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AN EVALUATION OF TWO VISUALIZATION TOOLS FOR URBAN WATER MANAGEMENT DECISION MAKING: SMURF AND S-CITY VT.

From a user's point of view

by

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An evaluation of two visualization tools for urban water management decision making: SMURF and S-City VT. From a user's point of view.

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Executive summary

Cities in both developed and developing countries are increasingly suffering global pressures, such as population growth, climate change, etc. These problems directly affect the water resources, which are becoming scarcer and less reliable with the time. For that reason, the need of developing new ways of managing the urban water systems has been stated in many water events or policies. Thus, in order to achieve a more sustainable integrated urban water management (IUWM), which takes into account social, economic and environmental factors, many projects have been or are being developed to deal with this issue.

Decision-making processes and public participation are key elements within the process of changing the current urban water management to a more sustainable one. First of all, it is important to understand the need of this change, which is explained in this MSc thesis. Secondly, it is identified that this change is not an easy task because the processes of decision making in relation to water issues are very complex – as in IUWM they must take into account social, environmental and economic aspects-. Moreover, they must try to involve as many stakeholders as possible - they usually have different interests. In addition, there is often a lack of communication between them, and this fact makes the decision-making process even more complicated. Thirdly, it is explained that there are some tools that can assist to deal with the complexity of the decision-making processes. Finally, two decision making tools -SMURF and S-City VT- are evaluated to check whether they are user's friendly and really assist to environmental decision making.

SMURF and S-City VT help the general public to participate in IUWM decision making because these tools improve their understanding of the real world situation. By this way, the decision-making processes become more transparent.

Acknowledgements

This MSc thesis is part of the SWITCH Project (Sustainable Water management Improves Tomorrow's Cities Health). One of the topics of the SWITCH Project is the participation of the different stakeholders, including the general public, in the decision-making processes regarding Integrated Urban Water Management. This thesis summarises the evaluation carried out about two visualization tools which aim to facilitate the participation of all the stakeholders in the decision-making processes.

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Abbreviations

BOD: Biochemical Oxygen Demand.

DST: Decision Support Tool.

EDAR: Spanish abbreviation of wastewater treatment plant.

EPFL: Ecole Polytechnique Fédérale de Lausanne.

EU: European Union.

GIS: Geographical Information Systems.

ICTs: Information and Communication Tools.

IUWM: Integrated Urban Water Management.

IWA: International Water Association.

MCDA: Multi Criteria Decision Analysis.

MSc: Master of Science.

S-City VT – Sustainable City Visualization Tool.

SMURF: System for Monitoring URban Functionalities.

SWITCH Project: Sustainable Water management Improves Tomorrow's Cities' Health Project.

UWM: Urban Water Management.

UWSs: Urban Water Systems.

Chapter 1

Introduction

The first chapter describes briefly the problem regarding the necessity of including as many stakeholders as possible, including the general public, in the decision-making processes in order to achieve IUWM. This existing problem justifies the evaluation, from a user's point of view, of two visualization tools which aim to assist with the participation of different stakeholders in the decision-making processes; the topic of this MSc thesis. The scope, objectives and structure of the thesis are also presented in this chapter.

1.1. DESCRIPTION OF THE PROBLEM.

The number of people living in the cities is continuously increasing in both developed and developing countries. This fact, together with other pressures such as global climate change, makes the management of the conventional Urban Water Systems (UWSs) more and more difficult over the time. Moreover, it must bear in mind that the water resources are becoming scarcer as well as less reliable and it supposes a problem due to water is essential for human life.

Conventional UWS were designed in terms of providing high quality of water for all uses. They were also thought to provide enough quantities of water at the same time that being able to drainage and treat the huge quantities of wastewater produced (Pinkham, 1999). Although this design solved the existing problems in the past, it is not longer sustainable. Thus, a paradigm shift in Urban Water Management (UWM) is needed.

Nowadays, many policies and water events highlight the importance of achieving an Integrated Urban Water Management (IUWM). The fact of viewing the UWS in a holistic way increases the difficulty of the existing decision-making processes. In those, several stakeholders with different interests and knowledge are involved. In addition, the public participation is getting greater importance in this processes over the time

During the last decade, several researchers and projects are trying to deal with the improvement of the current UWM. They have provided new approaches for IUWM, however one of the key areas of research to improve the complex decision making processes is focused on the development of tools that allow the visualization of different indicators in order to encourage the public participation.

1.2. SCOPE

Making decisions related to IUWM is quite difficult. There are two main reasons: i) sustainable IUWM includes many aspects; such as water scarcity, water catchment and treatment, etc., and ii) a lot of stakeholders with different interests are involved.

Different researches and projects focus their studies on diverse aspects of the IUWM decision-making processes in order to ease them. Some research areas are the establishment of indicators, the development of new technical alternatives, the encouragement of public participation, etc. Among the projects, it is important to mention the European Union (EU) SWITCH Project (Sustainable Water management Improves Tomorrow's Cities' Health) and some PhD thesis due to its relation with this MSc thesis.

Along the development of this MSc thesis there has been two approaches. The initial one, framed within the SWITCH Project, was related to the development of a SMURF (System for Monitoring URban Functionalities) decision-making tool for the city of Zaragoza. It was not possible to undertake it due to lack of data. For this reason, the approach that has been researched on this thesis was established: an evaluation of two visualization tools -SMURF and S-City VT (Sustainable City Visualization Tool) - for UWM decision-making, from a non-expert user's point of view. The objectives are to identify the difficulties found by the users and propose potential improvements in the tools.

Finally, it is important to stand out that at the beginning the time schedule was set in six months, but due to this change of approach the thesis was longer.

1.3. RESEARCH AIM, OBJECTIVES AND HYPOTHESIS.

The aim of this master project is to carry out an evaluation of two visualization tools for urban water management decision making: SMURF and S-City VT - from a user's point of view.

For the achievement of this aim, the following objectives were set:

- Gather information related to IUWM, decision making and sustainable development indicators.

- Gather information about different Decision Support Tools (DSTs), specially those ones focused on visualization techniques. This includes SMURF and S-City VT.

- Gather data needed, for the adaptation of SMURF, from Zaragoza and the River Ebro Catchment near to the city, including scientific data and GIS cartography.

- Create minimum requirements to be able to start the SMURF software for Zaragoza.

- Translate the SMURF difficulties into an easy language to help other people who want to improve this decision-making tool for Zaragoza or adapt it to another location around the world.

- Elaborate a survey in order to evaluate the two visualization tools, SMURF and S-City VT.

- Identify the weak and strong points of SMURF and S-City VT, from a user's point of view, in order to use and understand the functionalities of the tools.

The hypothesis that wants to be determined whether is true, partly true or false is: “The visualization tools, SMURF and S-City VT, are useful to general public for participating in IUWM decision making”.

1.4. STRUCTURE OF THE THESIS.

This thesis report is structured in different chapters. A brief description of each chapter is given next.

Chapter 1, in which one this section is included, describes the existing problem related to the water resource, the scope and the research aim and objectives of this MSc thesis

Chapter 2, based on literature review, presents the necessity of achieving an IUWM and the complex processes for making decisions in relation to urban water issues. Also, the contributions of the SWITCH Project to this decision-making processes is analysed.

Chapter 3 explains some of the means that can assist with the decision-making processes in urban water issues. It is focused on tools which show environmental indicators. Thus, in this chapter is also described the two visualization tools evaluated along this thesis: SMURF and S-City VT. This chapter is also based on literature review.

Chapter 4 focuses on the participation of the different stakeholders in the decision-making processes. The lack of communication between the different stakeholders and the role of Internet in assisting the enhancement of the public participation are highlighted.

Chapter 5 presents what has been done during this thesis, i.e. it is the methodology. Some sections included in this chapter are: the literature review process, the selection of the two visualization tools used in this MSc thesis, the adaptation process of a SMURF decision-making tool to Zaragoza and the elaboration and development of the survey for the evaluation of SMURF an S-City VT.

Chapter 6 refers to the results obtained from the survey and the discussion related to them. Also some other discussions about different issues are included: the state of achievements during the period of this thesis, the contribution of SMURF and S-City VT to the complex decision making processes related to IUWM and the adaptation of SMURF to de city of Zaragoza.

Finally, in chapter 7, the conclusions as well as the recommendations for improving SMURF and S-City VT and other for possible further work are presented.

Chapter 2

Decision making in urban water systems

First of all, it is important to understand the need of changing from the current UWM to a more sustainable IUWM. The differences between the conventional UWM and the new emerging paradigm are also stated in the first part of this chapter. Later, the complex decision-making processes regarding the UWM are explained, including the main difficulties found to achieve a more sustainable IUWM. The contributions of the SWITCH Project to the decision-making processes are also stated.

2.1. INTEGRATED URBAN WATER MANAGEMENT

Approximately 49% of the world's population now live in cities (UNDESA, 2006). This percentage is increasing and so is their demand for natural resources in addition to their pollution loads to the environment (UNESCO, 1999). Around 70% of Europe's population live in cities (European Environmental Agency), while in underdeveloped nations only 43% of the population does (UNDESA, 2006).

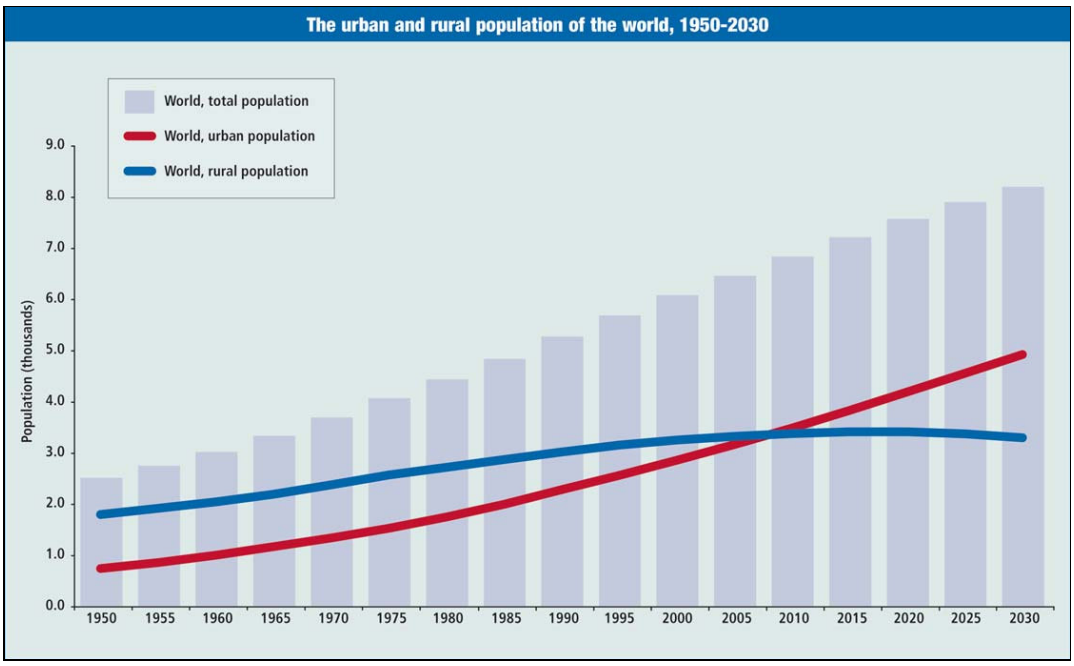

Figure 2.1: The urban and rural population of the world (1950-2030) (Source: UNDESA, 2006).

Moreover, in the EU, urban areas account for 25% of the total land area and unfortunately this percentage is growing much faster than the population. (European Environmental Agency).

This confirms that cities are certainly a major factor in the environment with the result that sustainable urban management is an issue of upmost importance. As urban management is a really wide topic, this thesis will be focus on the UWM.

Water is of great importance due to it is an essential source for human life and has become scarcer and scarcer as population have increased. The importance of water for sustainable development was highlighted in the 4th World Water Forum which took place in Mexico in 2006, where its ministerial declaration started with: " Reaffirm the critical importance of water, especially freshwater, for all aspects on sustainable development, including poverty and hunger eradication, water related disaster reduction, health, agricultural and rural development, hydropower, food security, gender quality, as well as the achievement of environmental sustainability and protection " (WWF, 2006).

In the cities existing nowadays, water is the largest single flow of material as shown in figure 2.2 (Brunner. and Rechberger, 2002).

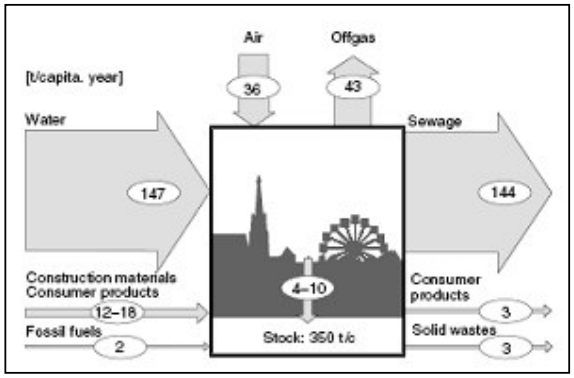

Figure 2.2: The flows and stocks of materials in the city of Vienna (all units in tons per capita per year) (Source: Brunner. and Rechberger, 2002).

Conventional UWM involves water supply, urban drainage, wastewater treatment and sludge handling (Larsen and Gujer, 1997).

The key question is whether an extrapolation of the current UWM for the "city of the future" is desirable or even feasible. Whether the conventional UWM is sustainable or not nowadays and in the future, is shortly discussed next.

In the World Commission on Environment and Development (1987), shortly referred to as the Brundtland Report, the well-known definition of sustainable development is stated: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their owns needs" (World Commission on Environment and Development, 1987, p.54). Despite of the common use of this definition, it is too imprecise when practical implementation wants to be developed (Lundin, 1999; UNESCO, 1999; Ashley *et al.,* 2004). It is also seem to represent a very contested concept, prone to different interpretations (Larsen and Gujer, 1997; Lundin, 1999; Foxon. *et al.,* 2002; Ashley *et al.,* 2004). Moreover, according to Gilmour and Blackwood (2006), interchanging "sustainability" and "sustainable development" terms, because it is though that they are synonymous, makes much more difficult to understand this concept. Sustainability is the "desirable state" of something (Lundin, 1999) or the "quality" which something has (Forum for Future, 2005) and sustainable development is the process over time by which sustainability is achieved (Lundin, 1999; Gilmour and Blackwood, 2006).

Nowadays, it is easier to define what is unsustainable practice rather than what is sustainable (Ashley *et al.,* 2004). It is not clear what sustainable UWM is, but it is possible to affirm that the current UWM carried out nowadays does not fit with the sustainable concept if we look at the following facts:

- "Conventional urban water management considers water supply, wastewater and stormwater as separate entities, planning, delivering and operating these services with little reference to one another" (Mitchell, 2004, p.5).

- UWSs were developed mostly in a linear manner (Pinkham, 1999; Guio-Torres, 2007), to provide high quality drinking water for all purposes and drainage in large amounts (Pinkham, 1999; SWITCH Project, 2006)

- In relation with wastewater, even the best wastewater treatment systems are not able to eliminate properly compounds such as Nitrogen, Phosphorus, endocrine disruptors and xenobiotics from water, which results in contaminated water resources. Also, the existing "mega city masterplanning" should be lead to the "household centred sanitation approach" for a better wastewater management (SWITCH Project, 2006).

- The report 'Europe's Environment: the third assessment', prepared by the European Environment Agency in 2003, shows that "most of the progress towards environmental improvement continues to come from 'end-of-pipe' measures to limit pollution or as a result of economic recession and restructuring in many parts of Europe" (European Environment Agency, 2003). In the water sector, passive action instead of active one exists (Ashley *et al.,* 2004), it means that ad-hoc actions (problem/incident) are carried out instead of measures in advance (SWITCH Project, 2006). However, environmental measures would be more effective if they are taken before environmental damage has occurred (European Environment Agency, 2003).

- Water management in many countries in the EU as well as in developing countries presents highly fragmented institutional division of responsibilities and tasks, resulting in a sub-optimal governance of UWSs (SWITCH Project, 2006).

- Urban populations are growing while there are increasing difficulties to expand the existing systems. In some cities, some areas still do not have a safe drinking water, sanitation and drainage services and these are usually the poorest ones due to the high costs of conventional UWM, which do not stop increasing (SWITCH Project, 2006; Guio-Torres, 2007)

- The water resources are becoming increasingly scarcer and with larger variation stocks and flows, i.e. that they are becoming less reliable, as consequences of global climate change (SWITCH Project, 2006; Guio-Torres, 2007)

All this means that "although the systems of over 100 years ago had the same inefficiencies, nowadays, due to fast population growth and higher per capita demands, higher industrial consumption and increased chemical load of the wastewater, the providing and receiving environments (respectively upstream and downstream) are often not able anymore to 'naturally' compensate for the huge abstractions and pollution loads, resulting sometimes in severe ecological damage" (SWITCH Project, 2006, p.43) Thus, the current UWM has drawbacks and could be improved.

It is particularly difficult to define exactly what Sustainable Urban Water Management is. However, it is clear that to achieve a more sustainable UWM, a movement towards IUWM is needed. Indeed, third action area of the nine actions established in the "Framework for Action on Water and Sanitation", one of the most important outcomes of the World Summit on Sustainable Development in Johannesburg in 2002, is the development of Integrated Water Resources Management by 2005 (WEHAB, 2002). This has not been achieved on time, what means it is not an easy issue and big efforts must been done if an IUWM wants to be achieved. Also, this necessity of an IUWM was highlighted in other water events like in the UN Conference on Environment and Development in Rio de Janeiro in which the Agenda 21 was established or in the 13th Commission of Sustainable Development in 2005.

"Integrated Water Management takes a comprehensive approach to urban water services, viewing water supply, stormwater and wastewater as components of an integrated physical system and recognises that the physical system sits within an organisational framework and a broader natural landscape" (Mitchell, 2004, p.5).

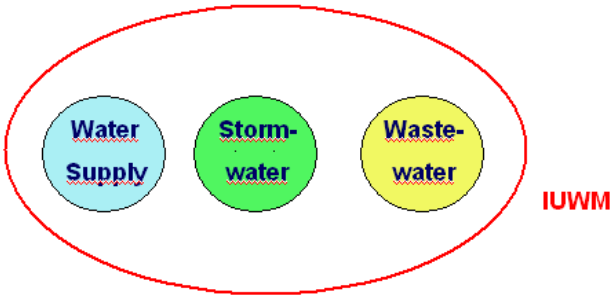

Figure 2.3: Integrated Urban Water Management.

Moreover, the aim of any sustainable urban development is to provide "more effective and efficient services which maintain public health and welfare, whilst reducing harmful resource and environmental impacts" (Foxon. *et al.,* 2002, p.286) So, making any efficient decision related with environmental issues, in this case in relation with Water Management, must take into account several of aspects including the competing but often complementary economic, social and environmental considerations.

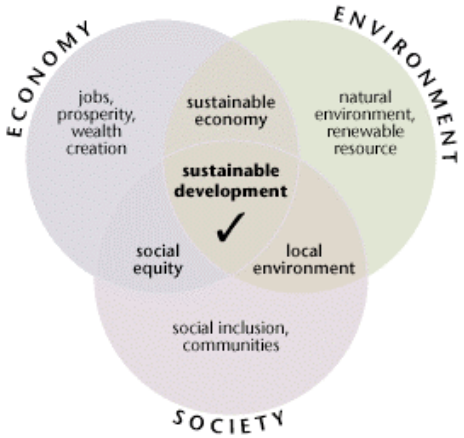

Figure 2.4: Sustainability aspects (Source: UK. Forestry Commission, 2005).

The characteristics of the 'old' or current and the 'emerging' paradigms of UWSs, according to Pinkham (1999), are shown in table 2.1.

Achieving an IUWM is not easy at all because it is very difficult to apprehend the water system as a whole, with all its interactions, as well as many stakeholders, with different interests, are involved (Schenk and Soutter, 2006).

The SWITCH Project will assist to the achievement of a more sustainable and effective UWM in "the cities of the future", i.e. cities existing in 30-50 years from now, through a paradigm shift with the help of the Learning Alliances. A Strategic Approach for IUWM will be developed, resulting in a SWITCH Global Training Package on IUWM focused on the different stakeholders, including also end-users.

Table 2.1: Differences between the old paradigm and the emerging paradigm in UWM (Source: Pinkham, 1999).

The Old Paradigm	The Emerging Paradigm
Human waste is a nuisance. It should be disposed of after treatment	Human waste is a resource. It should be captured and processed effectively, used to nourish land and crops.
Stormwater is a nuisance. Convey stormwater away from urban area as rapidly as possible	Stormwater is a resource. Harvest stormwater as a water supply, and infiltrate or retain it to support aquifers, waterways and vegetation.
Demand is a matter of quantity. Amount of water required or produced by different end-users is the only parameter relevant to infrastructure choices. Treat all supply side water to potable quality, and collect all wastewater for treatment	Demand is multi-faceted. Infrastructure choice should match the varying characteristics of water required or produced for different end-users in terms of quantity, quality, level of reliability, etc.
One use (throughput). Water follows one-way path from supply, to a single use, to treatment and disposal to the environment	Reuse and reclamation. Water can be used multiple times, by cascading from higher to lower quality needs, and reclamation treatment for return to the supply side of infrastructure.
Grey infrastructure. Infrastructure is made of concrete, metal or plastic	Green infrastructure. Infrastructure includes not only pipes and treatment plants, made of concrete, metal and plastic, but also soils and vegetation.
Bigger/centralised is better for collection systems and treatment plants	Small/decentralised is possible, often desirable for collection system and treatment plants.
Limit complexity and employ standard solutions. Small number of technologies by urban water professionals defines water infrastructure	Allow diverse solutions. Decision makers are multidisciplinary. Allow new management strategies and technologies.
Integration by accident. Water supply, wastewater and stormwater may be managed by the same agency as matter of historical happenstance. Physically, however, three systems are separated.	Physical and institutional integration by design. Linkages must be made between water supply, wastewater and stormwater, which require highly coordinated management.
Collaboration = public relations. Approach other agencies and public when approval or pre-chosen solution is required	Collaboration = engagement. Enlist other agencies and public in search for effective solutions

The current problems of the conventional UWM as well as the emerging water problems due to global change are addressed by SWITCH Project through different thematic themes as summarized in the following table 2.2.

Table 2.2: State of the art and emerging problems versus SWITCH themes (Source: SWITCH Project, 2007).

State of the Art/Problems	SWITCH Themes
Ineffective 19th century concepts (conventional urban water cycle)	Urban water paradigm shift (sustainability & integrated urban water management)
Urban water quantity problems (flooding & droughts)	Stormwater management (water sensitive urban design)
Urbanisation and inequality/disparity	Efficient water supply and use for all (demand management & recycling)
Poor sanitation coverage with ecological and public health damage	Innovations in sanitation and waste management (Ecosan & decentralisation)
Limited use of natural systems and processes	Urban water environments and planning (Natural systems)
Poor governance and fragmented institutions	Governance and institutional change
Fragmented response to problems	***More sustainable solutions for the City of the Future.***

Summarizing, the decision-making process to be able to reach a more sustainable IUWM, including as many stakeholders as possible, is complex and difficult. Thus, different decision-making tools will have to be developed in the future to support these new decisions.

2.2. DECISION MAKING

2.2.1. Introduction

Decision making covers many disciplines and this leads to different concepts. The follows show some examples of these possible definitions for “decision making”.

According to Wikipedia, decision making is the cognitive process leading to the selection of a course of action among variations. Every decision-making process produces a final choice. It can be an action or an opinion. It begins when we need to do something but know not what. Therefore, decision making is a reasoning process which can be rational or irrational, and can be based on explicit assumptions or tacit assumptions.

One further definition, using a business approach, would be that "decision making is a process of first diverging to explore the possibilities and then converging on a solution(s)" (Kotelnikov).

Thus, decision making might be defined as a process that consists of the selection of one choice among others based on preferences, where usually different constraints exist. Moreover, the decision-making process is the core element of any management, in IUWM too; all the other functions flow directly on from it (Rogers, 2001).

Normally, decisions in relation with IUWM are non-programmed or ill-structured. Non-programmed decisions are complicated in nature, involving a large number of factors where only correct actions will give rise to desired results; and correct actions call for correct decision carried out within an analytical framework (Rogers, 2001). This kind of high level decisions are also known as strategic ones (Ashley *et al.,* 2004). The probability of the correct choice being made in such situations is greatly increased by adopting a "reasoned" or "rational" approach that provides the appropriate analytical structure within which a coherent decision can be formulated (Rogers, 2001).

2.2.2. The decision-making process

According to Ashley *et al.* (2004), any decision process should contribute to:

- Establishing the decision-making context by identifying the actors, the various possibilities of action, their consequences, the stakes, etc.

- The organization and/or structuring of how the decision-making process unfolds in order to increase coherence between the values underlying the perceived goals and those embodied in the final decision.

- Getting the actors to cooperate by providing a decision framework favourable to mutual understanding and debate.

- The elaboration of recommendations using results taken from models and computational procedures conceived within the framework of a working hypothesis.

- Maximizing participation in the final decision and securing "buy in" from all the stakeholders.

It could be said that the primary objective of a decision-making process in relation with UWSs is to achieve informed and rational choices regarding the most effective use of the available scarce resource called water (Rogers, 2001).

2.2.3. Transforming the decision-making process from SWARD to SWITCH

SWARD is the acronym for Sustainable Water industry Asset Resource Decisions and it is a project undertaken by a consortium of UK academics in collaboration with services providers in Scotland (Foxon. *et al.,* 2002; Ashley *et al.,* 2004). In this project a decision-making process was designed and even it was created for private companies, it can be used as the base of any decision-making process in relation with UWSs.

Even the SWARD framework (Foxon. *et al.,* 2002; Ashley *et al.,* 2004) is taken as base to explain the decision-making process in UWM, it must be point out that it only has 7 phases, missing one important phase, the problem recognition, in accordance to other

authors as Rogers (2001), for instance. The following section examines these 8 criteria, including problem recognition, in the context of the SWITCH approach.

- **Phase 0. Recognition of the problem.** It is needed to ascertain that a problem exist and clarify in what it consists (Rogers, 2001).

  The boundaries of a system, which is being analysed, will significantly influence the final result of an assessment and also the possible solutions devised (Larsen and Gujer, 1997).

  The SWITCH Project identifies the current problems of conventional UWSs and management and tries to assess the emerging problems due to global change. By doing so, SWITCH makes decisions now for actions a long time in the future (approximately 30-50 years from now). SWITCH has clear that for achieving an IUWM a paradigm shift is needed; thus, many, both technological and non-technological changes are needed and these can not be made in a short time frame due to different reasons such as some regulations can not be modified as easy as wanted.

- **Phase 1. Definition of decision objectives**. A review of past performance or the formulation of new targets, which leads to the setting of the objectives for improving the performance of the UWSs, must be carried out.

  The SWITCH Project has two main objectives: a) achieving a paradigm shift in UWM by converting from ad-hoc actions (problem/incident driven) into a coherent and consolidated approach (sustainability driven); b) achieving a better governance, i.e. less fragmented and more coordinated, in water issues at city, river basin and global level through the help of the multi-stakeholders learning alliances.

- **Phase 2. Generation of options.** Once the objectives have been defined it is necessary to generate different conceptualised options that will satisfy these objectives. One of these options must always be “to do nothing”. As the number of options generated can be enormous it is needed to eliminate those ones that

are considered unsuitable and only maintain a reduced number of potential options for next stage.

Within the SWITCH Project, different researches in collaboration with the demonstration cities will developed, applied and demonstrate a range of innovative and tested scientific, technological and socio-.economic solutions and approaches which contribute to the achievement of a IUWM. These researches will be carried out in accordance to the six different thematic themes of the SWITCH Project (Annex C). The development of different and new water management options will contribute to finish with the current decision-making processes in which the "stakeholders" take few options, and always the same ones, under consideration, when dealing with UWM:

- **Phase 3. Selection of criteria and indicators.** Sustainable decisions must take into account economical, social and environmental aspects as well as technical ones. In this step, the selection of the relevant qualitative and quantitative criteria to the decision in question and the options under consideration takes place. Usually, it is needed to develop specific criteria because the generic ones for the different categories are irrelevant or impractical. According to Foxon. *et al.* (2002), these criteria chosen must be comprehensive, applicable, tractable, transparent and practicable.

  These criteria will allow judgments to be made between the different options based on their relative intrinsic worth. So, only those criteria that demonstrate differences between the various options are of relevance to the decision-makers; any criterion where the options perform identically will not form the basis for making an informed choice (Rogers, 2001).

  SWITCH will develop sustainable criteria as well as new science based indicators. The last ones, common for Europe and developing countries, will express quantitatively and qualitatively the sustainability of UWSs as well as the risk associated to these systems. They will allow accountability oriented decision-making processes and will facilitate the discussions between the various stakeholders included in the learning alliances.

- **Phase 4. The collection of data and generation of information.** In this part of the process, it is needed to collect data about the performance of the UWSs in the past and combined it with the information that some simulation modelling tools can provide about the future performance of these different options because the future performance of the UWS under different options is being considered. Environmental analysis tools and simulation model, among others, are used to collect data or generate information for relative sustainability assessment.

  SWITCH will collect data from the nine demonstration cities within the project, which are situated in Europe as well as in developing countries. Also, several modelling tools will be developed and implemented in the different cities to be able to generate useful information about the performance of different options or solutions in cities which present different geographical, climatic and socio-cultural setting. Then, SWITCH will extrapolate this information generated and will disseminate it, allowing other cities to improve its knowledge about water management.

  All this information gathered in this stage is used later to score or rank each option according to the chosen criteria selected in phase 4.

- **Phase 5. Analysis of options**. One or more of the formalized multi-criteria decision-making methods are used as a screening tool and can be very useful in making clear some of the key issues and conflicts, taking into account the broad concept of sustainability. All of these decision support methods attempt to map the attributes of each decision outcome onto a preference structure via de various decision criteria. Basically, it is a step where the weighting and ranking of the different options is carried out.

  The SWITCH Project will develop, within the theme 1, a SWITCH toolbox that will include different contributions coming from theme 2, 3, 4 and 5. This performance assessment tool will assist the analysis of several options, in a specific situation, through a multi-criteria analysis approach.

If the decision-making process regarding UWSs finishes here we would find two main drawbacks, which become worse when much more controversial and complex the problem is:

- The apparent objectivity can imply an unwarranted degree of precision.

- The process by which the measures and weights are determined is both difficult conceptually and, where there are several decision-makers, can be extremely contentious.

That is why the decision-making process does not finish at this point.

- **Phase 6. Selection and implementation of preferred option**. The different Multi Criteria Decision Analysis (MCDA) methods, used in the previous stage, provide information to guide the decision makers about the relative sustainability of the options, but a further stage is required in the analysis before the final option selection.

  Different stakeholders could have used different MCDA methods and obtained different results or indeed take the same ones and interpreted them in a different ways. That is why the final decision must only be arrived at after appropriate consultation have taken place between all stakeholders involved in making the decision (Rogers, 2001). The diverse stakeholders have different interpretations of sustainability and boundaries of UWSs, as well as diverse interested linked (Guio-Torres, 2007). So, when more stakeholders are involved, there is less risk to overlook some aspects, although longer time is spent (Guio-Torres 2007)

  The use of a transparent Multi-criteria Decision Analysis is of upmost importance because it allows other stakeholders to criticize the weightings or choices used in it, and assess whether different values would affect preferred choice of option; it is know as sensitive analysis. This transparent MCDA can also help to check the robustness of the decision considering the best and the worst scenario, for example.

Human judgment is needed on issues such as risk and uncertainty and on the influence of intangible issues on the final decision.

Finally, an open and auditable discussion/analysis must be carried out among the stakeholders to conclude with a solution.

Within the SWITCH Project, the learning alliances will play a key role in this phase of the decision process. They will contribute, through the learning alliances' facilitators, to a more transparent decision-making process as well as to open discussions between all the stakeholders to create win-win solutions.

- **Phase 7. Post project monitoring and feedback.** It is the decision review stage that will provide information for future decision making. It can confirm that the evaluation undertaken in the decision stage was realistic and it should also be used to refine the generic and specific criteria, the database and indicators (where used).

  At present, the SWITCH Project is not a decision-making process itself and it does not really have great contribution to this stage of the process, even it does to other phases.

Although this decision-making process for UWSs is explained in a linear way for its better understanding, really it is dynamic and it will require continual re-appraisal, revision and feedback among different stages.

From the decision-making process in UWSs explained before, it becomes clear that they should be multi-disciplinary and multi-participatory processes which involve multi-objective tradeoffs (UNESCO, 1999). It results in very complex processes, in which the complexity should be made manageable instead of trying to reduce it, as many times happens (Geldof, 2005).

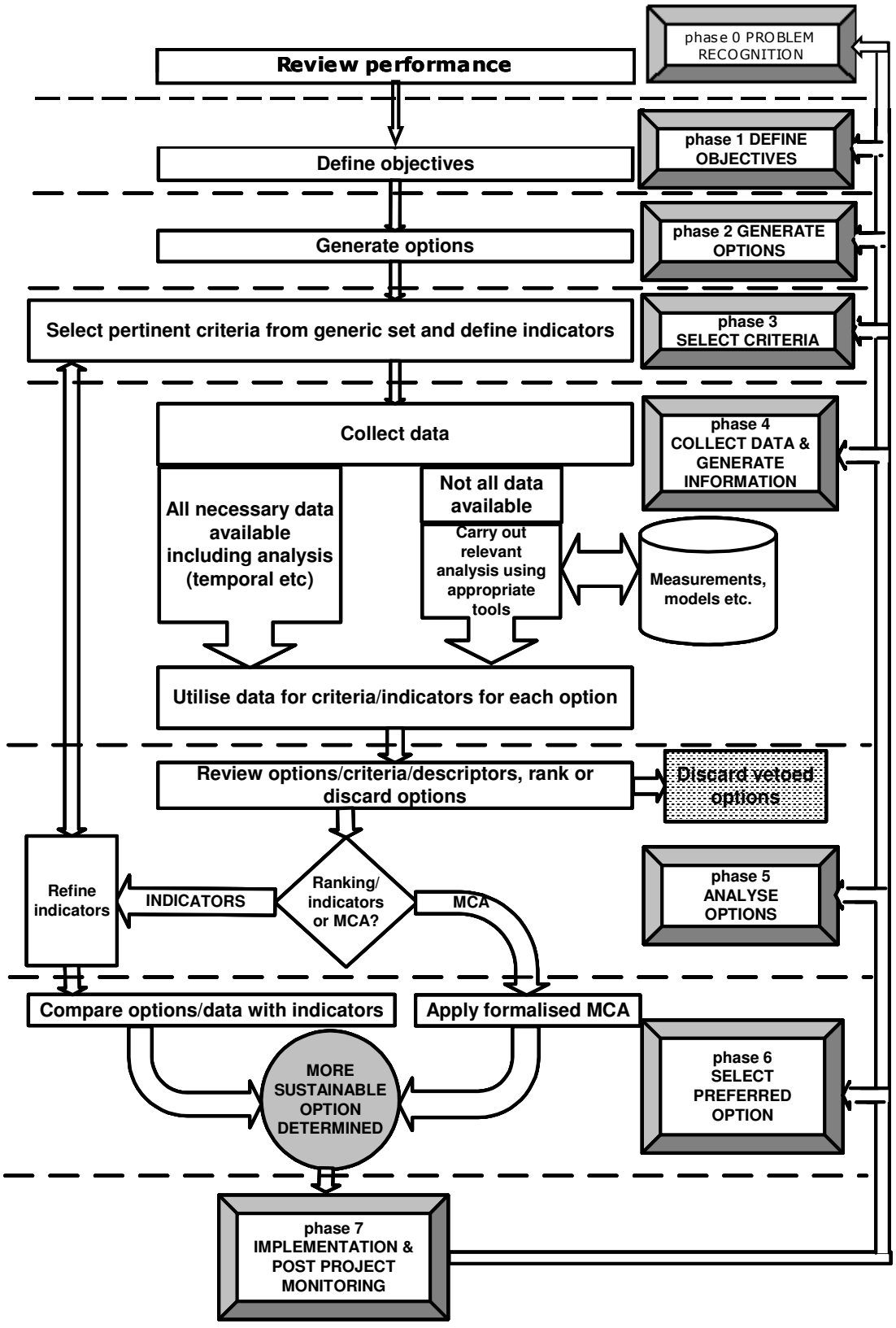

Figure 2.5: Decision-making process (Source: Adapted from Ashley *et al.*, 2004).

2.2.4. Decision-making difficulties in water management

Some general difficulties can be found when taking decisions regarding to urban water issues:

- Urban water system problems are usually complex. “According to Webster’s, things are “complex” when they have many varied interrelated parts, patterns or elements” (The Institute for Strategic Clarity).

Decisions are generally both multi-attributed and multi-criteria. The attributes are simply non-judgmental objective characteristics of the design options, whereas the criteria are a reflection of the preferences of those making the decision (Ashley *et al.,* 2004).

- Many stakeholders are involved and each one seeks to satisfy several decision criteria according to their own (or their perception of their organization’s) preference structure (Ashley *et al.,* 2004). Nowadays, there is a bigger concern about the importance of public participation in making decisions.

- Uncertainty exists and it means that the exercise of a particular choice does not guarantee the actual decision outcome, so an element of risk is included in the decisions (Ashley *et al.,* 2004).

- Constraints, such the scarcity of economic resources or different regulations, limit the feasible choices (Ashley *et al.,* 2004).

All it means that the complex decisions to difficult problems cannot be reduced to a simple mechanistic process and it results in real limits to objectivity.

When decisions regarding to complex problems must be taken, like in the case of UWSs, one of the most difficult and critical steps in the decision-making process is to identify and clarify the problem. Governments are pressed for time and by society when the problem is felt as urgent. As result of it, they usually rush through this step and the

incomplete diagnosis or assessment restricts the adequate selection of options (Scott). The common practice to answer the social demands for quick solutions is to consider a reduced range of technological and managerial options, determined by the jurisdictional boundaries of related agencies and past practices (Guio-Torres, 2007).

The hurries on the problem identification step might mean that the solution the government or others come up with fails to address the real problem (Scott). To achieve a more IUWM is of upmost importance to pay special attention on identifying and clarifying the “real” problem after continuing.

Chapter 3

Decision-making tools and methods

Many researchers have developed different approaches and DSTs in order to deal with the complex decision-making processes regarding UWM. This chapter describes the two different groups of DSTs which can be found. Special attention is given to the indicators and the Geographical Information Systems (GIS). These DSTs can be included within other tools, such as SMURF and S-City VT, which are also explained.

3.1. CLASSIFICATION OF THE DECISION-MAKING TOOLS

Due to the complexity of the decision-making process, some tools have been developed over the last years in order to facilitate the process to aid the transparency and understanding. A DST is any tool used as part of a formal or informal decision-support process (Sahota and Jeffrey, 2005). However, different issues arise in decision making and there are different types of tools. According to Ashley *et al.* (2004), two type of tools exist:

- **Procedural tools**. Focus on procedures to guide the way to reach a decision. SWARD can be considered one of these tools.

- **Analytical tools.** Provide information on the consequences of choice. Some analytical tools that can help by providing information about environmental issues are: Indicators[1], Life Cycle Analysis (LCA), Cost Benefit Analysis (CBA), Geographical Information Systems (GIS), SUTRA, Simulation Modelling, System for Monitoring URban Functionalities (SMURF), S-City VT, etc.

[1] Some authors, as Ashley *et al.* (2004), do not consider indicators as tools. However there is no doubt about their assistance to the decision-making processes. Thus, in this thesis, indicators will be considered clearly as decision-making tools. However, at some points they must be processed into more readily available information through other tools to help to make decisions.

The use of some DSTs has become more and more popular due to their ability to manage large amounts of complex data. They can also be installed and used on many personal computers (Kapelan, Savic and Godfrey, 2005). However, most are never or hardly ever used (Sahota and Jeffrey, 2005) either because most DSTs are designed for a single purpose or the systems are so generic that any detail can be found (Isaacs *et al.,* 2007). According to Isaacs *et al.* (2007), nowadays "there is no single tool which can effectively support the decision making process for every aspect of a whole sustainable development" and the simultaneous use of several DSTs does not seem to appropriately solve this problem.

Most of the analytical tools are used as screening tools in the stage within the decision-making process where the analysis of the different options is carried out. However, these tools have not been used to communicate and integrate the various stakeholders to improve sustainable decision making and stakeholder interaction (Isaacs *et al.,* 2007). These tools could be called "decision-making communication tools" and visualization is now a key component of these "new" decision-making tools.

3.2. INDICATORS

It is important to difference between principles, criteria and indicators when considering sustainable development (Foxon. *et al.,* 2002).

- Principles, which are used to achieve sustainability, are usually idealistic and abstract goals.

- Criteria are the set of quantitative and qualitative factors that may be used to make a judgement about the relative sustainability of a group of options.

- Indicators measure the past and current values of specific criteria, and may be used to set standards against which future performance can be assessed.

It must be pointed out that the principles should remain constant over time, while the criteria and the indicators used to measure them might change as fast as new knowledge is developed (Foxon. *et al.,* 2002).

The definition of indicators provided above is not the only one that can be found. Indeed, some authors call them "sustainability" indicators and others "sustainable development" indicators. The author believes that there are no differences between the two ideas. Both aim to find changes in the "quality" of something, and two indicators at two different points in time must be compared. As it is relatively difficult to define what is sustainable or not, and it is easier to define whether something is more sustainable or not when compared with an earlier point in time, the terminology "sustainable development indicators" will be used from this point in this dissertation.

Recently, since quantifying sustainability is of upmost importance to policy implementation (Guio-Torres, 2007), different academics, researchers, local authorities, national and international organizations have developed their own definitions and indicators. The development of a range of different suitable sustainable development indicators reflects the need to put the imprecise concept of sustainable development in an operational form (Simon, 2003).

According to Soutter (2007, p.5), "indicators may be raw data themselves or a combination of different raw data, sometimes in a simple linear combination or in the form of the results of a more complex simulation model". And, although the indicators can be either quantitative or qualitative, it must not be forgotten that one of their essential functions is to quantify (Lundin, 1999).

A good indicator should have the following six characteristics:

- **Materiality**. The indicators must show the information the stakeholders want to know (Gilmour and Blackwood, 2006).

- **Accessibility.** The information contained in the indicators has to be easily understood and acquired by the stakeholders (Gilmour and Blackwood, 2006).

- **Comprehensiveness.** The indicators should take into account economic, social and environmental aspects in order to ensure that sustainable development objectives are being achieved or not (Lundin, 1999; Zaragoza. Servicio de Medio Ambiente - Unidad de medio ambiente, 2002; Simon, 2003; Gilmour and Blackwood, 2006; Guio-Torres, 2007)

- **Tractability.** Indicators should estimate spatial and temporal trends through sufficient reliable numerical or qualitative data (Gilmour and Blackwood, 2006).

- **Transparency.** The indicators should be chosen in a transparent way which allows the different stakeholders to identify why indicators are being considered (Gilmour and Blackwood, 2006).

- **Practicability.** The indicators must be operational, i.e. they must be practical in terms of time and resources available for any analysis and assessment (Gilmour and Blackwood, 2006; SWITCH Project, 2006).

The development of universal indicators, which can be used worldwide, is very difficult, if not impossible, nowadays. According to Guio-Torres (2007), five difficulties are identified when setting common sustainable development indicators for UWSs: the system boundaries are not clear; the definition of sustainable development is too vague and leads to different interpretations; the time frame of analysis and action in UWM is quite short; doubts exist about whether external causes are more important than internal performance or in the other way around; and, finally, the different stakeholders involved have diverse interests.

Sustainable development indicators "are not useful when considered in isolation, rather their, usefulness comes from monitoring relative changes in the state of the environment" (Adinyira, Oteng-Seifah and Adjei-Kumi, 2007, p.49). They help the different stakeholders to understand "where we are, which way we are going and how far we are from where we want to be" (Simon, 2003, p.2). Moreover, according to Reppetti, Soutter and Musy (2006), the relevance of an indicator is due to its intrinsic qualities as well as its place and relationships to other indicators.

Indicators are useful decision-making tools which anticipate future conditions and trends, provide early warning information and provide information for spatial comparison (Lundin, 1999). Thus, indicators can be used for benchmarking (Zaragoza. Servicio de Medio Ambiente - Unidad de medio ambiente, 2002; Soutter, 2007).

Nowadays, visualization of the indicators, through GIS, has great potential to assist the different stakeholders in accessing and understanding them. However, multiple indicators must be shown at once in order for relationships and tradeoffs to be spatially explored and it is not as easy as visualizing one indicator at a time (Donlan *et al.*, 2007).

It is also very important to stand out that, usually, general public does not understand easily the different indicators (Reppetti, Soutter and Musy, 2006), even if they are graphically shown.

Finally, within the SWITCH Project, new science-based indicators are being developed based on physical models of the UWS as well as stakeholder discussion within the learning alliances. These will be operational, i.e. they will be able to be used in practice, and will assess the sustainability of UWSs as well as the risk associated with these systems. They will also allow accountability oriented decision-making processes and will become common indicators for use by decision makers in Europe as well as in developing countries.

3.3. GEOGRAPHICAL INFORMATION SYSTEMS

"Information and Communication Technologies (ICTs) are powerful tools that can potentially improve the sharing of information among decision-makers and stakeholders. ICTs can support the appropriation of information about land-use and relating conflicts" (Reppetti, Soutter and Musy, 2006). So, ICTs help to get a better knowledge of the area and a better understanding about real situations. Geographical Information System are a sub-set of ICTs tools, which offer powerful management capabilities (JBA Consulting Engineers & Scientists, 2005) The use of participative GIS

is being increasingly used nowadays (Reppetti, Soutter and Musy, 2006) to support sustainability objectives.

A Geographic Information System (GIS) is an organized collection of computer hardware and software designed to create, manipulate, analyse and display all types of geographically or spatially referenced data as efficiently as possible (JBA Consulting Engineers & Scientists, 2005).

GIS provides map production capabilities coupled with query and analysis tools to provide a means of investigating geographic relationships in the data and to link and define relationships within multiple datasets (JBA Consulting Engineers & Scientists, 2005).

GIS can afford data input from several sources and in many different formats: tables, images, grids, databases, vector files, text files, CAD, photos (Tagg and Millington, 2004).

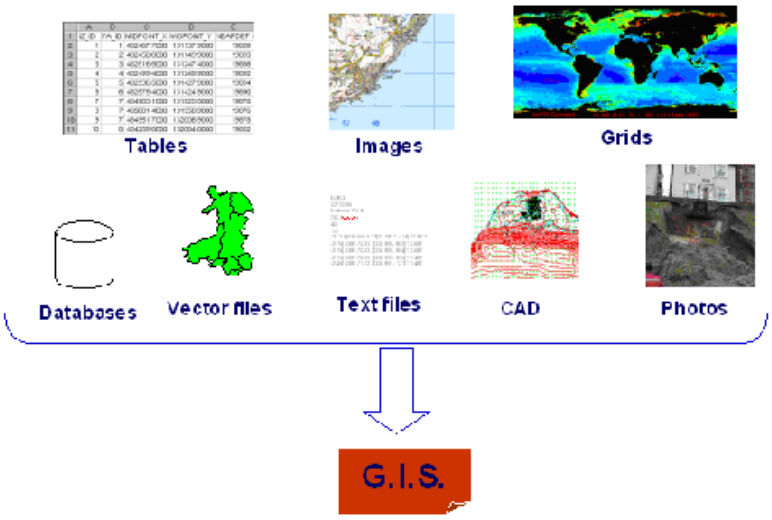

Figure 3.1: Data which can be included in a GIS (Source: Tagg and Millington, 2004).

It is important to point that ICTs (GIS tools are included) can contribute to strengthening management processes only when they are adapted to the context (Reppetti, Soutter and Musy, 2006). However, according to these authors, the existing GIS and planning support systems have not yet been adapted to the contexts and needs.

Moreover, ICTs usually require high computer skills and significant financial investment for their implementation and maintenance, which limits the participation of different stakeholders, especially the general population, in decision-making processes. Consequently, alternative GIS solutions which are more adapted to real situations are desirable. They must suit stakeholders who normally lack computer skills, limited information availability limited financial resource availability. (Reppetti, Soutter and Musy, 2006).

The development of these GIS tools as a platform to share information among different stakeholders faced with the problem of a huge amount of existing data not all of them are shared for different reasons such as the reluctance to open official data to the public (Donlan *et al.*, 2007). Hopefully, the Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE) will assist with this issue. This Directive aims to assist policy-making in relation to policies and activities that may have a direct or indirect impact on the environment. It will improve the accessibility and interoperability of spatial data by laying down general rules applying to data and services held by or on behalf of public authorities and by private operators who choose to make their data available through the INSPIRE infrastructure (INSPIRE Geoportal).

3.4. SMURF

SMURF is the acronym for "System for Monitoring Urban Functionalities". It is a software instrument, based on GIS and on urban indicators, for sharing information, editing information and evaluating city development. It assists with the involvement of the different stakeholders related to UWM, from political representatives and administrative services to associations, NGOs and the general public, etc. in the decision-making processes. (Reppetti, Soutter and Musy, 2006)

SMURF was created for supporting participatory planning and management in mid-sized Africa cities in 2000. It was also applied to the Seychelles Islands. Within the SWITCH Project, the EPFL (Ecole Polytechnique Fédérale de Lausanne), in Switzerland, is developing this decision-making tool to apply and adapt it to any

location around the world to assist with IUWM The development of the SMURF software is led by Marc Soutter and it is part of SWITCH Work Package 1, urban water paradigm shift.

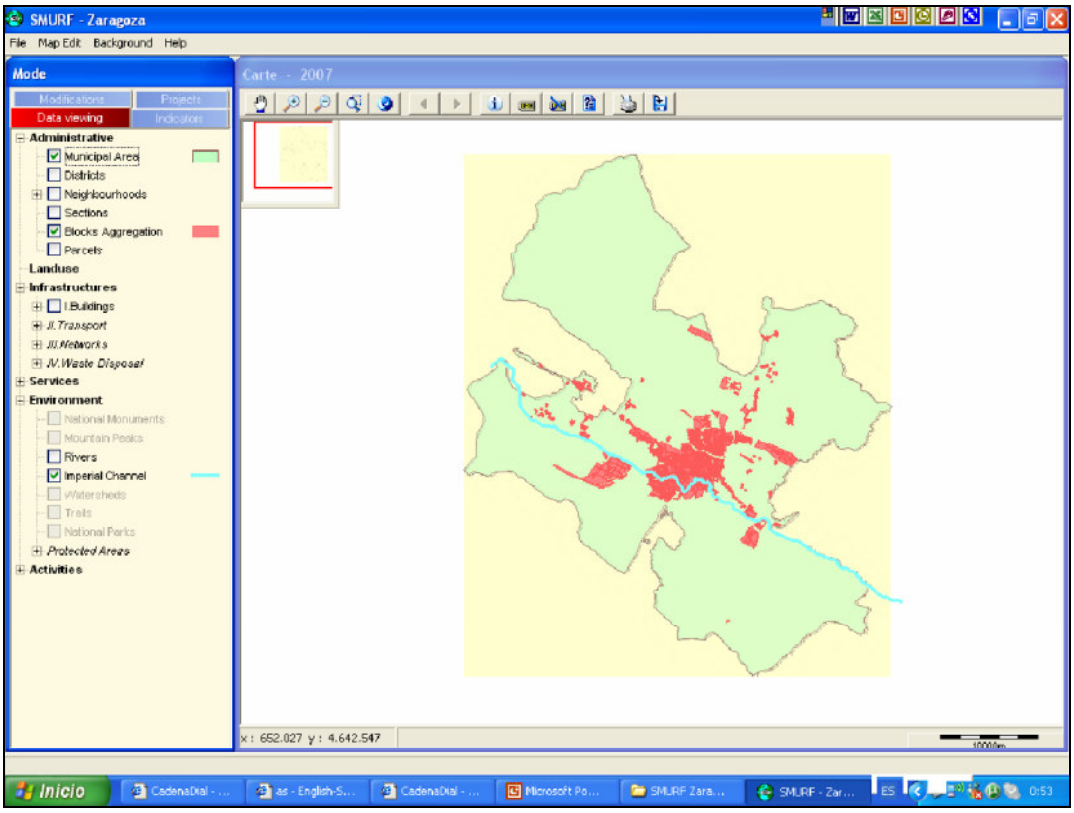

Figure 3.2: Data view mode of a SMURF decision-making tool adapted to the municipality of Zaragoza (Source: SMURF adapted to Zaragoza).

According to Reppetti, Soutter and Musy (2006), SMURF is a user-friendly and easy-to-use software consisting of "an interactive GIS mapper which is adapted to the needs of its users, to their computer skills, to the locally available infrastructures, and to the data quality".

The SMURF software is only useful if a constant process of data collection, update and validation is undertaken by the different stakeholders (including some with computer and GIS database management skills) in order to ensure the operability and durability of the system. According to Reppeti, Soutter and Musy (2006), this is not a difficult process due to the improvement of the quality of the diagnosis of the urban realities and the coordination of the decisions and actions will encourage the different stakeholders to

update this data platform. It means that while the different stakeholders find an added value to the SMURF software the data platform will be easy to update. When SMURF was used to improve urban management in some African cities, a participative forum was created to deal with those aspects of the decision-making process (negotiation, data updating, etc.) that a technical instrument is not able to support (Reppetti, Soutter and Musy, 2006).

Nowadays, SMURF is not yet available for use through the Internet.

SMURF has four different interlinked modes:

- **Data viewing.**

In this mode, the main spatial and statistical data related to infrastructures, environment, etc are shown. It is an interactive map which shows the main aspects that are seen in a traditional static map, including aerial images as well as GIS layers.

There are two main issues that lead to reduce the understanding of the system: (i) the excessive amount of data (information) and (ii) the lack of important data (Sahota and Jeffrey, 2005; Reppetti, Soutter and Musy, 2006); both of them should be avoided. For this reason, it is important to make a proper selection of the data that are going to be shown in this mode.

- **Modifications.**

This is a data editor for both spatial and statistical data. In this mode it is possible to modify the existing attributes in some GIS layers, adding new data, updating and deleting existing data and initial proposals.

When a change has been made, a RegEdit file, which registers this edition, is created and sent to the GIS database manager for its validation. It will not become part of the general GIS database before validation.

- **Indicators.**

In this mode, the different social, economical and environmental sustainable development indicators are shown through different colour scales and symbols. Only spatial distribution, distance and attribute indicators are represented in this display. The indicators layers are created by the statistical and spatial analysis components of SMURF software, using the information already stored in the database.

These indicators complement the data of "data viewing" mode and are able to "offer monitoring, controlling, benchmarking, and planning scenarios evaluation functionalities, as a decision-support instrument for participatory land management" (Reppetti, Soutter and Musy, 2006).

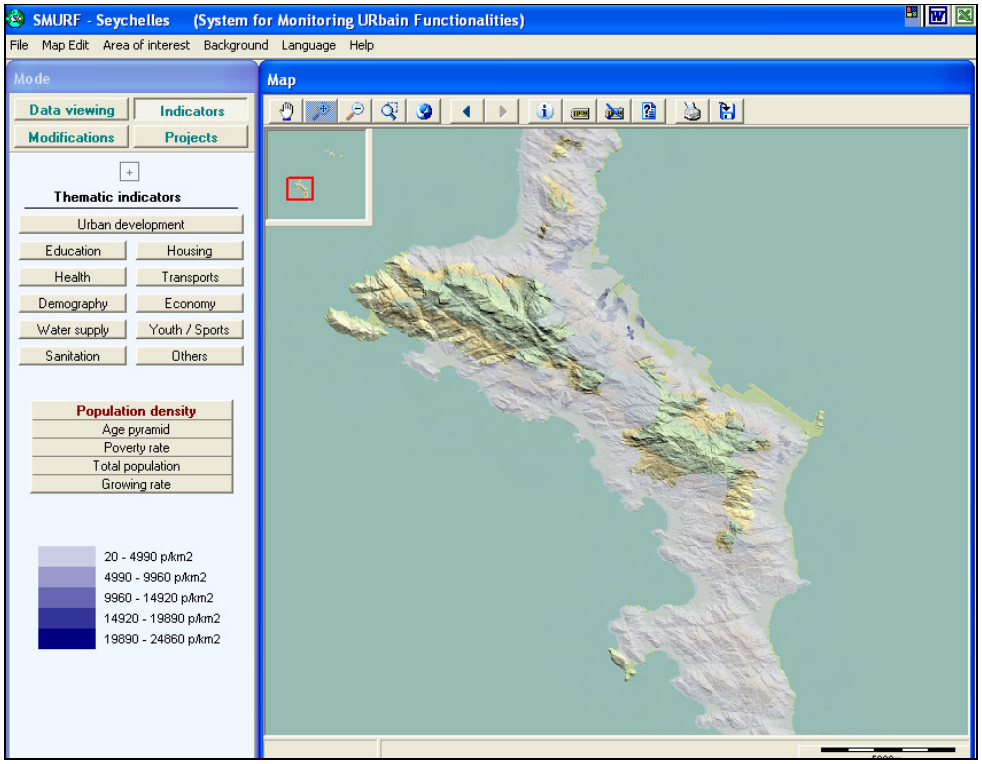

Figure 3.3: Indicators mode of a SMURF decision-making tool adapted to the Seychelles Islands (Source: SMURF adapted to the Seychelles Islands).

- **Projects**

This mode is basically the same as the modification mode, i.e. it is a data editor, but for information which does not relate to any existing feature. As this information can hardly be included into any existing layer, this is a specific database to store information about the projects.

Before this new information is added to the definitive GIS database, the GIS database manager must also validate it.

Summarizing, SMURF is, at the same time, an information exchange platform and a decision-support tool, which enhances public participation. "It consists of a database, which allows information storage, and spatial and statistical analysis components, which process the derived indicators from the database" (Reppetti, Soutter and Musy, 2006, p.691). Thus, SMURF is a decision-making tool to assist with complex urban management and planning, providing assessment monitoring, comparisons, communication and finally knowledge to the different stakeholders (Reppetti, Soutter and Musy, 2006).

3.4.1. The SWITCH toolbox.

Within the SWITCH Project, the main objective of the Work Package 1, urban water paradigm shift, is to "provide support to the cities' Learning Alliances in their process of self-.appropriation of integrated urban water management" through an integrated information tool or software (Soutter, 2007).

The scope of the SWITCH toolbox would be: to raise awareness of the trends for the future and the possible options in terms of planning and management, to be able to define, test, compare and evaluate scenarios or at least support the activity within the Learning Alliances and to provide assistance in judgment and decision making at a strategic level. This toolbox is in effect a decision support system (Soutter, 2007).

The SWITCH toolbox will include several components: data, indicators, simulation models, scenario builder, scenario evaluation, and scenario optimisation. Thus, SMURF, developed also within work package 1, will be part of the SWITCH toolbox. Figure 3.4. shows where SMURF (red rectangle) would be placed within the general SWITCH toolbox.

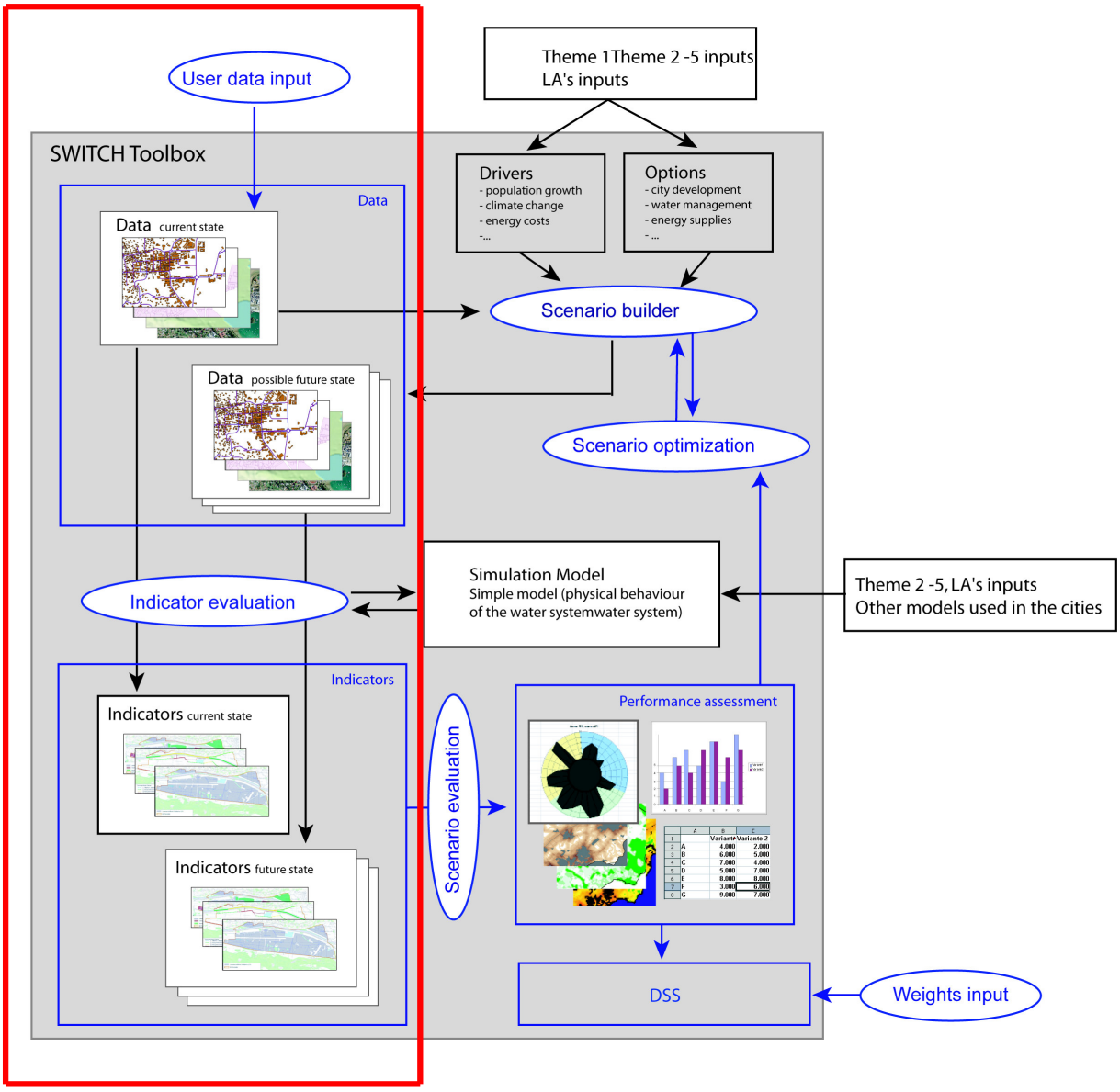

Figure 3.4: General features of the SWITCH toolbox and its relation with SMURF (Source: Adapted from Soutter 2007).

According to Soutter (2007), the SWITCH toolbox must have some characteristics. Thus, SMURF should have the same ones taking into account that it will be part of this SWITCH toolbox. The key characteristics are:

- **Easy to use**: SMURF must remain easy and widely accessible for all users, including those with lack of computer skills, limited experience with indicators, etc

- **Sustainable**: The data and information contained in SMURF must be relevant and easily updated.

- **Flexible:** SMURF will be adapted to different cities and problem. In each city different kinds of data will be available and SMURF must not be very strict in the data needed to adapt the software.

3.5. S-CITY VT

S-City VT is the acronym for "Sustainable City Visualization Tool". It is a DST which provides a 3D simulation of a city or other urban area in order to allow the different stakeholders involved in the urban developments, including the general public, to participate in the decision-making processes for creating sustainable urban environments (Sustainable City Visualization Tool). S-City VT also displays the consequences of stakeholders' proposed decisions through different indicators over the time. Thus, the participation of the stakeholders is encouraged through the better understanding of the "real" situation of the area which is going to be developed (Isaacs *et al.,* 2007).

By the moment of the development of this MSc thesis, S-City VT was being developed by John Isaacs, a PhD student from University Abertay Dundee (Scotland), and the prototype of this decision-making tool will focus on the Dundee waterfront regeneration, a 30 years project (Isaacs *et al.,* 2007).

This project is being done in collaboration with Dundee City Council. Thus, the economic, social and environmental sustainability criteria that would be modelled and visualized in S-City VT will be discussed with the council stakeholders. Also, most of the data of the different indicators decided to measure these criteria would be provided by the City Council (Isaacs *et al.,* 2007).

Figure 3.5: 3D view of a S-City VT decision-making tool (Source: S-City VT tool).

S-City VT is a combination of a simulation model with a visualization tool. Firstly, a simulation model will be developed which integrates and combines several social, economic and environmental indicators together with the effect of actor behaviour. This model should also contain some of built-in scenario and will have into account the affect of changes in government and council laws and guidelines on the indicators. Then, the evolution of a "potential" development area for a given set of indicators will be displayed to the stakeholders (end users) through a 3D visualization tool (Isaacs *et al.,* 2007).

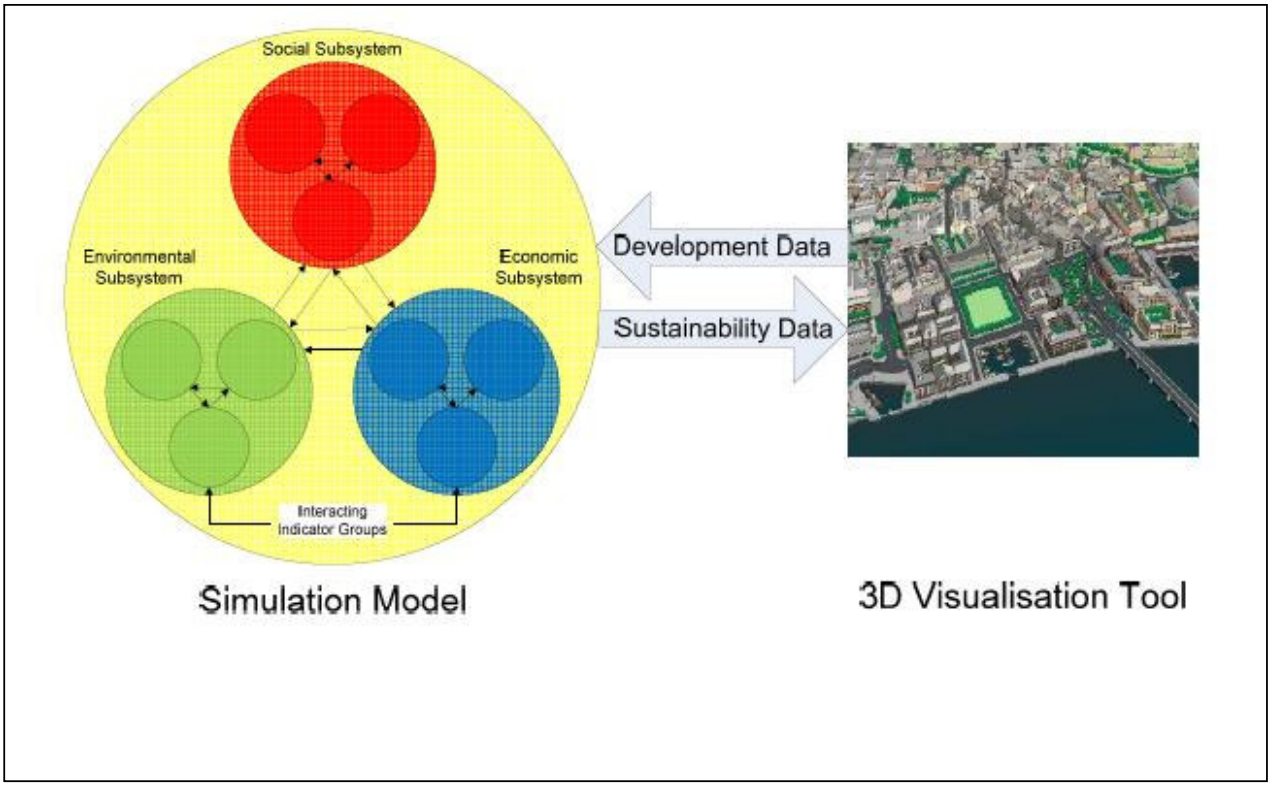

Figure 3.6: Structure of the S-City VT's prototype (Source: Isaacs *et al.,* 2007).

S-City VT has to different modes:

- **Design mode:**

This is the mode in which the urban development that later will be displayed in the 3D mode can be modified. Different parameters such as the position of traffic lights, the traffic density or the type of building can be easily changed (figure 3.7)

- **3D mode:**

This mode allows the 3D visualization of the development's design. The different indicators are also shown in this mode, together with their explanation.

At the moment of the realization of this MSc thesis, only one indicator was shown, the consumption of energy of the different buildings. It had been called the carbon model and differences of energy can be noticed over the time (figure 3.8). In the future, this

temporal scale will be more accurate and more than one indicator will be shown at the same time, if desired.

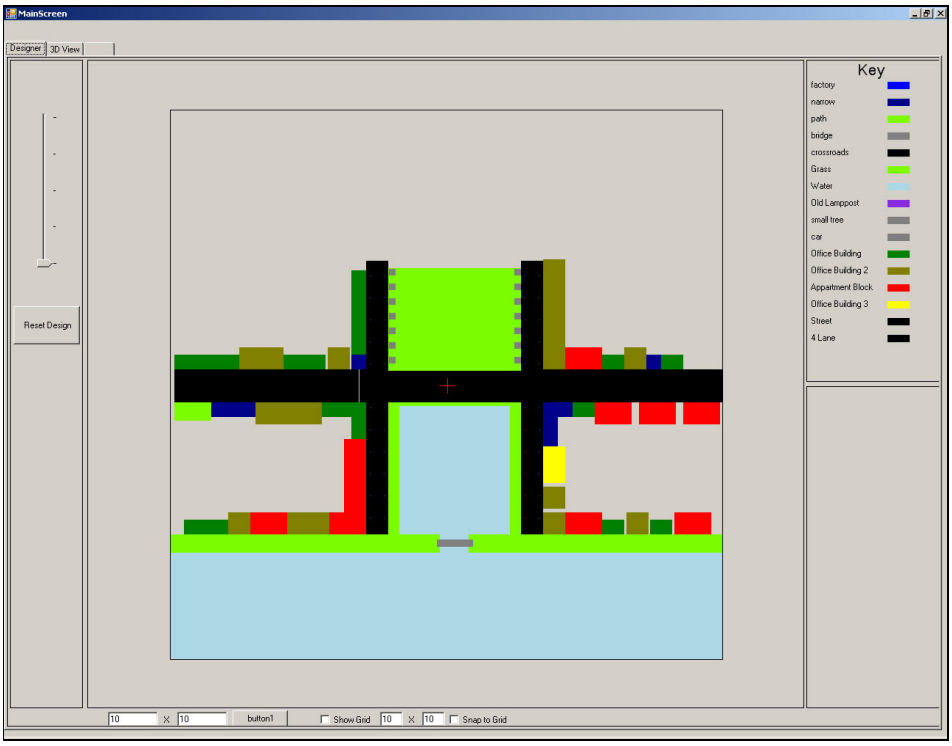

Figure 3.7: Design mode of a S-City VT decision-making tool.(Source: S-City VT tool).

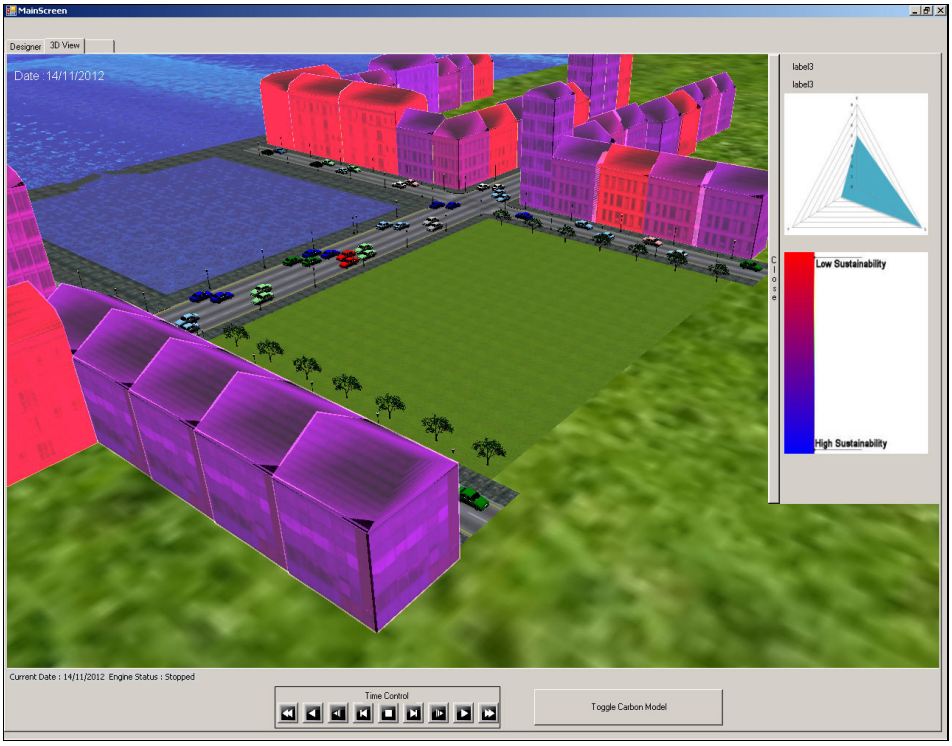

Figure 3.8: Carbon model in the 3D view of a S-City VT decision-making tool (Source: S-City VT tool).

Chapter 4

Stakeholders and public participation in the decision-making processes

Decision-making processes must include as many stakeholders as possible in order to achieve a more sustainable IUWM. Usually, the stakeholders have different interests and there is a lack of communication between them. All this makes the decision-making processes even more complicated. Moreover, the public participation in the decision-making processes is getting a great importance due to the new policies which have appeared during the last years, such as the Water Framework Directive. Finally, the role of Internet in assisting the enhancement of the public participation is highlighted.

4.1. INFORMATION MANAGEMENT WITHIN THE DECISION-MAKING PROCESSES

According to Geldof (2005), any effective sustainability assessment is dependent on the contribution of the different stakeholders during the decision-making process. However, nowadays, the usual practice is that the decision makers seek agreement for proposals after major decisions have been made.

The flow of information between the different stakeholders is shown in figure 4.1. The decision makers, urban planners and water managers within local or national government organization or within consultants engaged by these bodies are represented in the inner tier (light grey) of this diagram. These are the “experts”. The second tier (white) includes the immediate customers and the communities served by the infrastructure as well as the secondary stakeholders, which are affected only in general terms by a decision (Rogers, 2001); they are the “non-experts”. Finally, the third tier (dark grey) represents the societal, geographical and political frameworks within which the end-users and the secondary stakeholders are located.

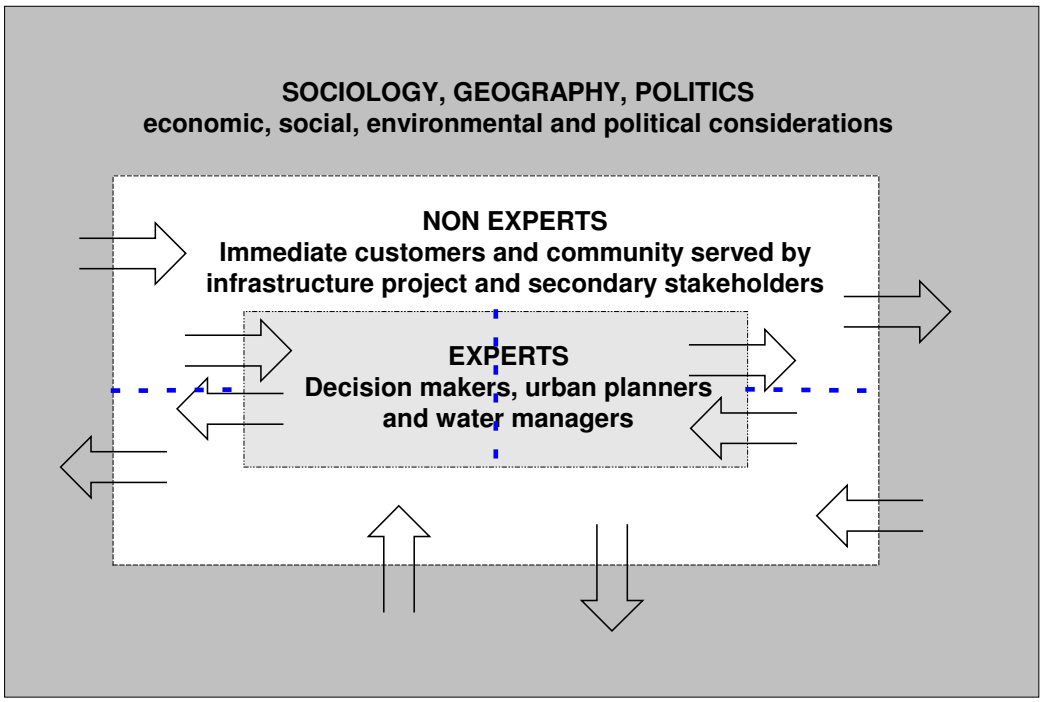

Figure 4.1: Stakeholders, boundaries and information flows (Source: Adapted from Gilmour, Blackwood and Picken, 2005).

The diagram above shows that communication failures occur, both horizontally and vertically, in UWM. The dotted blue lines represent the poor communication between the "experts" and between "non-experts" when decisions are taken. This horizontal "lack" of communication could lead to "fights" between different stakeholders, even when they have similar interests, instead of creating a bigger force to come up with win-win solutions.

The arrows represent the required information flows across possible boundaries if the "experts" consider the economic, social and environmental aspects of sustainability. Within these vertical communication flows, there is "lack" of communication, especially, between the "experts" and the general public. In the urban water design process, the engagement with the general public presents challenges in communicating not only the complex and interdependent aspects of sustainability in decisions, but also in providing an understanding to stakeholders of the short and long term implications of alternative courses of action (Isaacs *et al.,* 2007). Moreover, usually, there is "self-referential" communication (Geldof, 2005) in which the "experts" "refers to their own tasks and opinions and want to convince others of the accuracy of the ideas" (Geldof,

2005, p.10). It does not promote public participation, and when local or national governments really wants to involve the general public in decision-making processes the people do not trust them due to these past experiences (Geldof, 2005).

The "lack" of communication also occurs in the reverse direction, from the general public to the "experts" and decision-makers. It is a problem because decision-makers make their management decisions based on the information they have about the "real" situation (Reppetti, Soutter and Musy, 2006).

Within the SWITCH Project, the learning alliances, which are multi-stakeholder platforms, will help break down the barriers to the information flow. They will contribute to improve the sharing of information both horizontally and vertically. Coordinated information flows and regular exchanges between stakeholders are expected to facilitate good governance, resulting in more transparent decision-making.

SWITCH will also show to other sectors that the learning alliances are feasible within any management process, resulting in better decisions due to the participation of different stakeholders, including general public.

The "lack" of communication from the "experts" to the "non-experts" affects and limits the participation of the general public in the decision-making process. Thus, new DSTs which go beyond the technical orientation of previous tools are needed (Sahota and Jeffrey, 2005) for helping to solve this issue.

Recently, there has been increasing awareness about the importance of participation, especially of public participation, in making decisions processes in relation to water. The following examples illustrate this point.

In 1992, in the International Conference of Water and the Environment, that took place in Dublin, it was stated that management should be based on participatory approaches (The Global Development Research Centre).

In 1998, the Fourth Ministerial Conference in the "Environment for Europe" process took place in the Danish city of Aarhus. The UNECE Convention on Access to

Information, Public Participation in Decision-making and Access to Justice in Environmental Matters, commonly known as the Aarhus Convention, was adopted. It established that sustainable development can only be achieved through the involvement of all stakeholders and grants the public rights regarding access to information, public participation and access to justice in governmental decision-making processes on matters concerning the local, national and transboundary environment (UNECE).

In 1992, the Local Agenda 21 principles were established in the United Nations Conference on Environment and Development which took place in Rio de Janeiro, also known as the Earth Summit. This new approach put forward the mantra to "think globally but act locally" to deal with environmental problems. The principles of Local Agenda 21 such as public access to environmental information and public participation in decision processes were specified in the Aalborgh Letter of 1994.[2]

Later, in relation to water issues, the European Community applied the Aarhus principles in its legislation. The Water Framework Directive (Directive 2000/60/EC) highlights the importance of public participation in water management in its article 14: "The success of this Directive relies on close cooperation and coherent action at Community, Member State and local level as well as on information, consultation and involvement of the public, including users."

Due to the "lack" of communication between "experts" and "non-experts" within the decision-making process, new tools which support this aspect must be developed. They will support the appropriate involvement of general public as stakeholders in the decision-making process in relation to water.

4.2. INTERNET ASSISTING PUBLIC PARTICIPATION IN DECISION-MAKING PROCESSES

Nowadays, the Internet or World-Wide Web, in developed countries, is becoming more and more usual and accessible for everybody, especially young people. The lack of

[2] Local Agenda 21 was established in Zaragoza in 2001.

computers or Internet access in individual's houses is not an obstacle for surfing on the net because they have easy access to it in universities, cyber-cafes, some town councils, etc. It means that Internet based approaches have a great potential for enhancing public participation in decision-making processes.

According to Kingston *et al.* (2000, p.2) "the Web will generate a new public sphere supporting interaction, debate, new forms of democracy and "cyber cultures" which feed back to support a renaissance in the social and cultural life of cities".

According to Kingston. *et al.* (2000) web participation approaches present some advantages in relation to traditional participation methods which consisted in evening meetings:

- Meetings can take place in less accessible locations, mainly in disperse rural areas. With the Internet, there are no geographical location restrictions and information about the issues being discussed is easily available.

- Not everybody, who wanted to assist to the meetings, could do it because of their schedules and commitments. These time problems are solved by Internet having a "24/7".

- In the traditional approach, the fear of people to talk in public means that only some people participate, and it is possible that most common opinions or concerns are not articulated. Through the Internet, different points of view are made in a relatively anonymous and non-confrontational way.

Internet should be used as a means of enhancing current practices of public involvement in local environmental decision making, but it should not replace them (Kingston. *et al.,* 2000).

It is clear that the Internet can assist with better interaction between different stakeholders in the decision making processes; all the stakeholders need to understand the problem and the practical issue to encourage a real participation. To achieve this good understanding, much and easily accessible information about almost any topic can

be found in the Web[3]. Also, the use of online GIS can be very useful for this purpose. These have recently become more and more common in the Web, ranging from simple demonstrations to more complex spatial decision support systems (Kingston. *et al.,* 2000).

Google Earth is a good example of an online GIS. It is used by researchers as well as by the general public for different purposes such as scientific work, travel planning, etc. Although in the past many researchers have questioned the public's ability to understand a map, the Google Earth is visited by millions of people everyday. This online GIS, as well as any other, offers great improvements over traditional static maps: the user can click on a feature on the map and find instantly what it is, avoiding the problem many have of instantly recognizing a point in a map (Kingston. *et al.,* 2000).

In 1993, it was pointed out that GIS could be designed primarily for expert use or could be made accessible to the lay professional and even to the general public (Kingston. *et al.,* 2000). Thus, these GIS software, which offer many opportunities for spatial data management, can only be used by experts with high computer skills, limiting this way the general public participation in some decision-making processes.

To promote the participation of as many stakeholders as possible in decision making, some researchers are focused on developing simple and user-friendly online GIS software or models which offer some advantages of a classic GIS, excluding its disadvantages at the same time. Thus, the visualization of sustainable development indicators, indices and simulation results in these software and models will assist the different stakeholders in accessing and understanding them, resulting in a better interaction between stakeholders during the decision-making processes (Donlan *et al.*, 2007).

Finally, although Internet can promote public participation in decision making, it also has disadvantages. As the Internet is worldwide and accessible by anyone, people who may have other motivations can abuse the system. It could lead to wrong results and misinformation if a frequent check of the website, in terms of who has been looking at

[3] Sometimes, Internet offers so much information, and not all of it correct, that sometimes it might lead to misunderstandings and confusions instead of clarifying the issue.

the website and from where, is not done (Kingston. *et al.,* 2000). This is more likely to happen in websites based on forums or similar than in those in which GIS based models or software are shown or offered, due to the last ones are usually protected against changes done by users, at least in the proper website.

Chapter 5

Methodology

This chapter describes the different steps which have been carry out and the difficulties found during this MSc thesis. The main sections included are the selection of the two visualization tools used for this thesis, the adaptation process of a SMURF decision-making tool to Zaragoza and the elaboration and development of the survey for the evaluation of SMURF an S-City VT.

5.1. LITERATURE REVIEW.

The literature review is one of the main steps of any MSc thesis. This is a continuous process in which there is an evolution.

The first literature review done in this thesis, before writing the proposal, was related to the SWITCH Project, general water issues, the SMURF software and its area of application, the city of Zaragoza and the River Ebro basin. These issues were the main points of the first approach of this MSc thesis.

A second stage of literature review was carried out at the same time than adapting a SMURF decision making tool to Zaragoza for a better understanding of the software. It was focused on the IUWM issue, the decision-making processes to solve urban water problems.

After changing the approach of this MSc thesis (see section 1.2) a third stage of literature review was carried out to learn more in detail about other DSTs, mainly based on GIS and indicators. The objective of this stage was to find out a tool which offered the possibility of being evaluated from a user's point of view, as SMURF. The S-City VT tool was the elected one, so a deeper study about it was carried out.

The second and third stages were continuously undertaken till the end of this master thesis.

5.2 SELECTION OF THE TWO VISUALIZATION TOOLS: SMURF AND S-CITY VT.

From the beginning, the SMURF decision-making tool was chosen for this MSc thesis because it was one of the tools that was being developed within the SWITCH Project, by the realization of the current thesis. Once the second approach of this MSc thesis was set - since enough data were lacked to carry out the first study -, different visualization tools, such as SUTRA (Sustainable Urban TRAnsportation) were considered to be evaluated jointly with SMURF. Finally, S-City VT was chosen as the second tool.

The visualization tools, SMURF and S-City VT, were chosen because of three main reasons:

- Both of them were thought to visualize diverse sustainability factors, including economic, social and environmental ones. However, each one had totally different ways of visualizing the "real world". Table 5.1summarizes the main differences between these two visualization tools.

Table 5.1: Main differences between S-City VT and SMURF.

	S-City VT	**SMURF**
Stage of development	At the beginning	Suffering last improvements
Study area	Small and specific	Relatively big
Type of visualization	3D and dynamic	2D and static
Possibility of showing two indicators at the same time	Yes	No
Possibility of showing the same indicator at two points in time	High	Low
Simulation model	Yes	No

- There was enough information about them to do an evaluation. From most of the other tools only some summaries were available and although some contact information appeared in the websites, the process of getting the information needed is slow and even, sometimes, it is not possible to acquire the required data. However, in the case of SMURF and S-City VT, direct contact was kept with their developers.

- One version of each tool was available and that allowed the evaluation of their use and understanding from a user's point of view. Regarding the remaining tools considered, only some trial versions without possibility of modification were found.

5.3. SMURF

This section explains the different steps that were carried out for the adaptation of a SMURF decision-making tool to the city of Zaragoza. Moreover, some of the difficulties that a non-expert user could find during this process are stated.

5.3.1. The area of application

Initially a SMURF decision-making tool for the River Ebro basin was considered. The River Ebro is one of the most important rivers in Spain and it passes through Zaragoza, one of the ten SWITCH demonstration cities.

The River Ebro has the greatest flow of all Spanish rivers and its hydrographic basin is the largest, representing around 17,3% of the total peninsular area, i.e. approximately 85,362 km^2. Its total length is 910 km and it flows in Northwest-Southeast direction, from the Cordillera Cantábrica (Spanish mountains) to the Mediterranean Sea. (CHE). Figure 5.1 shows the approximate location of the River Ebro basin in Spain and its natural limits: the Cordillera Cantábrica and the Pirineos in the North, the Sistema Ibérico in the Southeast and the Cordillera Costero-Catalana.

Figure 5.1: The River Ebro basin (Source: Noticias24horas.com, 2007).

The greatest use of water from the River Ebro is for agricultural irrigation, followed by hydropower generation, urban supply and, finally, industrial activities. The river suffers significant seasonal variations. Consequently, to guarantee constant water supplies, 138 reservoirs have been constructed in the river basin since 1930 (CHE).

The quality of the water resource of the River Ebro is mainly affected by raised salinity and nitrate pollution due to irrigation (Spain. Oficina de Planificación Hidrológica, 2003).

Although the Ebro basin was thought to be an interesting area, when trying to gather the information needed for adapting a SMURF decision-making tool to this area it was found that insufficient data existed or was not easily accessible. There are many autonomous communities, provinces and municipalities within the Ebro basin, and each one has different competences in different areas (figure 5.2). Moreover, in some issues, some of the competences are not really clear, and it makes data gathering difficult.

In addition, this information should come from public administrations and it usually results in very long, and some time complicated, processes because of burocracy issues. Longer processes take place during summer periods due to it is the time of holidays for many people and the people who stay in the offices just try to do the most urgent work. Other times, there is no way of accessing to some “private” data.

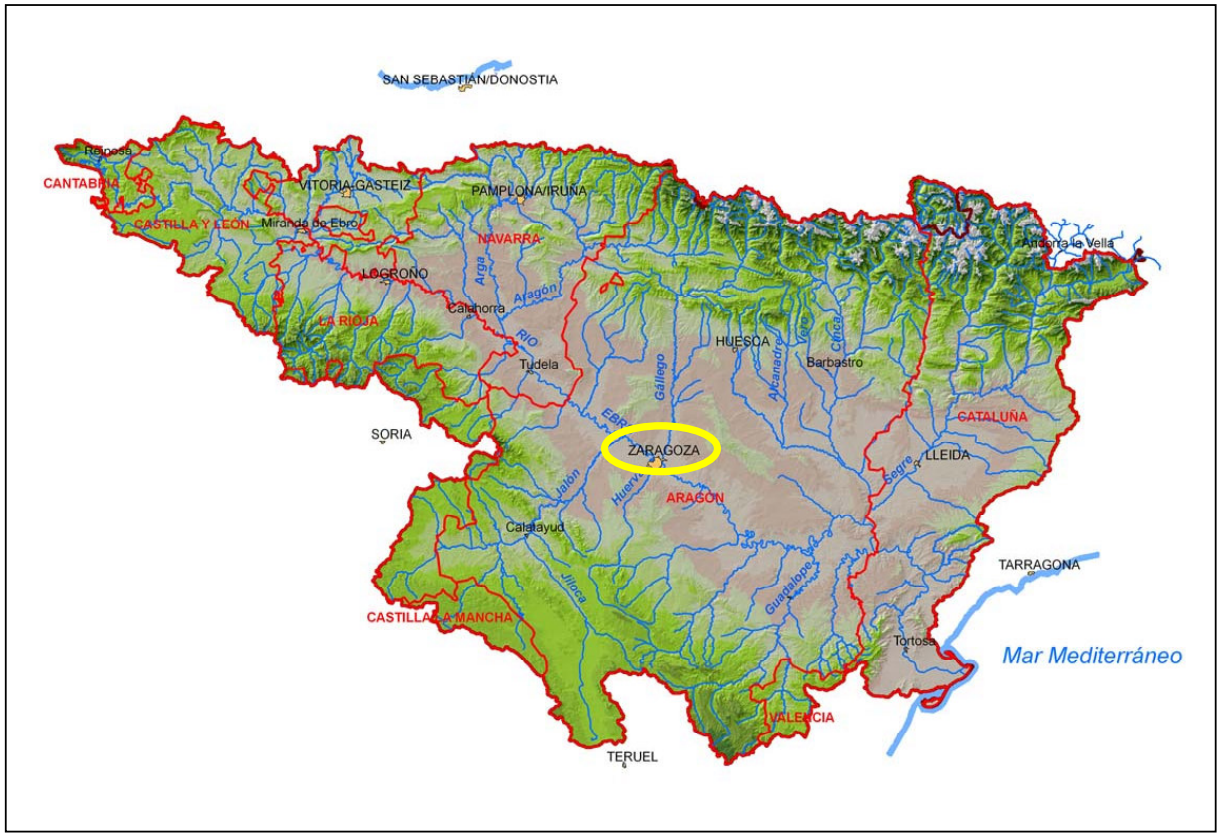

Figure 5.2: Autonomous communities (red letters), provinces (capital black letters) and some urban areas (black small letters) within the River Ebro basin (Source: CHE)

Due to the complications for data compilation in a period of six months, it was decided that the best option would be to adapt a SMURF decision-making tool to Zaragoza municipality. This is the area over which Zaragoza's city council has competences. It does not mean that all the competences correspond to the city council; also the autonomous community of Aragon and the province of Zaragoza have competences over this area. However, as Zaragoza city is a SWITCH demonstration city, more facilities existed to gather the needed information.

Zaragoza's municipality includes the city of Zaragoza and its surroundings. In the figure 5.3, it is possible to identify the built area, the imperial channel of Aragon, the river Ebro and two of its tributaries, the Gállego and the Huerva.

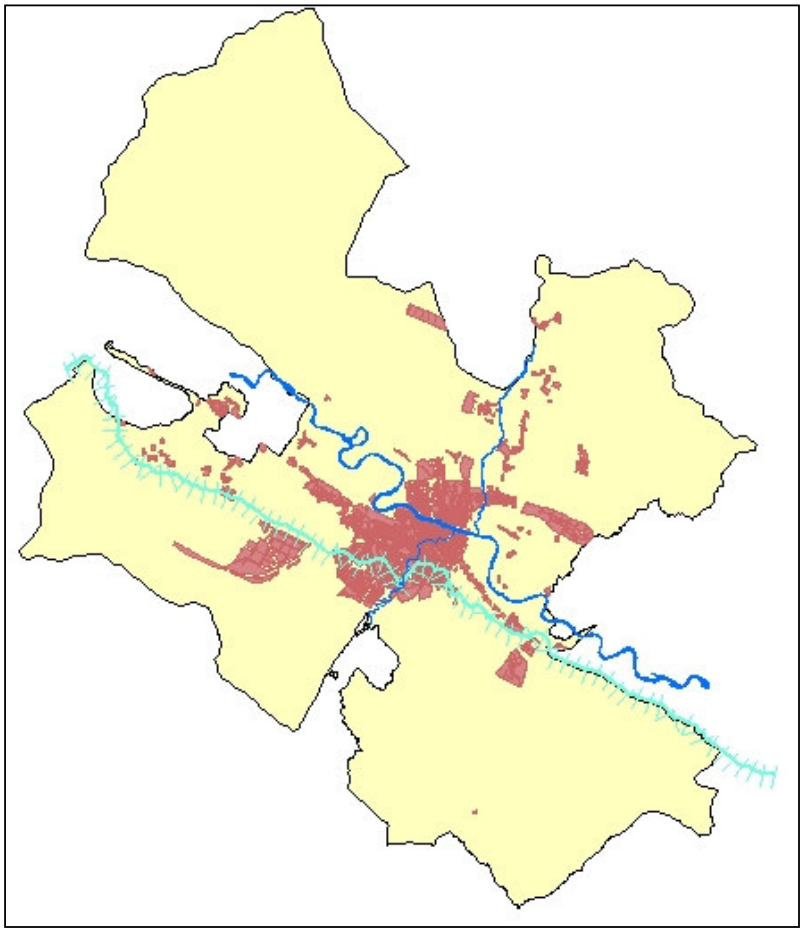

Figure 5.3: The area of application of the SMURF decision-making tool adapted to Zaragoza.

Although the municipality of Zaragoza is constantly reducing its water demand and does not have water scarcity because it is close to the River Ebro, it is also located in a drought area and if prevention actions are not taken, future problems may occur. Moreover, there are concerns that abstraction may exceed the natural recharge in the future if industries and public services continue using as large quantities of groundwater as they do it nowadays due to there is no regulatory control.

A special attention is paid to Actur's neighbourhood. This is the study area of the SWITCH Project in Zaragoza. The part of the work package 3.1, demand management for optimisation of urban water services, that is being developed in Zaragoza, is focused on this neighbourhood as well as another master project that studies water cycle of the city does.

However, although the municipality of Zaragoza is the main area of application of one part of this master thesis, not all the different attributes or data are restricted to these geographical limits. It is understood that some attributes, especially environmental ones, are better understood if they are represented without cutting them in the SMURF decision-making tool. Attributes as rivers, natural protected areas, etc. do not fit within this municipal area and showing them as they are, let the different stakeholders to understand better the real situation.

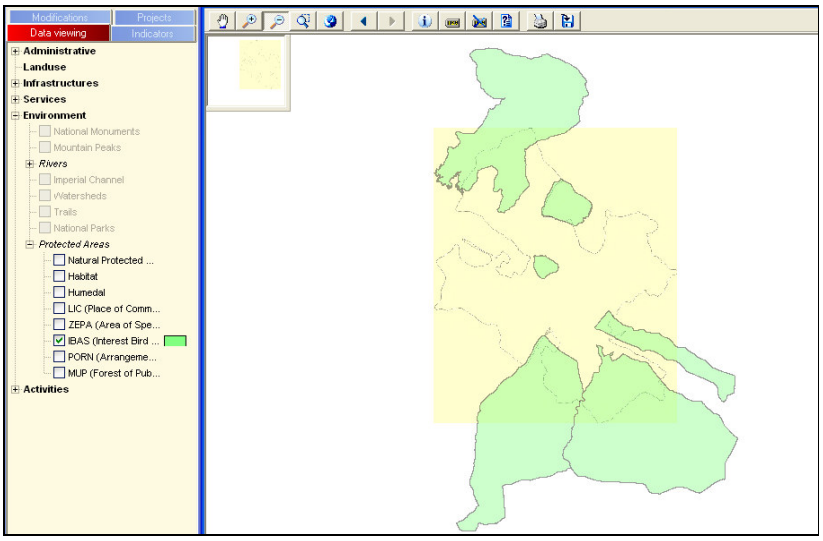

Figure 5.4: The municipality of Zaragoza and the existing natural protected areas (Source: SMURF adapted to Zaragoza).

After clarifying the selected area of application of the SMURF software, the process about how the data were collected is explained next.

5.3.2. Data collection

The data used are basically the georreferenced ones because the SMURF decision-making tool is based on GIS. This process could be divided in two steps, the data collection for the city of Zaragoza and the data collection for the River Ebro basin.

The data for the municipality of Zaragoza were gathered by two Spanish master students who were doing their internship in the Local Agenda 21 of Zaragoza. This

department within the city council develops many of the environmental aspects of the municipality and it is in direct contact with the rest of the departments related with environmental and water issues. The Local Agenda 21 provided a lot of information in relation to water issues: the new tariffs for water, general information about the environmental indicators that there are already in Zaragoza, etc.

The source of the data for the River Ebro basin was the website of Hydrographic Confederation of the River Ebro, also known as CHE (CHE). This is the oldest Hydrographic Confederation of Spain, also from Europe, and its main office is located in Zaragoza city. It has the statutory regulatory role for the river instead of the city council of Zaragoza. It is an autonomous organization, dependent on the Ministry of Environment, and it is in charge of managing, controlling and keeping the water resources and irrigations of the River Ebro catchment and its tributaries (Wikipedia).

Based on the experience of Zaragoza, when adapting a SMURF decision-making tool to a city or a small area not many problems are found, principally related to the burocracy of data acquisition. However, when the SMURF software has to be adapted to a bigger area, might be two types of problems: those related to the burocracy and that one regarding the data are represented in different scales.

Spain is divided in autonomous communities, which at the same time are divided in provinces and cities. There are different institutional organizations at each level and each has its own responsibilities. However, some of these competences are not really clear and can be overlapped. All this makes the process of data collection quite complicated. Moreover, when the information needed must be gathered from different sources, including non-government institutions, the process becomes quite longer and sometimes even it is not possible to obtain some private data, due to the institutions are reluctant to share them. Other times some information cannot be gathered due to it is non-existent at the moment; so, in this master thesis some important data for UWM, such as a GIS layer of the water supply network, are missed. Needless to say that, at least in Spain, the collection data process is much longer during summer periods due to it is the holiday's moment for most of the Spanish people and only the most urgent work is done in the offices.

Due to the different sources of data - national, regional and local entities – the users of the SMURF software should be aware that differences in scale and units could be present. It is important to translate all the information into the same scale in order to make valid comparisons.

5.3.3. Adaptation of a SMURF decision-making tool to Zaragoza.

Once the area of application was defined and it was checked that there were enough data to start, the process of adapting a SMURF decision-making tool to the municipality of Zaragoza was carried out. Thus, based on the fact that there is scarce information about the SMURF software as well as the existing manual "How to adapt the SMURF tool to a new set of data" (Soutter, 2007) is not clear enough, it was not easy to start with the adaptation of this tool. Thus, one month after this master project started, direct contact was established with Marc Soutter, the main responsible in developing the SMURF software. He works in the EPFL, in Switzerland; it is one of the 33 partners which participate in the SWITCH Project.

Several emails, more than twenty, were interchanged with Marc Soutter in order to know how to create the minimum requirements needed to start running the SMURF software adapted to Zaragoza and other issues related with the software. Based on these emails and on the old manual, a new and more specific manual about how to create these minimum requirements was developed (for more information see Annex A). It must bear in mind that the SMURF software was under development by the time of the development of this MSc thesis, and it suffered frequent changes; so, this manual is not the definitive one, but it might be considered as a starting point for a manual in the future when the software is totally developed. It is important to bear in mind that any useful manual must be design in terms of a user without high skills on computing or on GIS.

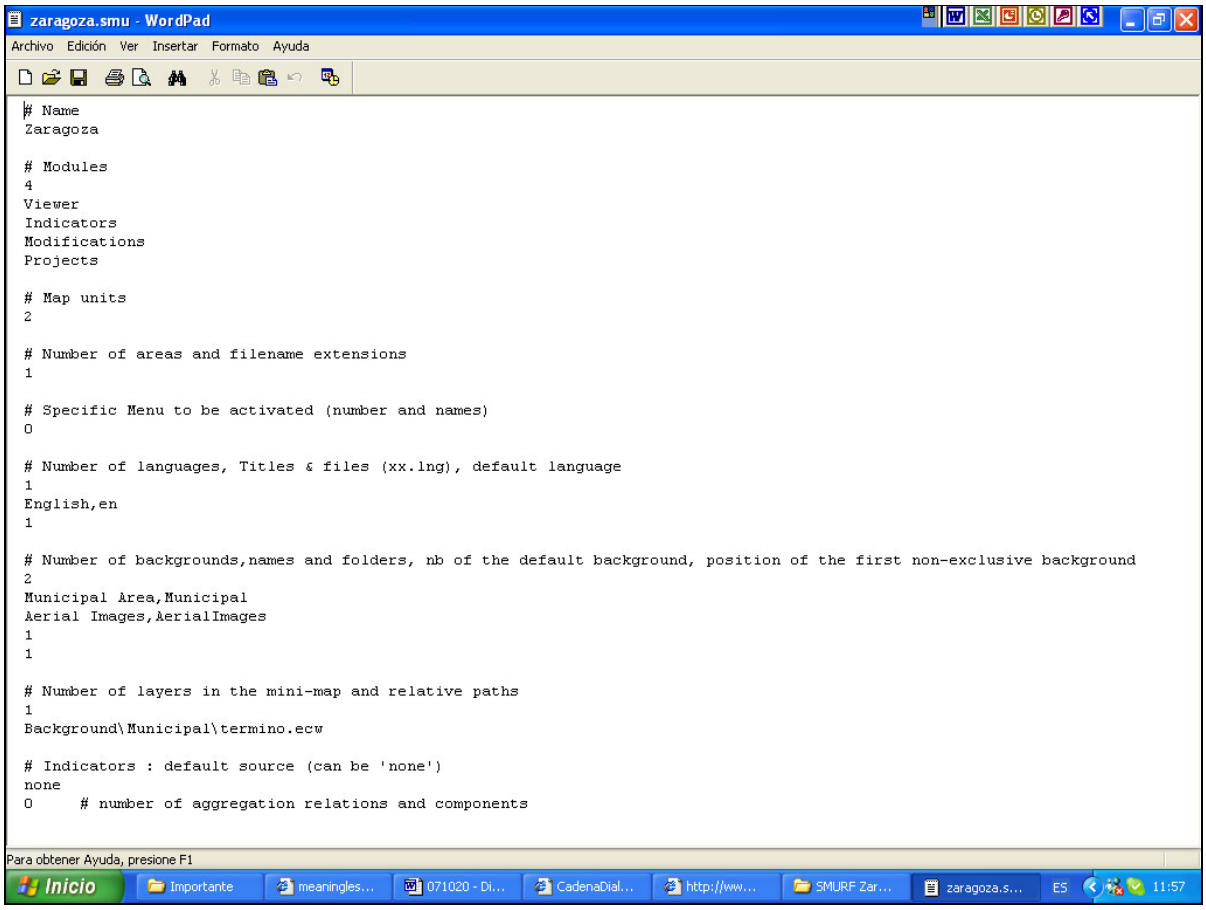

Figure 5.5: The *.smu file for the municipality of Zaragoza (Source: SMURF adapted to Zaragoza).

Once the empty_smurf.exe file is executed, the programme will not run unless some minimum requirements be created first. These are:

1. Create the *.smu file.
2. Create the topics.csv file for the list of layers that will be stored in the smurf/data/2007 folder.
3. Include the *.shp, *.shx, and *.dbf files for at least one layer that appears in topics.csv file.
4. Create in the Data/Background folder a file that contains the polygon that defines the maximum extent of the visible window.
5. Create the BD_info.txt file.
6. Include a background image.

Firstly, the *.smu file for Zaragoza was done according to the instructions of Marc Soutter and following the example of the *.smu file of the Seychelles Islands version (figure 5.5).

Later, the topics.csv file was created. It was necessary to think about which data (layers) wanted to be shown in the "data view" mode; including those data which are not available nowadays but should be shown in this mode. It was tried to select the key layers which contain the main data due to much information leads to overlapping and reduces the understanding and a scarcity of information also reduces the understanding. It is one of the key parts when adapting a SMURF decision-making tool to any place around the world.

Also, the hierarchy of how to show these data was thought and the result is shown in figure 5.6, in which it is possible to see words in black, corresponding to the existing layers, and words in grey that refers to data needed that are not available at the moment.

The main difficulty found in this part was related to the Microsoft Windows software more than with the creation of the file itself. When a *.csv file is created with this software, the different fields are separated with semi-colons (;) instead of commas (,); so, they must be changed one by one with the help of the Notepad or the Wordpad.

Next, the *.shp, *.shx and *.dbf files for every layer which appear in topic.csv file were included in the 2007 and the Empty folders as explained in the Annex A. Although only one layer is the minimum requirement to be able to run SMURF, all the layers listed in the topics.csv file were included in their correspondent folders to complete the information needed for "data view" mode. Thus, the non-existing layers were also created, and although they are empty they were included in the Empty folder as indicated in the Annex A.

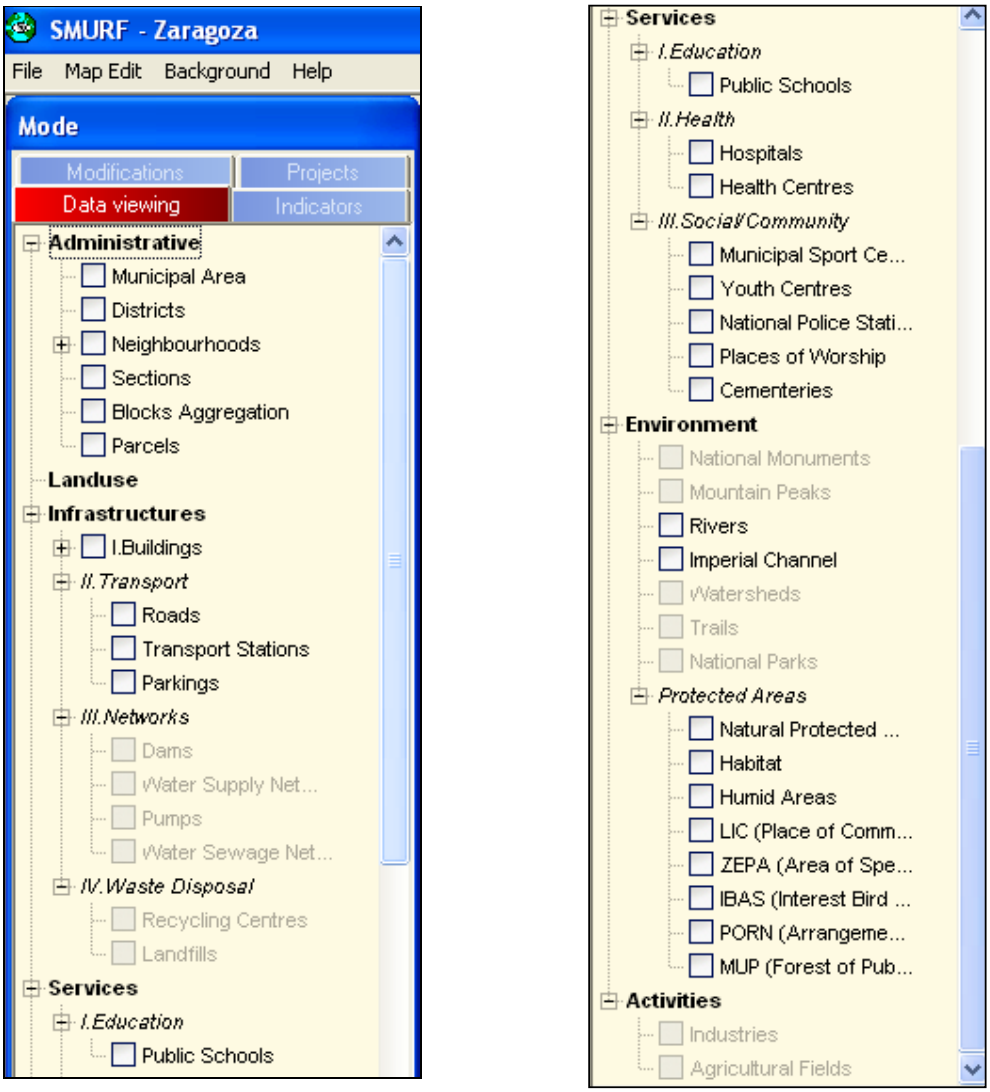

Figure 5.6: Hierarchy created for a SMURF decision-making tool adapted to the municipality of Zaragoza (Source: SMURF adapted to Zaragoza).

It must be pointed here that not all the layers stored in the 2007 folder have the same scale. In fact, the scale of the layers obtained from the website of the Hydrographic Confederation of River Ebro is 1:200.000, and the scales of those layers provided by the city council of Zaragoza are 1:10.000 or 1:5.000. It supposes a problem when the layers are seen in the "data view " mode due to some of them do not fit as they should and it could lead to some misunderstandings. Although these were the existing data and that is why they were used, these layers could be fixed using ArcGIS; however, it is too much time consuming and it was not worthy to do it in this master thesis due to it only lasts six months.

Then, the extent file, i.e. the file that defines the maximum extent of visible window when SMURF is started up, was created with ArcGIS and any special problem was found when doing it; only few trials were done before achieving the definitive extent file adjusted to the municipality of Zaragoza.

The next step, to include a background image in the Background folder, was the most difficult part when adapting a SMURF decision-making tool to Zaragoza. The main difficulty was related to the free software that exist for compressing images to *.ecw format. Any of them worked properly, so it was needed to send some basic shapes of the area to Marc Soutter and he compressed them using another GIS software, called Manifold, to obtain one background image. This image corresponded to the whole River Ebro basin due to it was the area of application before the municipality of Zaragoza was established as the area of application; so, it was not very useful later. Moreover, the background image was quite simple and it was thought about the possibility of other kind of background images such as some which shows the relief of the area; however this was not very significant neither due to the area of the municipality of Zaragoza is almost flat. Finally, it was decided that the best, taking into account the resources available, would be to create two background images. The first one would be just the shape of the municipality and it would be the start up image due to it is a small image, i.e. non-time consuming. The second one would be a background image built with the different existing ortophotos for the municipality of Zaragoza. Again, as the free image compressors did not work as they should, Marc Soutter compressed them using Manifold. This image is so big that it was not possible to send the different ortophotos by email and it was necessary to wait till the SWITCH meeting which took place in Egypt in July where both Chris Jefferies (one of the supervisor of this master thesis) and Marc Soutter assisted. Then, it was checked that the scale of the different ortophotos is different, and it resulted in a background image where not all the different features coincide.

Although there were two background images for the municipality of Zaragoza when only one is the minimum requirement, a new attempt was made to create a more clear background image. The background image created by the different ortophotos is too big and too much time consuming to be the start up image and the image based on a simple shape is good size to be use in the start up of SMURF but it is quite meaningless. Then,

after many vain attempts trying to compressed different images to *.ecw format, it was discovered that there have been a misunderstanding, believing that the background images could only be one image with *.ecw format. In fact, a background image could be formed by different layers with *.shp or *.ecw extension. Anyway, it must be taken into account that these layers would be shown in alphabetical order and it could be need to cheat the names of the layers due to transparency does not exist in the background layers yet. After being able to include both kind of extension to create the background image, the new problem appeared in relation with the colour: all the attributes appeared in black, resulting in not very clear images. Then, this problem was solved including a *.shp.ini file for per each .shp file, in which it was specified its different characteristics.

Finally, even it is known that a better background image can be achieved, it was giving some problems and it was decided to leave it like a simple shape due to time restrictions. Next figures show the current "data view" display when the SMURF software, adapted to Zaragoza, is started up (on the left) and a suggestion about a background image that would be much clearer (on the right).

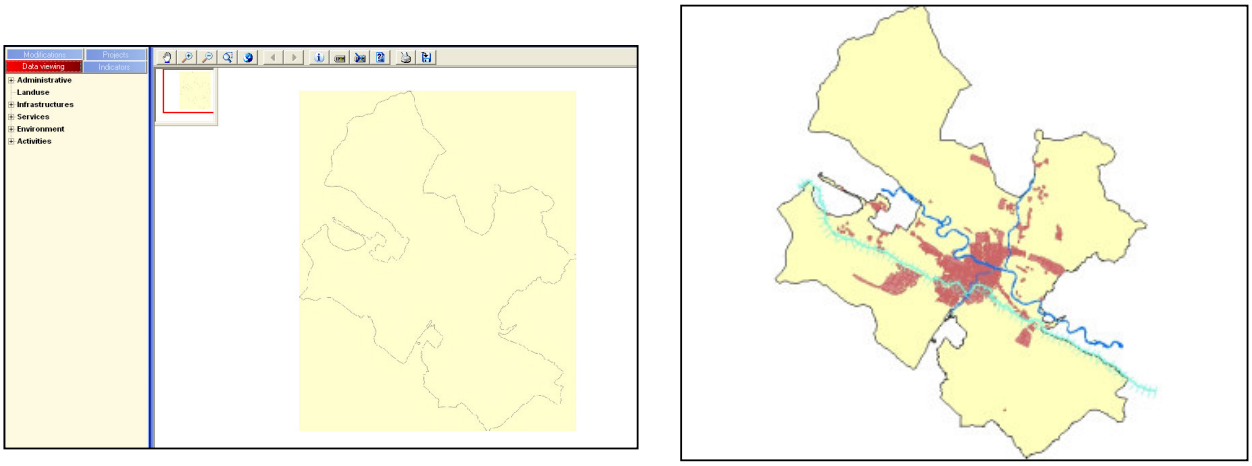

Figure 5.7: Current display and possible future display when starting up a SMURF decision-making tool adapted to Zaragoza (Source: SMURF adapted to Zaragoza).

To create the colourful image that would form the mini-map, the same problem was found than when creating the background image. It was necessary to include a *.shp.ini file per any *.shp file which was part of the final mini-map image. However, even the

mini-map did not give special unexpected problems, it was decided to remain a simple shape due to the background image when the SMURF is start up is a simple shape too.

In extent of the mini-map is just the shape regarding the municipality of Zaragoza. Thus, when using the “zoom in” tool it is easy to identify in the mini-map which area is being seen; however, when using the “zoom out” tool or using the “zoom in” tool for an area outside of the municipality of Zaragoza, is difficult to identify where this area is exactly due to the extent of the mini-map. It could be added a bigger extent to the mini-map including, for example, an image of the River Ebro basin, but it would be meaningless due to the main area of application is the municipality of Zaragoza and it would appear really small in the mini-map, not allowing to identify the areas which is being shown due to the small red square of the mini-map (the real identification of the area) would almost cover the whole municipality when zooming around this area. Then, the best option, by the moment, is to remain the mini-map image adjusted to the shape of the municipality of Zaragoza.

Finally, to complete the minimum requirements needed to be able to run the SMURF software, the BD-info.txt file, which hold information about the database status, was created according to the Annex A.

Above it is explained how the minimum requirements and basically the “data view” mode was developed to adapt a decision-making tool to the municipality of Zaragoza. However, it is important to point out that is thought about creating a special menu for the Actur neighbourhood, the study area of the SWITCH Project in Zaragoza, but it was impossible due to the software is under development and this is one of the part that is being improved at the moment.

Moreover, even the software is already in three different languages, English, French and Creole, not all the commands are translated into them. In fact, the brief help is only in French, which made a bit more difficult to understand something about the SMURF software at the beginning. Marc Soutter already knows about it and it will be improved in future versions of SMURF.

Before finishing this section, it should be commented that due to time restrictions it was impossible to adapt a complete SMURF decision-making tool to Zaragoza. Another master student could create the part of indicators in the future.

5.4. S-CITY VT

After analysing different visualization tools, the author of this MSc thesis considered that the best option for carrying out an evaluation was the S-City VT. This idea was communicated to the developer of the tool, the PhD student John Isaacs and his supervisors Ruth Falconer and David Blackwood They agreed to collaborate with this project offering their support and a version of this software to allow the MSc student to continue with the thesis. In addition, the evaluation of the S- City VT tool also means a feedback to their project. Several meetings were arranged between the John Isaacs and the author of this thesis in order to specify the aspects of interest that should be included in the evaluation. The main criterion was that these aspects should be useful for both studies.

It was considered to make also an evaluation about the difficulty of adapting a S-City VT decision-making tool to a new area. Some aspects to analyse were: the data needed, the data flexibility, the time consuming, the indicators which could be shown, etc. However, this possibility was rejected due to S-City VT was in its first stage of development and still many issues must be decided.

5.5. EVALUATION OF THE TWO VISUALIZATION TOOLS THROUGH A SURVEY

5.5.1. Elaboration of the survey.

A survey to evaluate the two visualization tools, SMURF and S-City VT, was elaborated in order to identify the weak and strong points of each one. This analysis is

done from a user's point of view due to both tools aim to encourage the participation of the diverse stakeholders involved in the complex decision-making processes. The objective is to discover how difficult is to use and to understand the different software for a non-expert user. Also, whether they are useful to make decisions is studied.

Firstly, taking into account that more knowledge had been acquired with SMURF because of its adaptation to the city of Zaragoza, some general questions related to what it was observed in the SMURF software were formulated for both tools. At first sight it seemed that the same questions would fit for SMURF and S-City VT and the time spent to answer "each" survey - if it was divided in two smaller surveys, one for each visualization tool - could be considered as an indicator of the difficulty found by the user when using each software. However, when the questions started to be adapted and specified for each visualization tool the situation changed. The S-City VT tool is in an early stage of its development and many aspects, such those regarding the indicators which will be represented, must be still decided. This makes necessary to have quite different questions for each tool. On the other hand, the version of SMURF used for this evaluation (the most complete one when this survey was done), i.e. the SMURF for Seychelles Islands, sticks quite often and sometimes it is necessary to reboot it to continue. All this does not help in measuring the real difficulty found by the user when using each software by taking into account the time consumed in replying "each" survey.

Once realized that the questions should be different for each decision-making tool, some questions remained similar for both tools in order to make some comparison between them and other questions were formulated specifically for each tool to identify whether some of its characteristics are useful for the final non-expert users. Thus, when the new question had been developed new doubts appeared:

- **The way of formulating and answering the questions.** There were doubts about if questions should be formulated to have a yes/no answer, a reply within a scale - i.e. from 1 to 5, from "strongly agree" to "strongly disagree", etc. – or a mix of both. Also it was not clear if the questions should be written in an affirmative way, an interrogative way or as an order or command.

After some discussions with John Isaacs, it was decided that the best option would be to use the same scale of answer for as many question as possible. By this way, more accurate information would be acquired than just using yes/no answers. Also, the time and effort needed to do the survey would be diminished due to the people would get easily used to this answer's pattern. The scale used is: "strongly agree", "agree", "no preference", "disagree" and "strongly disagree". However, not all of the questions of the survey fit this answer's pattern and for few of them other answers had been considered: i) another scale: "like it a lot", "like it", "it's ok", "dislike it" and "hate it"; ii) to choose between several options; iii) to score in order from the most important to the least one and iv) free answer or comments.

Regarding to the questions themselves, most of them were formulated like affirmative statements in order to create also some kind of pattern and do it easier to those who would reply the survey.

- **Making the questions concrete**. The reason of specifying the questions as much as possible according to the different software is to avoid the possibility of answering the questions just using the intuition. The objectives of this survey are to check if the users understand the tools and whether they are useful for making their environmental decisions. There is no interest in checking people's knowledge. For example, maybe someone considers that showing two indicators at the same time helps in making a decision but here, with specific indicators of the tool, is tried to prove it.

  In the survey, some questions are more specific than others. Those ones regarding the indicators of SMURF were the most complicated to concrete (the S-City VT tool only has one indicator by the moment when this thesis was undertaken). The SMURF software, the version on Seychelles islands, has many indicators but not all of them work properly, they stick or do not work. Moreover, it was intended to find easy indicators everybody could quickly understand and if possible related to water issues. Three main points wanted to be checked out

i) Whether there is any difference in making a decision when only one indicator is seen and when more than one indicator are seen. This wants to be checked independently if the indicators were shown at the same time or not. Anyway, it is important to point out that by the moment SMURF does not offer the possibility of showing more than one indicator at the same time. To summarize, this in an issue about the amount of information available to make a decision and not about the accuracy of the information acquired when more than one indicator are seen at the same time (see next section iii)).

For this issue two indicators were chosen: "distance to schools" and "population density"(figure 5.8). Thus, first there is a question about the decision made when only the first indicator is seen and later the same question after seeing the two indicators. Both questions have the same answers: a) I would remove some schools, there are too many; b) I would build some more the schools in areas where schools are too far away and c) I would do nothing. Only looking at the indicator "distance to schools" it could be thought that best answer would be b), but then looking also at the "population density" indicator it is clear that no more schools are needed, where people lives there are enough schools.

ii) Whether seeing an indicator at two different points in time would help in making a decision. For that, supposedly, any indicator could fit and the indicator "Distance to schools" was chosen due to it was also used for the previous case.

iii) Whether it is helpful to show two indicators at the same time in making a decision (this application it is not yet included in the SMURF tool).

In this case to "undefined" indicators were chosen, i.e. really scattered ones. By this way, it was very difficult to have a clear idea of the general situation if both indicators are not shown at the same

time. The indicators are: "% main supply treated" and "connected to sewerage" (figure 5.9).

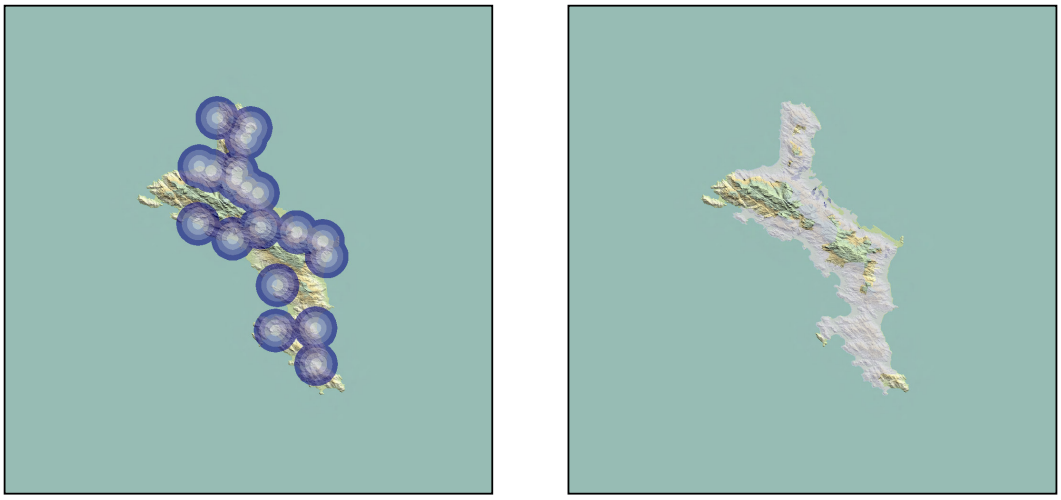

Figure 5.8: Indicators of SMURF: "distance to schools" and "population density" (Source: SMURF adapted to the Seychelles Islands) [4].

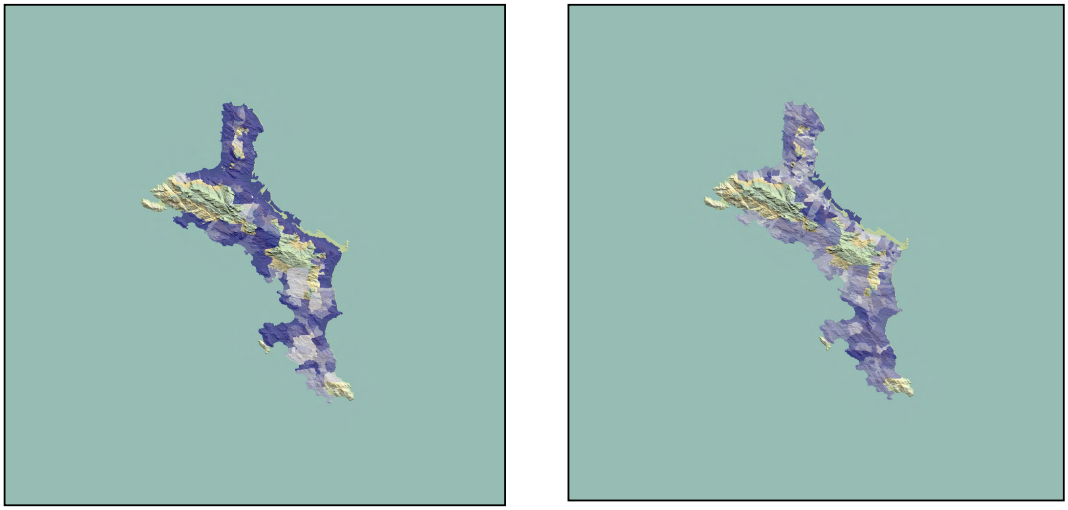

Figure 5.9: Indicators of SMURF: "% main supply treated" and "connected to sewerage" (Source: SMURF adapted to the Seychelles Islands)[5].

[4] These indicators have an scale when shown in SMURF, but not after the software saves the image. The scale always increase from light colours to dark ones.
[5] These indicators have an scale when shown in SMURF, but not after the software saves the image. The scale always increase from light colours to dark ones.

- **Too many questions and the way of arranging them.** One of the main problems found in developing this survey is the answering time. It is essential the survey not to take too much time to those who would answer it, if not nobody would make it voluntarily. Also it is needed to consider that the people do not just answer the survey, they have to use the different visualization tools for a while due to questions are related to their use and understanding. This is also time to take into account.

  First of all, some questions were deleted because there were too many. Among them, the repeated ones were included. In many cases, the same question formulated in different ways helps to check out whether the people understood correctly the question. However, this possibility was finally not considered for this survey due to time constrictions.

  Then doubts about how to arrange the questions came up. Maybe the ideal would have been to put them at random, but this would make the survey longer that if questions follow some order. Thus, the survey was divided into three smaller sections: one for SMURF, other one for S-City VT and the last one for both tools. Moreover, the structure of the questions in the sections of SMURF and S-City VT is as similar as possible. Also the number of questions in the two first sections is intentionally almost the same in order to keep a balance. By this way the person who makes the survey can predict more or less how far he is from the end.

- **Personal information.** Just some general personal information, as in many other surveys, was asked for possible statistical analysis. The data collected are: gender, age (using ranges of age because if not some people could feel bothered), level of education, occupation and the first (mother) language.

The final survey consists of 49 questions: 24 for the SMURF section, 22 for the S-City VT and 3 for the both tools section. Most of them are answered using the same scale – from “strongly agree” to “strongly disagree”, although some of them have other kind of answer. Thus, the last question of the SMURF and the S-City VT is for any comment regarding these visualization tools. The complete survey can be found in Annex D.

5.5.2. Development of the survey.

Once the survey was elaborated, some guidelines about how the survey would be undertaken were set:

- The survey would be developed in a quiet room if possible in order to avoid as much absent-mindedness as possible.

- S-City VT and SMURF would be installed in the same laptop. All users would carry out the survey using the same laptop. Some problems for the installation of S-City VT can appear if the graphic card is not powerful enough.

- There was a folder containing the images of the indicators of SMURF. Many times these do not work properly, the software sticks and must be rebooted again. By this way, it this problem appears, as questions about indicators are almost at the end, the user saves time.

- The two tools would be analysed independently. First SMURF and later S-City VT, following the sections of the survey.

- Before starting the survey, the author of this thesis would explain to the user what the survey was about and a bit about each tool. This is not explained in a written way due to the survey was already too long and making it denser and longer would just lead to the discouragement of the user before starting.

- Before giving the survey, the users would have around 3 minutes to start discovering the SMURF software (the first one). This does not mean that later they could not use it; in fact they would have no time restrictions along the development of the survey.

- The author of this MSc thesis would be always present in order to solve any doubt that could come up. Some of them were explained only after the users

answered some specific questions to let them to continue with the survey without big difficulties; i.e. if the user was not able to find the way of using the mouse properly in the 3D screen of S-City VT, this was not explained until they had answered the question about it - I can easily navigate the 3D view using the mouse.

- Taking into account the availability of the laptop with the two tools, it would be intended to do the survey to 30 people approximately.

Finally, the author of this thesis would be always aware about the behaviour of the user or any other comment they could do during the development of the survey.

Chapter 6

Results and discussion

This chapter presents the results obtained and the discussions carried out during this thesis. It is divided in four main sections: the limitations of the thesis, the survey, the adaptation of SMURF to the city of Zaragoza and the contribution of SMURF and S-City VT to the complex decision making processes related to IUWM.

6.1.LIMITATIONS OF THIS THESIS

Due to the scope of this thesis was to analyse the user-friendly feature of SMURF and S-City VT, there are not technical specifications for their improvement. The last ones should be made after the final development of S-City VT and SMURF – after its full adaptation to an area - by calibrating and validating the results with cases fully documented in which the reliability of the results can be assessed.

Summarizing, this thesis analyses if SMURF and S-City VT are user-friendly tools and whether they fulfil their objective – help in making a decision- or not. According to it, potential improvements in the tools are proposed.

6.2. ADAPTATION OF A SMURF DECISION-MAKING TOOL

6.2.1. Data collection

According to the experience of adapting a SMURF decision-making tool to the city of Zaragoza, two types of problems regarding the data collection can appear (see section 5.2.2). Those related to the burocracy of data acquisition and the different scales of the GIS information gathered. These difficulties or similar ones may be applied to other adaptations of SMURF to different areas.

While the burocracy problems do not seem to have easy solution, that one regarding the different scale of some GIS layers could be solved by the manual modification of each layer using some GIS software, such as ArcGIS or Manifold. However, it is a high time-consuming process and maybe not worthy.

Moreover, there is the possibility that there are not some important data regarding specific topics, in this case IUWM. In the current MSc thesis, some data, such as a GIS layer of the water supply network of the city of Zaragoza, were missed.

6.2.2. Technical aspects

The SMURF decision-making tool is a software based on GIS. In fact, to introduce the GIS information in this software is needed that the different GIS layers had been created before using another GIS software, such as ArcGIS or Manifold. Once the minimum requirements of the software have been developed for an area, another GIS software is not needed. Thus, it is not needed all users to have installed an expensive legal GIS software in their computers. It means a great advantage thinking in terms of economic resources.

Although a normal GIS software can show the same information than the SMURF tool, the truth is that SMURF presents an easier format for non-expert users. SMURF has four different modes, allowing the user to look easily at any information (the general data or the indicators) or to propose some modifications of existing data or even to introduce new data.

Moreover, some non-expert users may feel confident to use the SMURF tool due to it is not possible to erase or change easily anything in it. By this way, they are not able to eliminate some important information or make any damage to the software by mistake.

When adapting the SMURF tool to the city of Zaragoza, some advantages and disadvantages of the software were found. These are briefly discussed next:

- A default window is set up for the software boot, but it does not mean that it is the biggest area you can access to. Bigger layers can be stored in the software database and they can be easily seen using the "zoom out" tool.

- The background layers are opaque, meaning that two background images cannot be seen at the same time. It is likely this issue to be solved in other versions of SMURF in the future.

- The free compressors to create *.ecw images, such as Ermapper, do not work as they should. Quite expensive compressors, as Manifold, may be used to create some of the background images that will be included in the SMURF software.

All the difficulties, regarding technical aspects, found when adapting a SMURF decision-making tool to Zaragoza may appear when adapting SMURF to other areas. A detailed and visual manual, with many examples, might solve them easily. Thus, non-expert users, without high skills on computing or GIS, may also use it. This manual would also avoid the misunderstandings that appear when emails are interchanged.

6.2.3. SMURF within the SWITCH toolbox

Within the SWITCH Project, the work package 1, urban water paradigm shift, aims to create an integrated information tool or software, the SWITCH toolbox, to help to understand the urban water resources as a whole and promote, by this way, the IUWM. The SMURF tool will be part of it, as explained in section 3.4.1.

SMURF will be the main visualization tool of the SWITCH toolbox due to it shows the main information: the real features of an area, represented in an interactive map, and their corresponding indicators. The diverse components of the toolbox, developed by the other work packages, will be linked to SMURF through several software interfaces. The idea is that users only need to follow simple procedures to be able to visualize and compare easily the different scenarios or the results of several models, by looking at the

changes of the indicators. This kind of comparisons could also be made only using the SMURF software, but the different data should be included one by one by the user. This is a high time-consuming process and can result in the discouragement of the user to know about these differences.

In the SWITCH toolbox is likely that some data and indicators to be fixed, for example, for some of the model software. From this point of view, it seems that the SMURF software itself is more flexible in terms of data needed than the SWITCH toolbox. SMURF does not need any specific data to work properly.

6.2.4. Non-technical aspects

The SMURF software is a powerful tool in terms of data storage, consultation and editing, but it cannot create or update the data. This remains a task of the different stakeholders who have data about the different urban states and those who validate these data, as explain in section 3.4. It means that some human resources and organization are required in order to ensure the good operability and durability of any SMURF tool adapted to a specific location.

Moreover, if a SMURF decision-making tool adapted to a specific location is put on the Internet to facilitate the participation of the different stakeholders into the decision-making process, checks on comments must be made. If this is not done, since the Internet is accessible worldwide, some people may just make comments or propositions with malicious intent.

It is likely the maintenance of SMURF, such as its updating, to be carried out by public administrations since SMURF is not thought in terms of obtaining financial benefits. So, the real contributions of the SMURF software must be clearly presented due to, at least in Spain, the human resources within the public administrations are scarce and there is no money to hire more people unless there is a good reason and clear benefits.

6.3. SURVEY.

6.3.1 Introduction

The survey was done to 20 people instead of 30, the initial objective, because of time constrictions. The availability of the laptop with the two software tools, SMURF and S-City VT, was limited, there were difficulties in getting people who made the survey and the time to fill in the survey was a bit longer than expected. The times of the realization of the survey oscillated between 20 minutes and 1 hour and 20 minutes, being the average 50 minutes approximately. These big differences in the time of realization were due to the low interest of some people in the manipulation of the software and the intention of others to understand till the minimum detail of them. Also, in general, people spent more time for the SMURF section of the survey than for the S-City VT one. Some reasons for it may be that people got familiarized to the type of questions and S-City VT was less developed than SMURF:

The survey was done within the University of Abertay Dundee, where the laptop was available. The people who answered the survey were randomly chosen. It was a quite heterogeneous group in terms of the nationality and their ages varied between 19 and 40years old. Their studies can be classified in three groups: computing, business and environmental issues.

Next subchapters show the analysis of the data obtained from the survey.

6.3.2. SMURF

This section shows the analysis of the data related to the exclusive characteristics of the SMURF software.

SMURF has two tools, the information on data attributes () and the label one (). The first one gives several data, including the name, of a selected attribute and

the second one just offers the name of any attribute. Thus, the intuition and ease of using any of these tools to identify specific named buildings, such as Grande Anse Hospital, is checked. A high percentage of the people (75%) did not find easy this task, which means these tools are not as intuitive or easy to find out as expected, at least when manipulating the software just for a short period of time (figure F.1).

On the other hand, most of the people "agreed" or "strongly agreed" with the statement "having specific named buildings helps to understand the real world situation", i.e. it helps getting a better orientation (figure F.2). The better understanding of the real situation is one of the aims of SMURF. All this confirms the need of improving the information and the label tools, making them more intuitive, if possible. If people had found these tools difficult to use, once they knew about them, it is likely that less people would had considered the specific named buildings helpful to understand the real situation, due to it would mean too much effort. It must be taken into account that many people asked for an explanation of how to see the names of specific buildings in order to be able to answer this question of the survey.

Then, the intuition of using the "Area of interest" menu is analysed through the statement "I can find the Takamaka district in Mahe Island easily". The easiest and quickest way of getting to this district is following the commands "Area of interest" →"District"→"Mahe"→Takamaka. However, most of the people, once they have learned how to use the information and labels tools, just tried to find this district using these tools. Very few people realized about the "Area of interest" menu, although it seemed quite intuitive. Nevertheless, more than 50% of the people found this task easy, which confirms the idea that using the information and label tools is quite easy or, at least, entertaining. However, there are still around 30% of the people who thought it was difficult to find a specific location and, even, some of them never found the district of Takamaka (figure F.3).

SMURF has four modes: data viewing, indicators, modifications and projects. The two first ones are quite clear, while the others could be more confused. According to results obtained, more people seemed to understand the purpose of the modifications display than the projects one; even some people thought they could be the same thing. The main difference is that modifications displays, as its name suggests, is for modifying the

features of the existing GIS layers while the projects ones is to create new GIS layers (figures F.4 and F.5).

SMURF has a mini-map in the left top corner of the map. Its purpose is to make easier the orientation, allowing the exact identification of the area within the map which is being looked at. Although, at first sight, it may seem very useful, 30% of the people did not find it helpful and other 15% had no preference in relation to it (figure F.6). Some comments regarding the mini-map were made: “the mini-map is too small to see anything in it”, “the small map should be more active”, “it would be better a bigger mini-map to be able to hang around” and another person would add the “possibility to move the quadrangle in the mini-map for an easier navigation”

Also, while adapting a SMURF decision-making tool to the city of Zaragoza, some disadvantages regarding the mini-map were found. It does not offer the possibility of identifying a location outside of its extent area – defined in the *.smu file of SMURF as the biggest area the mini-map can show. Once solution would be to choose the biggest GIS layer included in the SMURF’s database as the mini-map’s extent area. Then, using the “Area of interest” menu the mini-map could be adjusted to more specific areas. However, there is a problem. Later, when using the “zoom out” tool, the mini-map remains fixed, its area does not change automatically into a bigger one and the initial problem reappears– any location out of the mini-map area cannot be identified.

Currently, the SMURF software is available in three different languages - French, English and Creole. However, not all the commands, including the help one, were translated into all these languages, being only in French. Also, the people complained about the help command itself due to it is very incomplete and useless.

Most of the people had lot difficulties to use the software till they found the way of changing the language into English. Among them, some asked for help to change the language. Moreover, 20% of the people used the SMURF software in French (figure F.7). Taking into account that these people coincide with all the French ones, plus another person, who made the survey, it means that people tend to use their first language despite they know English. Also, in this case, more information is offered in French than English.

Finally, some other observations and comments about the SMURF tool are next:

- SMURF offers the possibility of saving the images shown in the software, although without any kind of legend (see figures 5.8 and 5.9).

- Few people found a bit difficult to move around the map of SMURF when they tried to arrive to a specific location. According to them, “magnification tool is not good” and “moving around in the map should be made easier”.

- Several comments regarding the stability of SMURF were made. Among them, “lots of errors and bugs when running the application” and “how do you work with this program when some of the data/indicators do not reveal themselves” are included. Also, one person suggested decreasing the loading times.

6.3.3. S-CITY VT

This section shows the analysis of the data related to the exclusive characteristics of the S-City VT tool. From the beginning, it must be born in mind that this software, by the development of the current thesis, was in the first stages of its development and still many things had to be decided.

S-City VT has two different displays, the design view and the 3D one. Changing between these two displays is quite easy (figure F.8). However, most of the people did not realize about the 3D view until they read this question of the survey.

Then, when checking whether using the design view to change the position of the different features or create/remove them is easy, 50% of the people agreed (figure F.9). However, still many the people found this task difficult - those who replied “disagree” or “strongly disagree” - or not easy - those with “no preference” answer. The main reason for this big percentage was that once a feature had been moved, to put it back exactly in the same location was quite complicated; i.e. to place a feature in a specific point is a bit difficult. Moreover, few people realized about the function of the

command “reset design”, which allows coming back to the original design without problems. Finally, two comments, regarding the movement of the features in the design view, should be pointed out: i) “it would be easier to change the buildings, streets, etc. in the 3D screen” and ii) “when assets are being moved in the design view it would be good if the cursor could change to a move icon”.

A relatively high percentage of the people (60%) found helpful changing the parameters of S-City VT – for example, the building types and the traffic levels -, in the design view, in order to understand the real world situation (figure F.10). This is one of the objectives of the S-City VT software.

Focused on the 3D display of S-City VT, the difficulty of navigating through it, using the mouse, was tried to check out. The mouse allows three types of movements: i) zoom in and out using the roller of the mouse, ii) dragging movements by pressing the left button while moving the mouse and iii) other movement – simulating the view of a camera, like in some videogames – by pressing the right button while moving the mouse. Many people (70%) found easy or really easy to navigate the 3D view by using the mouse (figure F.11). However, among them two groups are identified: i) those used to play videogames and ii) those who just were unaware of the third type of movement. In fact, most of the people within the second group commented about the difficulty of this movement, once they knew about it. On the other hand, 30% of the people found difficult any type of navigation through the 3D display. Some comments about all this were: “I find difficult to use the mouse to move in the 3D screen”, “The navigation in the 3D view should be easier” and there should be some “explanation on how to use the mouse controls”.

In S-City VT, the people, in general, were able to easily tell the date the simulation is currently at and turn the carbon model on and off (figures F.12 and F.13). However, most of them did not understand what the carbon model was till they arrived to the question about whether it is possible to easily distinguish between a building using a lot of energy and a building using little energy. Then, the relationship between the carbon model and the energy consumption seemed clear.

Finally, another observation about S-City VT is that it does not offer the possibility of saving any image, shown in the software, or any other kind of data.

6.3.4. BOTH TOOLS

In this section, the analysis of data related to both tools, SMURF and S-City VT, is carried out. It is divided in two parts, indicators and other aspects.

6.3.4.1 INDICATORS

Currently, several researchers debate about different aspects regarding the indicators. Due to it, this section is dedicated exclusively to them. Next aspects will be discussed:

1. Understanding of the indicators.
2. Differences in making a decision depending on the quantity of information given.
3. Usefulness of showing the same indicator at two different points in time when making a decision.
4. Usefulness of showing more than one indicator at the same time when making a decision.
5. Usefulness of the indicators when making a decision.

Table 6.1: Characteristics regarding the indicators of the versions of SMURF and S-City VT used for developing the survey.

	SMURF	**S-City VT**
Number of indicators	Several	Only one
Classification of the indicators in different categories	Yes	No
Possibility of showing temporal trends of an indicator	No	Yes
Possibility of showing more than one indicator at the same time	No	No

Table 6.1 shows the characteristics, regarding the indicators, of the versions of SMURF and S-City VT used for their evaluation through this survey.

Understanding of the indicators

Some people have the idea that many stakeholders, including the general public, do not easily understand the indicators. Thus, whether it is applied to the cases of SMURF and S-City VT is analysed. The indicators selected and the way of representing them are key factors in order to general public to be able to understand the indicators.

First of all, whether it is easy to identify features – houses, rivers, trees, etc.-, in SMURF and S-City VT, should be checked. In SMURF the features are represented through different colours and shapes, having the "legend" on the left. S-City visualizes its features differently depending on the display: i) in the design view they are represented using different colours and shapes, with the legend on the right – similar to the SMURF representation – and ii) in the 3D view mode the features are shown in 3D. According to figure 6.1, the features of S-City VT were easier to identify than the SMURF's ones. Nevertheless, the most important thing is that, in general, everybody was able to easily identify the different features in both tools. Finally, it should be taken into account that, only in SMURF, some people found this task a bit hard. It is likely that this difficulty appeared due to the version of SMURF, used for this survey, offers the possibility of seeing more features than the design view of S-City – most of the people did not realize about the 3D view to answer this question. This made impossible to see all the "legend" of SMURF at the same time.

Other observations regarding the identification of features were:

- In SMURF, few people realized about the ortophotos –aerial images. They used them to identify the diverse features, like if they were using the Google Earth or similar. Moreover, almost anybody discovered the possibility of changing the parameters – colour and shape - of the features. Maybe, a question regarding the easiness of changing the parameters of the features of SMURF may be included in other survey in the future.

- In S-City VT, “the relation between the two different displays is not so easy to see” in terms of identifying a specific feature of the design view in the 3D display and vice versa. By this way, “recognising the same building in the design and 3D displays should be simpler”. Moreover, “the first time that one uses the 3D screen, it is not easy to identify the type of building”.

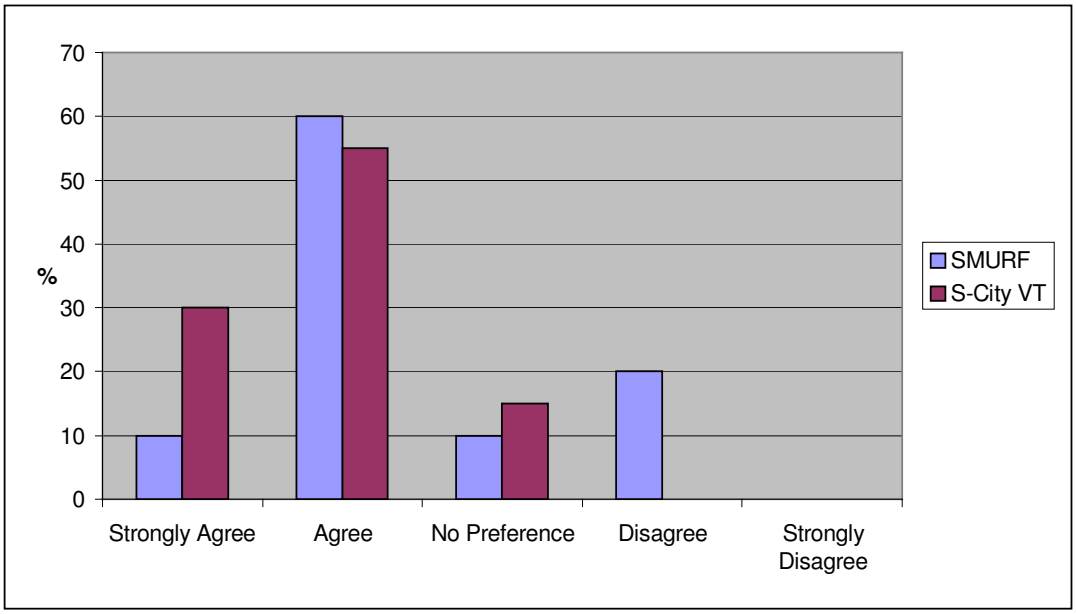

Figure 6.1: Statement: It is easy to identify features (houses, rivers, trees, etc.) in SMURF and S-City VT.

Once it has been checked that the people easily identified the several features, the analysis based on the indicators themselves is started. If the people had not been able to recognize the simple features, such as houses, next analysis would not have too much sense.

The analysis about if people understand the several indicators of SMURF and S-City VT is started with the only indicator of the S-City VT tool – the energy consumption. A high percentage of the people could easily tell the difference between a building using a lot of energy and a building using little energy (figure F.14). The colours used – blue and red - to show the differences in the energy consumption are very intuitive since most of the people did not understand its legend, specially the sustainability triangle. Moreover, the people, in general, found this legend by mistake. On the other hand, the name of the command – carbon model – to be able to see this indicator is not so clear.

Most of the people did not realized about the link between the carbon model command and the energy consumption indicator till they arrived to this question of the survey.

There was a clear difference between SMURF and S-City VT when understanding their indicators (figure 6.2). The people understood better the meaning of the indicators of SMURF than the only indicator of S-City VT. However, the results regarding the indicators of S-City VT would be more reliable if it had more indicators since people may have a better global idea. Thus, if some people did not understand the meaning of S-City VT's indicator, it does not mean that they would not understand others. Moreover, it is likely that the classification in categories of the several indicators of SMURF facilitated their understanding. However, almost anybody was interested in changing the parameters of the several indicators of SMURF or, at least, they did not realize about this possibility - command +.

Everybody also understood the meaning of the indicator people/km^2. However, only one person answer "an indicator" to the question about what the term people/km^2 was. That was the expected answer, but the most important thing is that the people understood its meaning.

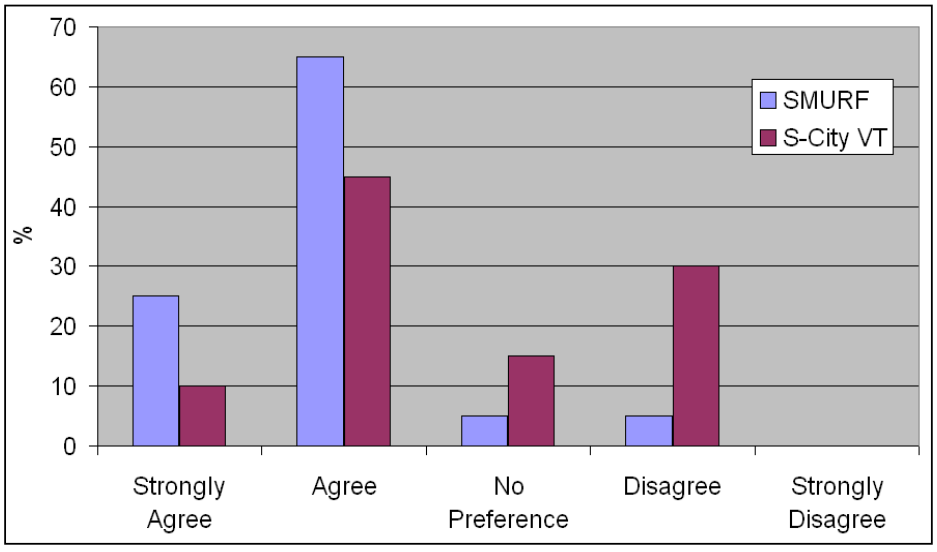

Figure 6.2: Statement: I understand the meaning of the indicators represented in SMURF and S-City VT.

Finally, the indicators of SMURF and S-City VT would be easier to understand if they were explained (figure F.15). That does not offer too much information due to it is evident that anything is easier to understand if it is explained. Nevertheless, more explanations would be needed for the indicator of S-City VT than for the SMURF ones (figure 6.2). Further research about the best way of showing these explanations – by pop-up labels, through the help command, etc. - should be done. Moreover, changing the way of formulating the question in the survey may offer better information about this issue. One example of question may be: "Explanations on screen about the indicators are unnecessary in order to understand them".

Differences in making a decision depending on the quantity of information given

This section analyses whether there is any difference in making a decision when only one indicator is seen and when more than one indicator are seen. This wants to be checked independently if the indicators were shown at the same time or not. The analysis was carried out only in the SMURF software because S-City VT had only one indicator, by the development of this thesis.

There were two questions of the survey regarding this analysis. The first one was "what decision would you take based on the indicator "distance to schools" in Mahe Island" and the answers expected for it were "I would build some more schools in areas where the schools are too far away" or " I would do nothing" (figure F.16). The second question was "what decision would you take based on the indicators "distance to school" and "population density in Mahe Island" and the answer expected was "I would do nothing" (figure F.17) (see also figures 5.8 and 5.9). The author of this thesis does not understand the answers "I would remove some schools, there are too many" to any of the questions unless the people had understood the term "remove" like "changing the use" given to the building (school).

In relation to the first question, only 15% of the people demanded more information – i.e. the population density - in order to be able to answer it. They tried to look for that information in the "Data viewing" and the "Indicators" modes of SMURF. Thus, some of them realized about SMURF offers the possibility of seeing one indicator and several data at the same time. The rest just did what the question asked them for. In this point, it

must be borne in mind that the users did not have any restrictions regarding the manipulation of the software, at any moment.

In this point, it must be reminded that a folder containing the images of the indicators of SMURF was available. When SMURF did not work properly, sticking, these images were shown to the people in order to they were able to make their decisions – i.e. they could answered the two questions regarding to this section. The images saved did not have any legend because SMURF does not offer this possibility. However, only one person of those who had to use them asked for the units of the indicators in order to be able to make his decision. It is the likely that the rest supposed that the lightest colours corresponded to the lowest units and the darkest colours to the highest ones.

The lack of interest in knowing more information in order to answer the first question and the issue that many people tried initially to look for the indicators in the "Data view" mode, might lead to think that the people were not really interested in or used to the indicators - even if they were easily understood (figure 6.2). However, this is only an idea and further research should be carried out to check it. Thus, some other questions may be added to the survey – for example, "only one indicator is not enough to make good decisions".

Finally, the figure 6.3 shows the results of the main analysis of this section. 55% of the people made different decisions when they saw only one indicator and when they saw two. This percentage is not high enough to confirm that people make different decisions depending on the quantity of information (indicators) given. However, 65% of the people who made the same decision in both cases answered "I would do nothing " to the questions. Once this is known, it might be affirmed that, in general, there are differences in making a decision depending on the quantity of information provided.

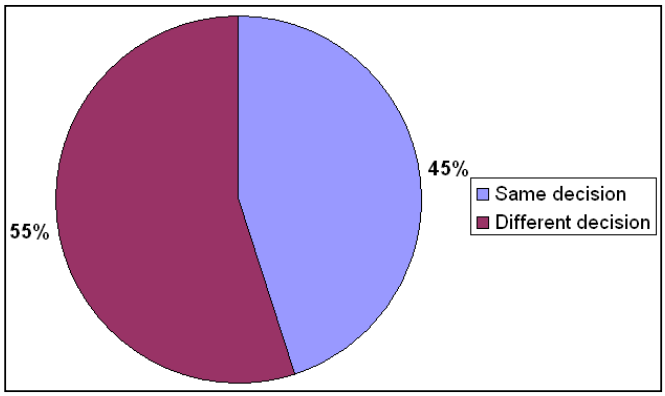

Figure 6.3: Differences in making a decision depending on the quantity of information (indicators) given.

Similar results would be expected when one indicator is seen at one point in time and when it is seen at two points in time.

Usefulness of showing the same indicator at two different points in time when making a decision

Sustainable development indicators are only useful if they monitor changes in the state of the environment – as explained in chapter 3. Thus, it is important to have and represent the same indicator at two points in time or, if possible, to show the continuous evolution of an indicator over time.

Firstly, the study of this section focuses on the S-City VT tool. It shows that most of the people found helpful to see how a building's energy use changes over time – for example, summer and winter – in order to make a better decision than when this indicator is only seen at one time (figure F.18). Nobody found useless the issue of seeing the S-City VT's indicator over time to make a decision In addition, 60% of the people considered helpful to use the time control to go to points they were interested in when making a decision (figure 6.4). The last results might slightly improve if the statement regarding this issue was located after the questions related to the energy consumption. It was then when the people really understood the meaning of the S-City VT's indicator, including why the buildings in the carbon model changed their colours between blue and red. It seems that the people answered this question based on, basically, their intuition due to the other attributes of S-City VT did not change over time, by the realization of current thesis. Moreover, a "higher resolution time" should be considered in upgrading versions of S-City VT.

In SMURF, the indicator "distance to schools" was chosen in order to check whether people consider useful to see one indicator at two points in time when making a decision. The results show that 60% of the people considered that seeing this indicator at two points in time would help them in making a decision. However, still many people answered "no preference", "disagree" or "strongly agree" in relation to this statement (figure F.19). They considered that the "distance to schools" indicator does not change quickly over time and seeing it at two points in time would not offer them added information to make a decision. A better indicator of SMURF should have been selected

to check whether people find helpful to see one indicator at two points in time when making a decision.

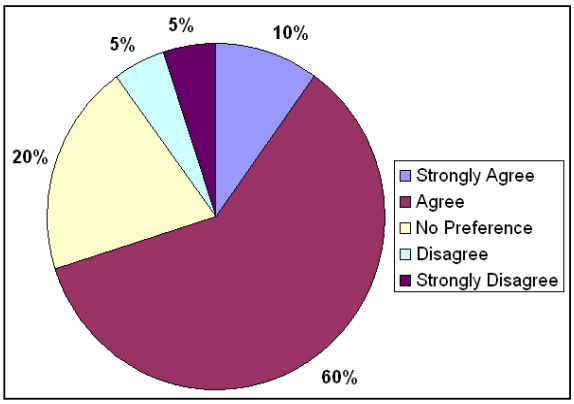

Figure 6.4: Statement: It is helpful to use the time control of S-City VT to go to points in time I am interested in when making a decision.

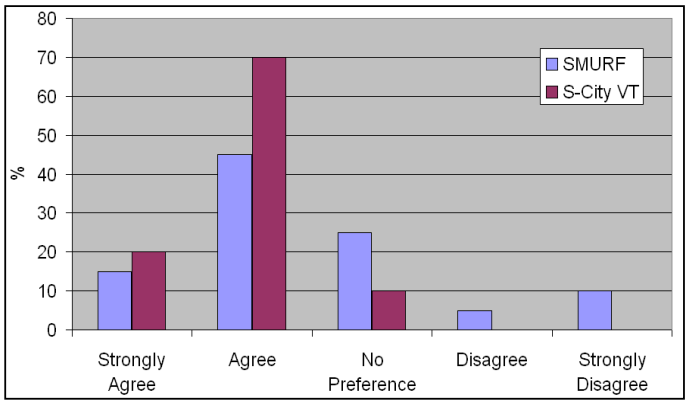

Figure 6.5: Comparison of the answers of S-City VT and SMURF in relation to whether seeing the same indicator at two points in time is useful when making a decision.

Finally, it is concluded that, in general, seeing the same indicator at two points in time is useful when making a decision (figure 6.5). The differences between the answers of SMURF and S-City VT are explained above.

Usefulness of showing more than one indicator at the same time when making a decision

Showing more than one indicator at the same time would make easier the spatial exploration of the relationships between them; thus, it would be useful to make decisions. This idea is analysed in this section.

In SMURF, 40% of the people answered " strongly agree" and 50% "agree" to the statement "it would be helpful to make a decision if the indicators "%main supply treated" and "connected to sewerage" of SMURF are shown at the same time" (figure F.20). It means that, at least, when talking about undefined – scattered – indicators, people find helpful to see more than one indicator at the same time when making a decision. Similar results would be expected in the case of more defined indicators due to many free comments were made in relation to the issue of showing two indicators at the same time. Some of them were: "it would be better to show different indicators at the same time", "more than one indicator need to be seen at the same time", etc. On the

other hand, nobody commented the need of showing the same indicator at two points in time when making a decision. This fact leads to think that people consider more important, to make a decision, to see two indicators or more at the same than seeing the same indicator at two points in time.

In addition, along the survey, few people realized about the possibility, which SMURF offers, of seeing one indicator and several data at the same time. In S-City the indicators are always shown over the different attributes on the 3D display.

Most of the people considered that it would be more helpful to make a decision if more indicators – including the energy consumption one – were shown at the same time in S-City VT (figure F.21).

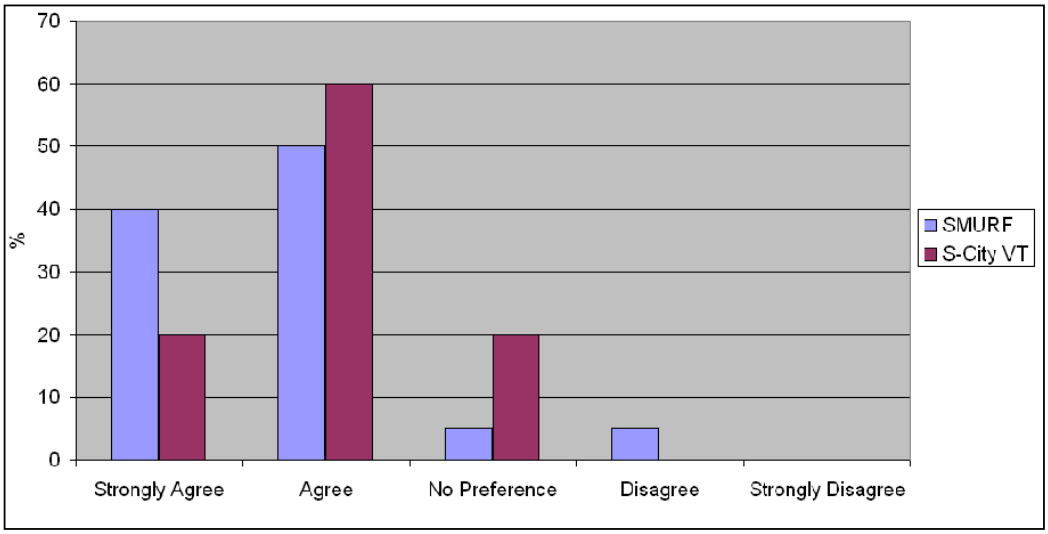

Figure 6.6: Comparison of the answers of SMURF and S-City VT in relation to whether seeing more than one indicator at the same time is helpful when making decisions.

Finally, it is concluded that seeing several indicators at the same time helps when making a decision (figure 6.6). This conclusion may be extrapolated and it may be said that showing different information (data or indicators) at the same time makes easier the identification of spatial relationships, allowing to make better decisions. Thus, similar results to those got in this section would be expected if one indicator at two points in time was represented at the same time.

Usefulness of the indicators when making a decision

The two analyses carried out in this section close the subchapter regarding the indicators.

Firstly, there were diverse opinions in relation to whether the indicators used in SMURF and S-City are useful to make a decision or not. Regarding SMURF, the people considered that its indicators are useful. However, in the case of S-City, almost 50% of the people did not find its only indicator useful in making a decision. These results are related to the understanding of the indicators (figure 6.2). If some people did not understand the indicator of S-City VT, it was unlikely that they found it useful to make a decision.

Once again, more reliable results would be obtained if S-City VT had more than one indicator. People might have a better global idea and they would not base their answer only on one datum.

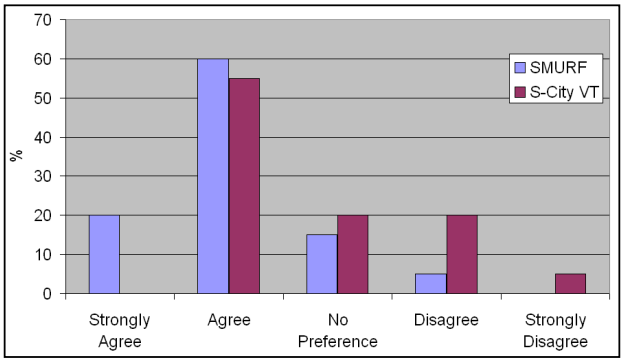

Figure 6.7: Statement: The indicators used in SMURF and S-City VT are useful in making a decision.

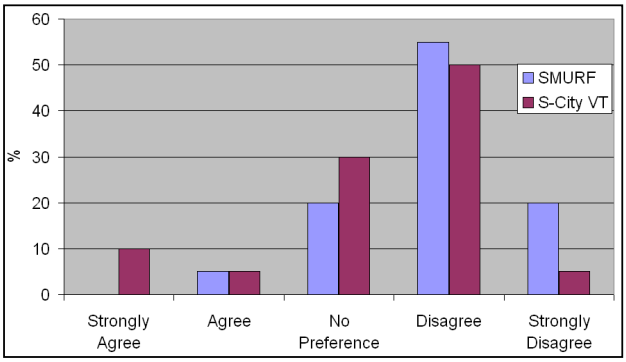

Figure 6.8: Statement: I would make equally good decisions without using the indicators of SMURF and S-City VT.

Finally, many people considered that they would not make equally good decisions without using the indicators of the visualization tools. In S-City VT, more people than in SMURF answered "strongly agree", "agree" or "no preference" to the question of the survey regarding this issue (figure 6.8). In the same way, more people in SMURF than in S-City VT replied "strongly disagree". These differences are related to the easiness of understanding the diverse indicators and to whether they are considered useful or not in making a decision (figures 6.2 and 6.7).

6.3.4.2. OTHER ASPECTS

This section analyses other aspects – excluding the indicators – of SMURF and S-City VT.

There were diverse opinions in relation to the easiness of using the SMURF and S-City VT's software. A high percentage of the people considered them difficult or really difficult to use (figure 6.9). Some reasons may be the way of using the mouse to navigate though the 3D view of S-City VT and the difficulty of finding how to change the language in SMURF. Thus, some aspects of SMURF and S-City should be improved (see chapter 7), simplifying them or making them more intuitive. Also, some complete help command, a manual or some training would help in making their use easier. In fact, many comments regarding the need of explanations about how to use the software were made. According to figure 6.10, the best would be to have a manual and some training in order to facilitate the use of SMURF and S-City. Among those who chose between them, some training was considered more important than a manual. Some further research should be made in relation to what main characteristics would make the manual and the training useful for the non-expert users.

It is likely people to find the software easier to use after manipulating them for a bit longer.

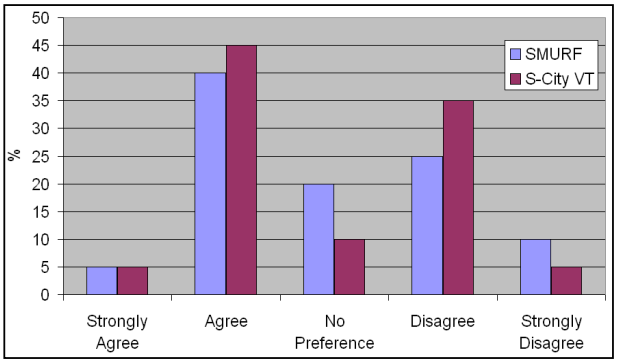

Figure 6.9: Statement: I found SMURF and S-City VT easy to use.

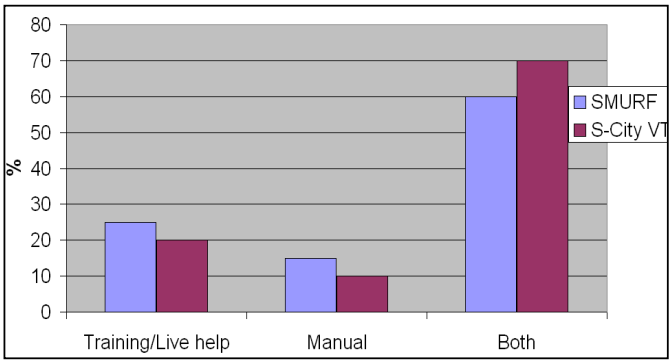

Figure 6.10: Statement: Which of the following do you think would help you to use SMURF and S-City VT.

Regarding the overall appearance of the software, the people had a more favourable opinion about S-City VT than SMURF (figure 6.11). In S-City VT, the people thought that the "3D is cool" and the "visual featuring is good". However, in SMURF, some people considered that the "graphics are not very good", the "colour schemes need some upgrading" and it should also be "more attractive in a visual way".

At this point, whether SMURF and S-City VT help to understand and make decisions about a real world situation is checked. That is the main objective of these visualization tools. Thus, although around 50% of the people thought that these software achieved their objective, still many people felt indifferent to this fact (figure 6.12). It means that something fails in the tools. In the case of S-City VT, it is likely that the indifference shown was due to it was at the first stages of its development; and so, truly, it is a bit difficult to have a global idea about whether the software will fulfil its objective or not. However, in the case of SMURF, further research about the reasons of it should be carried out in order to be able to improve the software.

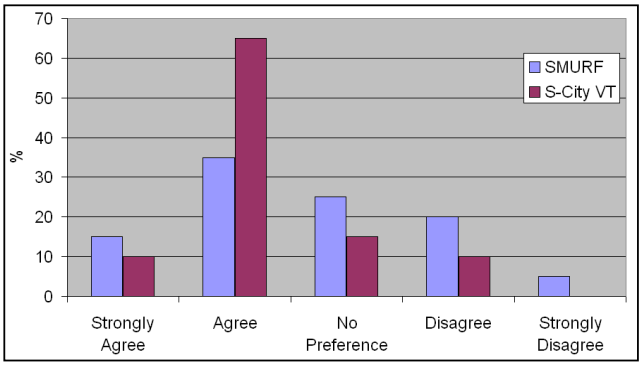

Figure 6.11: Statement: I liked the overall appearance of SMURF and S-City VT.

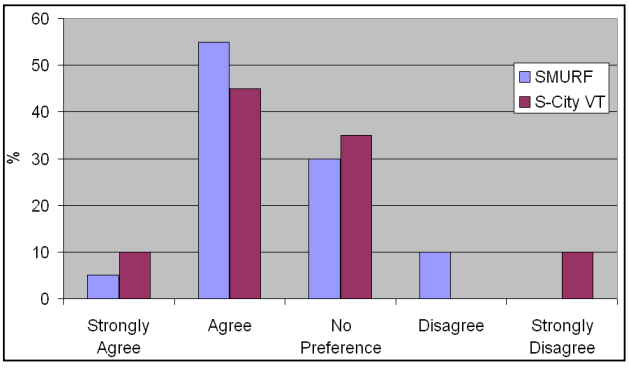

Figure 6.12: SMURF and S-City VT help me to understand and make decisions about a real world situation.

Next, an analysis about the differences between the first impression of SMURF and S-City VT, before their use, and after their manipulation is done.

In the case of SMURF, just looking at figure 6.13, it may seem that the last impression of SMURF was slightly worse than the first one. However, when making a deeper analysis about how the final impression of SMURF was related to the first one, the perspective changes: 25% of the people had a better impression, 40% the same one and 35% a worse one (figure 6.14). The last percentage may be due to the software did not

fulfil its objective (figure 6.12), it did not work as desired – the version of SMURF used stuck many times- or it was not so easy to use as expected (figure 6.9). Anyway, although the software may be improved, the impression of SMURF was, in general, good or acceptable.

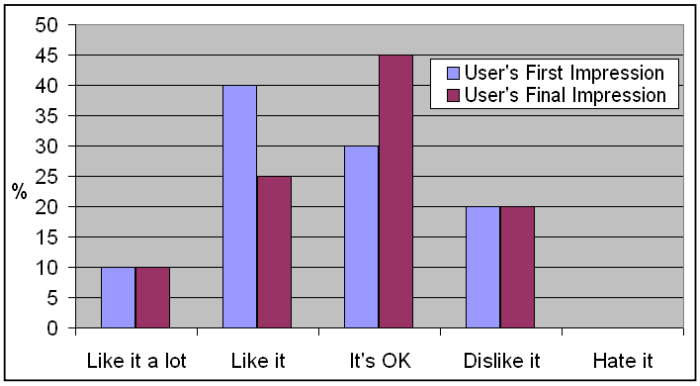

Figure 6.13: Statement: SMURF's impressions before and after using it.

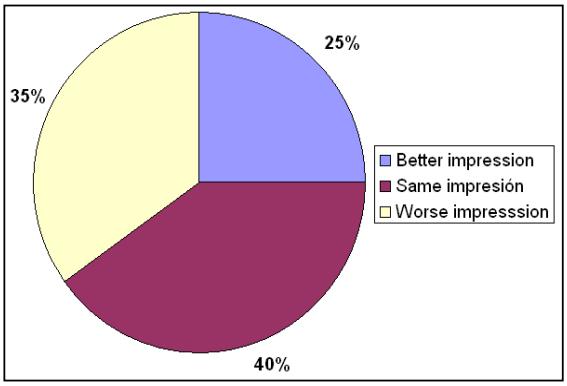

Figure 6.14: Final impression of SMURF related to the first one.

In S-City VT, it may seem, at first sight, that the last impression of SMURF was slightly better than the first one (figure 6.15). However, a deeper analysis about how the final impression of SMURF was related to the first one shows that: 15% of the people had a better impression – less people than in SMURF -, 60% the same one and 25% a worse one (figure 6.16). The last percentage may be due to the people considered that the software did not fulfil properly its objective (figure 6.12)- by the development of the current thesis, S-City VT was in the first stages of its development. Also, maybe, it was not as easy to use as expected. Anyway, it should be borne in mind that there is still a high percentage of the people who did not like the software. Several reasons may explain this dislike: i) the first thing the users saw, once S-City VT was booted, was the design display – less attractive than the 3D one-, ii) the difficulty of placing a feature in a certain place in the design view iii) the way of moving the mouse through the 3D display, iv) the carbon model command is not intuitive enough and v) the legend of the indicator is not clear.

As explained in chapter 4, the Internet is a mean which can improve the communication between the different stakeholders, including the general public, involved in the decision-making processes. Thus, some aspects regarding the Internet are studied next.

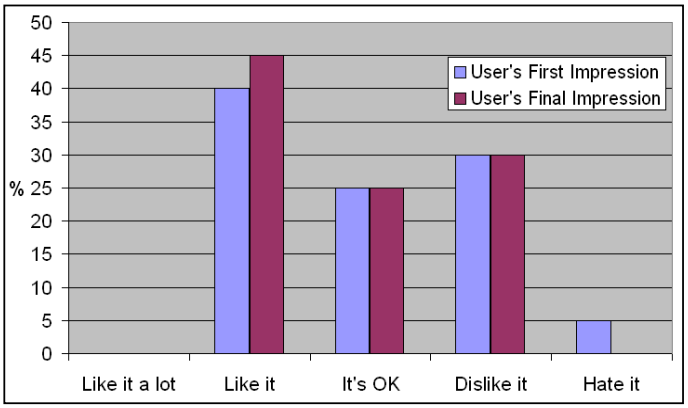

Figure 6.15: Statement: S-City VT's impressions before and after using it.

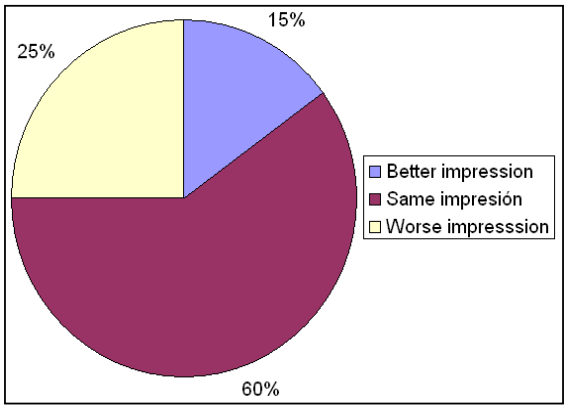

Figure 6.16: Final impression of S-City VT related to the first one.

First of all, it must be commented that one of the statements regarding this issue – both tools are useful if they are not on the Internet - was not easily understood and the author of this thesis explained it to everybody during the realization of the survey. A better way of formulating this statement would have been "both tools are useful only if they are on the Internet" – this is they way it was finally explained to everybody. Many people (55%) considered that both tools are useful only if they are on the Internet (figure 6.17). They would not look for these tools in any other place. Other 35% of the people found them useful independently on they were on the Internet or not. The most curious thing is those who thought that these tools are not useful if they are on the Internet. If they had access to the Internet they would use the Google Earth, the Mappy or similar programs to make their decisions. Clearly, they were not interested in the indicators function of SMURF and S-City VT in order to make a decision.

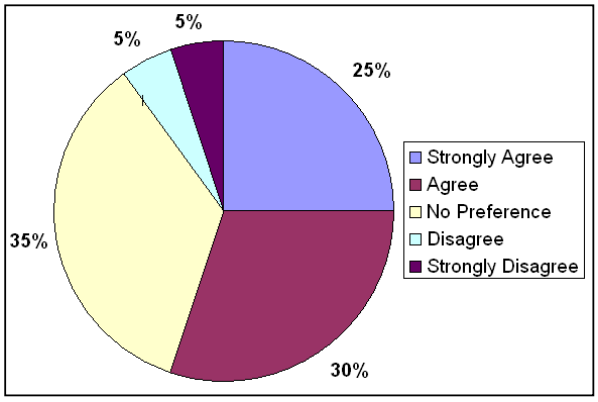

Figure 6.17: Statement: Both tools are useful only if they are on the Internet.

By the realization of the current thesis, the SMURF software was only available in a CD format. It was likely that this software was soon on the Internet to download it easily. However, it was more difficult that any version of SMURF adapted to a specific location be available on the Internet, even if it was able to facilitate the participation of

the several stakeholders. A power platform, such as the Google Earth one, would be needed and that was something difficult to obtain, at least, without high costs. Without this platform, the version of SMURF adapted to an area would be very slow, unseful or even non-operative. In the case of S-City VT, the way in which it would be available had still to be decided.

The main reasons to use both tools, if they were found on the Internet, are – in order (figure 6.18):

1. The tool is free.
2. The benefits of using it are clearly explained on the main page.
3. There is a clear manual
4. There is a developer contact number or email for more information
5. Other. In general this was the last option by default. However, there were two suggestions: i) there are good recommendations and ii) they are for business or private analysis

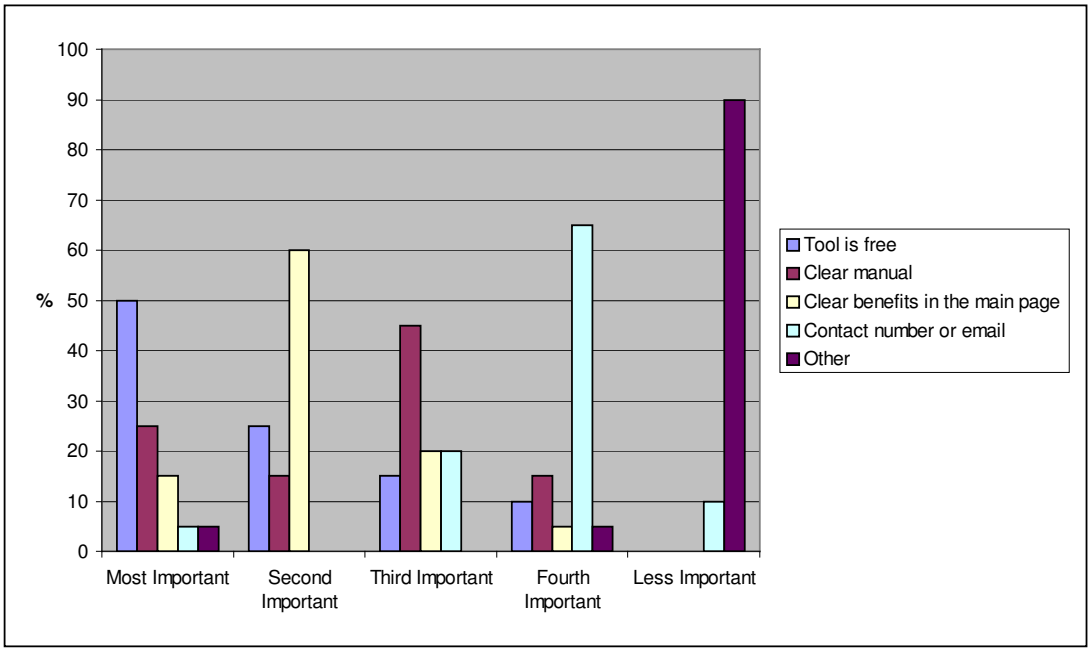

Figure 6.18: Reasons for using SMURF and S-City VT if found on the Internet.

Finally, the users had to choose between SMURF and S-City VT to make a decision based on a real situation. The London City Council wants the London 2012 Olympic

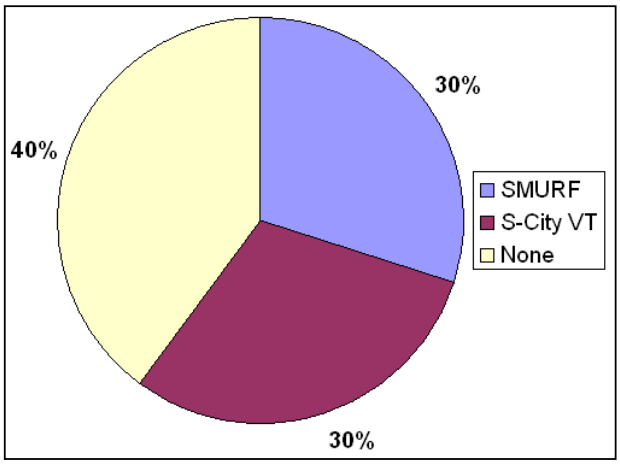

Figure 6.19: Tool chosen for planning the London 2012 Olympic Games.

Games to be the first sustainable games. Knowing this, they were asked about which tool they would use if they had to choose where in London specific events or new stadiums had to be built to be sustainable. Three options could be chosen: SMURF, S-City VT and none. There was not the option "both" due to the interesting thing was that the people selected one of them, and if this was impossible they would have to explain why. If there was the option "both", it was likely that most of them had chosen this option. Thus, the fact is that a high percentage of the people did not choose any of the tools – figure 6.19- arguing that they would use both, first SMURF for having a better global idea of the area and then S-City VT for seeing the area selected in greater detail. Everybody also commented that, anyway, S-City would useless to make a decision unless it was completed with more indicators. Moreover, most of those who selected SMURF or S-City VT also considered that the best would be a combination of both tools. The different reasons for choosing SMURF, S-City VT or any of them are included in Annex E, answers of the survey.

6.4. CONTRIBUTION OF SMURF AND S-CITY VT TO IUWM AND TO THE DECISION-MAKING PROCESS

A new more sustainable IUWM is needed, as explained in chapter 2, to improve the current management of the scarce and less reliable water resources. To achieve this IUWM, the commonly used conventional UWM approach must be changed. Three difficulties of this new approach could be mentioned due to the SMURF and S-City VT software can contribute to make them easier:

- The decision makers' team must be multidisciplinary, allowing new management strategies and technologies.

- There must be an institutional integration by design. Thus, through high coordinated management, water supply, wasterwater and stormwater could be linked between them.

- It is important to encourage the collaboration of different agencies and general public in order to find effective solutions.

In these three points, it is clearly necessary the collaboration between the different stakeholders through a good communication where the SMURF and S-City VT software can assist. They contribute to clarify the real problems and provide a decision framework favourable to mutual understanding and debate between the several stakeholders. By this way, they contribute to the involvement of different stakeholders in the decision-making process regarding water issues.

As explained in chapter 3, the decision-making processes to achieve a more sustainable IUWM are quite complicated. That is why different DSTs have been developed and are currently being developed and improved to assist it. In this MSc two tools are evaluated, SMURF and S-City VT. They assist to different phases of the process due to they are DSTs as well as communication tools. Thus, SMURF and S-City VT really contribute to all the phases in terms of improving the communication process between the different stakeholders. It results in a better involvement of them in the different stages of the process, encouraging their participation, including the general public participation.

SMURF and S-City VT provide a common GIS and a 3D decision framework, respectively, which promote a better understanding of the actual world situation and the real problem, phase 0 - identification of the problem- (figure 6.12). Moreover, they also clarify the several ideas that different stakeholders can have in the other phases of the process. It is known that the knowledge and a good understanding of the real world situation, the concepts, etc. encourage the participation. Thus, the objectives can be easily discussed and different stakeholders can generate more options or alternatives.

Furthermore, the criteria and indicators selected as well as the analysis of options can be easily discussed and the selection of the preferred option can be more balanced.

Finally, SMURF and S-City VT also contribute to phase 4 of the decision-making process - the collection of data and the generation of information-. A good decision-making process usually requires a huge amount of data. However, some stakeholders are reluctant to make public or for a general use the data they have gathered to avoid a bad use of them. SMURF and S-City VT contribute to make the decision-making process more transparent and, by this way, some stakeholders are more confident to share their own data in order to get a common benefit. These tools also generate information. S-City is a simulation model and SMURF creates indicators form a GIS database and represents them spatially in order to they can be used for monitoring, controlling and benchmarking different urban water functionalities.

Chapter 7

Conclusions and recommendations

This chapter presents the conclusions of this MSc thesis jointly with recommendations for improving SMURF and S-City VT and other for possible further work.

7.1. CONCLUSIONS

The conclusion section is divided in three sections: i) the aspects regarding the use and understanding of SMURF and S-City VT, ii) the adaptation of SMURF and iii) the survey itself.

7.1.1. General

The main objectives of the current thesis were to: i) create the minimum requirements to start the SMURF software for the city of Zaragoza and ii) to identify the weak and strong points of SMURF and S-City VT, from a user's point of view. Both of them were achieved along the development of the thesis.

The results obtained confirm that the hypothesis is partly true. A big percentage of non-expert users considered that SMURF and S-City VT help to understand and make decisions about a real world situation, not being anybody that thought they were useless. The main difficulty for SMURF and S-City VT not to be useful to general public for participating in IUWM decision making would be the possible lack of important data regarding this aspect - such as information about the supply network of an area or the water consumption. What it is clear is that the decision-making processes in which a large group of different stakeholders, including the general public, are able to participate are more transparent than those in which a limited number of stakeholders do.

SMURF and S-City VT have some strong and weak points, from a non-expert user's point of view. The last ones might be improve in order to make these visualization tools more useful to the general public when making a decision. Table 7.1 shows a summary of the current strong and weak points of SMURF and S-City VT, excluding the aspects about indicators

Table 7.1: Current strong and weak points of SMURF and S-City VT (excluding the aspects about indicators)[6].

	SMURF	**S-City VT**
Easiness of use	Medium	Medium
Manual or training	---	---
Overall appearance	Good	Regular
Availability on the Internet	---	---
Possibility of different languages	Regular	---
Possibility of saving	Regular	---
Easiness of identifying features	High	Very high
Identification of the different modes (at first sight)	Good	Regular
Easiness of changing between the different modes	High	High
Having specific named features	Good	---
Easiness of identifying specific named features	Medium	---
Easiness of identifying specific areas	Medium	---
Easiness of changing the position of features or creating/or removing them	(Further research)	Medium
Reset design command	---	Good
Mini-map for orientation	Regular	---
Easiness of using the mouse to navigate through the 3D view	---	Medium
Easiness of telling the date the simulation is currently at	---	High

[6] --- means that the tool does not have that aspect.

Regarding the indicators, some conclusions were found out. First of all, it must be borne in mind that S-City VT was in the first stages of its development, by the realization of the current thesis. Thus, any results regarding to the indicators of S-City VT would be more reliable if the software had more than one indicator. Knowing this, three main points are concluded:

- General public easily understands the meaning of the indicators of SMURF and S-City VT. In fact, they, especially those from SMURF, are useful in making a decision.

Table 7.2: Current strong and weak points, regarding the indicators, of SMURF and S-City VT[7].

	SMURF	**S-City VT**
Number of indicators	Good	Insufficient
Type of indicators (in general)	In areas	Punctual
Understanding the meaning of the indicators	High	Medium
Easiness of identifying the name of a command with its indicator	High	Low
Classification of the indicators in different categories	Good	---
Easiness of understanding the legend of the indicators	High	Low
Usefulness of the indicators in making a decision	High	Medium
Possibility of showing more than one indicator at the same time	---	--- (but yes in the future)
Possibility of showing one indicator and different features at the same time	Medium	High
Possibility of showing the same indicator at two points in time	Low	Medium
Time control	---	Good

[7] --- means that the tool does not have that aspect.

- Showing the same indicator at two points in time is useful when making a decision. By this way, changes in the state of the environment are easily identified.

- Showing more than one indicator at the same time makes easier the identification of spatial relationships, allowing to make better decisions. In the same way, showing the same indicator at two points in time at the same time would be useful to make a decision.

Table 7.2. summarizes the strong and weak points, regarding the indicators, of SMURF and S-City VT.

The best visualization tool to make a decision would be that one which combined both software, SMURF and S-City VT. SMURF offers a general idea of the real world situation of a relatively large and georreferenced area while S-City VT visualizes smaller areas in a greater detail.

7.1.2. Adaptation of a SMURF decision-making tool

The minimum requirements, for being able to start SMURF, were adapted to the city of Zaragoza. In doing this, several difficulties were found and may be divided in two categories: data collection and technical aspects. The same difficulties or similar ones could be found when adapting a SMURF decision-making tool to another area. This section also shows some conclusions about the non-technical aspects of SMURF.

7.1.2.1. Data collection

SMURF is a tool, based on GIS, really flexible regarding the data needed. Only few requirements are compulsory in order to run the software. Then, any kind of georreferenced data can be included, depending on the kind of decision which will be made. The main problem is that there were not some important data. For example, for IUWM of Zaragoza, its water supply network was an important datum and it was

missed. The lack of important data regarding IUWM would make that SMURF did not improve the water management as expected.

Some other problems regarding burocracy issues or different scales of the data may be found while collecting the data.

7.1.2.2 Technical aspects

Many difficulties regarding technical aspects were found while adapting a SMURF decision-making tool to Zaragoza, as described in section 5.3.3.These might also appear when adapting SMURF to another area. Creating a detailed and visual manual, with many examples, might easily solve them. It must be born in mind that this manual would be used by non-expert users, probably without high skills on computing or GIS. It would also avoid the misunderstandings which may appear if emails were interchanged. A first draft of this manual might be the Annex A of this thesis – how to adapt a SMURF decision-making tool to a new set of data.

The SMURF tool is able to show the same information than a GIS software, but in an easier format for the non-expert users. It means a great advantage thinking in terms of economic resources, due to it is not needed all the stakeholders to have installed expensive GIS legal software. However, on the other hand, the necessity of compressing most of the background images to *.ecw format makes the adaptation of SMURF to a specific location more expensive than expected due to the free ecw compressors do not work as well as they should.

Finally, SMURF will be included in the SWITCH toolbox, a more powerful decision-making tool than SMURF itself.

7.1.2.3. Non-technical aspects

In order to maintain updated the database of a SMURF decision-making tool adapted to a specific location, some financial and human resources are needed. They are in good balance in terms of the benefits obtained by using SMURF.

Due to SMURF is not thought in terms of obtaining financial benefits, it is likely that the public administrations will carry out the maintenance of a SMURF tool adapted to an area. If that was the case, it is very important that the real contributions of the SMURF are clearly presented due to, at least, in Spain, the human resources within the public administrations are scarce. Thus, there is no money to hire more people unless there is a good reason and clear benefits for doing it.

7.1.3. Survey

The survey, developed along the current thesis, gave a general idea about the strong and weak points of SMURF and S-City VT, from a user's point of view. All it results in feedbacks for their developers.

The survey was quite long to answer due to the people who answered it had to use a bit the two visualization tools before. This time issue and that the survey had to be done inside the university, because of the laptop was there, made difficult to find volunteers easily. If there had been more time available more people had participated in doing the survey and the results would be more reliable.

Finally, the survey could have been improved in some points. As explained in the discussion, some questions should have been stated in a better way, other should have been in other positions and other could have been included to get more exact information about certain issues. These modifications would have slightly changed the information and results obtained.

7.2. RECOMMENDATIONS

This chapter shows the recommendations that the author of the current MSc thesis suggests in order to improve the SMURF and the S-City VT tools. There are also some recommendations about some possible further work.

7.2.1. General

First of all, in this section, some common recommendations for SMURF and S-City VT are given.

7.2.1.1. Internet

SMURF and S-City VT should be available on the Internet. For spreading their use quickly and easily, the following issues – in the order shown - should be taken into account:

1. The tool is free.
2. The benefits of using it are clearly explained on the main page.
3. There is a clear manual.
4. There is a developer contact number or email for more information.

Moreover, a forum, where different aspects about the tools could be discussed, would be a good idea. Any doubt, which may appear about the adaptation of SMURF or S-City VT to other areas, may be solved easily.

The SMURF and S-City VT decision-making tools adapted to a specific location should also be available on the Internet, if possible. By this way, different stakeholders, including the general public, may easily participate in the decision-making processes.

7.2.1.2. Manual and explanations

Once SMURF and S-City VT have been totally developed, a manual, in different languages, about how to use them would be very useful. It should be visual and with many examples in order to everybody understands it easily. It would show all the possibilities that the different software offer, from those commands or options which are very intuitive to those which are not.

An introductory screen may also appear immediately when the software is booted. It should contain a brief introduction about the software and later a brief trial explaining how to use it. The option of skipping these explanations should be included.

Moreover, a complete help command would be useful to solve any doubt which may appear during the manipulation of the tools. It should include information about the software itself, what every command is about, how to use the commands, information about the different indicators, etc. In the case of SMURF, there was already one, but it did not have too much information, by the realization of this thesis. The help command should also be available in as many languages as possible.

Some live training, in groups, would help in understanding the different tools and how to use them properly.

7.2.1.3. Languages

SMURF and S-City VT should be translated into as many languages as possible in order to spread their use easily and quickly. It includes all the commands and files, including the help file. Some languages to have under consideration would be English, French, Spanish and Chinese; they are spoken by a large number of people in the world.

SMURF was already in three languages: French, English and Creole, but not all their commands and files were translated, by the realization of this thesis. Also, the language by default was French instead of English, a more international language. Thus, it would be better that the default language was English.

In order to people could easily identify the possibility of changing the language some small flags could be added in the main window. These flags should coincide with the most representative country of that language they represent.

7.2.1.4. Search command

A search command may be added. I would be helpful to find easily any specific area or feature included in the tools. People may use this command to find important points for them, which would facilitate their orientation in the area.

7.2.1.5. Indicators

The indicators of SMURF and S-City VT are easily understood by everybody due to they are simple ones. That is the main idea, but these tools may also have some indicators a bit more complicated with some explanations. By this way, some experts or very curious people may have more detailed information about the area the tools are adapted to.

SMURF and S-City VT should be able to show two or more indicators at the same time. By this way, the spatial relationships would be easier to identify. Creating indicators "layers" with different symbols and grades of transparency would help to achieve this purpose. By this way, showing the same indicator at two points in time at the same time should also be considered.

7.2.2 SMURF

This section describes some recommendations for improving the SMURF tool.

The mini-map, in the top left corner of the map, may be improved by making it more active. It means to add the possibility of moving the red quadrangle within the mini-map for making the navigation easier. Moreover, the mini-map should include different extent files, changing automatically from one to another depending on the area which is being studied.

Regarding the indicators of SMURF, others may be included. Among them, some fixed indicators might be included in order to allow the benchmarking between different cities

or areas; although it means the flexibility of SMURF in terms of data needed would be reduced. Different indicators may be thought for the developed countries and the developing ones. Moreover, the possibility of showing more punctual indicators should be considered.

The background layers of SMURF should include the option of several grades of transparency. It would make possible the visualization of more than one background image at the same time, mixing, for example, ortophotos with simple relief images.

The colour scheme may be also upgraded in order to make the SMURF software more attractive to the new users.

Finally, the option of saving the images of the indicators may be improved by adding the legends in the image. Without the legends, they are not very useful for making a decision, although they offer a general idea of the situation due to by intuition the lightest colours are identified with the lowest values and vice versa.

7.2.3. S-City VT

This section shows some recommendations for improving the S-City VT tool. It must be born in mind that S-City VT was in the first stages of its development, by the realization of the current thesis, and many issues had to be decided.

S-City VT starts with the design view as its default window. It does not seem really attractive, at first sight, to the users. It would be more interesting to set the 3D view as the default window. It may show the whole area or only a part of it, in a bigger size, in order to people feels curiosity of seeing more by navigating though it. The image should not be too big neither because if not people could not identify they are looking at some kind of 3D simulation.

The identification of the two modes does not seem clear, at first sight, due to the people who answered the survey did not find the 3D view until they were asked about it.

Making the flaps, which show each mode, more eye-catching would help. They may be in some colour, with bigger and bold font.

S-City is thought in terms of assisting with new developments. It should show the area of development and its close surroundings. That would make easier the orientation in the area which will be developed.

Regarding the design view, some difficulties appear when placing a feature in a specific location. This aspect should be improved and if that is not possible, at least, some explanations about how to do it properly should be given through a help command or similar.
Some people found difficulties in identifying the features of the design view with the same ones in the 3D view. In order to make easier the orientation, it would be nice that the feature selected on the design view appeared selected also in the 3D view. Or, if possible, by some command, for example, by pressing CTRL in the keyboard and at the same time making click on a feature of the design view, S-City VT would automatically redirect you to the same feature in the 3D view.

As in the 3D view there is no legend, some times is difficult, by the moment, to identify the type of building. This same may happen with other features which are added to the simulation in the future. Displaying some pop-ups labels when the mouse is place over a building or other features would solve this problem. Some kind of information tool, similar to that one that SMURF has, would also be useful.

The way of navigating through the 3D view should be changed. It that is not possible, at least, it should be explained clearly how to use the mouse properly. Only those who were used to play video games found the use of the mouse easy, the others found it quite difficult.

Regarding the indicators part, the first thing to bear in mind is that S-City VT had only one indicator – the building's energy consumption -, by the realization of the current thesis. That is not enough for making decisions, and, without doubt, more indicators should be included. These should be economic, social and environmental indicators.

People easily understood the energy consumption indicator of S-City VT. However, some changes would improve its understanding. First of all, the name of the command that shows the indicator - carbon model - should be changed. Nobody identified the carbon model command with the energy consumption indicator till they read some questions, in the survey, about the energy consumption of the buildings. An easier name, such as building's energy consumption, would be more straightforward. If the name was not changed, a pop-up label appearing when the mouse is place over this command would also solve this problem. This label should have clear information about what the command is about.

The legend of the indicator is not easily understood. The legend is "divided" in two parts: the sustainability bar and sustainability triangle. The sustainability bar is more or less understood, but the words "low sustainability" and "high sustainability" seem to mix the people up because the colours used for the indicator are quite intuitive. In fact, if these concepts were maintain, maybe the legend would be clearer if the bar was in the other way, the "low sustainability" down and the "high sustainability " up. Also, more ranges, including the units, may be considered; creating similar legends to those used for the indicators in SMURF. The sustainability triangle is not understood at all and some kind of explanations would be needed if it was not erased. Moreover, the legend does not appear automatically with the indicator, it must be "open". It would better if it appeared automatically at the same time than the indicator. Including the option of closing or minimizing the legend is a good idea.

The time control should have higher resolution. By this way, the differences between the day and the night of the building's energy consumption, or other significant indicator, may be shown. Information in more detail would mislead the people instead of given them a general idea of the real world situation; and S-City VT would not fulfil its objective.

Moreover, an indicator about the total energy consumption in the area could be added. By this way, some easy comparisons between different scenarios may be made. This "total indicator" may be created for more than one indicator.

When making some kind of decisions, for example, in relation to IUWM, it would be interesting that S-City VT showed some information about the underground level, such as the water supply network.

If S-City added much more tools that it already has, a toolbar would be helpful. It should have the tools more used and be in a visible and accessible place in the main window.

Finally, S-City VT should add the option of saving different images or scenarios in order to be able to compare them later, if needed.

7.2.4. Further research

Another master student, with high knowledge on GIS, may complete the adaptation of a SMURF decision-making tool to the municipality of Zaragoza. He may develop the indicators functionality and improve the data view mode, including those data which were not available, by the realization of the current thesis. He could also create a special menu for the Actur's neighbourhood, the study area of the SWITCH project in Zaragoza. Later, the adapted SMURF tool may be used in the municipality of Zaragoza to improve its urban water management.

Some study may be done in relation to the difficulty of adapting S-City VT to another area. This should be done once S-City VT is more developed or almost finished. Some aspects to analyse would be: the data needed, the data flexibility, the time consuming, the indicators which could be shown, etc.

Finally, regarding the survey, one similar may be carried out once the software have been improved. By this way, the results obtained may be compared with those gathered for this thesis. Also, some comparisons may be done in relation to whether there are differences between the answers of people related with environmental issues, computing, etc. On the other hand, some more specific surveys may be developed in order to get valuable feedback regarding some important issues, such as indicators.

With shorter surveys, it would be easier to get volunteers to do them. Moreover, the time spent to do some tasks may be measure in order to evaluate objectively whether they are easy; asking about whether something is easy or not is quite subjective.

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Annex A

How to adapt a SMURF decision-making tool to a new set of data (based on Soutter (2007))[8]

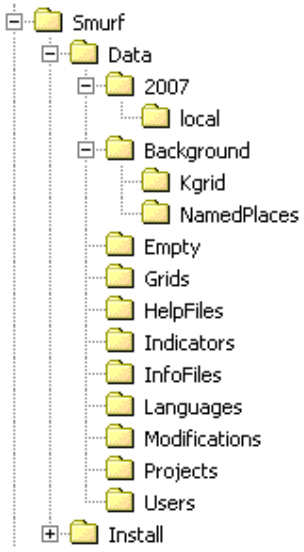
TABLE OF CONTENTS

1. THE SMURF FOLDER

First of all, the best is to describe what it is found in smurf folder when it is opened. In this section only a rough description will be given and in the following ones the different issues will be explained in more detail.

When empty_smurf.exe is executed, the following adequate empty folder is created:

[8] This manual is basically focused on the steps for creating the minimum requirements needed to start SMURF and for creating the "data view" mode.



The different folders within this structure are:

- **Smurf.** Contains the data folder, the "How to smurf" manual (at the moment it is like that), the *.smu parameter file and the executable smurf.exe.

- **Data.** Contains the topics.csv file and various folders where the data will be stored. The first time SMURF is run, a Tree.dat file is automatically generated and it will be also stored in this folder.

- **2007.** Contains the data files for the year 2007, (time management is deactivated at the moment). It means that for each layer specified in topics.csv file the three " Esri" files (*.shp, *.shx and *.dbf) will appear in this folder. The local folder is aimed to store user added or created specific layers.

- **Background.** Contains the folders that contain the various background images (or shapes).

- **Empty.** It is similar to the 2007 folder and it contains the "Esri" files (*.shp, *.shx and *.dbf) for layers, which were also specified in topics.csv file, that don't have data yet, but for which the structure (fields) has been decided.

- **Grids.** Hosts the predefined grids (for the moment sets of square polygons in a shp layer)

- **Helpfiles.** Contains the help file(s) and possibly a file called about.png containing an addition to the standard 'about' image (an example is given in the OpenOffice Dra. File about.odg where the back rectangle represents the available space. The objects have to be selected and exported in png format with no compression).

- **Indicators.** Basically contains two source files, Indic.csv and indicComp.csv and an Indic.dat file that is created on the basis of Indic.csv. If the Indic.dat file is present, it will be used to populate the default indicators lists. If not, Indic.dat will be created from indic.csv. If none of those two files are present, the indicator part will be deactivated.

- **Infofiles.** They are information files. There should be one for each layer in the 2007 data folder. They are used to access the real meaning of the field shortcuts; usually the characteristics linked to the attributes of a layer are written down with shortcuts and sometimes it is not easy to understand their meaning if it is not explained somewhere, that is why these infofiles exist. If not present the shortcuts will be used directly.

- **Languages.** Contain the translation into other languages. Nowadays it is possible to have the software in English, French and Creole. This folder must be improved since everything is not yet translatable and more languages are needed.

- **Modifications.** Contains the files hosting the proposed changes in the data, which later will have to be validated by the GIS database manager.

- **Projects.** Host the Project database, i.e. it contains the new layer, which have data that are not related to any attribute that already exist in other layer. Later,

the GIS database manager must validate these layers to become part of the general GIS database.

- **Users.** Contains an ASCII file with the user data.

- **Install.** This folder contains a template script to create a set-up file for the new SMURF tool using the inno setup software. The XXX sequences have to be adapted (by a localization name such as the city or area for which the tool is adapted) and changing the relative pathways (starting with ..\) to full pathnames. Better test the setup before distribution

2. MINIMUM REQUIREMENTS

Once empty_smurf.exe file has been executed, the programme will not run unless some minimum requirements be created first. These are:

7. Create the *.smu file.
8. Create the topics.csv file for the list of layers that will be stored in the smurf/data/2007 folder.
9. Include the *.shp, *.shx, and *.dbf files for at least one layer that appears in topics.csv file.
10. Create in the Data/Background folder a file that contains the polygon that defines the maximum extent of the visible window.
11. Create the BD_info.txt file.
12. Include a background image.

3. CREATE THE *.SMU FILE

The *.smu is a general 'ini' file. Some example of it can be found in smurf folder. The best is to take any of them and modify it according to the new data. Either, WordPad or Notepad can be used to do it.

How to create the *.smu file is basically explained through the *.smu file created for Zaragoza city and the sample.smu file, corresponding to Seychelles islands.

IMPORTANT: The lines starting with # are comments and the blank lines between sections have to be maintained.

a) Name of the smurf application

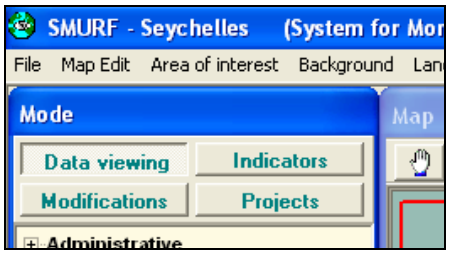
```
# Name
Zaragoza
```

Zaragoza must be changed for the name of the new smurf application (e.g. Lodz, Accra, etc), i.e. the name of the area for which SMURF decision tool is being adapted.

b) Modules

```
Modules
# Modules
4
Viewer
Indicators
Modifications
Projects
```

This must not be modified and must be included in the new *.smu file exactly like it appears here. It refers to the different commands that appear on the left in the screen display (See below).



c) Map Units

```
# Map units
2
```

Check in what units are your maps (GIS layers) and write here down 0 if they are undefined, 2 if they are meters and 3 if kilometres.

d) Zones and filename extensions.

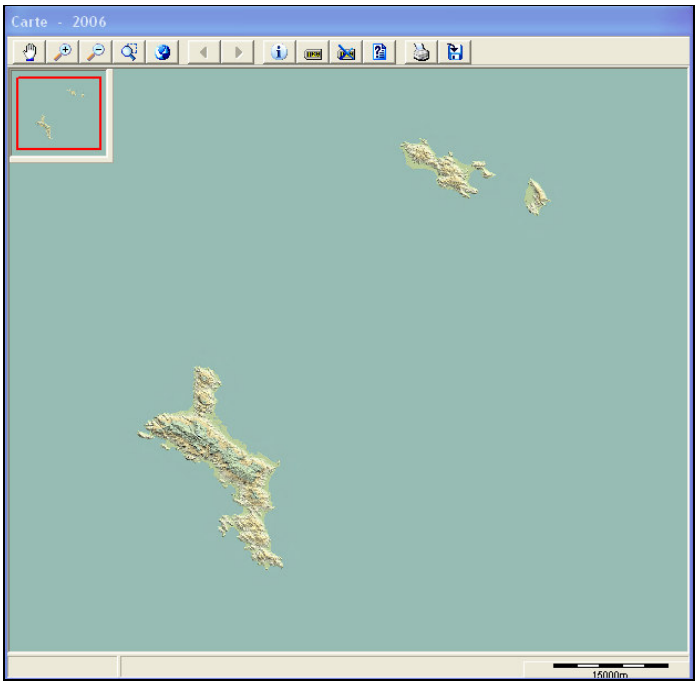
```
# Number of areas and filename extensions
1
```

This is the case of an area with just one zone, so no special filenames extensions are needed for the data filenames.

To understand this point a bit better, this section of the sample.smu file, found in smurf folder, is shown next.

```
# Nombre de zones et extensions du nom
3
_M Mahe
_P Praslin
_L La Digue
```

This *.smu file belongs to the SMURF decision tool developed for Seychelles Islands. In this case, the area to which SMURF is applied is composed of three islands – Mahe, Praslin and La Digue. (See below how this area looks like).



In the Seychelles case, the original data were split into separate files for each island. It means that for the same layer, there is a file for each one of the islands. For example, for the road layer, there is one road.shp file for each island.

The fact is that when a layer needs to be added to the map view, three shape files have to be added. For example, for road layer, road_M.shp, road_P.shp and road_L.shp files must be added. So, all this is indicated to SMURF software as explained next.

In the first line of this section, the number of zones that compose the total area must be indicated.

Then, there are specified the two characters extension that will correspond to each zone and will be added to the generic filename (also see Create the topic.csv file); followed by a gap and the name of the zone. There must be one line per zone according to the number declared in the first line.

NOTE: It could have been possible to merge these three files into a unique one and the filenames extension wouldn't have been needed. However, in this case, keeping the

independent files for each island, it is also achieved an easy and transparent data update process.

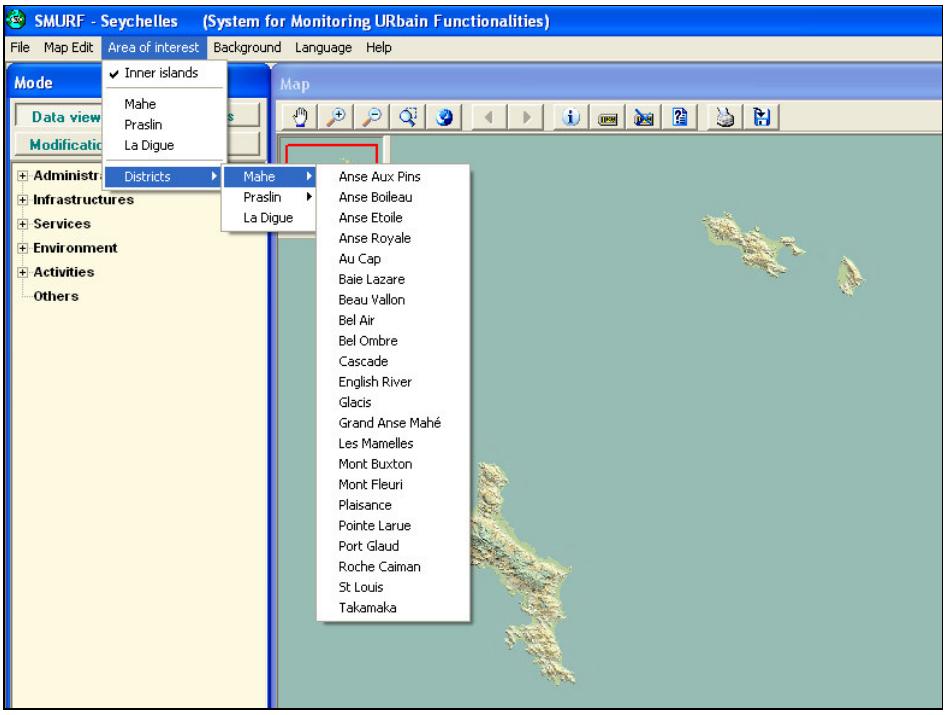
e) Specific menu to activate

```
# Specific Menu to be activated (number and names)
0
```

This would be the case of Zaragoza city, where no specific menu needs to be activated. The section of sample.smu file (found in smurf folder) corresponding to this part is again used here to clarify this point.

```
# Menus special à activer
1
_Zone_d'intéret
```

In the specific case of Seychelles Islands, when the SMURF decision tool was adapted, it was needed to differentiate clearly the diverse districts that existed. Each district administration is mainly interested on its own district. So, a Seychelles's specific menu, called 'Area of interest', was created. It contains the list of the districts. (See below how this specific menu for Seychelles islands looks like)



Then, in the first line, the number of specific menus created for the area must be written down (0 if none).

The second line is used to specify the names of the specific menus. One line per specific menu item according to what was specified in the first line.

NOTE: For some areas, like Zaragoza city (see above), this menu would be meaningless and is disabled; however for another areas other site-specific menus might be needed.

f) Languages to use

```
# Number of languages, Titles & files (xx.lng), default language
1
English,en
1
```

The first line corresponds to the number of languages.

Then, one line will be used for each language. In each of these, the name of the language must be specify followed by "," and the two letters of the prefix of the related language file. These languages will appear in the language menu in the same order than they are in this list, so it is better to have them in alphabetical order.

IMPORTANT: The same order (in relation with languages) must be kept in all other files, such as topics.csv.

Finally, the last line refers to the position in the list of the language that will be the default language.

NOTE: For the moment, only English, French and Creole languages are available. The two letters of the prefixes used till now are 'en' for English, 'fr' for French and 'kr' for Creole. Needles to say, the languages files, for example en.lng, need to be included in

the Languages folder that is found in the smurf/Data folder. Moreover, the help file is only in French by the moment.

g) Background layers

```
# Number of backgrounds,names and folders, nb of the default
background, position of the first non-exclusive background
1
Provincial Limits,Provincial
1
1
```

The first line refers to the number of background layers among which it will be possible to choose when SMURF is running. For the moment, the number of background layers is limited to 4, without taking into account those layers (with *.shp extension) that can be stored in named places and grid folders, that are already stored within the smurf/Data/Background folder.

The following lines specify the names of the different backgrounds layers and the name of the folders in which these layers will be stored within the smurf/Data/Background folder. In this example, only one background image exists, but there must be so many lines as background layers are included in smurf/Data/Background folder.

IMPORTANT: The background layers can be images, which have to be compressed to *.ecw format before including them in SMURF, or shapes files. Some tricks must be done when deciding the names of the different layers that will compose a background layer in SMURF due to they are shown in alphabetical order (a background layer of SMURF can be formed by more than one layer or image).

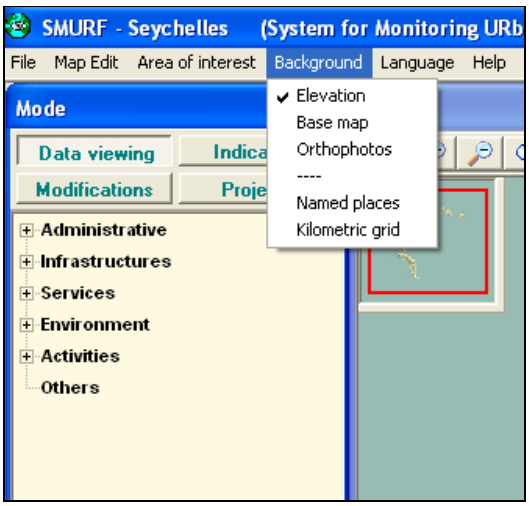
IMPORTANT: The names of the background layer must be written down in so many languages as it was specify in the 'Languages to use' section. For better understanding, find below the 'Background layers' section of sample.smu file developed for Seychelles Islands (found in smurf folder).

```
# Number of backgrounds,names and folders, nb of the default
background, position of the first non-exclusive background
4
Relief,Elevation,Kart relief,Relief
Carte de base,Base map,kart baz,Base
Orthophotos,Orthophotos,Ortofoto,Orthophotos
OrthophotosHR,OrthophotosHR,OrtofotoHR,OrthophotosHR
1
1
```

As seen in 2nd, 3rd and 4th lines, the names of the backgrounds layers are in French, English and Creole, as it was specify in the 'Language to use' section of its corresponding *.smu file. It means the same order of the languages that was used in that section must be used now here. The last word of each line refers to the subfolder in which each background layer will be stored within smurf/Data/Background folder.

NOTE: The names of the backgrounds layers, in the different languages (in the same order that they appear in the Languages section of the *.smu file), must be separated using commas. As well as the subfolder must be separated from the names of the background layers by comma, with no gaps in between.

The names included in this section for the background layers will be the names displayed when the Background menu is activated (See image below)



The next line in which a number appears shows the default layer that is used at start-up. This number will be specified taking into account that the first background layer (the above one) is considered the number 1. If only one background layer exist, then 1 must be written down here.

NOTE: It must be taken in mind that the best background layer used as default should not be too time consuming, i.e. not be an image with large memory. Otherwise, at each start up of Smurf a certain amount of time would be spent on loading this background layer (image), which is not necessarily useful and not very user friendly.

The last line of this section refers to the layer position from which the layer activation is no more exclusive. The idea here is that the background layers might be "non cumulative layer"(excluding each other, i.e. when you add one background layer you take the other ones away) and "cumulative layers" (those ones that can be switched on at the same time). So, the number here indicates the first "cumulative" layer in the list above. For example, if this number is set to 3 (when there are 3 or more background layers), then activating any of the two first background layers will hide the other ones whereas activating the 3rd and following layers will simply switch them on and off.

NOTE: In the future, this part will change since transparency levels for the background layers will be added in a next version of Smurf.

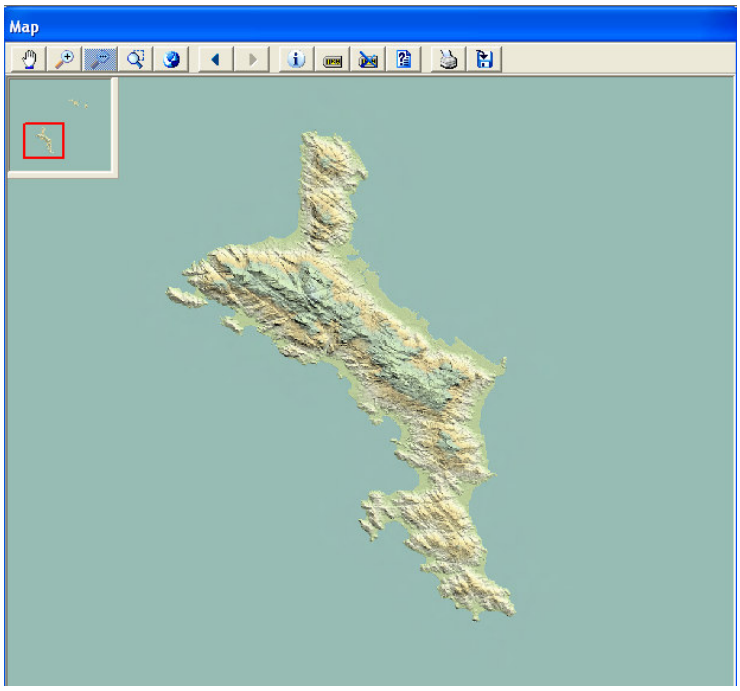
NOTE: The minimum requirement to be able to run SMURF software is just one background layer.

IMPORTANT: Any georeferenced image that is included in the Background folder has to be compressed in ECW format. Free compression software can be found in the following websites: www.ermapper.com or www.advisory-unit.org.uk/AU_ECW_Compressir/AU_ECW.html. On the other hand, a 300 dollar GIS software, called Manifold, found in www.manifold.net, can be used to produce ECW compressed georeferenced images. Moreover, it is not needed to store the images themselves in smurf/Data/Background folder, it is also possible to store symbolic links (*.lnk files) to ecw images that are stored somewhere else.

h) Layers to be added in the mini-map

```
# Number of layers in the mini-map and relative paths
1
Background\Provincial\Extent.ecw
```

The mini-map is the small map that appears at the top left corner of the map window. When it is zoomed around in the 'real' map, a red rectangle in the mini-map shows where the zone is actually located inside the total area. (See the image below)



The first line indicates the number of layers that will be displayed in the mini-map.

The second one refers to the layers relative path. It is written only the part of the path that would appear after -/smurf/Data, i.e. if the real layer path is -/Data/Background/Provincial /Entent.ecw only Background/Provincial /Entent.ecw will be written in this line.

If the mini-map is formed b more than one layer, there should be one line per layer. Nowadays, some ticks must be done with the name of the different layers due to they are shown in alphabetical order.

IMPORTANT: The layers that will be displayed in the mini-map can be in .ecw or .shp format.

i) Indicators

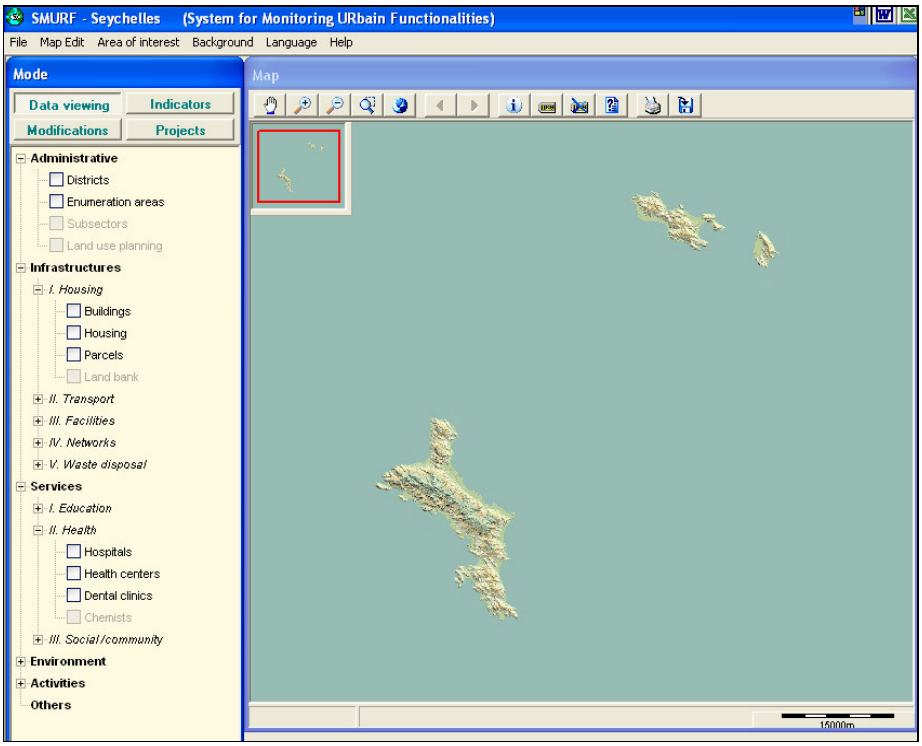
```
# Indicators : default source (can be 'none')
none
# number of aggregation relations and components
```

If no indicators exist, then this section should look like shown above.

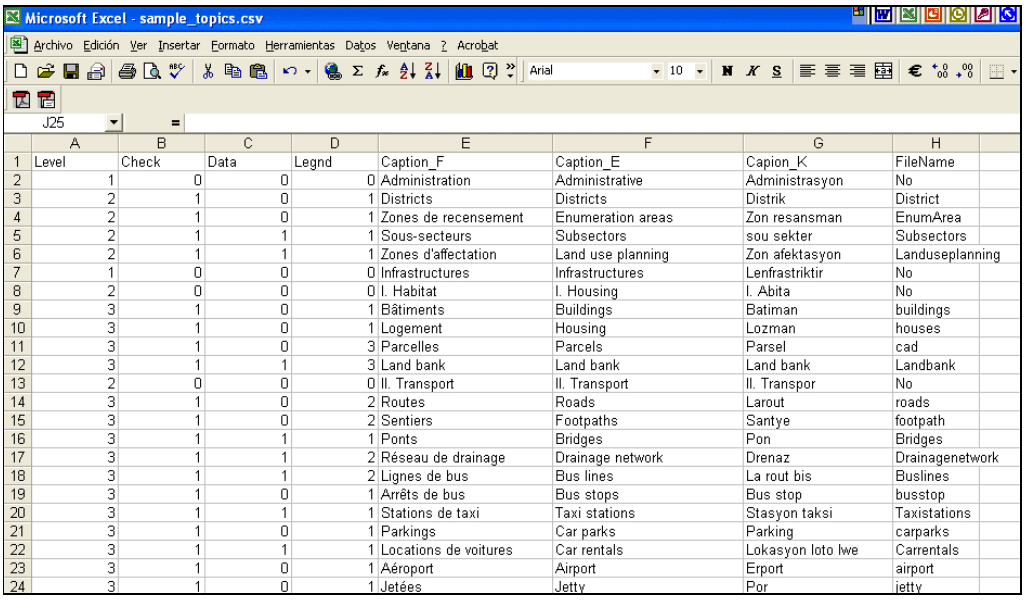
IMPORTANT: Once the new *.smu file is created, it is needed to delete any other *.smu files that exist in smurf folder.

4. CREATE THE TOPICS.CSV FILE

Topics.csv file is used to set up the GIS layers' tree-view. It is the "hierarchy tree" that appears on the left when smurf is run. (See image below)



The easiest way to create the topics.csv file is to prepare a spreadsheet, using OpenOffice Calc or Excel, with a first line for the column names and then a line for each layer as shown below (this is the spreadsheet prepared for Seychelles Islands):



Microsoft Excel - sample_topics.csv

	A	B	C	D	E	F	G	H
1	Level	Check	Data	Legnd	Caption_F	Caption_E	Capion_K	FileName
2	1	0	0	0	Administration	Administrative	Administrasyon	No
3	2	1	0	1	Districts	Districts	Distrik	District
4	2	1	0	1	Zones de recensement	Enumeration areas	Zon resansman	EnumArea
5	2	1	1	1	Sous-secteurs	Subsectors	sou sekter	Subsectors
6	2	1	1	1	Zones d'affectation	Land use planning	Zon afektasyon	Landuseplanning
7	1	0	0	0	Infrastructures	Infrastructures	Lenfrastriktir	No
8	2	0	0	0	I. Habitat	I. Housing	I. Abita	No
9	3	1	0	1	Bâtiments	Buildings	Batiman	buildings
10	3	1	0	1	Logement	Housing	Lozman	houses
11	3	1	0	3	Parcelles	Parcels	Parsel	cad
12	3	1	1	3	Land bank	Land bank	Land bank	Landbank
13	2	0	0	0	II. Transport	II. Transport	II. Transpor	No
14	3	1	0	2	Routes	Roads	Larout	roads
15	3	1	0	2	Sentiers	Footpaths	Santye	footpath
16	3	1	1	1	Ponts	Bridges	Pon	Bridges
17	3	1	1	2	Réseau de drainage	Drainage network	Drenaz	Drainagenetwork
18	3	1	1	2	Lignes de bus	Bus lines	La rout bis	Buslines
19	3	1	0	1	Arrêts de bus	Bus stops	Bus stop	busstop
20	3	1	1	1	Stations de taxi	Taxi stations	Stasyon taksi	Taxistations
21	3	1	0	1	Parkings	Car parks	Parking	carparks
22	3	1	1	1	Locations de voitures	Car rentals	Lokasyon loto lwe	Carrentals
23	3	1	0	1	Aéroport	Airport	Erport	airport
24	3	1	0	1	Jetées	Jetty	Por	jetty

The topics spreadsheet must have the following columns: Level, Check, Data, Legend, Captions and Filename.

Level. This is the level in which it is wanted that the layer or title appear in the treeview. As you can check in the example provided two images up, in 'Data view' mode it is possible to see 'Administrative', 'Infrastructure', etc as level 1 items, "Housing", "Transport", etc as level 2 items and so forth. So, number 1 is for the top level and a maximum of 4 levels are possible.

IMPORTANT: The layers must me written down in order, as they will appear in the treeview later.

Check. This column sets whether the related item will have a checkbox or not. It the item relates to a data layer that can be shown in the map (even if these data are not yet available) then it needs a checkbox. If it is only a title in the hierarchical description of the data (such as "Administrative", "Housing", etc in the example above), then it should

not have a checkbox. So, those layers that can be shown in the map must have a 1 in the cell corresponding to this column and the other ones will have a 0.

Data. This refers to the availability of the data and where these will be stored. If there is a 0 for 'Check' column then this column will also have 0 indicating that this "layer" is only a title in the hierarchical description of the data. If "Check" column has a 1 (i.e. the data layer has a checkbox), two possibilities exist:

- 0 if the data layer is available. So, it will be 'checkable' and will appear in black in the treeview. Then, the files of this layer need to be stored in smurf/Data/2007 folder (later it will be explained how to do this).
- 1 if the data layer is not available for the moment. Although having a checkbox, this layer won't be checkable and will appear in grey in the treeview. Anyway, even it is an "empty" layer it must be stored in smurf/Data/Empty folder.

Legend. It doesn't really matter the value included in the cells corresponding to this column, however one value has to be there. One suggestion is to write down a 0 for the title items and 1 for the layers items.

Captions. It refers to the layer and item names in the treeview. They must be written exactly how the names will appear in the treeview when the "Data View" mode is activated.

IMPORTANT: There must be one column for each language according to the number and sequence declared in the *.smu file.

Filename. The generic filename, without the extensions, that will be use for the layers when they be stored in 2007 and Empty folders. For example, if the full filename of a file is M_Districts.shp, in this field only Districts will be written down.

Once the excel file has been completed, it is necessary to save it as .csv file.

IMPORTANT: Open the new *.csv file with WordPad or Notebook and check that the separators between 'columns' are commas (,). If there are semicolons (;) instead of comas (,), just edit the *.csv file replacing all occurrences of semicolons (;) by commas (,) manually. Normally this error happens when Microsof Excel is used to create the *.csv file; however, if OpenOffice is used it doesn't happen.

IMPORTANT: Once the new topics.csv file is created, it is needed to delete any other sample_topics.csv files that exist in smurf /Data folder or any other place. This file always has to be called topics.csv, not Zaragoza_topics.csv or any other similar.

IMPORTANT: Whenever the topics.csv file needs to be changed, the Tree.dat file (if exists) must be deleted first.

5. INCLUDE THE *.SHP, *.SHX AND *.DBF FILES IN THE 2007 AND EMPTY FOLDERS.

Although the minimum requirement to run smurf is to include the *.shp, *.shx and *.dbf files for at least one layer that appears in topics.csv file, the truth is that the same must be done for each layer. Some small differences exist between those layers that will be stored in smurf/Data/2007 folder and those ones that will be in smurf/Data/Empty folder.

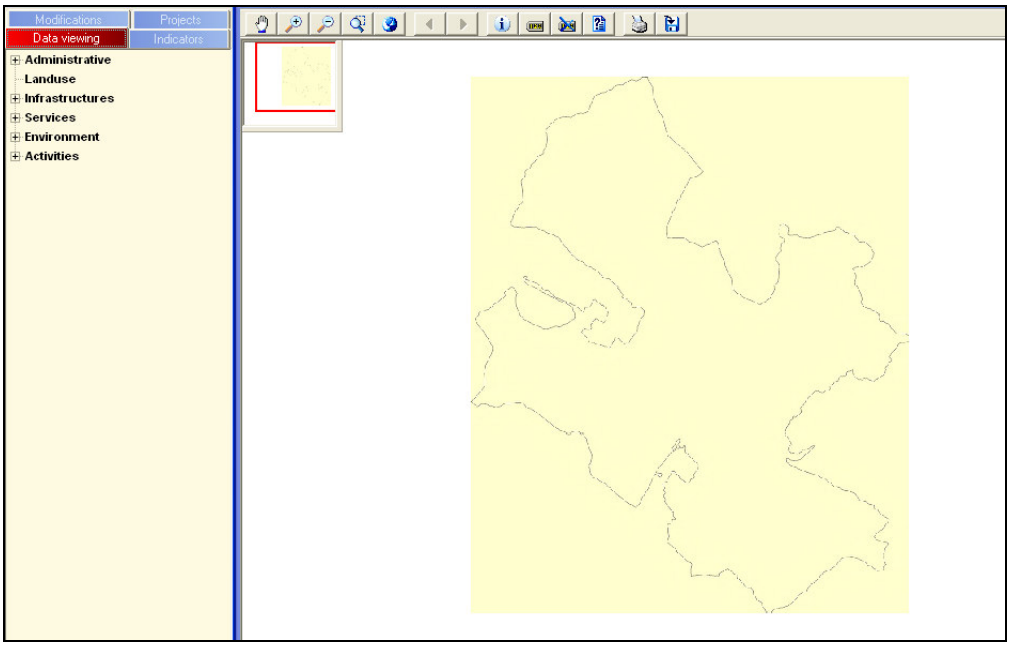
The layers that have 1 in the 'Check' column and a 0 in the 'Data' one, in the topics.csv file, must be stored in smurf/Data/2007 folder. The *.shp, *.shx and *.dbf files of each layer with these characteristics must be included here.

The layers that have 1 in the 'Check' column and 1 in 'Data' one, in the topics.csv file, must be stored in smurf/Data/Empty folder. These layers are felt as being necessary although there are no data available for the moment. Anyway, the *.shp, *.shx and *.dbf files of these layers must be included in the previous folder mentioned because they will be active in the 'Modification' mode. With ArcGIS or Manifold software it is possible

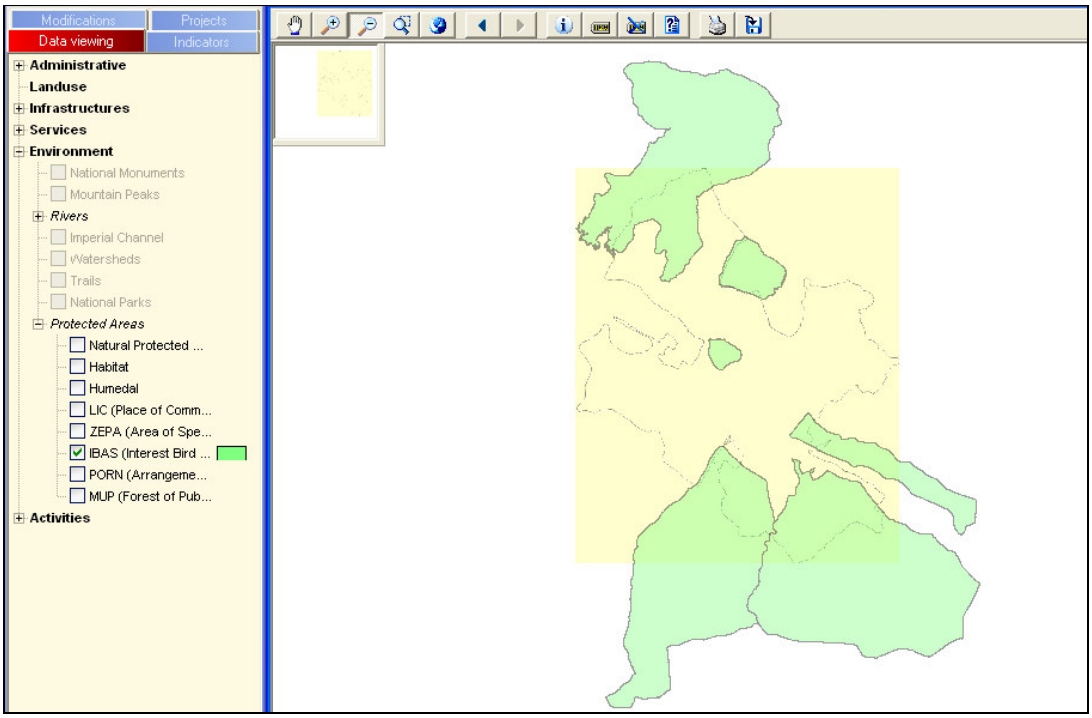
to create a new layer, define the objects attributes and save the file, with no features added. Alternatively, it is also possible to copy an existing layer, modify the attributes and delete the existing features to have an empty layer with the adequate structure.

6. CREATE THE EXTENT FILE.

This point refers to the creation of the file that will define the maximum extent of the visible window when smurf is started up. See below the default window for the SMURF decision-making tool adapted to Zaragoza.



It does not mean that it is the maximum extent of the window at any moment. If there is a bigger layer it can be seen using the 'Zoom out' tool. (See image below)



In smurf the extent of the default window is not given directly by coordinates, it is set by a shape file containing a rectangle that covers the entire are of interest. This shape file, created with ArcGIS or Manifold, might have many attributes, among which ones must be one titled “item” with a value of 1 for the default extent.

This file must be called extent and the *.shp, *.shx and *.dbf extensions of it must be stored in smurf/Data/Background folder.

7.CREATE THE BD_INFO.TXT FILE

A text file called BD_info.txt must be added in the smurf/Data/2007 folder. It is possible to write whatever is needed on it using any text editor (WordPad or similar) or word processor. It is supposed to hold information about the database status.

This file is meant to keep track of the changes made to the database. For example, if in two years from now there is an update of the layer showing the building in a city because the city is growing, a new building layer will be in a 2009 folder, but the older

version of this layer will be kept in the 2007 folder. So, this BD_info file should help to keep track of what has changed, who made the change, where the new data come from, etc. (Time management exists although it is deactivated for the moment because it has to be updated)

IMPORTANT: Even this file is empty by the moment, it must be there.

8. INCLUDE A BACKGROUND IMAGE.

It doesn't matter the name of the file that will be use as background, because the name that later will be displayed is that one that was specified in the *.smu file. Anyway, it must be also stored where it was specified in the *.smu file (see Create the *.smu file, part g) Background layers)

IMPORTANT: The background layers can be images, which have to be compressed to *.ecw format before including them in SMURF, or shapes files. Some tricks must be done when deciding the names of the different layers that will compose a background layer in SMURF due to they are shown in alphabetical order (a background layer of SMURF can be formed by more than one layer or image).

IMPORTANT: The *.shp.ini files contains the characteristics of the *shp file: colour, line, etc

NOTE: Two predefined folders already exist in smurf/Data/Background folder. These are to host the named places and the kilometric grid shape files. If these files are missing, then these functionalities will be deactivated.

IMPORTANT: Any georeferenced image that is included in the smurf/Data/Background folder has to be compressed in ECW format. Free compression software can be found in the following websites: www.ermapper.com or www.advisory-unit.org.uk/AU_ECW_Compressir/AU_ECW.html. On the other

hand, a 300 dollar GIS software, called Manifold, found in www.manifold.net, can be used to produce ECW compressed georeferenced images. Moreover, it is not needed to store the images themselves in this folder, it is also possible to store symbolic links (*.lnk files) to ecw images that are stored somewhere else.

Annex B

Background information about Zaragoza

B.1. THE CITY OF ZARAGOZA

Zaragoza is the capital city of the autonomous region of Aragon and covers an area of approximately 1,058 km2 (Wikipedia). It is situated in the north-east of Spain, in the middle of the River Ebro Catchment, the most plentiful river in Spain. The city is located at the confluence of two tributaries of the River Ebro, the Gállego and the Huerva and the Imperial Channel of Aragon.

Its geographical situation is exceptional in terms of communication since it is centrally located between the four most important cities in Spain – Madrid, Barcelona, Valencia and Bilbao.

Figure B.1: Zaragoza's city location (Source: Google Earth).

Figure B.2: City of Zaragoza (Source: Google Earth).

Zaragoza has a mediterranean-continental climate, with and average temperature of 15ºC (National Institute of Meteorology). "The Ebro River Valley at Zaragoza is a semiarid region with an average annual precipitation of 367 mm concentrated in 67 days, ranking as the driest inland region in Europe" (Penagos, 2007). Moreover,

according to the National Institute of Meteorology, the average velocity of the wind in Zaragoza is of 19km/h.

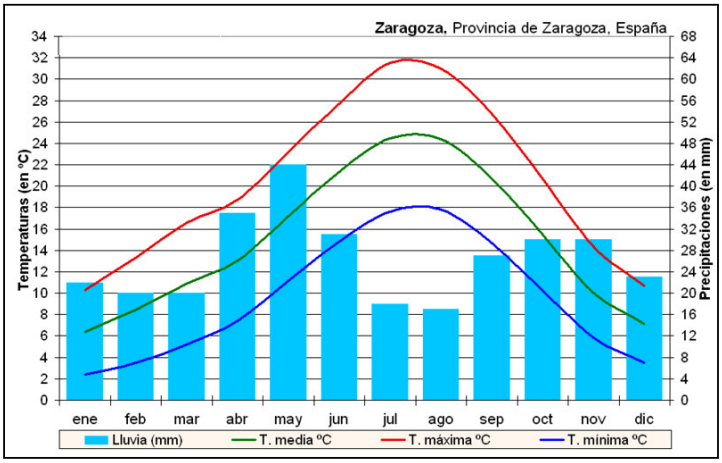


Figure B.3: Climate of Zaragoza based on data from the Spanish National Institute of Meteorology (1971–2000) (Source: http:// es.wikipedia.org/wiki/Zaragoza; temperaturas: temperature, precipitaciones: rainfall, lluvia: rainfall, T. media: average temperature, T.máxima: maximum temperature , T. mínima: minimum temperature).

Zaragoza ranks as the fifth most populated city of Spain, having 649,181 inhabitants (1st January 2006) (INE). As many any other cities in Europe and around the world, its population has experienced a big increased since last century, as shown in figure B.4.

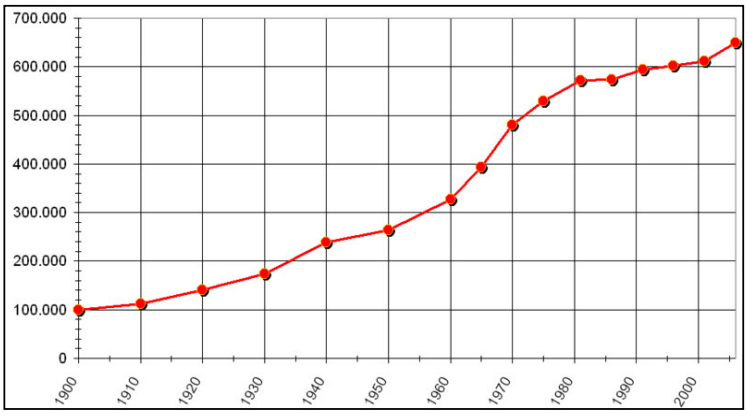


Figure B.4 : Population growth based on data from the Spanish National Institute of Statistics (1900-2006) (Source: http://es.wikipedia.org/wiki/Zaragoza).

In relation with water issues, the responsible for water planning and management in the city is the municipality of Zaragoza. It is in charge of drinking water supply, sewer

system and wastewater treatment plants. It means that many different departments contribute to water management in the city; among them the following are found: Local Agenda 21-Environmental Department, Infrastructure Department, Tributary Management Department, etc.

Zaragoza has a higher environmental awareness about water issues than most Spanish cities. Thus, considerable efforts have been carried out during last decade to improve water management, focused specially on reducing water demand. The following are the more significant:

- A project called "Zaragoza, water saving city", promoted by the NGO Ecology and Development and approved by LIFE program of the EU, started in 1997. It consisted of a serie of educational programs which promoted to reduce water demand at households and industries by improving consumption habits and using water saving devices. One of its phases, called "50 good practical actions for urban water use" in public spaces, industry and the commercial sector, got really good results due to the active participation of Zaragoza's population, who have a relatively high environmental awareness. Due to the success of this phase in relation with water saving it was selected by Habitat UN as one of the 100 successful projects concerning urban sustainability worldwide in 2005.

- In 2000, a project which aimed to change the main source for potable water source from the River Ebro, specifically from the Imperial Channel of Aragon, to the River Aragon was approved. The objective was to build the "Yesa" reservoir in the Pyrenees, and bring the water from it to the city due to the water quality in this point is more suitable for human consumption than in Rio Ebro, where the water salinity is quite high. It is possible that the use of "Yesa" reservoir will begin before the year 2007 finishes due to almost all the infrastructure is ready and only some administrative authorizations are left (Zaragoza. Agenda 21 Local, 2007).

- In the year 2002, a seven years project was started to improve supply in Zaragoza. It focuses on three aspects: upgrading the drinking water treatment plant at Casablanca, repairing or eliminating existing tanks and break pressure

tanks and replacing a high percentage of the pipes of city due to their antiqueness and their deteriorated state.

- A project called OPTIMIZAGUA, within the EU LIFE program, which promotes water saving in garden watering started in 2003. It resulted in a water saving of 68% approximately (Aragón. Consejería de Turismo, Medio Ambiente y Política Territorial, 2006).

- A review of the water tariffs in the city of Zaragoza was carried out by the Economic Department of the University of Zaragoza in collaboration with the municipal Tributary Management Department. It resulted in a different and innovative water tariffs "in steps", in accordance to Water Directive Framework principles, for the city of Zaragoza. Nowadays, the Ministry of Environment wants to promote them at nation level (Zaragoza. Agenda 21 Local, 2007). Also a new water bill, which promotes water saving, has been implemented this year.

- The Commission 21 of Water was established in Zaragoza in 2001. It is a work team that involves different stakeholders related with water issues to discuss about any topic in relation when necessary. There are 29 members, including representatives from different municipal departments, labour unions, neighbours associations, etc., The Agenda 21 office holds the secretariat.

All the previous projects mentioned, among others, made possible to achieve in 2005 the objective that Zaragoza has set about reducing the total drinking water consumption to 70Hm3/inhabitant per year in 2007. The objective of reducing this drinking water consumption to 65Hm3/inhabitant per year for year 2010, has already been achieved in 2006. These water reductions have been achieved even during last years the population of the city has continued increasing. Nowadays, the domestic water consumption in Zaragoza is around 104l/inhabitant/day, far below from the Spanish average of approximately 176l/inhabitant/day. These data show the success of Zaragoza municipality in water demand management during last years.

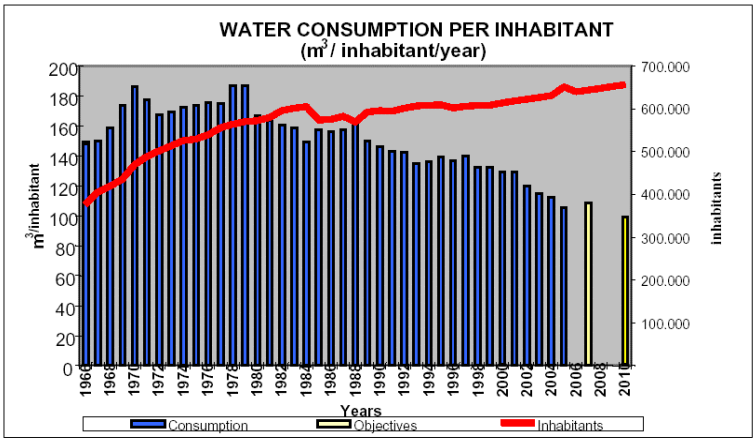


Figure B.5 : Water consumption in Zaragoza city (Source: Zaragoza. Agenda 21 Local, 2006).

The efforts that the Municipality of Zaragoza is making in relation with water issues will not stop here, new projects and lines of actions are being prepared as the following ones:

- The development of a water regulation about the efficient use of water. It will encourage improvements in households' water connections and the use of water saving devices in public buildings and new buildings. The regulation draft was approved in February, and it could be operational at the end of 2007 (Zaragoza. Agenda 21 Local, 2007).

- Following the successful project about "50 good practical actions for urban water used", now it is being tried to achieve 100.000 civic commitments for sustainable water use. In April of 2007, 50.000 commitments had already been achieved (Zaragoza. Agenda 21 Local, 2007).

- Collaboration with the SWITCH project in terms of demand management for optimisation of urban water services. It will be one of the nine demonstration cities within this project.

Finally, to point out that the International Exposition of 2008, which is specially focused on water aspects and sustainable development, will take place in Zaragoza between 14th June and 14th September.

B.2. LOCAL URBAN WATER SUSTAINABLE DEVELOPMENT INDICATORS

This MSc thesis is framed around issues in the municipality of Zaragoza. It is important to note that, according to the Local Agenda 21 of Zaragoza Municipality (Zaragoza. Servicio de Medio Ambiente - Unidad de medio ambiente, 2002), the main objectives of the sustainable development indicators developed in Zaragoza are the evaluation, measurement and implementation of the predicted actions needed for the achievement of the goals established in the process of Local Agenda 21:

- Public awareness and education in topics related with environment and sustainable development.
- Public access to environmental information.
- Public participation.
- Collaboration with NGOs, companies, etc.
- Measurement, monitoring and preparation of reports about the sustainability progress.

The municipality of Zaragoza has the ten Indicators of Sustainability defined by the OECD (Organization for Economic Co-operation and Development), under the initiative "Towards a profile of local Sustainability. European Common Indicators". Also, 25 Specific Local Indicators have been developed, among which water sustainability indicators are included.

The five water sustainable development indicators which the municipality of Zaragoza use, show appropriate tendencies, highlighting the important and continuous reduction of water consumption. The last update of these indicators, which are available for general public, was the 31st December (Oficina de Agenda 21 Local del Ayuntamiento de Zaragoza, 2006). A brief description of these water indicators follows.

Ag 1. Aptitude of public water supply

The aim of this indicator is to have water suitable for human consumption in the urban water supply network. It has been measured annually for the last three years.

The suitability of the water for consumption is evaluated at the outlet of the Casablanca drinking water treatment plant. This indicator is expressed in terms of percentage of its physic-chemical quality (in grey) and its microbiological quality (in khaki), as shown in figure B.6.

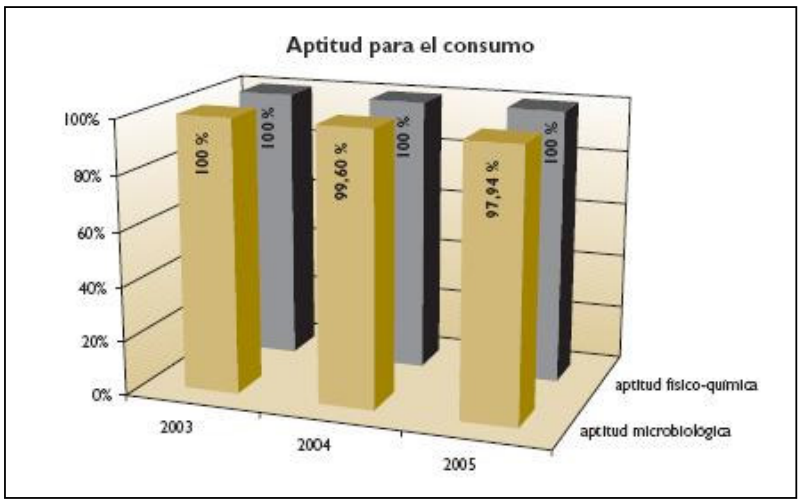


Figure B.6: Indicator Ag1. Aptitude of public water supply (Source: Oficina de Agenda 21 Local del Ayuntamiento de Zaragoza, 2006; aptitud fisico-quimica: physic-chemical quality, aptitud microbiológica: microbiological quality).

The goal that this indicator is required for is the improvement of drinking water quality, the reduction of its inappropriate use and the encouragement of its study.

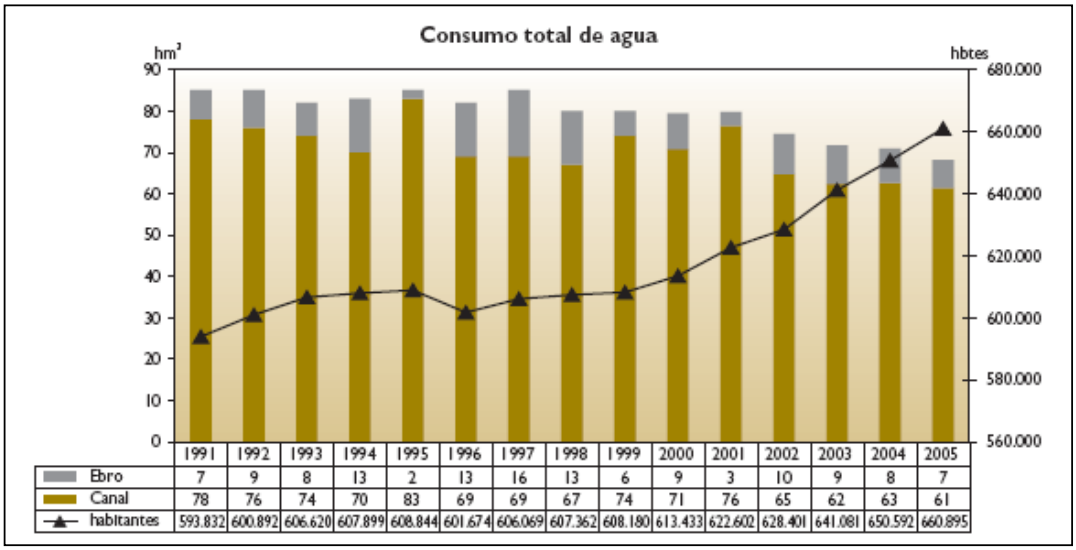
Ag1 has been defined as close as possible to the water quality indicators developed by the International Water Association (IWA), although in this case potable parameters are not taken into account.

Values of Ag1 follow an increasing trend, which is desirable.

Ag2. Total consumption of water

The aim of this indicator is to improve the efficiency of water consumption. It has been assessed annually since 1991.

Ag2 measures the quantity of inflow to the Casablanca drinking water treatment plant. Values are shown in figure B.7, the two main water catchments, Imperial Channel of Aragon (in grey) and the River Ebro (in khaki) are clearly identified. The black line represents the population of the municipality of Zaragoza.



	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Ebro	7	9	8	13	2	13	16	13	6	9	3	10	9	8	7
Canal	78	76	74	70	83	69	69	67	74	71	76	65	62	63	61
habitantes	593.832	600.892	606.620	607.899	608.844	601.674	606.069	607.362	608.180	613.433	622.602	628.401	641.081	650.592	660.895

Figure B.7: Indicator Ag2. Total consumption of water (Source: Oficina de Agenda 21 Local del Ayuntamiento de Zaragoza, 2006; canal: channel, hbtes=habitantes: inhabitants).

The goals which require Ag2 to be measured are the same as for the indicator Ag 1, i.e. the improvement of drinking water quality, the reduction of its inappropriate use and the encouragement of its study.

This indicator has three sub-indicators:

- Ag 2.1. Water supply distribution by activity sectors
- Ag 2.2. Efficiency of the water supply network
- Ag 2.3. Satisfaction of consumers

This indicator has diminished over the time as desired. This is due to improvements carried out on the water supply network and in the drinking water treatment plant. The campaign "Efficient use of water" has increased the public awareness in relation to water issues and this has also assisted in reducing Ag2.

As seen in figure B.5 (Annex B.1)and in figure B.7, the per capita water consumption has decreased considerably since 1991, to an average water consumption of 104 litres/inhabitant/day in the municipality of Zaragoza. This is far below from Spanish average of 176 litres/inhabitant/year.

Ag3. Water inflows to EDAR trough the net of municipal collectors.

The purpose of Ag3 is to limit the water flows to be treated in the EDAR (Spanish abbreviation of wastewater treatment plant). The indicator has been measured annually since 1996.

Ag3 compares the amount of water annually received by the EDAR with the pollutant concentration expressed as biochemical oxygen demand (BOD). The khaki lines in figure B.8 represent the flow and the black lines represents the concentration expressed in BOD. Two plots are required since there are two EDARs in Zaragoza, "La Cartuja", the largest, and "Almozara".

The goal that Ag3 follows is to encourage the reduction of the supply of water and wastewater. It has a sub-indicator: Ag3.1, the connection of the municipal sewers to the EDAR.

The goal is for Ag3 to diminish. The inflow in "La Cartuja" EDAR reduced from 1997 till 2000 due to a reduction in water consumption as a result of the improvements carried out in the water supply network which started in 1996. However, the inflow increased in 2001 because of the connection of the River Huerva sewer, a tributary of the River Ebro, to the EDAR while the BOD remained similar.

The total inflow incorporated to the EDARs, "La Cartuja" and "Almozara" together, is of 70.7 x 10^6 m^3/year.

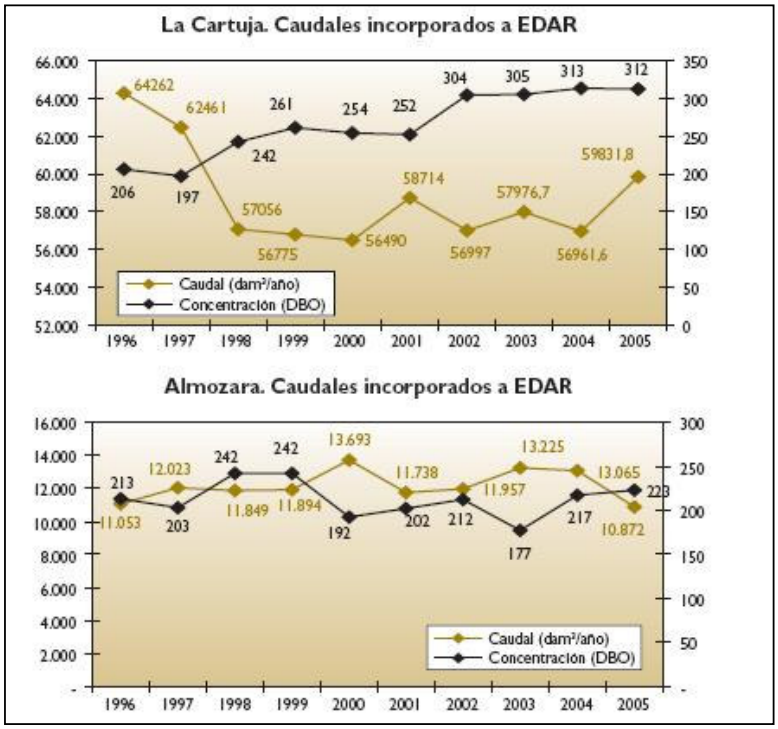
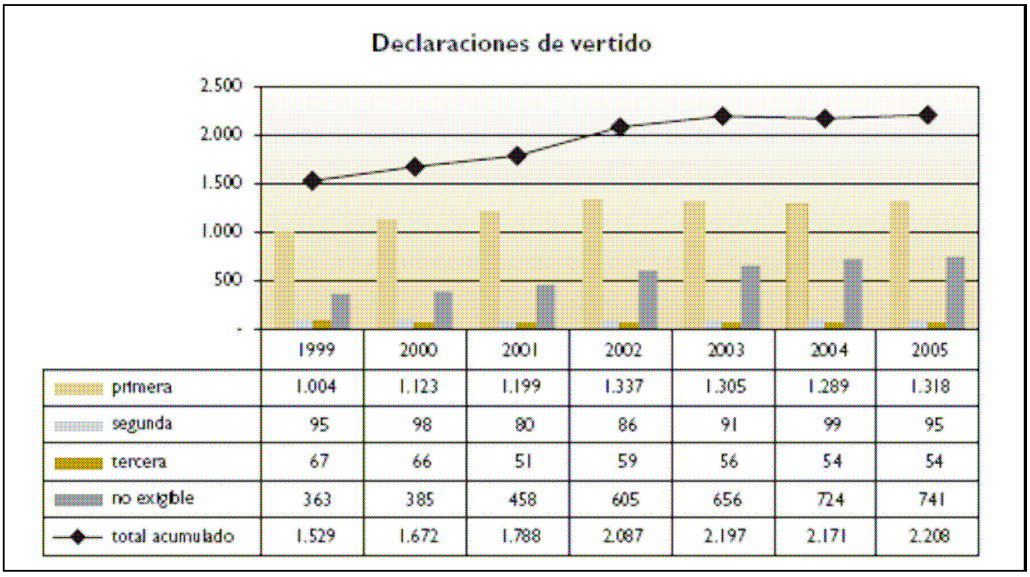


Figure B.8: Indicator Ag3. Inflows to EDAR trough the drainage network (Source: Oficina de Agenda 21 Local del Ayuntamiento de Zaragoza, 2006; caudal: flow, concentración (DBO): concentration (BOD)).

Ag4. Concessions of authorizations of wastes for industrial activities

The aim of Ag4 is to control the industrial wastewater load.

It is an annual indicator and measures industrial loads authorizations. Any activity likely to produce industrial wastewater has to obtain consent to discharge. These consents are divided into four categories according to the Municipal Environmental regulations. They are: first class (in light brown), for flows below 15 m^3 per day and without toxic compounds; second class (in light grey), for flows between 15 and 50m^3 per day, with some toxic compounds; third class (in khaki), for flows above 50 m^3 per day, and those which do not need to have the load taken into account. The black line refers to the total load authorizations (See figure B.9).



	1999	2000	2001	2002	2003	2004	2005
primera	1.004	1.123	1.199	1.337	1.305	1.289	1.318
segunda	95	98	80	86	91	99	95
tercera	67	66	51	59	56	54	54
no exigible	363	385	458	605	656	724	741
total acumulado	1.529	1.672	1.788	2.087	2.197	2.171	2.208

Figure B.9: Indicator Ag4. Concessions of authorizations of wastes for industrial activities (Source: Oficina de Agenda 21 Local del Ayuntamiento de Zaragoza, 2006; primera: first class, segunda: second class, tercer: third class, no exigible: no load authorization needed, total acumulado: total load authorizations).

The goal that Ag4 supports is the encouragement of clean technologies as well as the adoption of waste management systems, resulting in a water quality improvement.

As seen above, this indicator has been trending upwards, especially in the first class discharges and those ones in which authorization is not needed.

Ag5. Ecological state of rivers

The aim of Ag5 is to preserve the rivers aquatic ecosystem.

Ag5 is calculated based on the measurement of the basic parameters that determine the ecological state of the rivers. In figure B.10, the fist plot shows the ecological state of the River Ebro, representing the states of: water quality (medium grey), morphology/hydrology (khaki), aquatic fauna habitats (light grey), river bank vegetation quality (light brown) and river bank fauna habitats (dark grey). The range of these parameters is: optimum (10-9), sub-optimum (8-6), regular (5-3) and bad (2-0).

The results, for each case, are that the river Ebro basin is subject to significant pressures. Its impact is checked and has a high risk of not achieving the good ecological state required by the Water Framework Directive.

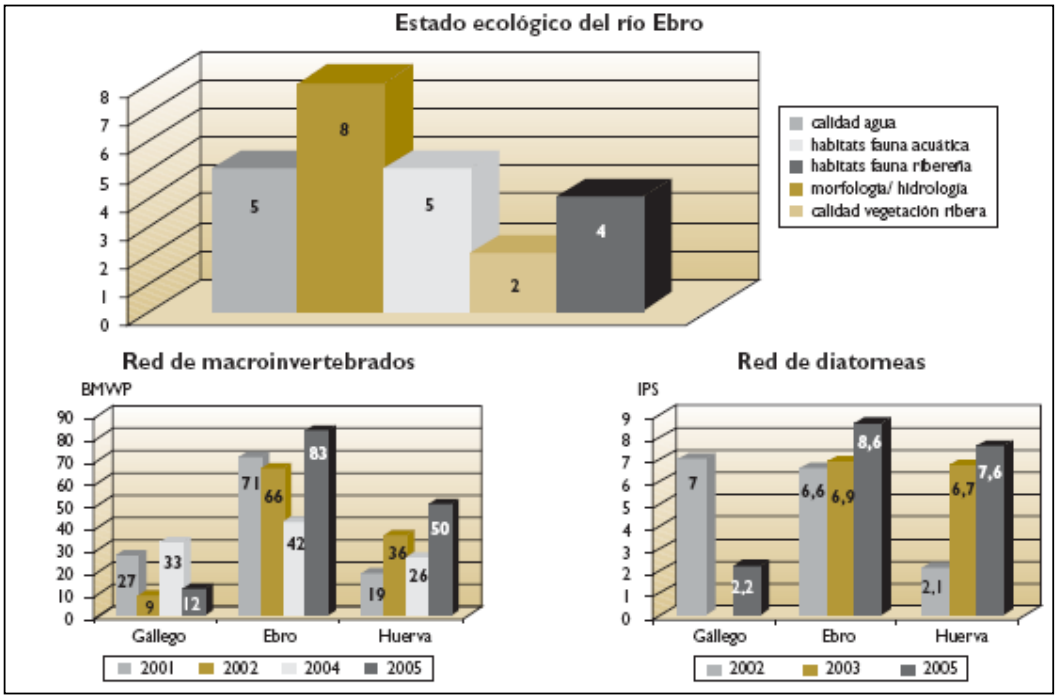


Figure B.10: Indicator Ag5. Ecological state of rivers (Source: Oficina de Agenda 21 Local del Ayuntamiento de Zaragoza, 2006; estado ecológico del río Ebro: ecological state of river Ebro, calidad de aguas: water quality, habitats fauna acuática: aquatic fauna habitats, habitats fauna ribereña: river bank fauna habitats, morfología/hidrología: morphology/hydrology, calidad vegetación ribera: river bank vegetation quality, red de macroinvertebrados: macro-invertebrates net, red de diatomeas: diatoms net).

The goals of measuring this indicator are the same than for both Ag1 and Ag2, i.e. the improvement of drinking water quality, the reduction of its inappropriate use and the encouragement of its study.

Ag5 indicator has two sub-indicators, both based on biological indicators, necessary for the assessment of the ecological state of rivers:

- Ag 5.1. Characteristic of the aquatic flora (diatoms). The assessment of the diatoms net is: very good (20-17), good (17-13), moderate (13-9), bad (9-5) and very bad (5-0). The third

graph of figure B.10 shows the diatoms net, indicator Ag 5.1, of the River Ebro and both of its tributaries, the Gallego and the Huerva.

- Ag 5.2. Characteristics of the benthic fauna of macro-invertebrates. The assessment of the macro-invertebrate net is: very good (>65), good (65-56), moderate (56-41), deficient (40-20) and bad (<20). The second graph of figure B.10 shows the marco-invertebrate net (indicator 5.2) of the River Ebro and both of its tributaries, the Gallego and the Huerva.

Annex C

SWITCH

SWITCH is the acronym for “Sustainable Water Management Improves Tomorrow’s Cities Health”. SWITCH is a 5 years project (started in February 2006) included within the Sixth Framework Program of the EU, within the priority 1.1.6.3 "Global Change and Ecosystems" of the General Research Management Team of the European Commission and it is leaded by UNESCO - IHE (Institute of Water Education) (SWITCH Project).

“The SWITCH Integrated Project aims at the development, application and demonstration of a range of tested scientific, technological and socio-economic solutions and approaches that contribute to the achievement of sustainable and effective urban water management (UWM) schemes in ‘The City of the future’ (projection 30-50 years from now)” (SWITCH Project, 2006, p.6).

SWITCH project involves 33 partners from 15 different countries and 4 continents, which will develop new water management proposals (Table C.1) (SWITCH Project, 2007). This cross-disciplinary team includes the fields of academic, urban planning, water utility and consulting interests.

This researchers and practitioners are working directly with several stakeholders in the ten demonstration cities around the world within the project. These are: Zaragoza (Spain), Accra (Ghana), Alexandria (Egypt), Bello Horizonte (Brazil), Birmingham (U.K.), Hamburg (Germany), Lodz (Poland) and Tel Aviv (Israel), Beijing (China), Chongqing (China). The incorporation of New York and Sidney (Australia) in the project is been studied, in order to have representation of the 5 continents (figure C.1) (SWITCH Project, 2007).

SWITCH is an action research project and to achieve its overall goal, i.e. a more sustainable urban water management in the cities of the future, is needed a paradigm shift in urban water management by converting from ad-hoc actions (problem/incident driven) into a coherent and consolidated approach (sustainability driven).

Table C.1: SWITCH partners (Source: SWITCH Project, 2007).

Netherlands	Hamburg Municipality (FHH/BSU/LP)
UNESCO-IHE	HafenCity University Hamburg (HCU)
Stichting International Water & Sanitation Centre (IRC)	**Greece**
ETC Foundation (ETC)	National Technical University of Athens (NTUA)
Wageningen University (WU)	**Israel**
Brazil	Mekorot Israel National Water Company (MEKOROT)
Prefeitura Municipal de Belo Horizonte (SUDECAP)	**The Hebrew University of Jerusalem (HUJI)**
Univesidade Federal de Minas Gerais (EFMG)	**Palestine**
China	House of Water and Environment (HWE)
Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Science (IGSNRR CAS)	**Peru**
Chongqing University (CHONU)	IPES – Promocion del Desarrollo Sostenible (IPES
Colombia	**Poland**
Centro Inter-Regional de Abastecimiento y Remocion de Aqua (CINARA)	University of Lodz (UL)
Universidad Nacional (UNAL)	**Spain**
Egypt	Ayuntamiento de Zaragoza (AYTO)
Centre for Environment and Development for the Arab Region and Europe	**Switzerland**
Ghana	Swiss Federal Institute of technology Lausanne (EPFL)
International Water Management Institute (IWMI)	**United Kingdom**
Department of Civil Engineering, Kwame Nkrumah University of Science and Technology (DCE-KNUST)	Middlesex University Higher Education Corporation (MU)
Germany	The University of Birmingham (UNI BHAM)
Technische Universitat Hamburg-Harburg (TUHH)	Ove Arup and partners Limited (ARUP)
ICLEI – European Secretariat, GmbH (ICLEI)	UGMT Limited (UGMT)
Ingenieurgesellschaft Prof. Dr. Sieker mbH (IPS)	Loughborough University (WEDC)
Technische Universitat Berlin (TU Berlin)	University of Abertay (UA)

Figure C.1: Demonstration cities and study sites within the SWITCH Project (Source: SWITCH Project, 2007)

The SWITCH research approach is a combination of (SWITCH Project, 2007):

- **Action research.** Water problems will be addressed through innovative drinking water, wastewater, strormwater and natural system technologies and users involvement in local demonstrations…

- **Learning alliances.** They are "a group of individuals or organisations with a shared interest in innovation and the scaling-up of innovation, in a topic of mutual interest", (SWITCH Project, 2006, p.7) in this case water. They link up stakeholders at city and global level to encourage their involvement in decision-making processes and to create win-win solutions.

  Learning alliances is one of the most relevant contributions of SWITCH project due to they are "designed to break down barriers to both horizontal and vertical information sharing, and thus to speed up the process of identification, adaptation and uptake of new innovation" (SWITCH Project, 2006, p.7). They also promote a new form of "demand-driven" research within the demonstration cities, ensuring that the researches take into account and respond all the problems and constraints identified by the different stakeholders, including municipalities and civil societies among others.

- **Multiple-way learning.** Demonstration cities from Europe and developing countries, with different geographical, climatic and socio-cultural settings, learn

from each other through its knowledge dissemination and some training activities. Thus, the replication of the more sustainable solutions can be accelerated and it might be said that demonstration projects are learning instruments. SWITCH must not been seen as partial "coverage" project, including only the mentioned demonstration cities, because its learning activities go beyond SWITCH city borders through some outreach activities such as training of educators, municipal staff, policy- and decision-makers and implementers from other cities.

- **Multiple-level or integrated approach**. The social, economic and environmental aspects of the urban water system will be taken into account at city level. Also, a better understanding and knowledge will be acquired about the city systems impacts and dependency on the natural environment in the water basin and in relation to global change pressures. It results in the consideration of three different levels in the project: city, river basin and global level.

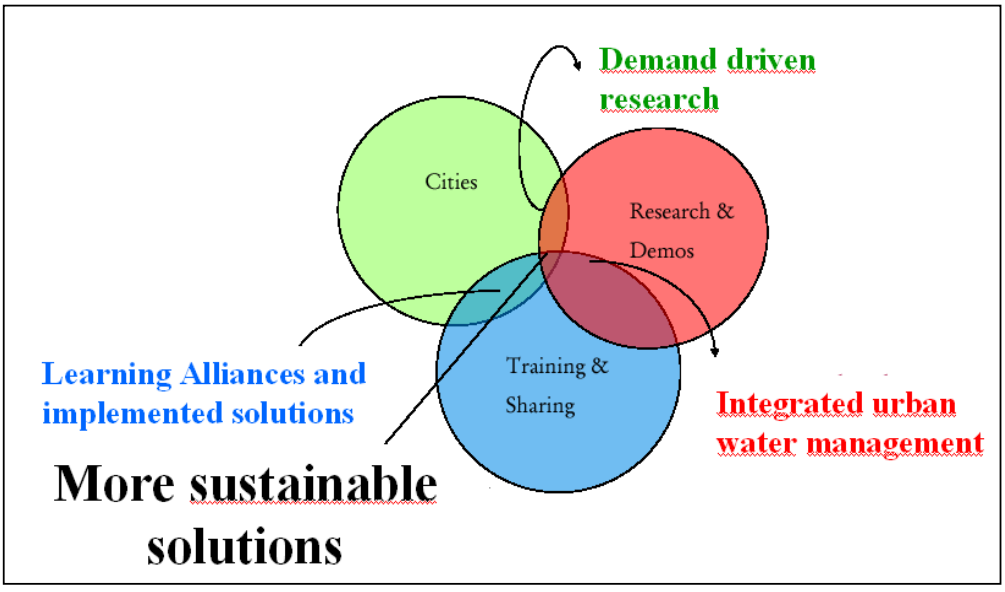


Figure C.2: SWITCH Project approaches (Source: WITCH Project, 2007)

The SWITCH project is divided in 6 complementary and interactive thematic themes, each of which is sub-divided in work packages (SWITCH Project). These are:

1. Urban water paradigm shift
2. Storm water management
3. Efficient water supply and use
4. Waste water
5. Urban water planning
6. Governance and institutions

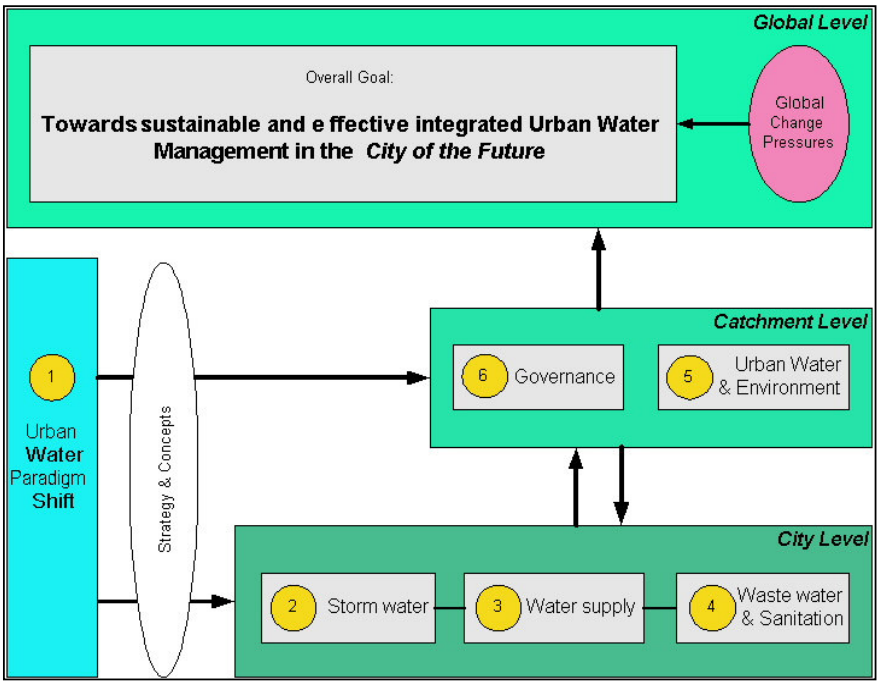


Figure C.3: SWITCH Project approach relating the 6 different thematic themes (SWITCH Project, 2006).

Zaragoza, the Spanish demonstration city within the SWITCH project will participate actively in work package 3.1 called "Water demand management for optimisation of urban water services". Local Agenda 21 of Zaragoza is working jointly with the Infrastructure and Tributary Management Departments and Loughbourogh University, as well as other technological partners in this part of the project. It will be carried out specifically in Actur neighbourhood and it will try to be extended to other parts of the city in the future. Different activities will developed as the following ones: division of Actur neighbourhood in five smaller areas for a better study, measurement of the real water consumption using digital water meters, evaluation of water losses in municipal network as well as in private installations, etc.

The outcomes of the SWITCH project will be complement by other research programmes on urban water services and on integrated water resources management. Among them, the UNESCO International Hydraulic Programme (IHP), the EU Water Initiative, the European Strategy for Environment and Health and the Environmental Technology Action Plan can be pointed out (SWITCH, 2006)

The SWITCH project will participate in EXPO 2008, in Zaragoza, although it is not yet clear what will be the exact nature of the collaboration. Also, in 2009, SWITCH will prepare in collaboration with IWA in the International Conference on "Water in the City of the Future"

Finally, this chapter could be finished telling that "the lasting impact that SWITCH is striving for is a paradigm shift from our global cities being vast consumers and importers of critical water, energy and food resources to being zero impact or net producers of these products" (SWITCH Project, 2007, p.4).

Annex D

Survey

SMURF (System for Monitoring URban Functionalities)

1. What is your initial impression of SMURF?	Like it a lot	Like it	It's OK	Dislike it	Hate it

2. It is easy to identify features (houses, rivers, trees etc)	Strongly Agree	Agree	No Preference	Disagree	Strongly Disagree

3. I can easily identify specific named buildings (e.g. Grande Anse Hospital)	Strongly Agree	Agree	No Preference	Disagree	Strongly Disagree

4. Having specific building names helps to understand the real world situation	Strongly Agree	Agree	No Preference	Disagree	Strongly Disagree

5. I can find the Takamaka district in Mahe Island easily	Strongly Agree	Agree	No Preference	Disagree	Strongly Disagree

6. What do you think the term people/km^2 is?	

7. I understand the purpose of the modifications display	Strongly Agree	Agree	No Preference	Disagree	Strongly Disagree

8. I understand the purpose of the projects display	Strongly Agree	Agree	No Preference	Disagree	Strongly Disagree

9. I find the mini-map (top left corner) helpful	Strongly Agree	Agree	No Preference	Disagree	Strongly Disagree

10. What decision would you take based on the indicator "Distance to Schools"(Education Tab) in Mahe Island		I would remove some schools, there are too many
		I would build some more schools in areas where the schools are too far away
		I would do nothing

11. Seeing the "Distance to Schools" indicator (Education Tab) at two different points in time would help in making a decision	Strongly Agree	Agree	No Preference	Disagree	Strongly Disagree

12. What decision would you take based on indicators "Distance to Schools" (Education Tab) and "Population Density" (Demography Tab) in Mahe Island		I would remove some schools, there are too many
		I would build some more schools in areas where the schools are too far away
		I would do nothing

13. It would be more helpful to make a decision if the indicators "% Main Supply Treated" (Water Supply Tab) and " Connected to Sewerage" (Sanitation Tab) are shown at the same time	Strongly Agree	Agree	No Preference	Disagree	Strongly Disagree

14. I understand the meaning of the different indicators represented in SMURF	Strongly Agree	Agree	No Preference	Disagree	Strongly Disagree

15. It would be easier to understand the indicators if they were explained	Strongly Agree	Agree	No Preference	Disagree	Strongly Disagree

16. The indicators used in SMURF are useful in making decisions	Strongly Agree	Agree	No Preference	Disagree	Strongly Disagree

17. I would make equally good decisions without using the indicators	Strongly Agree	Agree	No Preference	Disagree	Strongly Disagree

18. SMURF helps me to understand and make decisions about a real world situation	Strongly Agree	Agree	No Preference	Disagree	Strongly Disagree

19. I liked the overall appearance of SMURF	Strongly Agree	Agree	No Preference	Disagree	Strongly Disagree

20. I found SMURF easy to use	Strongly Agree	Agree	No Preference	Disagree	Strongly Disagree

21. Which language did you use?	English	French	Creole

22. Which of the following do you think would help you to use SMURF	Training / Live help	Manual	Both

23. What is your impression of SMURF after using it	Like it a lot	Like it	It's OK	Dislike it	Hate it

24. Any comments on SMURF. Anything you would add, remove or improve	

S-City VT (Sustainable City Visualisation Tool)

25. What is your initial impression of S-City VT?	Like it a lot	Like it	It's OK	Dislike it	Hate it

26. It is easy to identify features (houses, rivers, trees etc)	Strongly Agree	Agree	No Preference	Disagree	Strongly Disagree

27. I can easily change between the design and the 3D displays using the tabs	Strongly Agree	Agree	No Preference	Disagree	Strongly Disagree

28. I can easily use the design view to change the position of buildings or create/remove buildings	Strongly Agree	Agree	No Preference	Disagree	Strongly Disagree

29. I can easily navigate the 3D view using the mouse	Strongly Agree	Agree	No Preference	Disagree	Strongly Disagree

30. I can easily turn the Carbon model on and off	Strongly Agree	Agree	No Preference	Disagree	Strongly Disagree

31. It is helpful to use the time control to go to points in time I am interested in when making a decision	Strongly Agree	Agree	No Preference	Disagree	Strongly Disagree

32. I can easily tell the date the simulation is currently at	Strongly Agree	Agree	No Preference	Disagree	Strongly Disagree

33. I can easily tell the difference between a building using a lot of energy and a building using little energy	Strongly Agree	Agree	No Preference	Disagree	Strongly Disagree

34. Seeing how a building's energy use changes over time helps me to make a better decision than if I only see it at one time (e.g. summer or winter)	Strongly Agree	Agree	No Preference	Disagree	Strongly Disagree

35. It would be more helpful to make a decision if more indicators were shown at the same time	Strongly Agree	Agree	No Preference	Disagree	Strongly Disagree

36. I understand the meaning of the different indicators represented in S-City VT	Strongly Agree	Agree	No Preference	Disagree	Strongly Disagree

37. It would be easier to understand the indicators if they were explained	Strongly Agree	Agree	No Preference	Disagree	Strongly Disagree

38. The indicators used in S-City VT are useful in making decisions	Strongly Agree	Agree	No Preference	Disagree	Strongly Disagree

39. Changing the parameters (building types and traffic levels) helps me to understand the real world situation	Strongly Agree	Agree	No Preference	Disagree	Strongly Disagree

40. I would make equally good decisions without using the indicators	Strongly Agree	Agree	No Preference	Disagree	Strongly Disagree

41. S-City VT helps me to understand and make decisions about a real world situation	Strongly Agree	Agree	No Preference	Disagree	Strongly Disagree

42. I liked the overall appearance of S-City VT	Strongly Agree	Agree	No Preference	Disagree	Strongly Disagree

43. I found S-City VT easy to use	Strongly Agree	Agree	No Preference	Disagree	Strongly Disagree

44. Which of the following do you think would help you to use S-City VT?	Training / Live help	Manual	Both

45. What is your impression of S-City VT after using it	Like it a lot	Like it	It's Ok	Dislike it	Hate It
46. Any comments on S-City VT, Anything you would add, remove or improve					

Both Tools

47. London City Council wants the London 2012 Olympic Games to be the first sustainable games. If you had to choose where in London specific events or new stadiums had to be built to be sustainable, which of the tools would you be happier using, or would you not want to use either tool? (please, include a reason for your choice)

Tool	Reason For Choice
SMURF	
S-City VT	
None	

48. Both tools are useful if they are not on the Internet	Strongly Agree	Agree	No Preference	Disagree	Strongly Disagree

49. If I found the tools on the Internet I would use it if ? (Please score your answers in order from 1-5 , 1 being the most important)

The tool is free	
If there is a clear manual	
The benefits of using it are clearly explained on the main page	
There is a developer contact number or email for more information	
Other (Please State).....	

Personal Information (this is completely anonymous and is for statistical purposes only)

Gender	Male			Female			
Age	16-18	19-21	22-25	26-30	31-40	41-50	>50
Level of Education	Primary School	Secondary School	College (please state)		University (please state)		Post Grad
Occupation							
First Language							

Annex E

Answers of the survey

Table E.1: Direct answers of the survey (number 1 correspond to "Strongly Agree" or "Like it a lot" and 5 to "Strongly Disagree" or "Hate it").

Number		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Time spent		1h.	45 min.	35 min.	50 min.	45 min.	1 h. 20 min.	55 min.	35 min.	55 min.	1 h.	30 min.	45 min.	1 h.	30 min.	1h.10 min.	50 min.	50 min.	55 min.	30 min.	20 min.
Gender		Female	Male	Male	Male	Female	Female	Male	Male	Male	Female	Male	Male	Male	Male	Male	Male	Male	Female	Female	Male
Age		22-25	22-25	31-40	22-25	31-40	19-21	22-25	26-30	19-21	22-25	19-21	19-21	22-25	26-30	19-21	19-21	22-25	22-25	31-40	26-30
Education Level																					
Education		MSc Env. Sciences	BSc Hons Computing	Computer Sciences and Psychology	Graduate Computing	Open University(Business Studies)	Nutrition and food	Business and Law	Environmental management	Business management	Business	Computing	Computing	Business Economics	Environmental Engineering	Ethical Hacking and counter measures	Business and Finance	Engineering of the industrial and management	Law	Computing	Environmental issues
Occupation		Casual worker	Research Student	PhD Student	PhD student	Administration Assistant	University Student	University Student	Research Assistant	University Student	University Student	University Student	University Student	University Student	PhD Student	University Student	University Student	University Student	University Student	Lecturer	Project Officer
First Language		Spanish	English	Russian/Hebrean	English	English	Cantonese	Spanish	English	French	French	English	English	German	Hindi	Swedish	French	Finnish	Finnish	Computing	English
																				Lecturer	
SMURF																				English	
1		3	4	3	2	1	4	2	4	2	3	2	2	2	1	2	3	2	3	3	4
2		2	3	4	3	2	2	2	4	2	1	2	2	2	2	2	2	1	2	4	4
3		5	4	4	2	4	4	4	5	4	4	1	2	3	3	5	4	4	4	5	4
4		2	2	2	2	2	3	3	5	1	3	1	2	2	1	2	2	2	2	4	2
5		1	5	5	1	2	1	4	5	2	3	1	2	2	2	1	1	3	3	5	4

6		Indicator	Number of people per square kilometre	Population density network	Residents per Km^2	Population per Km 2	The total number of people living in an area	Population density. Number of inhabitants per surface measure (km2)	How many people live in 1 square kilometre area	Number of people per km2	The number of people by km, it is an average	Population Spread	The number of people living in a certain area	Number of inhabitants that inhabit the area of one square kilometre	Density	Population Density	Maybe it is the number of people per km2	How many people lives inside the area of 1km times 1 km.	Amount of people living in square kilometre	Population density	Number of people in square kilometre
7		2	2	5	2	3	2	2	2	2	2	2	2	2	2	2	4	2	2	2	2
8		5	4	5	2	3	2	2	2	2	1	1	2	2	2	4	5	2	4	5	2
9		2	5	3	4	1	4	4	2	3	1	1	2	1	2	2	4	1	5	2	3
10		2	3	3	3	1	2	2	2	2	3	2	1	3	2	3	3	3	2	2	3
11		5	5	3	3	1	1	2	3	1	2	2	2	2	2	3	2	2	2	4	3
12		3	2	3	1	1	3	2	2	3	1	3	2	3	2	3	3	2	1	3	3
13		2	1	3	2	1	1	2	2	2	1	2	2	1	2	1	2	2	1	1	4
14		2	2	2	2	2	2	2	1	4	1	1	2	3	2	1	1	2	2	2	2
15		1	2	1	1	1	2	4	3	1	3	3	2	1	2	2	2	1	1	2	2
16		3	2	2	2	1	1	3	2	1	2	2	2	2	2	2	2	1	3	4	2
17		2	4	4	5	4	4	4	5	4	5	4	3	5	3	4	4	3	4	3	4
18		3	4	2	2	2	2	3	2	2	2	2	2	3	2	3	2	1	4	3	3
19		4	3	3	2	1	4	3	2	5	2	1	2	2	1	2	3	2	3	4	4
20		3	4	2	2	2	4	2	4	5	3	1	2	3	2	3	2	2	5	4	4
21		1	1	1	1	1	1	1	1	2	2	1	1	1	2	1	2	1	1	1	1
22		2	1	3	3	3	3	1	1	1	3	2	3	2	3	3	3	1	3	3	3
23		4	4	3	2	1	3	3	3	3	1	2	2	3	2	3	3	2	4	3	4
S-City VT																					
25		4	2	3	2	2	5	2	4	4	4	3	2	2	3	4	4	2	3	2	3
26		2	1	1	1	3	2	3	2	2	2	2	2	1	3	1	2	2	1	2	2
27		1	1	1	1	1	3	1	3	2	2	3	2	1	4	1	1	1	2	2	1
28		3	3	4	2	2	2	2	3	5	3	2	2	3	2	4	3	1	2	2	3
29		5	2	2	2	1	4	2	1	1	2	1	4	1	5	2	1	2	4	4	1
30		1	1	2	1	1	2	2	3	1	2	1	2	1	1	1	2	4	4	2	1

31		2	2	3	2	2	3	2	3	5	1	1	3	2	2	2	4	2	2	2	2
32		1	2	4	1	1	2	2	2	1	2	1	2	2	3	1	2	3	1	2	1
33		2	3	2	1	1	2	2	3	5	2	1	2	2	2	1	3	3	2	2	2
34		1	2	3	2	1	2	2	3	2	2	2	2	2	1	2	2	2	1	2	2
35		2	1	3	2	2	2	2	3	2	2	3	3	2	1	1	2	2	2	1	2
36		2	3	3	2	2	2	3	2	4	4	1	2	4	4	1	4	2	2	2	4
37		2	1	2	2	2	3	2	2	2	1	3	3	1	1	3	1	1	2	2	2
38		2	2	4	2	2	3	4	3	2	5	4	2	2	3	2	4	2	2	2	3
39		2	2	2	2	2	2	3	3	3	3	2	2	2	2	3	4	1	5	3	2
40		4	4	1	4	4	4	3	3	1	3	3	3	4	4	4	2	4	5	3	4
41		2	2	3	2	2	3	3	3	5	5	1	2	3	2	2	3	1	2	2	3
42		2	2	2	2	2	3	2	2	4	2	1	2	2	2	4	3	2	3	1	2
43		2	2	2	2	2	4	2	4	5	4	1	3	3	4	4	4	2	4	2	2
44		2	3	3	3	3	3	2	1	1	3	1	3	1	3	3	3	3	3	3	3
45		2	3	2	2	2	4	3	4	4	4	2	2	3	2	4	4	2	3	2	3
Both Tools																					
47		2	2	3	2	2	3	3	3	2	1	3	1	1	1	3	1	1	3	2	3
48		4	3	3	2	5	5	4	3	5	1	3	3	3	3	5	4	4	5	4	4
49	The tool is free	1	1	2	3	1	2	1	4	3	1	2	1	4	1	1	1	1	2	2	3
	Clear manual	3	3	3	4	2	1	4	2	1	3	1	2	3	3	3	3	4	3	1	11
	Benefits clearly explained	2	2	1	2	3	3	2	1	2	2	4	3	2	2	2	2	2	1	3	2
	Contact number or email	4	4	5	1	4	4	3	3	4	4	3	4	5	4	4	4	3	4	4	4
	Other			4										1							

QUESTION 24: COMMENTS ABOUT SMURF

Person 1

- It would be better to show different indicators at the same time.
- What about future situations?

Person 2

- Pop-up explanations of indicators.
- The ability to overlap indicators.

Person 3

- No comments

Person 4

- French rollovers!
- Stability issues.
- Is fairly straight forward but a manual would help to explain.

Person 5

- With no training I was fairly quickly able to grasp the concept of the tool and how it works.

Person 6

- The legend symbols need to be clearer.
- Need other indicators, like mortality rate per age group.
- Colour scheme needs some upgrading.
- Manual would be helpful.
- How do you work with this program when some of the data/indicators do not reveal themselves? Or is not there?

Person 7

- I would make it more attractive in a visual way and also commercial.

Person 8

- Difficult to find locations.
- Training/live help is required.
- Not very useful for people who don't have clear idea about decision making indicators.
- Without explanation it is difficult to understand the function of software.

Person 9

- Too difficult to use.
- Graphic not very good.
- Not any explanations.
- However useful of the program.
- Good idea.

Person 10

- Good but I think better if:
  - We can use 2 indicators in a same time
  - Colours are more different in several cases.

Person 11

- Attempt to decrease loading times.

Person 12

- Give more information on how the program runs.

Person 13

- Possibility to move quadrangle in mini-map for easier navigation.
- Activation of several indicators at the same time.
- Travelling on the map through mouse movement while one mouse button is pressed.

Person 14

- More GIS functionalities could be added.

Person 15

- Overlaying any layer with another to create combined information, not only static information considered interesting by the program developers.

Person 16

- No comments.

Person 17

- No comments.

Person 18

- Moving around in the map should be made easier.
- More than one indicators need to be seen at the same time.
- Small map should be more active.

Person 19

- Data overlaps would be better for comparisons.
- Magnification tool is not good.
- Lots of errors and bugs when run the application.
- Quite good to have an integrated approach + have indicators from social, environmental and economic factors.

Person 20

- No comments.

QUESTION 46: COMMENT ABOUT S-CITY VT

Person 1

- I find difficult to use the mouse to move in the 3D screen.
- It would be easier to change the buildings, streets, ….in the 3D screen.
- The indicator is easy to understand, but there is only one.
- The designer screen could be improved for a better and faster understanding, but I don't know how.
- The first time that one uses the 3D screen, it is not easy to identify the type of building. I would suggest to display a label where you place the mouth.
- It would be interesting to view the underground level (water supply system, ground water, soil type, …)

Person 2

- More explanation of indicators and triangle graph thing.
- Maybe pop-ups on selected stuff.

Person 3

- 3D is cool.

Person 4

- When assets are being moved in the designer view it would be good if they cursor could change to a move icon.

Person 5

- Not quite as easy to understand as the SMURF tool.

Person 6

- At first, it appears to be difficult to use it, but after playing with it, it's easier.

- Although the 3D view is great, it still needs improvements for other researchers to use not first for environmental studies.

Person 7

- Not developed enough.
- Good visual featuring.
- Useless in decision-making.

Person 8

- Not self-explanatory.

Person 9

- Not very long to use the software.
- It will be easier if there are more explanations.
- If it is easier, the software will be so greater.
- But good idea.

Person 10

- It is not INTUITIVE.

Person 11

- Moving buildings is quite difficult.

Person 12

- Make it easier to navigate in the 3D mode.

Person 13

- Use of “designer” in parts difficult as objects are difficult to move.
- Scales of energy use would be nice for a better understanding of the simulation.
- Handling of the “3D view” with right mouse button is very good!
- Sense of some key objects in “design” mode is not clear as some don’t seem to be relevant.

Person 14

- Please add more indicators.
- Improve design display.

Person 15

- Higher resolution time.
- Easier navigation in 3D.

Person 16

- No comments.

Person 17

- No comments.

Person 18

- Moving around the picture should be easier.
- Recognising the same building in designer and 3D-model should be simpler.
- Also the tools should be seen all the time in the picture, maybe a toolbar.
- Because of two different windows comparing aren't that easy.

Person 19

- An introductory screen explaining ideas would be good.
- Labels on the sustainability triangle.
- Explanation on how to use mouse controls.

Person 20

- No comments.

QUESTION 47: REASONS TO CHOSE SMURF. S-CITY VT OR NONE FOR PLANNING THE 2012 OLYMPIC GAMES

SMURF

- Because it is easier to use and for the first use it is better.
- It was easy to navigate and gave good information to make decisions.
- Because of a better overall image with exact relations and very detailed information. Disadvantage: time is not measured -> important for sustainability.
- Because it has more indicators.
- Easiest and more helpful.
- Easier to see the "big picture".

S-City VT

- I will use S-City VT, taking into account that it is in developing process and it will be improved showing more useful indicators for the above-mentioned case study. I find it easier for use and clearer to understand. It is also more attractive for use.
- Although looks like it would struggle to view large parts of London.
- SMURF would give a good overall view – linking together zones that are for apart or spread out, but not as specific as S-City VT. S-City VT perhaps more relevant to the project due to the environmental concerns and building / interacting with the tool.
- SMURF is good for assessment of population + land use. S-City VT is good for assessing current sustainability of land use.
- Because the map in 3D and designer is better than SMURF, but SMURF is easier to use.
- Easier to use initially but further you might find lack of information.

None

- SMURF has more indicators there and S-City VT has better visual and it is easier to navigate. He would use Google Earth.
- Both. SMURF: you could get information of what effects, there are in terms of a range of indicators. S-City VT: The ability to see it in 3D perspective (i.e. traffic & buildings). ===> For now, I prefer the SMURF program because as a nutrition and health student, seeing the actual demographics and the actual indicators of data helps me make inform decision for my studies. The S-City VT would not be as useful to me unless improvements were made.
- Both. I'd make a mixture, combining both programs, some kind of 3D google maps.
- I am unable to find any decision base on the software before I properly understand it.
- SMURF is better for area views and levels of population, etc. S-City VT is better for up close street level.
- I have not seen the flexibility required to plan sustainability of Olympic Games in any of them.
- SMURF and S-City VT give different view cause the other focuses to larger area and the other is local. These two should be unified somehow.
- I wouldn't use SMURF as it has static view. I wouldn't use S-City VT as it models only one indicator but if extended then this tool may be useful.

Annex F

Graphs of the answers of the survey.

F.1. SMURF

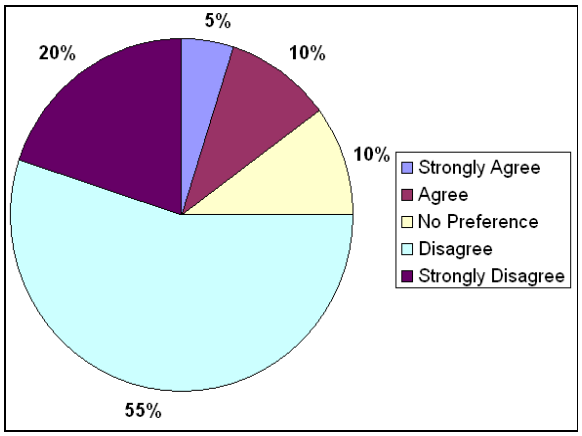


Figure F.1: Statement: I can easily identify specific named buildings in SMURF (e.g. Grande Anse hospital).

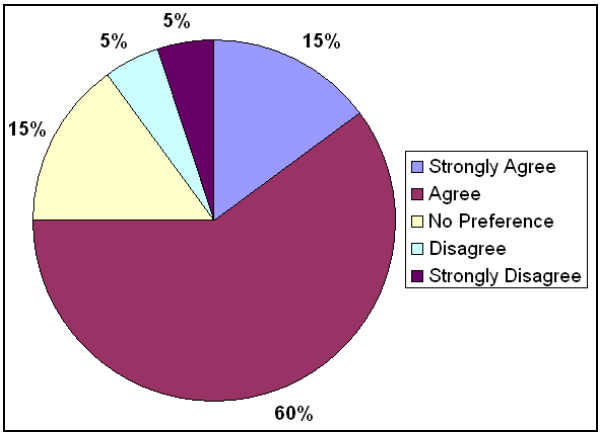


Figure F.2: Statement: Having specific building names in SMURF helps to understand the real world situation.

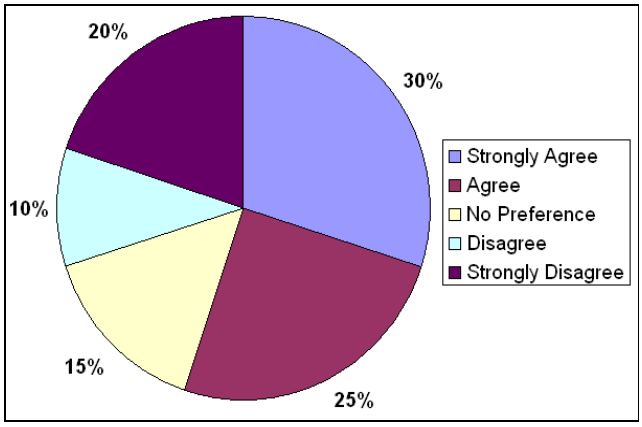


Figure F.3: Statement: I can find the Takamaka district in Mahe Island easily in SMURF.

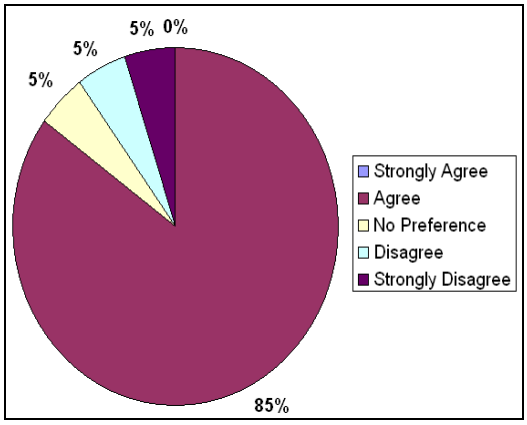


Figure F.4: I understand the purpose of the modifications display of SMURF.

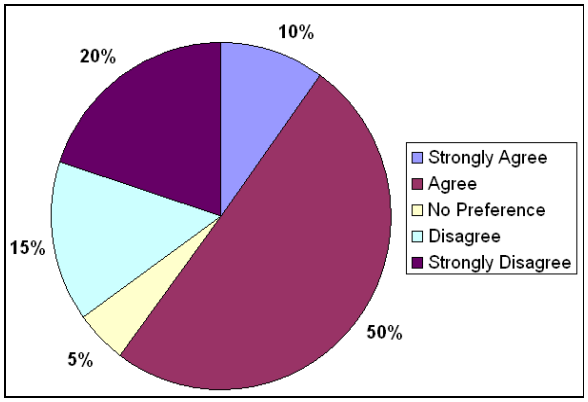


Figure F.5: Statement: I understand the purpose of the projects display of SMURF.

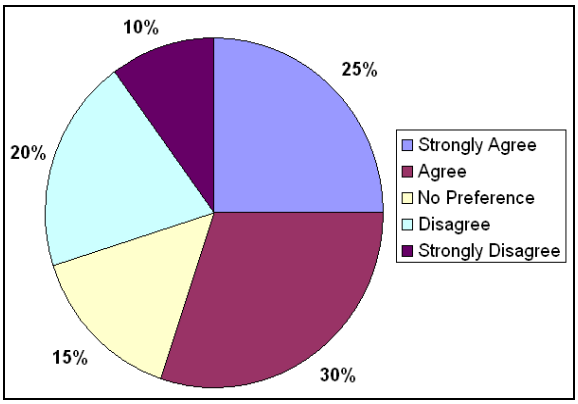


Figure F.6: Statement: I find the mini-map of SMURF helpful.

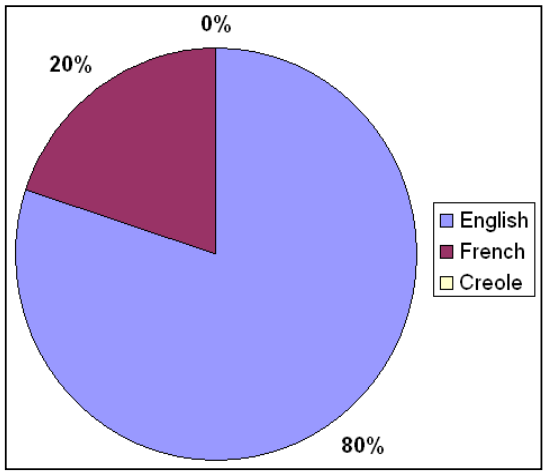


Figure F.7: Statement: Which language did helpful. you use in SMURF.

F.2. S-CITY VT

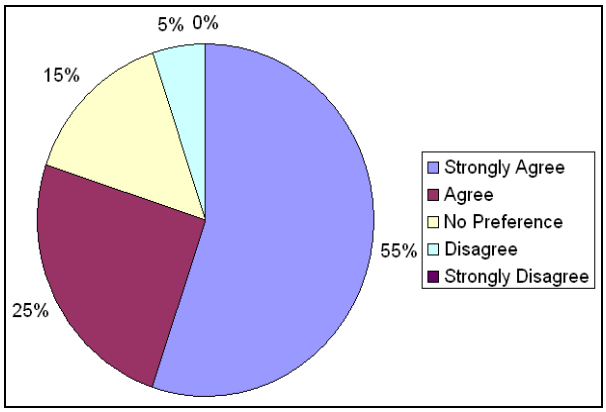


Figure F.8: Statement: I can easily change between the design and the 3D displays of S-City VT using the tabs.

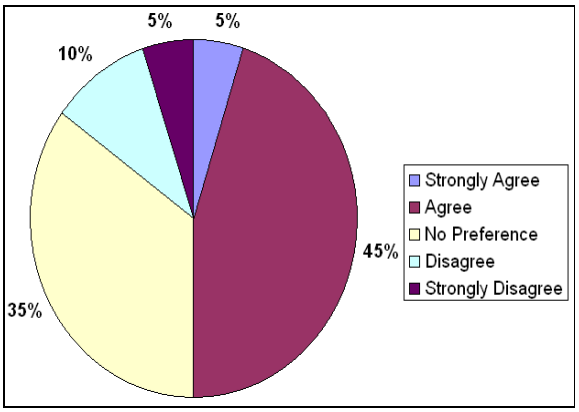


Figure F.9: Statement: I can easily use the design view of S-City VT to change the position of buildings or create/remove buildings.

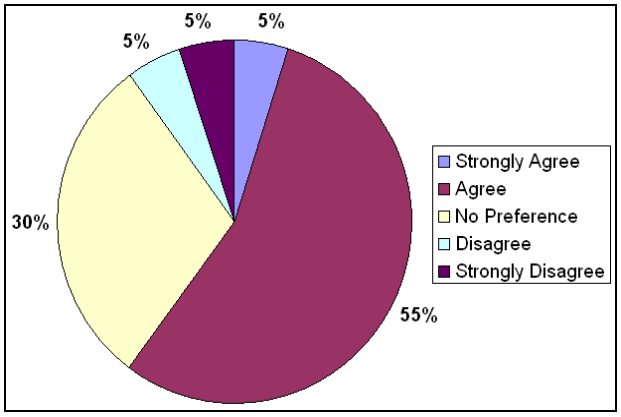


Figure F.10: Statement: Changing the parameters (e.g. building types and traffic levels) in S-City VT helps me to understand the real world situation.

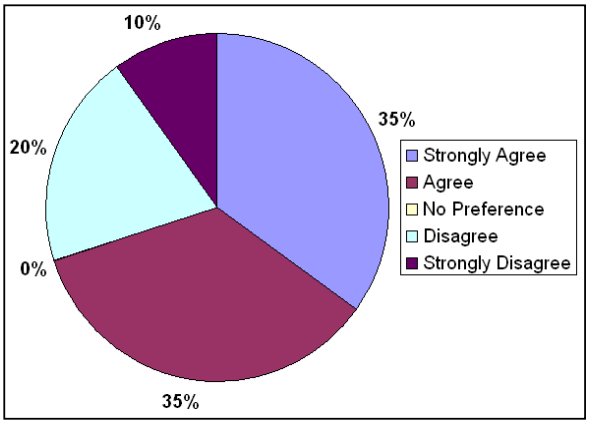


Figure F.11: Statement: I can easily navigate the 3D view of S-City VT using the mouse.

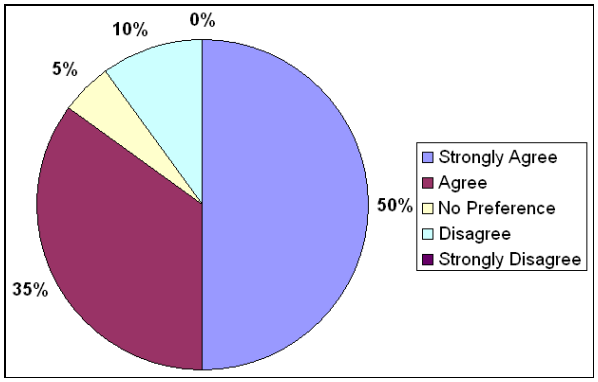


Figure 6.12: Statement: I can easily turn the Carbon model of S-City VT on and off.

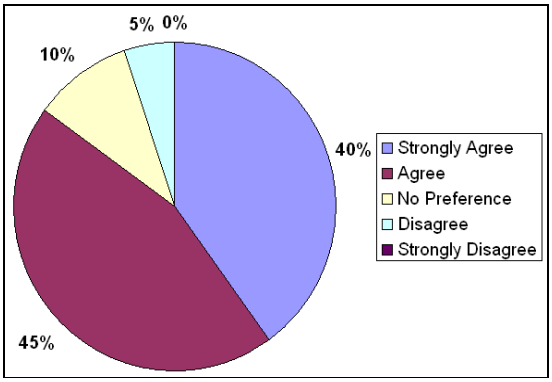


Figure 6.13: Statement: I can easily tell the date the simulation is currently at in S-City VT.

F.3. BOTH TOOLS

F.3.1. INDICATORS

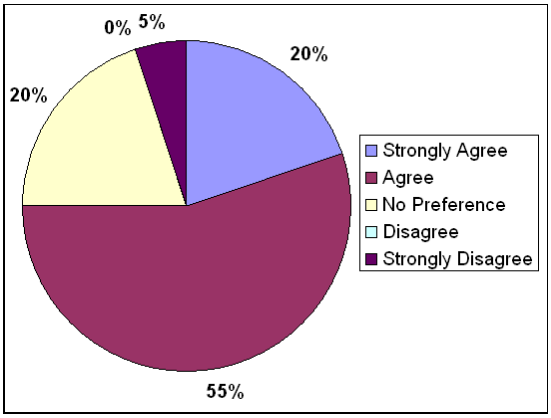


Figure F.14: Statement: I can easily tell the difference between a building using a lot of and a building using little energy in S-City VT.

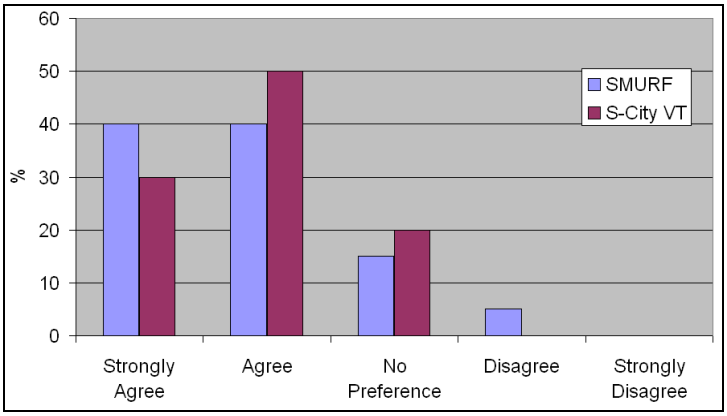


Figure F.15: Statement: It would be easier to understand the indicators of SMURF and S-City VT if they were explained.

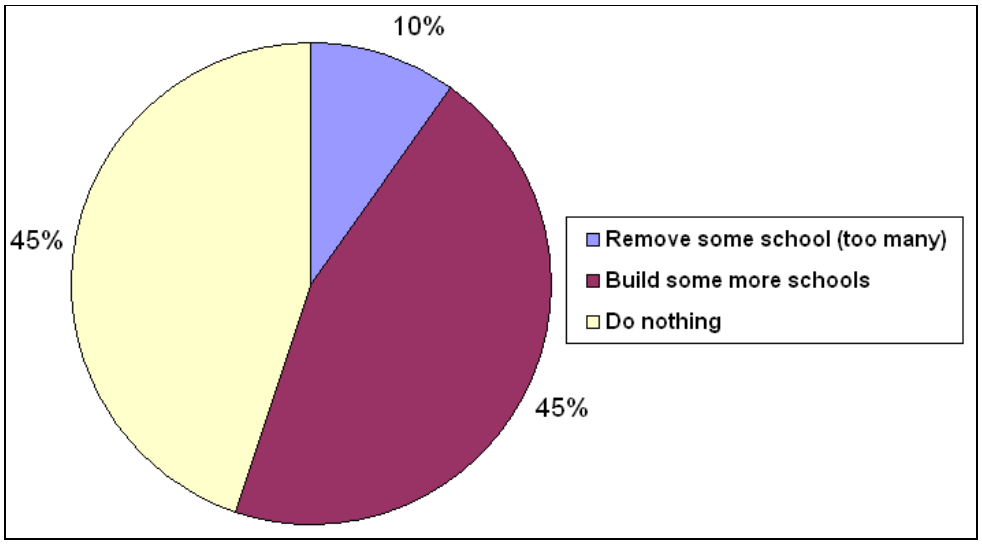


Figure F.16: Statement: What decision would you take based on the indicator "Distance to Schools" of SMURF in Mahe Island.

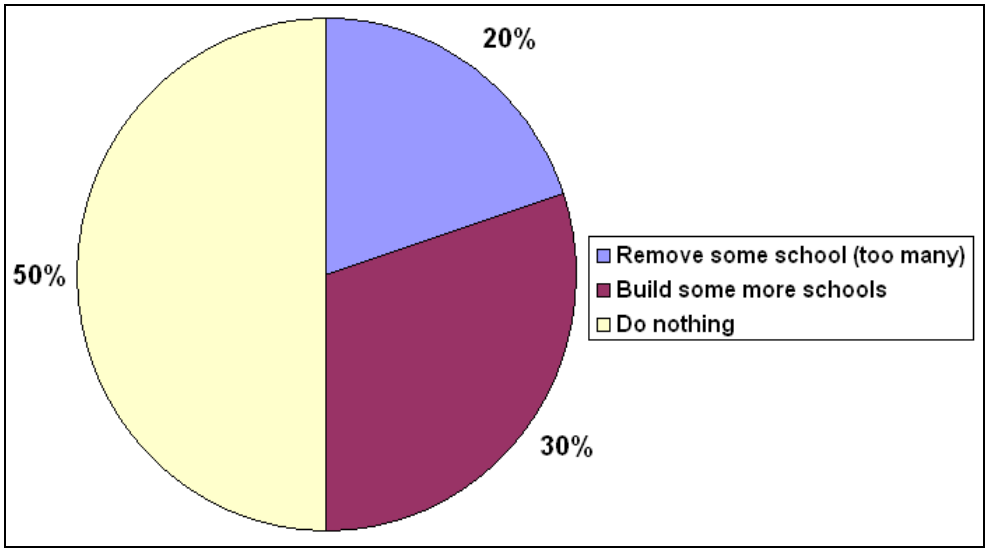


Figure F.17: Statement: What decision would you take based on the indicators "Distance to Schools" and "Population Density" of SMURF in Mahe Island.

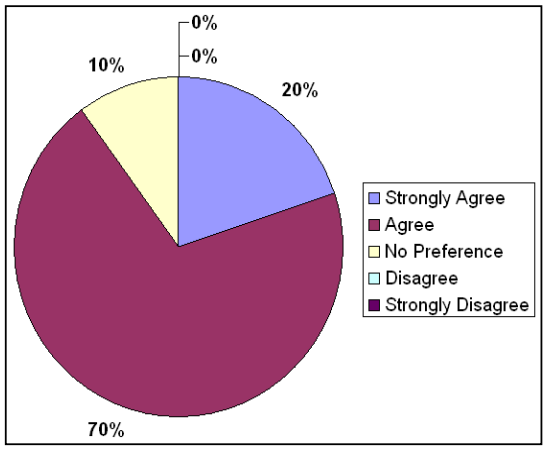


Figure F.18: Statement: Seeing how a building's energy use changes over time in S-City VT helps me to make a better decision than if I only see it At one time (e.g. summer or winter).

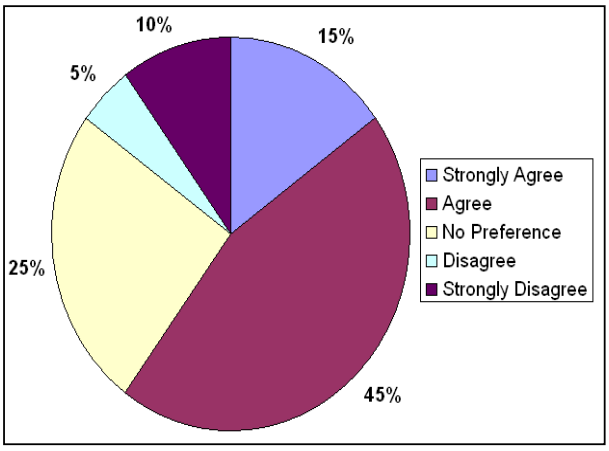


Figure 6.19: Statement: Seeing the "Distance to Schools" indicator of SMURF at two different points in time would help in making a decision.

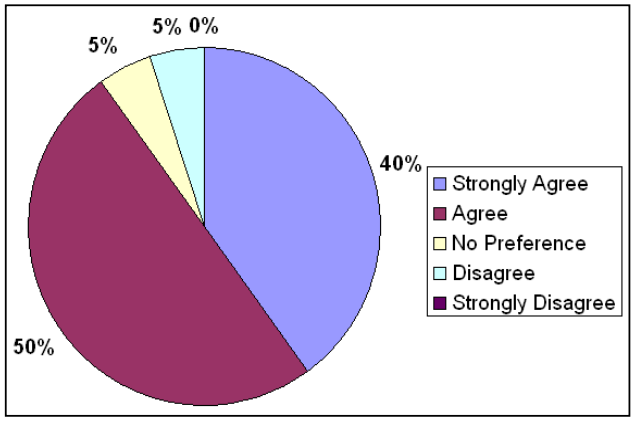


Figure F.20: Statement: It would be helpful to make a decision if the indicators "% Main Supply Treated" and "Connected to Sewerage" of SMURF are shown at the same time.

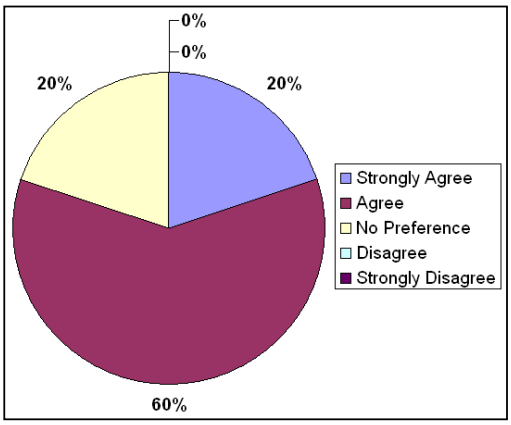


Figure 6.21: Statement: It would be more helpful to make a decision if more indicators (including the energy consumption one) were shown at the same time in S-City VT.

F.3.2. OTHER ASPECTS

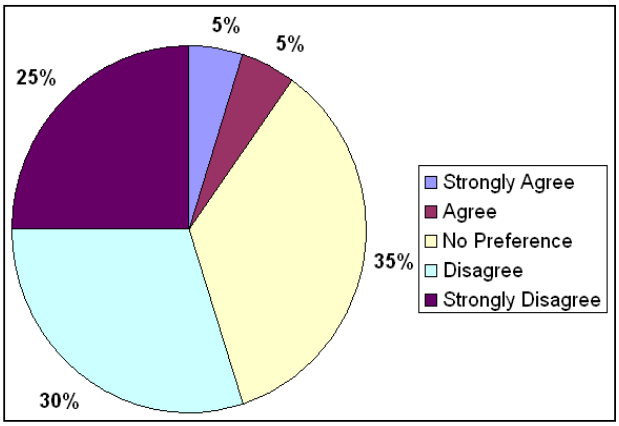


Figure F.22: Statement: Both tools are useful if they are not on the Internet.