizens to new urban developments (e.g. in case of bigger transportation projects). Either way a project could greatly benefit when stakeholders are involved from the start.

4.2.7 Visualisation

Visualisations of data, decision processes and simulation results mainly support human sense making and decisions based on it. Visualisation tools are thus an important support for decision-making. Besides the tools presented below, the reader is referred to Deliverable D2.1 Social and open data visualization methods and data sources report.

Javascript InfoVis Toolkit[46]

With this toolkit it is possible to create interactive data visualizations for the web and it is free to use. This toolkit features different visualizations including: Hypertree, Treemap, Sunburst, Bar and Area. The interactivity creates an extra dimension in understanding the complex data.

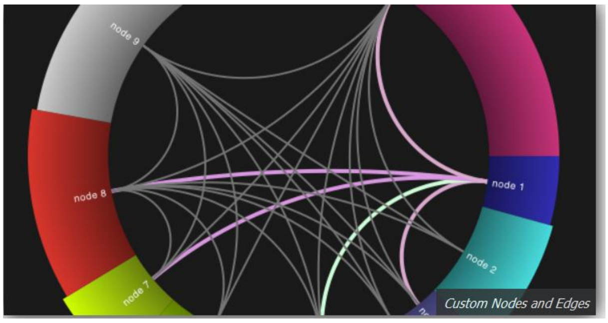

Figure 18: Example of data visualisation with the Javascript InfoVis Toolkit

Basic Information	
Name	Javascript InfoVis Toolkit
Year established	2013
Organisation	Unknown
Funding	No
Location	Worldwide
Access	Free
Features	Discussion platform, community
Visuals	Multiple visual processes, charts, graphs
Usability	Easy to use
Reference (URL)	http://philogb.github.io/jit/index.html

[46] http://philogb.github.io/jit/index.html

Quadrigram[47]

The Quadrigram software can be used to create custom data visualizations in an intuitive way with the flexibility of its visual language. It enables to prototype and share ideas rapidly, analyze and monitor data, as well as produce compelling solutions in the forms of interactive visualizations, animations or dashboards. A number of scalable pricing options are available based on the number of users, processing power, storage capacity, traffic and access privileges that users require. Although it is a commercial tool, it does offer a free 30 day trial.

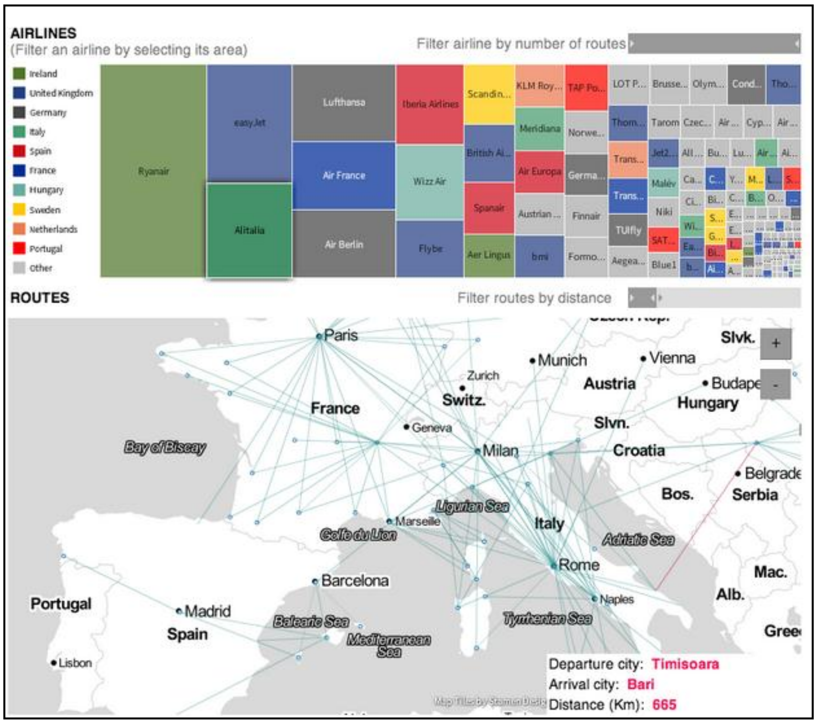

Figure 19: Example of data overview with Quadrigram

Basic Information	
Name	Quadrigram
Year established	Unknown
Organisation	Quadrigram
Funding	No
Location	Worldwide
Access	Commercial with free features
Features	30 free trial, multiple data sources, easy to share
Visuals	Interactive visualizations, animations, dashboards
Usability	Easy to use
Reference (URL)	http://www.quadrigram.com/

[47] http://www.quadrigram.com/

4.2.8 Reporting tools

Love Clean Streets[48] is a mobile application for citizens so that they can easily report environmental crime such as graffiti, fly-tipping or potholes though their mobile phones. Through integrated services authorities can manage and respond.

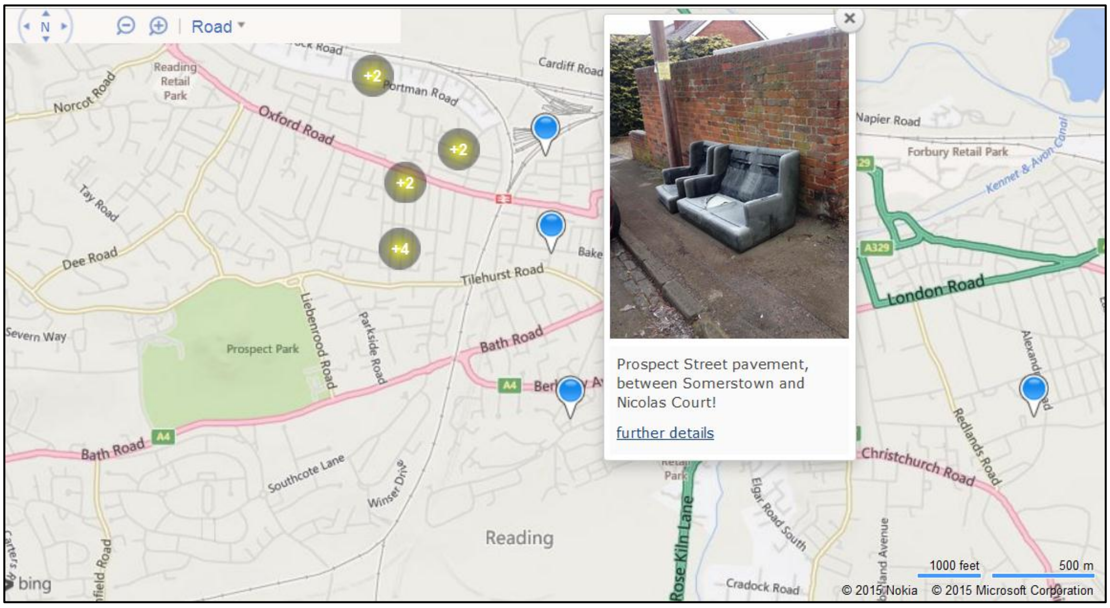

Figure 20: Cartographic interface of the citizen reporting tool

Basic Information	
Name	Love Clean Streets
Year established	2015
Organisation	BBITS
Funding	No
Location	UK
Access	Free
Features	Community based involvement, report and tag, location-based service
Visuals	Map, pictures
Usability	Easy to use
Reference (URL)	http://www.lovecleanstreets.com

48 http://www.lovecleanstreets.com

MachMit![49]

MachMit! is a location-based service that functions as the interface between citizens and the city administration. It is part of the Open Government initiative in Austria to engage citizens in urban development processes. The mobile application includes the following functionalities: publish news and send out surveys by the city administration, citizens can vote, post opinions, pictures and can report problems.

Basic Information	
Name	MachMit!
Year established	Unknown
Organisation	Datentechnik Innovation GmbH
Funding	No
Location	Austria
Access	Free
Features	Creates a feeling of involvement, publish news by city administrations to inform citizens, sendouts, surveys, votings, citizens can post opinions and report problems, post pictures, location-based
Visuals	Map, pictures
Usability	easy to use
Reference (URL)	http://www.buergerplattform.at/

4.2.9 Geographic Information Technology

The relevance of space has been discussed in chapter 3.3 of this report. A most suitable way to capture the spatial component of urban challenges and decisions is with Geographic Information Systems (GIS) which is why we are emphasizing in this section on GIS a tool supporting urban decision-making. GIS is one of the most common ICT tools employed in urban management and is prevalent among both the public and private organisations which have a role in making our cities more sustainable. The main role of GIS is as a decision support tool for both technical experts and decision-makers alike. GIS allows users to conduct complex geospatial analyses combining data from various sources such as socioeconomic statistics, satellite imagery and monitoring data that have a spatial reference. In this sense, GIS decision support tools function as social-technical instruments (a cross between computer and management sciences) which help users understand complex systems. GIS-based decision support applications are available for fields ranging from transportation, resource management, crime analysis, energy infrastructure, land use planning and disaster management to

[49] http://www.buergerplattform.at/

real estate, business development and marketing. GIS also plays an important role in informing and involving citizens in the planning process and promoting more sustainable lifestyles (Schrenk et al. 2010).

GIS contains multiple themes for a common geographic area. The collection of themes acts as a stack of layers. Because layers are spatially referenced, they overlay one another and can be combined in a common map display. In addition, GIS analysis tools, such as polygon overlay, can fuse information between data layers to discover and work with the derived spatial relationships.

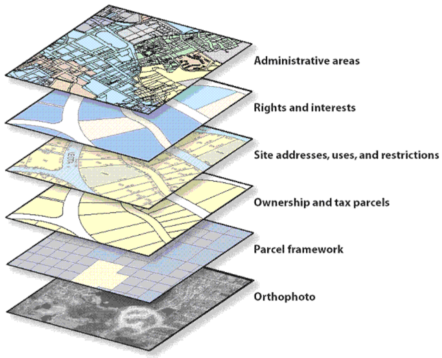

Figure 21: Overlay of data (Source: URL 1, ESRI Webhelp)

Urban Managers were among the first and most prominent users of geospatial technologies from the time when they became more widely accessible and affordable in the 1980s until today (Masser and Craglia 1997, Warnecke et al. 1998). Geographic Information Systems provide a powerful set of tools for analysing and modelling spatial conditions where several layers of data are involved. For example well field protection takes into account potential hazards to well field from flood risk, septic tanks, storage tanks, industrial areas, and delineating buffer zones to protect well fields from such hazards. Further GIS can be used to simulate the effects of adopting different spatial policy options. Also, GIS can be particularly used for monitoring of spatial changes over time, for example the changes in coastal saline intrusion, urban growths, temperature, carbon emissions, etc. These changes may be difficult to detect in a tabular form. Hence the spatial expression of a GIS supports the analysis and understanding of urban structures and developments. A successful GIS operates according to a well-designed plan and business rules, i.e. methods and processes, which are the models and operating practices unique to each organisation. Today, GIS software runs on a wide range of hardware types, from centralised computer servers to desktop computers used in stand-alone or networked configurations, and also in the web.

Geographic data and tabular data containing a geographic dimension can be collected in-house, purchased from a commercial data provider, or collected from other open data sources, e.g. open government data by public administration, user generated data incl. social media data. Examples and potential fields of applications of GIS are presented in the sections 4.2 and 5.

5 USE CASE SPECIFIC DECISION SUPPORT SYSTEMS

This section addresses decision support tools in urban decision-making in relation to the areas relevant for the case studies that underpin the project. The first subsection focuses on decision support for safety and security management. The second focuses on decision support for spatial planning. It will not come as a surprise that the kind of decision support differs in both areas. Safety and security management is part of the operational aspects of governance, requiring day to day monitoring of developments, whereas spatial planning involves long term participatory processes. In both cases state of the art tools though involve visualisation of and interaction with data through maps.

5.1 Decision support systems for safety and security management

Law enforcement agencies record thousands of crimes every year. Initially a recorded crime will most likely constitute of only details from the victim's statement, but once it is recorded it will require further investigation. Depending on the severity of the crime the information generated from the investigation will vary, but even less serious crimes will generate a considerable amount of information (Oatley, Ewart and Zeleznikow, 2006). As an example, a burglary from a dwelling house will not only constitute details from the victim's statement, but also time and location for the crime, forensic evidence such as shoeprints and details about stolen property (Ibid, 2006).

Given the example above, it is clear that each recorded crime, regardless of severity, will generate a large amount of raw data. This data will vary in quality and validity, but the investigator will be confronted about how to relate to it, which might be problematic considering the volume of raw data. Assuming that the investigator also would like to analyze crime patterns, examine linkages, and identify suspects, the investigation process will get even more complicated (Ibid, 2006). Especially since we, as individuals, have limited information processing capacities, meaning that people will select some particular information to process because that type of information is easier to process (Tasdoven and Sahin, 2010). To process, analyze and make conclusions about crime patterns, linking of suspects will therefore most likely be beyond the human capability without any support system.

The ability to utilize data analysis tools in a crime investigation process is therefore very important. Data analysis tools will allow investigators to query and extract data of importance to the case in order to detect crime patterns, linkages, and suspects to support their decisions (Ibid, 2010). However, much of the data generated from a crime investigation will be unstructured, making it harder to utilize the capabilities of data analysis tools. Furthermore, the data might be stored in different databases, making the data inaccessible and difficult to retrieve (Chen et al., 2002). As crime investigations usually are dependent on time, issues like these might have negative effects on the investigation as a whole. The possibility to query and analyze unstructured data from multiple databases at the same time would therefore be a huge benefit for law enforcement agencies.

COPLINK

As we mention above, data generated from crime investigations can sometimes be inaccessible since it is stored in different formats and databases. The inaccessibility derives from data being captured in different data systems or databases according to different formats, standards or no standards at all (Chen et al., 2002). Non-transparency, incompatibility and inaccessibility can cause a lot of issues when a crime occurs. For instance, if a crime happens and one of the suspects can only be identified by his alias, the investigator would probably need to do a search query to see if the alias will return any results about real name, previously committed crimes, gang involvement or pictures of the suspect. The problem is that this information might be stored in different databases, which would mean that the investigator would have to make several search queries in different databases, with different user interfaces, to get a hit (Ibid, 2002). This will be a time consuming task and require a lot of prior knowledge from the investigator on where to find which records. To cope with these problems, for example a software named COPLINK[50] has been developed at the University of Arizona's Artificial Intelligence Lab in collaboration with the Tuscon Police Department (TPD) and the Phoenix Police Department (PPD).

The COPLINK system allows investigators and officers to query multiple databases at the same time from one user interface, making it easier to access and link information to each other. Since COPLINK was developed in collaboration with TPD and PPD, the system is specifically designed to fit the police department's needs. This means, for instance, that the system is accessed through a web browser (eliminating the need to install and maintain anything on local machines) and that it incorporates the possibility to access both remote and local databases, making it possible to add additional information to the analysis (Chen, Zeng, Atabakhsh, Wyzga and Schroeder, 2003). Furthermore, COPLINK also allows law enforcement agencies to access information from each other. When an investigator or officer makes a query in COPLINK, the system will not only search for information in their own, local, database, it will also query databases belonging to other police jurisdiction that also use COPLINK. This makes the collaboration between different police jurisdiction more effective since they do not have to make specific requests to each other every time they need information outside of their own jurisdiction (Chen et al., 2002). The interface has also been developed with respects to the police's specific requirements, making it possible to make search queries based on incomplete information, matching misspelled names or aliases with plausible ones, the possibility to keep track

[50] http://www-03.ibm.com/software/products/en/coplink

of previous searches (making it easier to document the investigation process) and map links between suspects and evidence (Ibid, 2003).

According to an article by Robert O'Harrow Jr and Ellen Nakashima in the Washinton Post, Coplink was used by almost 1 600 law enforcement agencies in 2008 (O'Harrow Jr and Nakashima, 2008). Law enforcement agencies connected to COPLINK will therefore have access to a vast amount of information, making it easier to conduct investigations and make decisions based on data.

Basic Information	
Name	COPLINK
Year established	Unknown
Organisation	IBM Corporation
Funding	No
Location	Worldwide
Access	Fully commercial
Features	Query multiple crime databases, make search queries based on incomplete information, match misspelled names or aliases with plausible ones, keep track of previous searches
Visuals	unknown
Usability	Highly sophisticated tool for professionals
Reference (URL)	http://www-03.ibm.com/software/products/en/coplink

COMPSTAT

A globally applied system for management, reduction and control of crime is COMPuter STATistics or COMParative STATistics (COMPSTAT) (Weisburd et al., 2001; Weisburd et al., 2003). COMPSTAT can be seen both as work process and operating system. This operational system started to be used in New York's police force in the 1990s and has become an important part of America's Police reforms since then (Willis 2013).

COMPSTAT is based on various strategic and operational decision-making principles. One is to make available accurate information and statistics, such as type of crimes, time and location, and other specific data about crimes mentioned above, to different levels of the police organization. A second principle is about selecting the most effective methods and approaches to solve particular problems. A third is to be able to quickly mobilize police officers and resources to deal with specific criminals and crimes. A fourth is about to systematically and consistently identify and analyze lessons learned about the crimes and police operations to make necessary strategic and operational improvements for future events (McDonald, 2002; Silverman, 1999).

COMPSTAT contains spatial information and geographical tools to support the analysis of crimes and a work process in which police officers responsible for different areas, and sometimes representatives from other agencies and stakeholders, discuss current problems and decide on various strategic and operational solutions, such as targeted police operations towards places with high crime rates (e.g. hot spots). Accordingly, COMPSTAT can be seen as a good example of a data-driven decision support system in that way it incorporates important steps as collection and computerization of large amounts of data, geographical and statistical analysis, identification of crime patterns and problems, strategic decisions making, and on the basis of decisions, rapid deployments of police officers and material resources to solve crime-related problems at certain places in the community.

Basic Information	
Name	COMPSTAT
Year established	1995
Organisation	Unknown
Funding	No
Location	Worldwide
Access	Commercial with free features
Features	Crime data management, spatial and statistical analysis
Visuals	Maps, graphs
Usability	More sophisticated tool for specialists
Reference (URL)	http://en.wikipedia.org/wiki/CompStat

5.2 Decision support systems for urban renewal

Urban renewal is regarded as one of the most practical and promising approach to developing modern cities across Europe. Terms such as urban renewal, urban regeneration, urban redevelopment, and urban rehabilitation have closely related meanings to the town-planning field (Zheng, Shen, & Wang, 2014). Urban renewal and urban regeneration describe a comprehensive integration of vision and action aimed at resolving the multi-faceted problems of deprived urban areas to improve their economic, physical, social, and environmental conditions (Ercan , 2011; Zheng et al., 2014). Urban renewal thus combines spatial planning with economic, cultural and social initiatives, and relies heavily on citizen participation both to provide input in the decision-making and in order to assure sustainability of changes. Socio economic data, maps as well as unstructured data from the citizen participation process is used to decide on concrete initiatives.

Furthermore, research in the inclusion of decision support in context to spatial planning and citizen involvement has given rise to a broad range of approaches and software support. One can distinguish two threads of discussions: one focuses on mathematical modeling based spatial decision support systems (MSDSS) which often work with simulations; a second line of research emphasizes public participation (PP), involving provision of community and municipal information (Barton, Plume, & Parolin, 2005). Both approaches overlap when geographical information is used to display data and for simulating results to inform citizen participation. This can be seen, when PP approaches use graphical information systems (PP-GIS) for the public with the aim of involving citizen decision-making process (Bugs, Granell, Fonts, Huerta, & Painho, 2010; Renate steinmann, 2004). Whereas the MSDSS research focuses on mathematical models and multi-criteria, which might be evaluated with respect to real data normally for a limited problem domain, research emphasizing public participation often has the form of case studies. In the latter cases, the data aggregation and visualization is very specific with respect to the development targets, requirements, and aspirations of the specific urban renewal of planning projects.

In the following we first exemplify and discuss the application of traditional mathematical modeling based decision support for urban planning. We then do the same for the research addressing public participation and finally the meeting of both traditions in the geographic data and visualization-based support for public participation.

Mathematical spatial data based decision support

Throughout the decade, a significant amount of research papers and Journals such as the Computer, Environmental and Urban Systems (CEUS), Cities, Buildings and Environment (BE), and the European Journal for Operational Research (EJOR), published a number of articles on decision support with focus on the use of spatial data and planning strategies. In this literature, mathematical models, optimization, and simulation are explored, but little emphasis is given to supporting urban renewal.

By far the most research focuses on how to apply mathematical models such as fuzzy rules, analytical hierarchy procedures (AHP) and multi-criteria methods to deliberate decisions in context with spatial planning (Jankowski, Fraley, & Pebesma, 2014; Kingston, Carver, Evans, & Turton, 2000; Mosadeghi, Warnken, Tomlinson, & Mirfenderesk, 2015; Verstegen, Karssenberg, van der Hilst, & Faaij, 2012). The application of these quantitative decision support techniques is done through ranking different planning scenarios based on prioritized, predefined criteria (Mosadeghi et al., 2015).

Only few of the quantitative methodologies are flexible enough to support scenarios with several decision criteria and data sources. In these cases MSDSS based methods rely on the participation of experts who make valued judgments about criteria and parameters. These judgments require expert knowledge of the quantitative models as well as qualitative information (Densham, 1991). More recent approaches support experts to engage in discussing and manipulating criteria and parameters in the mathematical models through iterative processes. The majority of the existing applications of mathematical decision support focusing on spatial planning targets rural or agricultural land use and environmental planning, and very little research addresses urban or spatial planning for cities and urban areas. Only the use of map based visualizations of spatial, climate and environmental data is commonly used for planning in the urban contexts (Kingston et al., 2000; Ren et al., 2012; Simão, Densham, & Haklay, 2009).

Urban renewal requires analyzing and relating heterogeneous data sources, often in an unanticipated way. Therefore systems must handle multi-faceted data with flexible methods of aggregation. Within the past thirty years two approaches to spatial decision support at operational level have emerged: multi criteria and spatial optimization. These approaches have been used to evaluate the suitability of alternative solutions based on criteria and site location (Jankowski et al., 2014). To give an example, Riera Pérez & Rey, propose the use of multi criteria simulation to compare urban renewal scenarios for an existing neighborhood in Lausanne (Switzerland). The approach allowed integrating socio-cultural, economic and environmental data in the simulation. Three different future scenarios were compared. (Riera Pérez & Rey,2013; Darren, 2011).

Where the application of MSDSS on spatial planning requires urban modeling technics with expert input and dialogue, public participation requires well-designed interactive visualizations that can be understood by a layperson. The complex nature of MSDSS is at odds with the inclusion of collaborative and participatory approaches used in real urban renewal projects.

Supporting public participation in spatial planning and urban renewal (PP)

Public participation (PP) approaches to support decision-making, facilitate the sharing of ideas and arguments in a community and mediates participation. These approaches focus on obtaining consensus from the community members and seek to establish collective intelligence that leads to a well-anchored decision. Public participation has existed for many years in its traditional form where people physically attend meetings. However, traditional public participation approaches are becoming more complemented by tools that support the participation process through information disbursement portals, community websites, and online forums, inviting online discussions.

A study conducted by Dittrich et al., (2012) ,based in Sweden, focused on how to enhance public participation around the comprehensive plan for the municipality. It used an interactive web application to visualize plans for citizens to annotate, using pictures and text. A Participatory Design approach was used to design the functionality of the interactive maps.

In another study from Berlin, a web application was provided for citizens to explore both, structured data such as statistics and unstructured data like pictures through a topographic map based interface. The files were store in the form of a pdf (Damurski, 2012). A Similar web application was implemented in Munich and Poland. For example in Poland interactive maps and forms were used to support communication between spatial planners and citizens in the context of spatial planning.

Spatial environments & tools used in spatial planning and urban renewal (PP-GIS)

Recent studies have used a number of approaches aimed at supporting urban planning by integrating mathematical methods to support the evaluation of measures, used to inform the public and citizens participation. Often these systems deploy Web 2.0 technologies as well (Barton et al., 2005; Bugs et al., 2010, 2010; Kingston et al., 2000; Rinner, Keßler, & Andrulis, 2008; Simão et al., 2009). The growth of open source spatial data platforms and tools, such as API libraries, Leaflet, Google maps , OpenStreetMaps, PostGis and CartoDB, has made it easier to not only provide spatial visualizations of data but also to support interaction with data through map-based interfaces. In addition to web 2.0 there are a number of free desktop tools such as QGis, GRASS Gis and gvSIG that can be used in the urban renewal context. The use of these tools would allow for more flexibilities for querying and aggregating data , and more flexible online discussions (Rinner et al., 2008).

In Bugs et al. (2010), the authors report the use of GIS based visualization of alternative scenarios with discussions among citizens and between citizens, planners and decision makers. Discussions can be navigated based on spatial data saved with the comments. Most of the research focuses on interaction, usability and visualization to support participation(Steinmann, 2004).

The potential to integrate simulation of different scenarios has not yet been fully incorporated in urban planning visualization and decision-making tools. The challenges here are the high variability in the decision-making process combined with the complexity of spatial planning and urban renewal projects. Urban planning and spatial planning mechanisms demand greater participation from citizen, pushing the threshold of innovation in decision support towards more flexible, visual and user friendly solutions.

6 CONCLUSIONS FOR THE URBANDATA2DECIDE PROJECT

Compiling the state of the art to underpin the design of the proof of concepts turned out to be a challenging endeavor. This should not come as a surprise as decision-making in municipal settings is a theme in the intersection of three different domains, each having discourses and rationales. The identified domains are: political sciences, big data and the methods provided by business intelligence, and computer based decision support both process oriented but also based on mathematical modeling.

The **political sciences** address decision-making from a governance point of view. The emphasis here is on transparency, processes and participation.

Big Data is fairly new concept that has gained a lot of attention in recent years. Decision-making based on Big Data is promising but still lacks well-tested methods, primarily in the public sector.

However, in many cases it might be difficult to manage large, and in some cases fragmented, data flows. Furthermore, managing Big Data can also challenge social, ethical and legal aspects of urban decision-making (see Deliverable 2.4 on Social, Ethical and Legal aspects of Big Data and Urban Decision-making).

Decision support tools are as heterogeneous as the information or forecasts deciders would like to have. They reach from mathematical modeling and simulation of complex systems to web crawlers collecting opinion information from both social media and online media. It is safe to say that there is an overwhelming amount of tools and techniques that could be helpful in the process of decision-making or parts of it such as analysis, monitoring, simulation/modeling, stakeholder participation, knowledge sharing and visualisation. The collection and analysis that was conducted and the examples that were given throughout this report illustrate the variety and the availability of a number of good practice tools and techniques that can be useful to support urban decision-making processes.

When it comes to urban planning, the literature study on diverse decision support systems mirrors the development from government to governance when it comes to (urban) planning which shows in the growing number of tools that can be used for stakeholder involvement and participation. However, there is still potential for the usage of both, structured (open) data and data mined from the social networks, in connection with expert knowledge in urban decision-making processes. Further, the existing tools often focus on a specific kind of data for a specific use case and often also a specific (spatial planning) project. Few tools aim at providing the possibility to interactively explore and analyze data or take into account that both data to be analyzed and the analysis method might evolve throughout the decision process. A common feature though is the use of maps as a way to render and navigate data in the process of human sense making. This provides a challenge for the use of social network data, as it is often difficult to establish a location related to the data volunteered by the citizen through these channels.

The approach of the UrbanData2Decide project is to explore different ways of using data and expert knowledge for different kinds of urban decision processes and abstract common modules data- and expert-driven decision support need to implement.

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ANNEX

Abbreviations

API**:** Application Programming Interface

GIS: Geographic information systems

GPS: Global Positioning System

MSDSS: Mathematical and Spatial Data based Decision support

PP: Participatory Planning

PP-GIS: Participatory Planning support using GIS functionality

Glossary of Terms

API: An Application Programming Interface (API) is an abstraction implemented in software that defines how others should make use of a software package such as a library or other reusable program. APIs are used to provide developers access to data and functionality from a given system[51].

Data: A value or set of values representing a specific concept or concepts. Data become "information" when analysed and possibly combined with other data in order to extract meaning, and to provide context. The meaning of data can vary depending on its context. Data includes all data. It includes, but is not limited to, 1) geospatial data 2) unstructured data, 3) structured data, etc[52].

Big data is high-volume, high-velocity and high-variety of information and data that demands cost-effective and innovative forms of information processing to enhance insight and decision-making. Where the three characteristics of high volume, velocity and variety, further describe the nature of all the available data (e.g structured, unstructured and Geospatial) and information, from which concepts, context and meaning can be derived to provide insights and improved decision-making. [53]

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[51] http://www.w3.org/TR/ld-glossary/#api

[52] http://www.data.gov/glossary

[53] http://www.gartner.com/it-glossary/big-data

Dataset: A dataset is an organized collection of data. The most basic representation of a dataset is data elements presented in tabular form. Each column represents a particular variable. Each row corresponds to a given value of that column's variable. A dataset may also present information in a variety of non-tabular formats, such as an extended mark-up language (XML) file, a geospatial data file, or an image file, etc[54].

In Linked Data, a dataset means collection of RDF data, comprising one or more RDF graphs that is published, maintained, or aggregated by a single provider. In SPARQL, an RDF Dataset represents a collection of RDF graphs over which a query may be performed[55].

Open Data: A piece of data is open if anyone is free to use, reuse, and redistribute it - subject only, at most, to the requirement to attribute and/or share-alike[56].

Open Data Resource: the datasets, their metadata and other documents published following the open data definition.

Open Government Data: Open data produced by the government. This is generally accepted to be data gathered during the course of business as usual activities which do not identify individuals or breach commercial sensitivity[57].

Stakeholder: A person with an interest or concern in something, especially a business. In open data, a stakeholder is anybody who can affect or is affected by the publishing and consuming of open data and their indirect economic and social influences. Five generic categories of open data stakeholder categories are derived deductively:

Web API: An API that is designed to work over Internet[58].

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[54] http://www.data.gov/glossary

[55] http://www.w3.org/TR/ld-glossary/#dataset-rdf

[56] http://opendefinition.org/

[57] http://opendatahandbook.org/en/glossary.html#term-open-government-data

[58] http://opendatahandbook.org/en/glossary.html#term-web-api