Urban River Basin Enhancement Methods

Decision Support Framework for Assessing and Managing Urban River Rehabilitation

Work Packages 5 & 9

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Summary

This report describes the URBEM Decision Support Framework for assessing and managing urban river rehabilitation. The Framework integrates the suite of tools, methods and information that has been developed on the EU 5th Framework Program URBEM project. The Framework aims to support decision makers and technical specialists in improving degraded urban watercourses and promotes public and stakeholder engagement and participation and provides methods for achieving this.

The Decision Support Framework has been encapsulated within an activity chart that shows the relationship between all the outputs of the URBEM project and allows the expansion of the chart to include wider sources of information, tools and methods. The activity chart, provided in full as an appendix to this report, provides a visualisation of the URBEM Framework and this report provides the explanation.

The Framework has been based on the management cycle of river rehabilitation that represents a holistic approach to urban river rehabilitation that feeds the lessons learnt from the outcome of rehabilitation projects into the policies and the planning of future enhancement initiatives. The management cycle and the Framework promote effective planning, construction, monitoring and feedback on rehabilitation projects and aims to enhance the ability of decision makers, project managers, land use planners, water managers, stakeholders and the public to communicate about river rehabilitation.

Multi-Criteria Decision Making methods are described in this report, as one of the tools in the URBEM Framework. Alternative approaches are described.

The URBEM Decision Support Framework includes three main elements. These elements are:

Support Guidance This includes all the information that is available to inform the decisions taken in the generic approach.
Decision Guidance This includes the tools and assessment procedures that elicit a decision.
The Generic Approach for Assessing and Managing River Rehabilitation The generic approach describes the processes of setting up the project, selecting options and implementing the project.

The generic approach includes a tool for assessing the potential of urban watercourse rehabilitation and all processes included in the generic approach are described in detail.

Contents

1. Introduction

1.1 The URBEM Project

Urban River Basin Enhancement Methods (URBEM) is an EC FP5 Project that started in November 2002 and will finish in October 2005. The overall aim of the project is to provide new tools, techniques and procedures to enhance watercourses located in urban areas. There are thirteen partners from six European countries working on URBEM and these organisations make up a multi-disciplinary team. This partnering approach means that the URBEM project has developed guidance, methods and techniques that are applicable throughout Europe and accommodate the wide range of issues that urban river rehabilitation must consider in order to provide sustainable solutions to the cities of tomorrow.

The URBEM project involves 11 work packages that have delivered a range of outputs in the form of information, guidance, tools and methods that will be useful and valuable to a range of decision makers, land use planners, water managers, technical specialists, stakeholders and the public. Essentially all organisations and individuals that have an interest associated with the urban or river environment will benefit from at least some of the outputs of the URBEM project.

This report presents the decision support framework and tool that have been developed within Work Packages 5 and 9. The framework provides a structured approach to the design of rehabilitation schemes and allows one to understand the linkages between the other outputs of the project. This report should, therefore, be used as a starting point for a river rehabilitation project and will direct the reader to the other outputs of the URBEM project for specific information or activities required by the project.

1.2 The wider context of river rehabilitation

Urban watercourses are often highly degraded because of the range of pressures that influence them as a result of their urban setting. The morphology of the river is often constrained and altered from its natural planform and channel geometry as a result of channelisation and culverting which has been carried out in the past to restrict the location of the river to allow development to spread up to the margins of the river corridor. Water quality in urban rivers can also be poor due to both point source and diffuse pollution that enters the watercourse from the urban environment. Diffuse pollution from highway runoff and other impervious surfaces can be a particular problem if lack of street cleaning or inadequate highway drainage means that pollutants on surfaces are washed directly into watercourses in the event of heavy rainfall. Point source pollution often occurs from industrial discharges to the river – although effluent discharges are regulated throughout Europe and should meet specified water quality standards – as well as combined sewer overflow (CSO) discharges to the rivers where storm

flows in the sewerage network discharge directly to the river when the sewer flows are greater than a certain amount.

These problems with the morphology and water quality of an urban river have ramifications for the ecology, flood control, aesthetics and amenity functions of the river. Urban rivers, therefore, often become a feature that degrades the urban landscape, which reduces the value of the land in terms of financial asset and reduces the quality of life for the urban community. In addition, degraded urban rivers can represent a cost to the responsible authority as maintenance activities such as dredging of the channel may be required to maintain conveyance or remove unsightly, odorous or dangerous pollutants.

The negative consequences of urban river degradation can be ameliorated through rehabilitation of the river, which can bring many benefits to the river, the city and the people living and working in the city. The term river rehabilitation is used rather than river restoration as it may not be possible or desirable, within the constraints of an urban environment, to return the river to its natural state, as is implied by the use of the term 'restoration'. Instead, rehabilitation aims to improve particular aspects of the river, so a rehabilitation project may aim to improve the morphology, water quality, ecology, amenity, aesthetics or flood conveyance functions of the river – or a combination of any number of these aspects and more. Common drivers for river rehabilitation are to increase the value of the land in close proximity to the river and also to increase the amenity in an urban space and improve the quality of living for the urban community. More recently, the European Water Framework Directive, which was introduced in 2000 and requires all surface water bodies to meet specified ecological standards, has motivated EU member states to introduce measures to improve the water quality and the hydromorphology of rivers in order to bring about an improvement in the river ecology.

River rehabilitation is carried out, therefore, to achieve a variety of different objectives and the type of scheme implemented will depend on the aims of the rehabilitation project. The URBEM project has developed methods for urban river basin enhancement that support this process of implementing appropriate solutions to urban river degradation.

1.3 Challenges for decision makers

The roles and responsibilities for river management vary throughout Europe and the organisational structures are different from river catchment to river catchment, country to country and often, city to city. It is likely, however, that despite this, there will be several different organisations and individuals that have a role in the management of the river, the urban environment and the socio-economic issues in a city that influence the state of urban river enhancement. All of these organisations and, indeed, other stakeholders, may have an interest in rehabilitating an urban river. It is a challenge for any of these bodies to embark on river rehabilitation due to the fact that the rehabilitation project may overlap with the domain of other organisation's responsibility or interest. Having the authority to carry out a rehabilitation

project, therefore, will often require the agreement and participation of a number of organisations.

Thus a true challenge for any river enhancement project is satisfying the often conflicting interests of a variety of stakeholders as well as the public. If this is achieved, however, then the project has the potential to attract additional funding from the benefiting organisations, achieve wider improvements and ensure the ownership and long term sustainability of the scheme after the life of the rehabilitation project itself.

Another challenge for decision makers is to understand the wide range of issues that river rehabilitation needs to address. These range from the engineering (scheme design, river hydraulics), to the scientific (river morphology, ecology), to the social and economic aspects of river enhancement. River rehabilitation is, therefore, likely to involve a number of technical experts from a range of disciplines and the decision maker must be able to understand the multi-disciplinary nature of the project.

The URBEM project aims to assist decision makers and technical specialists in dealing with the multi-disciplinary facets of urban river enhancement by providing a framework for assessing and managing river rehabilitation, as described in this report, and by providing a number of information resources, guidance documents, tools and methods that may be useful to technical specialists.

1.4 Structure of report

The main body of this report is structured into three main chapters; Chapter 2 explains the decision support framework that has been developed for Work Package 9, Chapter 3 describes the generic approach that is included in the decision support framework and Chapter 4 reports the multi-criteria decision making tool. The generic approach encompasses the tool for assessing the potential of urban watercourse rehabilitation which has been developed for Work Package 5.

The sections in Chapter 2 outline the three elements of the framework and direct the reader to other URBEM outputs where appropriate.

The sections in Chapter 3 explain the three processes and the five stages involved in the generic approach. This includes the tool for assessing the potential for rehabilitation developed for Work Package 5.

The multi-criteria decision making tool that is included in the decision guidance was developed under Work Package 5 and this is reported in full in this document in Chapter 4.

2. The URBEM Decision Support Framework

2.1 Context

Urban river rehabilitation is influenced by a wide range of urban land use planning and water management issues. The URBEM decision support framework contributes towards a holistic and sustainable approach to river rehabilitation. In the broader context, this is achieved through the fundamental cycle that is promoted implicitly throughout the URBEM guidance and is shown in Figure 2.1.

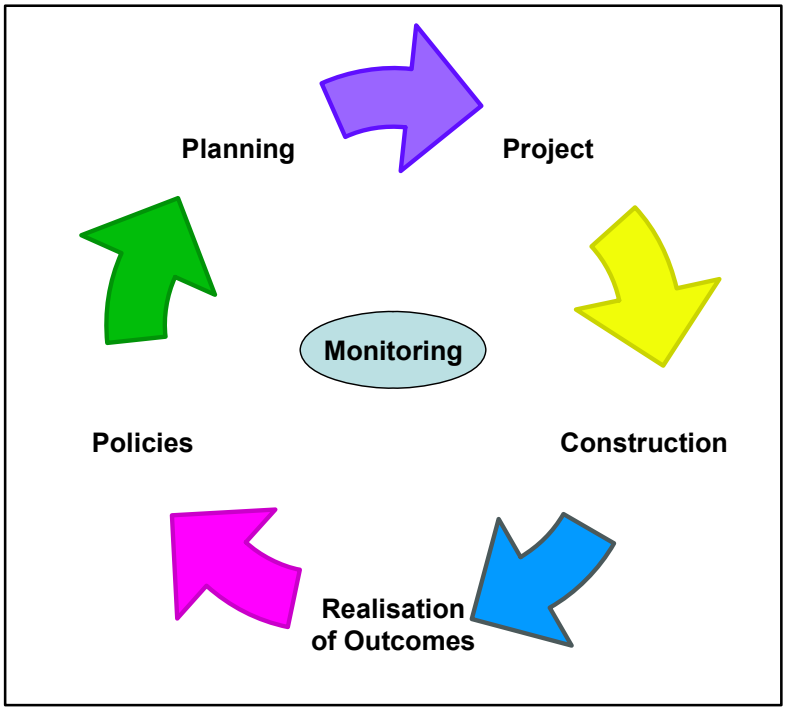

Figure 2.1 Management cycle for river rehabilitation

The stages involved in this cycle are

- **Planning** This is carried out at national, regional and local scales. Where river catchments are transboundary there may be planning at the catchment scale that influences national planning. Planning involves the production of land development plans, river catchment plans and drainage infrastructure plans that will have an influence on the types of projects that are carried out and the level of funding they receive. Planning determines a strategy for urban development and river enhancement.
- **Project** Can involve designing significant changes to the urban landscape and the river or can be very small schemes and initiatives. For example an urban river enhancement project may be as ambitious as the day-lighting and landscaping of many kilometres of river, with associated community initiatives and improvement of the urban drainage infrastructure; or a project may be a small scale as tree planting on the river banks to improve the aesthetics and ecological value.

- **Construction** This phase is the implementation of the schemes and options designed by the project. It involves carrying out the physical work.
- **Realisation of outcomes** A project may be carried out for long term or short term benefits and this phase describes the outcome of the project over the short and the long term. There may be a settling down period after the scheme has been constructed where the scheme requires time to fully realise its end goal – for example, achieving geomorphological equilibrium or vegetation succession.
- **Policies** Should be developed based on the outcomes of previous projects and plans. Policy will determine the level of investment in urban regeneration and enhancement and water management. Policy will also determine what planning is required in the next stage of the cycle.
- **Monitoring** This is central to the cycle as there should be audit and control at each stage in the cycle. This involves keeping a record of the processes and decisions made at each stage in the cycle and verifying the information on which decisions are based. Monitoring also involves collecting environmental data before, during and after the construction of a scheme.

Each of these stages, with the exception of the development of policies, is dealt with by the URBEM decision support framework. The policy phase is not covered by the project because it is likely to be very country specific and the project must be applicable throughout Europe. The information from the project and the effect of implementing the framework will, however, inform the development of policy.

2.2 The Activity Chart and the Tool for Assessing the Potential of Urban River Rehabilitation

The URBEM decision support framework links the multi-disciplinary outputs of the URBEM project and outlines procedures for public and environmental authorities to carry out river rehabilitation. Included in the framework is the tool for assessing the potential of urban river rehabilitation. This report is accompanied by an activity chart which sets out the elements of the framework described in this report. There is potential for this activity chart to be developed into an interactive digital version with links to the different outputs included in the framework. Figure 2.2 shows a summary version of the activity chart, which is presented in full in Appendix 1 of this report.

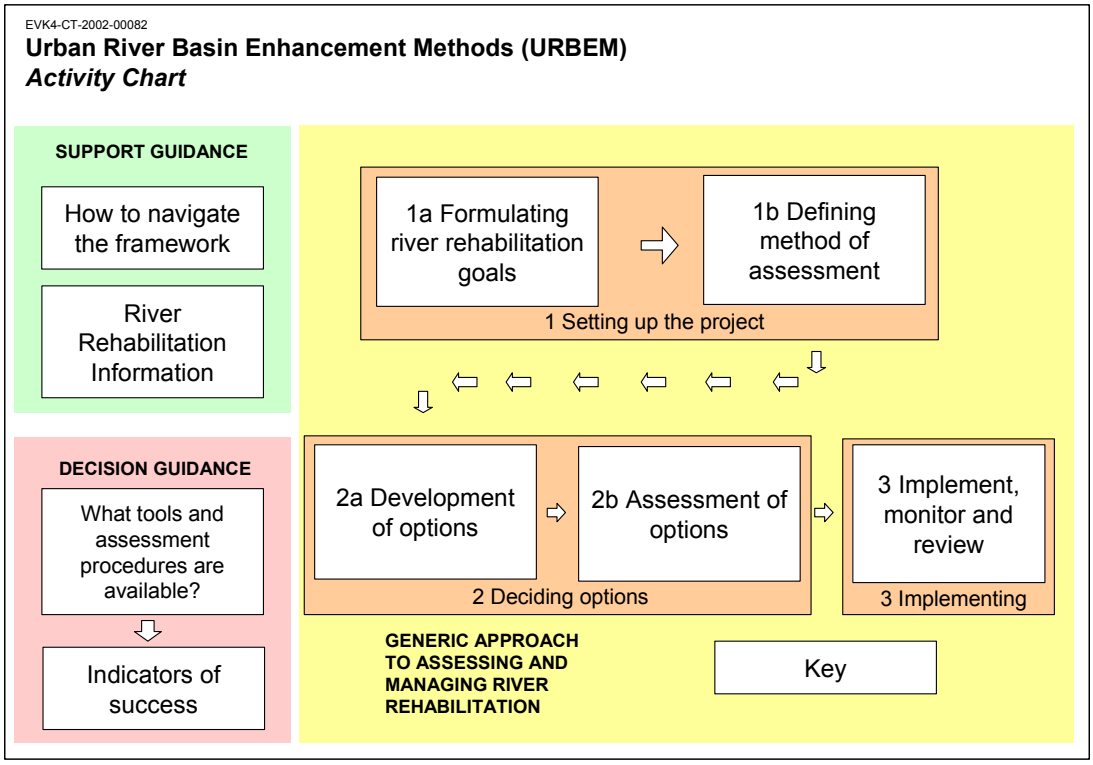

Figure 2.2 The URBEM decision support framework activity chart summary version

The framework is intended to support decision makers and technical specialists in their task of enhancing an urban river but may also be used to communicate the processes involved in the project to other stakeholders and the public. A non-technical explanation of the activity chart is given in work package 11 (Maksimovic & Tolic, 2005) for dissemination of the URBEM framework to the public.

The URBEM decision support framework has been developed using the Business Elements Theory (Mayon-White & Dyer, 1997) which sets out principles of information management that can be applied to any business context. The application of these principles has been successful in a number of other situations and the URBEM framework has benefited from the recent delivery of the UK Environment Agency Guidance for Flood Risk Assessment for New Development (HR Wallingford, 2005a, 2005b), the outputs of which can be found at http://www.hrwallingford.co.uk/projects/flood_risk_assessment/index.html.

The URBEM framework has three key advantages:

- **Efficiency** The framework enables users to carry out activities in a timely manner using the outputs from existing research. Each module and each process part in the activity chart is referenced by a unique code that enables the user to identify what outputs exist for each module and allows this report to reference the processes in the activity

chart easily. Table 2.1 shows the corresponding list of references of URBEM outputs for the module codes in the activity chart.

- **Effectiveness** The framework provides a means to communicate the assessment and decision making process to stakeholders in a transparent and unambiguous manner.
- **Evolution** The Framework is modular so that it can be expanded and updated as necessary. The URBEM Activity chart shows only the information, guidance, methods and tools that have been produced for the URBEM project but this could easily be expanded to include references to other resources that can be useful to decision makers and technical specialists. Likewise, the framework can be updated with new guidance documents, tools and methods as they become available.

Table 2.1 Linkages from the URBEM framework Activity Chart to URBEM outputs – a quick reference guide

Module code	Module		URBEM output reference
S1.1	Introduction to the framework	1	Bettess, R., Bain, V. (2005) Decision Support Framework for Assessing and Managing Urban River Rehabilitation. HR Wallingford.
S1.2	Glossary and appendices	1	
S1.3	Training and dissemination	1	Maksimovic, C., Tolic, J. (2005) Guidelines for the use of the training module for urban river basin enhancement methods. Imperial College, London.
S2.1	Existing case studies	1	Schanze, J., Olfert, A., Tourbier, J., Gersdorf, I., Schwager, T. (2003) Existing Urban River Rehabilitation Schemes. IOER/TUD, Dresden.
S2.2	Study site monitoring	1	Tellier, S. (2004) Existing Data from selected urban rivers. University of Newcastle, Newcastle.
		2	Tellier, S., Amezaga, J. (2004) Work Package 3: Study Site Monitoring – Deliverable 3.2. University of Newcastle, Newcastle.
S2.3	Rehabilitation techniques	1	Rocha, J., Alves, E., Brilly, M., Tourbier, J., Schwager, T.,

			Gersdorf, I., Olfert, A. (2004a) How to re-naturalise flow regimes – recommendations. LNEC, Lisbon.
		2	Rocha, J., Woods-Ballard, B., Faber, R. (2004b) New techniques for urban river rehabilitation – Incorporation of wetlands, floodplains and sustainable urban drainage methods into urban schemes. LNEC, Lisbon.
D1.1	Aesthetic evaluation methodology	1	Silva, J., Saraiva, M.G., Ramos, I.L., Bernardo, F., Monteiro, F., Câmara, C. (2003) Classification of the aesthetic value of the selected urban rivers – methodology. IST, Lisbon.
		2	Silva, J., Saraiva, M. (2004) Classification of the aesthetic value of the Jardas Stream – Application of the methodology to the study area. IST, Lisbon.
D1.2	Social appraisal tool	1	Higginson, S. (2004) Social Appraisal Tool: ProveIt! New Economics Foundation, London.
		2	Walker, P. (2005) How to do social appraisal. New Economics Foundation, London.
		3	Brilly, M. (2004) Analysis of social interests on the water bodies of the Ljubljanica, Mali Graben, Glinšča and Koseški Bajer for the needs of the URBEM project. University of Ljubljana, Ljubljana.
		4	Walker, P., Bain, V., Faber, R., Gersdorf, I., Brilly, M. (2004) Social appraisal tool: Results of implementation. New Economics Foundation, London.
D1.3	Multi-criteria decision making	1	Bettess, R., Bain, V. (2005) Decision Support Framework for Assessing and Managing Urban River Rehabilitation. HR

			Wallingford.
D2.1	Indicators of success	1	Tourbier, J., Gersdorf, I. (2005) Indicators of Success. TUD, Dresden.
Generic Approach	All processes within the Generic Approach	1	Bettess, R., Bain, V. (2005) Decision Support Framework for Assessing and Managing Urban River Rehabilitation. HR Wallingford.
		2	Silva, J. (2004) Assessing the Potential for urban river rehabilitation through an additive aggregation multi-criteria model. IST, Lisbon.
		3	Olfert, A., Tourbier, J., Gersdorf, I. (2004) Test of the draft tool for assessing potential for rehabilitation. IOER, TUD, Dresden.
		4	Brilly, M. 2005) Implementation and review of the new assessment tool – Work Package 6. University of Ljubljana, Ljubljana.

The URBEM Framework has three elements:

- **Support Guidance** This includes all the information that is available to inform the decisions taken in the generic approach. This element is described in Section 2.3.
- **Decision Guidance** This includes the tools and assessment procedures that elicit a decision. This element is described in Section 2.4 and includes the multi-criteria decision making tool that is presented in Chapter 4.
- **The Generic Approach for Assessing and Managing River Rehabiliation** The generic approach describes the processes of setting up the project, deciding options and implementing the project. This is outlined in Section 2.5 and described in detail in Chapter 3.

2.3 Support Guidance

The support guidance in the URBEM framework contains information, guidance, specifications and recommendations to help decision makers and technical specialists assess and manage river rehabilitation. The support

guidance helps, therefore, to carry out the tasks in the generic approach described in Section 2.5 and Chapter 3. The two parts of the support guidance explain how to navigate the URBEM framework and reference river rehabilitation information.

How to navigate the framework

2.3.1 Introduction to the Framework

This report gives the introduction to the URBEM framework by explaining the different elements of the framework including the description of the generic approach. When using the URBEM decision making framework it is recommended that users are familiar with this overview so that they can understand the range of aspects that should be taken into account when embarking on a river rehabilitation project, and to see how each of these aspects fit together in terms of their contributions to the project. This ensures that the team working on the project take a holistic approach to assessing and managing river rehabilitation, resulting in more sustainable solutions being reached. It is also beneficial for stakeholders to have an understanding of the elements in the framework so that they can appreciate the range of issues that a rehabilitation project must take on board and will understand the processes involved in river enhancement.

The level of detail in which the user must understand the URBEM framework will depend on their role and interest in the river rehabilitation project. Decision makers will need to have a thorough understanding of the generic approach and be aware of the support guidance and decision guidance that is available to help with the processes in the generic approach. Technical specialists should have an overview of the framework and the generic approach and will need a more in depth knowledge of support guidance and decision guidance that is relevant to their technical area. Technical specialists will have to feed information to the processes involved in the generic approach and may have to carry out some of the process steps themselves. Wider stakeholders and the public should have an overview of the framework and understand what elements it includes, which will enable them to understand where their feedback is used and whether they may have useful information or inputs to the project.

2.3.2 Glossary and Appendices

This module refers to the document produced to give definitions of the terminology used throughout the URBEM reporting and gives information relating to some of the outputs.

2.3.3 Training and Dissemination

This module refers to the training and dissemination outputs that have been produced for Work Package 11 (Maksimovic & Tolic, 2005). The training

package gives information and training on each of the elements of the framework and aims to give an appropriate level of detail for different types of user. The different audience groups are Group A, decision makers, Group B, technical specialists, and Group C, the public and other stakeholders. This module can be used on a demand basis so that users can take training in those modules that they need to use in their rehabilitation project. It is recommended that all users have at least a level C overview of each module so that they are aware of the resources, capabilities and benefits that the URBEM tools and information can provide.

2.4 Decision Guidance

The decision guidance in the URBEM framework contains the tools and assessment procedures that elicit answers to the questions posed in the generic approach and will help decision makers and technical specialists assess and manage river rehabilitation. There are two parts to the decision guidance; the specific tools and assessment procedures that have been developed and the information on indicators of success that can be used for decision making in several of the processes of the generic approach.

Sections 2.3.1, 2.3.2 and 2.3.4 give an overview of decision guidance modules that are fully specified in other URBEM outputs and Section 2.3.3 provides the full output of the multi-criteria decision making tool.

What tools and assessment procedures are available?

2.4.1 Aesthetic Evaluation Methodology

This module contains the outputs of URBEM Work Package 4 on aesthetic evaluation (Silva *et. al.*, 2003; Silva & Saraiva, 2004). This work introduces the concept of assessing urban river enhancement in terms of three key elements; river, city and people. The aesthetic appraisal method gives a range of appropriate criteria by which the aesthetics of an urban river can be measured and guides the user in applying appropriate criteria for the situation.

When assessing the potential for river rehabilitation with the generic method, there is a requirement to set objectives, assign criteria to those objectives and then evaluate the criteria against different options for rehabilitation. A common objective of river rehabilitation is to improve the aesthetics of the river and the river corridor. The aesthetic evaluation methodology provides a means of assigning and evaluating criteria for this objective, thereby giving support to the decision making process of the generic approach.

When considering the aesthetic attributes of a river, the methodology recognises that there are some characteristics that cannot be changed by a rehabilitation project, such as the basin size, the stream order or the valley morphology. An assessment of these factors, however, determines the river typology which then allows similar rivers to be compared and shows where

the typology of the rivers are different and should, therefore, not be directly compared.

As the generic approach is structured, the aesthetic appraisal method also requires each aesthetic criterion to be scaled on a normalised scale from plausible maximum to plausible minimum scores for each criteria. The evaluated scores for each criterion are then presented in a graphical profile to represent the aesthetic performance of the river and to identify where there is potential for improvement.

2.4.2 Social Appraisal Tool

This module contains the outputs of URBEM Work Package 7 on social appraisal (Higginson, 2004; Walker, 2005, Walker *et.al.*, 2004). This work has produced a toolkit for measuring social capital and for engaging stakeholders and the public. Social capital is defined as the social networks characterised by the norms of trust and reciprocity. The tool aims to measure how the river promotes people's interaction with each other and enhances the quality of life of the individual. The tool acts to engage stakeholders by providing a series of consultation and involvement techniques.

The social appraisal toolkit consists of four elements:

i) Project storyboard template
ii) Survey questionnaires
iii) Poster evaluation session
iv) Project reporting

The storyboard template is completed in order to predict the impact of a rehabilitation project. It involves producing a timetable of activities and estimating what impact each stage of the project will have on the value of social capital associated with the river.

The survey questionnaire is presented as a tool which automatically processes the results of the questionnaire and presents a graphical output for convenient interpretation. The questionnaire contains a core list of questions which can be adjusted or added to as appropriate for each particular rehabilitation project. A trained ProveIt! surveyor should carry out the questionnaire survey. A representative sample of people should be surveyed and should include people within community groups as well as those who are not involved in community groups.

The poster evaluation session aims to assess the impact that the rehabilitation project has had on the social capital. The session takes place in the form of a 1.5 to 2.5 hour meeting which is attended by up to 12 people including project managers, participants, and the wider community panel; and is chaired by an auditor who has not been directly involved in the rehabilitation project. The toolkit contains a set of instructions for the chair to follow to guide the group in creating posters to draw out the opinion of each member of

the group on what the impacts of the project have been and on the lessons that have been learnt. In this way, the session is used to evaluate the project in terms of people's attitude towards the outcomes.

The project reporting part of the toolkit gives guidance on how to interpret and present the findings of the storyboard, the questionnaire and the poster evaluation.

2.4.3 Multi-Criteria Decision Making

This module in the URBEM framework is contained within this report in Chapter 4. The module gives guidance on multi-criteria decision making methods and approaches for applying them. Refer to Chapter 4 for a comprehensive introduction to this topic.

Which indicators can be used for decision making?

2.4.4 Indicators of Success

This module contains the outputs of URBEM Work Package 10 on indicators of success (Tourbier & Gersdorf, 2005). Indicators of success can be used to measure the extent to which a rehabilitation project achieves its objectives. The indicators are developed to enable post implementation assessment, but are integrated into the process of setting up a rehabilitation project in the Generic Approach described in Section 2.5. This ensures that there is a process of audit and control throughout the planning of a project.

The report gives a list of indicators, categorised into ecological, social and economic indicators with subcategories shown in a tree diagram for quick reference. Guidance is given on the selection of indicators, presenting a range of questions that should be answered in order to check that indicators are selected and used in an appropriate way.

2.5 Generic Approach for Assessing and Managing River Rehabilitation

The generic approach for assessing and managing river rehabilitation is described in detail in Chapter 3. It comprises a set of processes which draw on the tools and information in the other modules in the URBEM framework to assess the potential for river rehabilitation and plan, implement and monitor a project. The generic approach forms the core of the decision support framework.

3. Generic Approach for Assessing and Managing River Rehabilitation

3.1 Introduction to the generic approach

The generic approach relates to all of the aspects in the management cycle explained in Section 2.1 except to the development of policies. There are three processes in the generic approach, with five sub-processes in total, which are described in detail in Sections 3.2 to 3.7. These processes are:

1. **Setting up the project**
   1a Formulating river rehabilitation goals
   1b Defining method of assessment
2. **Deciding options**
   2a Development of options
   2b Assessment of options
3. **Implementing**
   3 Implement, monitor and review

The management cycle and the generic approach have been developed as a result of the research that has been carried out across the URBEM project. The generic approach encompasses the Work Package 5 tool for assessing the potential for urban watercourse rehabilitation in processes 1 and 2. These processes represent the 'planning' and 'project' stages in the management cycle explained above and the generic approach sees an elaboration of the Work Package 5 tool to include process 3, which expands the guidance to include support for the implementation phase that represents the 'construction' and 'realisation of outcomes' stages in the management cycle.

Sections 3.2 to 3.6 outline the steps in the proposed methodology. The assumption is that these steps would be carried out sequentially. For particular applications some steps may be omitted, as being unnecessary, while in other applications it may be necessary to iterate round some of the steps a number of times.

3.1.1 Tool for assessing rehabilitation potential

Processes 1 and 2 in the generic approach provide a tool for assessing the potential for urban watercourse rehabilitation. There is a wide range of factors that are involved in deciding whether it is feasible to rehabilitate an urban watercourse. The objectives of a rehabilitation scheme may include the hydraulic, environmental, water quality, social and aesthetic aspects of a river system and its urban setting but the objectives of individual urban watercourse rehabilitation schemes may vary depending upon both the river and its surroundings. The purpose of the tool is to provide a framework for analysing the problem of assessing the potential for rehabilitation so that the user can:

a) decide whether a proposed rehabilitation scheme is appropriate in the particular circumstances or
b) select the most appropriate scheme from a shortlist of proposed options or
c) select a shortlist from a long list of possible options.

The method can be used to consider a number of different options for the same reach of river or may be used to consider rehabilitation schemes on a number of different river reaches either within the same river basin or in different river basins.

In deriving the tool, account was taken of the fact that a wide range of criteria have to be considered in the assessment procedure. In addition, for the system to be flexible and widely applicable, the tool does not specify the method to be used to assess particular criteria. Only the characteristics of the method are specified. Thus it will be possible to use the tool with whatever national or international assessment method that is commonly used in that country or region.

As indicated above, a rehabilitation scheme may impact on the hydraulic, environmental, water quality, social and aesthetic aspects of a river system and its urban setting. Where a number of potential options have been identified these will have different impacts on each criteria. In selecting an option one has to compare, therefore, very different criteria. There is a substantial body of work that has been developed on methods of decision making where there are multi-criteria and it is known as Multi-Criteria Decision Making. Chapter 4 gives an introduction to such decision making methods.

3.1.2 Usage of the generic approach

Within the context of river rehabilitation there are a number of different types of situation in which a number of potential options may need to be compared to determine the most appropriate one. In this section we explore the different types of problems that may arise and how these may affect the application of the generic approach.

It may be necessary for planning to take place at the city scale. Within a large urban area there may be a number of river basins. Within these basins there may be opportunities for river rehabilitation but budgetary constraints may mean that it is not possible to carry out all the possible schemes in the short-term. In this situation one may want to produce a short-list of the best schemes to carry out in the short-term or one may want to list the possible schemes in order of priority. In this context one will have to select objectives that are relevant to the urban area and that do not depend upon the characteristics of particular river basins. The objectives should, therefore, be area wide.

Another type of problem may arise when there is a desire to carry out rehabilitation works within a single river basin, so planning would take place at

a river basin scale. The problem may then be to decide the nature and location of works to provide the required improvements within the river basin. In this context the objectives would be set depending upon the characteristics of the particular river basin and the nature of the problems that need to be addressed. The aim of the analysis would then be to recommend the type and locations of interventions and possibly to list schemes in order of priority.

A third type of problem may arise in relation to a particular reach of a river when a decision has to be made as to what rehabilitation work should be carried out in that reach. The selected objectives would then have to reflect the local aims that have been selected for that reach.

3.2 Process 1a Formulating River Rehabilitation Goals

3.2.1 Assess baseline condition (1a.1)

Review information on urban catchment

There may be a number of sources of information and existing assessments for parts of the urban catchment that can be used to inform stages in the processes in the generic approach. In order to establish what may form the objectives of a river enhancement project, it is necessary to know the existing state of the river and urban environment so that the decision maker can establish where there is an opportunity for improvement. This is achieved by site characterisation based on existing data and collected data. For example, existing monitoring data will establish trends and existing status of water quality and biology whereas new surveys may have to be carried out in order to assess the existing social capital and aesthetic quality of the river environment (see D1.1 and D1.2).

Reviewing the information on the urban catchment will involve the decision maker, or project manager, identifying the key contacts in the main disciplines relating to the environmental science, engineering, social science and economics of the river and urban environment.

Identify stakeholders

It is important initially to identify the stakeholders that should be involved in the decision making process. These normally consist of those who will be affected by the decision. The issue of identification of stakeholders is addressed in detail in Work Package 7 (D1.2) and so will not be considered further here. There are a number of issues, however, that may need to be addressed. Throughout this report it is assumed that there is a decision maker. This decision maker may be a single individual or may be a group of individuals acting together. As should be clear from the above, in MCDM the values and beliefs of the decision maker affects the decision that is made. The decision maker has to select objectives and criteria, the method of analysis, score the options on the selected criteria and may have to select

weights if a method of analysis involving trade-offs is used. The fact that the decision making process depends so strongly on the decision maker is not a weakness but is a necessity when considering multi-criteria problems. To take a decision one has to take account of the different facets of the problem and this can only be done in terms of the different values associated with the different criteria.

The implication is that, when faced by the same problem, different decision makers who have different values and beliefs may come to different decisions. Where the stakeholders are diverse it is necessary to consider how their views should be obtained and how these are taken account of in the decision making process.

Any MCDM should take account of the informed preferences of people as a whole, to the extent that these preferences can be ascertained and used. This implies that one should ensure that the objectives used are sufficiently wide so as to encompass the main concerns of stakeholders. It may also be advisable to consider the preferences of stakeholders are ascertained and considered in the analysis. This can be done either implicitly or explicitly by involving stakeholders or their representatives in the decision making process.

It is recommended that the issue of involving stakeholders and how this should be achieved should be recognised and addressed explicitly rather than implicitly. Appropriate points for stakeholder consultation and participation have been identified throughout the generic approach.

3.2.2 Set goals and objectives (1a.2)

To carry out an MCDM analysis it is necessary to clarify the purpose of the project that is being considered. In this context words such as: goals, objectives and criteria are used. In the absence of any agreed terminology we will describe below how these words will be used in the rest of the work.

We will use the word ‘goal’ to describe the general ‘direction’ in which we should strive to do better. In the context of river rehabilitation of an urban water course this might be to ‘improve the river’. Broad goals may provide little insight into what should be undertaken or how different potential options should be judged. In cases they may also be mutually conflicting. Broad goals may provide a starting point for specifying more detailed, lower-level objectives. Thus ‘improving the river’, may be broken down into:

- improving the visual appearance of the river and
- improving public access.

These lower level objectives might be broken down into sub-objectives. Thus improving the visual appearance of the river may be broken down into:

- increasing the visual interest by putting bends in the river and

- increasing the number of contact points where members of the public may connect with the river.

The decision maker must be free to set their own goals and objectives. For some, the main goal of a rehabilitation scheme may be the visual appearance of the watercourse but for others the main motivation may be regeneration of the area. In addition the decision maker should not be limited to just one main goal. While the principal goal might be improving the visual appearance of the watercourse, in addition there may be a desire to improve the environment and some may also favour an increase in property prices in the area. Thus it is necessary that the tool be sufficiently flexible that the goals and objectives are defined by the user.

Goals and objectives should be selected in consultation with stakeholders including the local communities. It may be that by small additions to the objectives that otherwise would have been set, there can be a significant benefit and increased ownership which will secure the sustainability of the entire project. The very activity of consultation in itself may be enough to secure buy-in to the decision maker's goals and objectives.

For any urban river rehabilitation scheme the selection of objectives and criteria are likely to be specific to that scheme. There are likely to be common characteristics and issues and these are considered here.

The highest level goals of urban river rehabilitation are often to make an area more attractive to people, either for leisure, to work in or to live in.

In general the higher level goals for urban river rehabilitation projects will come under the following headings:

- Water quality
- Ecology
- Habitats
- Aesthetics
- Social
- Cost.

For river restoration in rural areas the main interest is often on issues related to Ecology, Habitats, Aesthetics with the specific social issue of flooding. In urban areas there is often less interest in ecology. In the urban context the objectives for water quality are set in relation to the water quality that is required to achieve other objectives, either in terms of:

- ecology – to support target flora and fauna,
- aesthetics – the visual appearance and odour of the river,

These are required to ensure that people are attracted to the area for leisure, to work or to live.

In this context it is often the aesthetics, which provide the main objective, with issues such as water quality improvements providing a means by which these improvements can be achieved.

When setting objectives, it is necessary to ensure completeness. The list of objectives should be complete in that all the important criteria which are relevant to the final decision should be represented by objectives on the list. The omission of significant criteria may distort the decision making process and lead to a decision that is not acceptable.

3.2.3 Set Boundaries (1a.3)

This stage sets the boundaries of the project management and the assessment and will determine the detail of analysis that will follow in further steps. Essentially this stage is 'planning the planning' and determines the boundaries within which the decision maker must work.

Defining the timescale of the project will determine how long is available for the planning, project and construction phases of the river rehabilitation. This will be a key controlling factor in determining the detail of the project management and assessment as well as the scale and ambitiousness of the rehabilitation option selected.

The spatial extent of the assessment should be defined with reference to the goals and objectives that have been set and based on the information on the catchment that was collected in Stage 1a.1. So, for example, having established that the goal may be to improve the community connectivity with the river, the spatial extent of the assessment can be set by using the catchment characterisation to find out for what locations this would be relevant.

The resources available for the project management and assessment is another boundary that may limit the level of detail with which further steps are carried out.

3.2.4 Identify controlling factors (1a.4)

This stage identifies the controlling factors that will have an implication for the final option selection. All options must meet the requirements of the controlling factors.

The legislative requirements must be checked, as there may be planning or environmental restrictions in force in the study location. Legislative requirements may also have an impact on the setting of goals and objectives- for example, the requirement to meet the Water Framework Directive- in which case it would be necessary to iterate round to Stage 1a.2.

There is a particular issue to do with the treatment of costs. Costs may be considered separately from an MCDM analysis. In this case cost will not be a factor in the selection or ranking process. The funding body may have an upper limit on the cost. In this case this can be accommodated using a satisficing method with all options that exceed the given upper limit being eliminated from further consideration.

In many situations the funding body is interested in value for money. In this case, cost can then be included within the MCDM as a criteria. In this case appropriate weightings relative to the other criteria have to be specified. These weightings reflect the decision makers willingness to pay for specific types of improvement.

Further controlling factors are the existing policies, plans and strategies that the project should satisfy. This may feed into the goals and objectives of the project, in which case it would be necessary to iterate back to Stage 1a.2.

Within an urban context there are often constraints that limit the potential for river rehabilitation. The situations that can potentially arise are so diverse that it is not possible to list here all the potential constraints that may have to be considered. We do give, however, a few illustrative examples which may indicate the types of problems that may arise. All the following are taken from practical experience of members of the URBEM team.

a) The presence of contaminated soil in the banks of the river may preclude any changes to the banks of the river channel as this might release contamination into the river system.

b) The presence of contaminated land near the banks of the river may preclude changes to the flow regime of the river that would permanently raise water levels, as increased water levels might lead to mobilisation of contaminants within the groundwater system. It may also limit the potential for channel re-alignment if the new channel cannot be constructed within the contaminated area.

c) The presence of drainage outlets along the river bank may significantly affect the cost of any channel re-alignment if this would involve modification or relocating the outfalls. To avoid this cost it may be necessary to constrain any changes to the alignment of the river so that the existing outfalls can be retained.

d) The presence of services, such as gas, electricity or water mains may constrain the potential for changes to the bank profile or for channel realignment if they are buried within, or close to, the river bank. The cost of moving such services may be prohibitively expensive. There may also be services running under the bed of the river channel. This may constrain options for modifying the bed of the channel.

3.3 Process 1b Defining Method of Assessment

3.3.1 Set criteria

For each of the lowest-level objectives we will need to associate a criterion that will indicate the degree to which different options meet this objective. Thus in the case of putting bends in the river the criterion might be the sinuosity of the river. This can be easily measured for each option and the options compared. The aim will be for each low-level objective to assign a suitable criterion.

Appendix 2 gives an indicative list of possible objectives and criteria. This list should only be regarded as indicative. In any particular scheme it may not be necessary to include all the objectives and some schemes may have additional objectives. It is hoped that the list should, however, provide a useful starting point for the application of MCDM to any particular rehabilitation project.

Define criteria for each specific objective

It is necessary that the list of criteria satisfy a number of conditions.

Operational: The criteria selected must be meaningful to the decision maker so that he or she can understand the implications of the alternatives.

Mutually exclusive: The same criterion should not be a significant element of more than one objective as this may lead to greater emphasis being placed on this criterion than on others

Minimum size: It is desirable to keep the number of criteria as small as possible subject to the constraint of completeness above. The difficulties of the subsequent analysis increase greatly as the number of criteria increases.

It should be noted that there may be no one ‘correct’ set of criteria for a particular problem. There may be a number of different sets of criteria that each provides a suitable basis for analysis of the problem.

Wherever possible, criteria should be selected in such a way as to utilise existing observation and measurement systems which are used locally. Most countries have a system of water quality monitoring and an associated classification system. In the area of ecology it is expected that the application of the Water Framework Directive will introduce systems to classify the ecology of rivers. The advantages of using such systems are that:

- any required historical data should be readily available,
- the methods of data collection should be familiar and
- the system is well-understood.

Defining success indicators

Success indicators are criteria against which the decision maker can measure the level of achievement of their objectives. These are defined separately from criteria as the criteria are used to evaluate a project before it has been carried out, whereas indicators of success evaluate a project after it has been carried out. There may be some success indicators that could not be used for criteria because it would be too difficult to estimate how the scheme would perform on that indicator. Criteria, however, allow the decision maker to see how the rehabilitation options may perform against the objective before the project is carried out so that they can assess the benefits of the project. The Work Package 10 output (D2.1) (Tourbier & Gersdorf, 2005) is the guidance that should be referred to for the method of the selection and application of success indicators.

The success indicators are defined at this stage so that, as far as possible, they can be defined to compliment and overlap the criteria as far as possible. If the decision maker can define a list of criteria and a set of indicators of success that are similar, it will be less onerous to carry out an evaluation of the project.

3.3.2 Define scale of measurement of criteria (1b.2)

When one is considering a particular criterion then it is necessary to compare the impacts of different options. To do this one must have some scale on which to judge a particular option. The scale may be numerical, for example, an assessment of the attribute may be given a score from 1 to 100, or it may be qualitative, for example, an assessment of an attribute may be rated on a scale very good, good, …, poor.

In general, there may be a number of methods of assessing particular criteria. For example water quality may be assessed in different ways. The methods proposed by URBEM need to be applicable across Europe and so it is necessary to build into the system enough flexibility to take account of the different approaches that are used within Europe.

Many of the criteria that we may think about using have well-defined objective methods of assessment, for example, cost which can be measured in pounds sterling. For these types of criteria there is a commonly understood scale for that criterion and its levels are objectively measurable. Other criteria, such as aesthetics, are more subjective in nature. For these types of criteria some form of appropriate measure needs to be constructed. In the particular case of ‘aesthetics’ the reader is directed to the report on Work Package 4 (Silva *et. al.*, 2003; Silva & Saraiva, 2004) which has developed such a measure.

For subjective criteria it may be necessary to construct a subjective index for the criteria. A first step might be to establish a 10-point scale from the lowest reasonable value to the highest reasonable value. One could then assign scores to a number of intermediate points within the scale.

3.3.3 Normalise criteria scales (1b.3)

In some of the analysis methods in Chapter 4 the notion of 'trade-offs' is introduced in which high scores on one criteria may be considered to compensate for lower scores on another criteria. In using such methods it is often necessary to normalise the scales so that scales for different criteria are comparable, which makes inter- criteria comparisons easier. Normalised scales have dimensionless units and normally the larger the value of the rating then the greater preference it has. We will classify criteria into three groups and then present normalisation methods for each group.

1) Monotonically increasing utility: The greater the value of the criteria then the greater is its preference.
2) Monotonically decreasing utility: The greater the value of the criteria then the smaller is its preference, for example, cost.
3) Non-monotonic utility: For such criteria the most preferred value of the criteria is located somewhere in the middle of the criteria range.

There are a number of approaches to normalisation of which only examples are given here.

1) Linear normalisation – increasing utility

We assume that the scores x_i are to be normalised between 1 and N where N may be 10, 100 or some other convenient number. We will denote the maximum and minimum values of x_i by Max x and Min x, respectively. The normalised values of x_i are then given by:

$$(x_i - \text{Min } x)\ (N - 1)/(\text{Max } x - \text{Min } x) + 1$$

2) Linear normalisation – decreasing utility

With the same assumptions as above the normalised values of the x_i are given by:

$$(\text{Max } x - x_i)\ (N - 1)/(\text{Max } x - \text{Min } x) + 1$$

3) Linear normalisation - Non-monotonic utility

We assume that there exists scores Max x and Min x which represent the most favourable value and least favourable values, respectively. One of the normalisation equations given above can be used depending upon whether the values of the utility between Max x and Min x are increasing or decreasing.

3.3.4 Select MCDM method (1b.4)

The decision maker then needs to select the method by which the MCDM is to be carried out. At this stage the decision maker needs to decide whether to use trade-off or non-trade-off methods or whether to use a combination of methods. The selection of the method should take account of the attitude of the decision maker.

Figure 4.1 guides the decision maker through the questions that should be answered in order to select a suitable MCDM method.

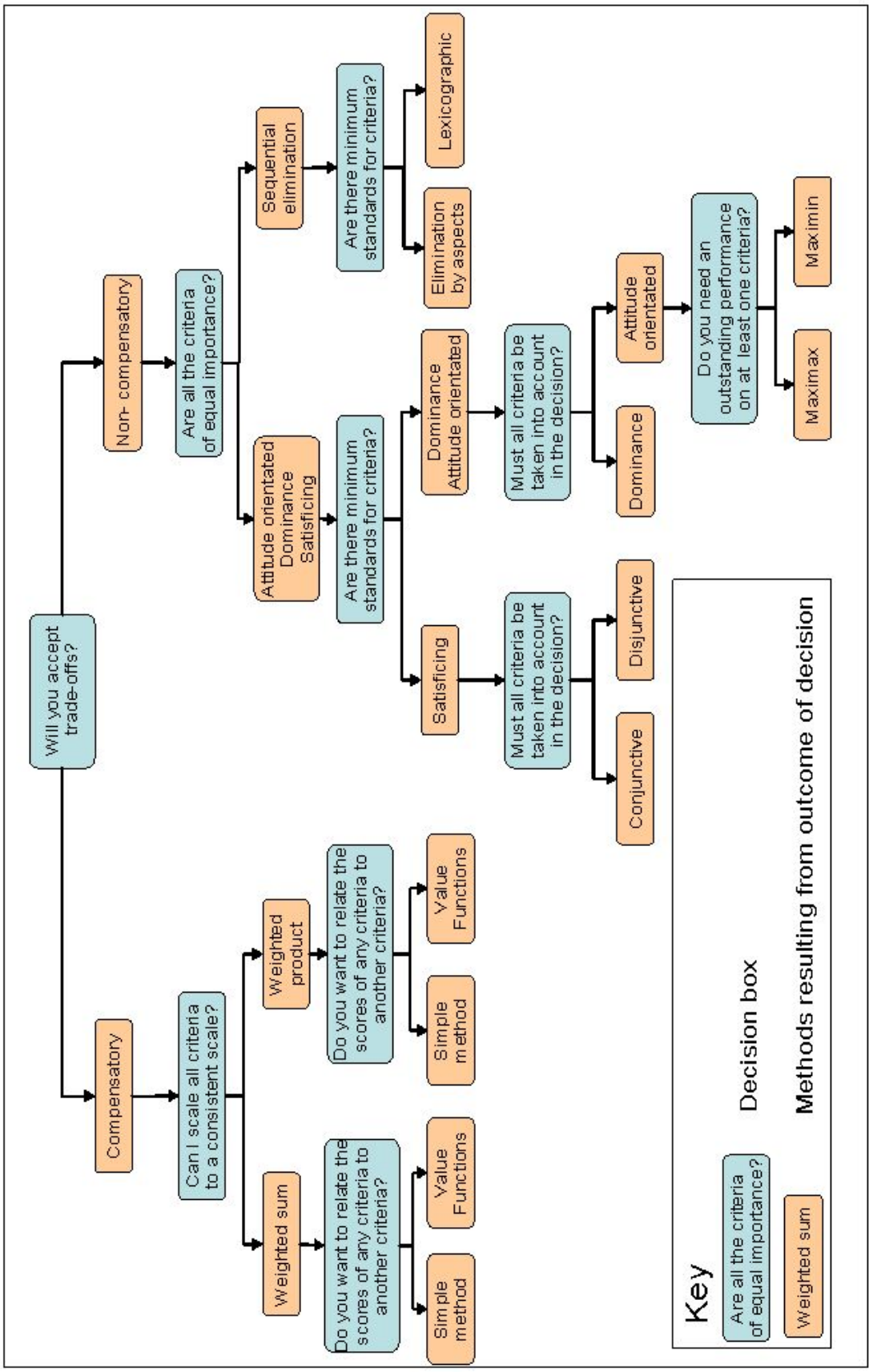

Figure 3.1 MCDM Selection Method

If a trade-off method is to be used then appropriate weights should be selected. These will reflect the decision maker's preferences. One approach is for the decision maker to assign weights to the highest level objectives. The sum of all the weights should be one. These weights can then be subdivided among the lower level objectives until all the relevant attributes have been assigned weights and the sum of all the weights is one, see the example in Appendix 3.

The selection of weights should be checked for consistency. The criteria can be considered in pairs. The ratio of the weights for the two criteria indicates how much of one criterion the decision maker is prepared to forego for a corresponding increase in the other criterion. For example, if the weights for Criterion 1 and Criterion 2 are 0.3 and 0.15 respectively then this implies that to compensate for a reduction in Criterion 1 of one unit would require a two unit increase in the score for Criterion 2. All the possible pairs of criteria should be considered to check that they accord with the views of the decision maker. If necessary adjustments to the weightings should be made.

It may be that the decision maker may be uncertain about the precise values to be used as weights. Any such uncertainty can be investigated during the analysis by carrying out sensitivity tests, that is, assessing whether the result of the analysis would change if the values of the weights were varied.

3.3.5 Assign weights to criteria (1b.5)

This stage need only be carried out if a compensatory MCDM method was selected at the previous stage, since the approach will not use weighting of the criteria in the selection process otherwise. By weighting the criteria, the method takes into account the relative importance that the decision maker attributes to each criterion.

Silva (2004) describes how weights are derived for each criterion and explains the use of value functions for criteria scores. The methods assign a mathematical representation to a human judgement of the relative value of criteria.

3.4 Process 2a Development of Options

3.4.1 Identify options (2a.1)

A set of realistic options for rehabilitation need to be developed for consideration. These need to take into account:

a) the objectives,
b) the physical constraints and
c) the likely cost.

It may be necessary to obtain professional advice in drawing up a list of potential options.

The level of detail required will depend upon the stage that the project has reached. At the feasibility stage one may only require an outline of each option. At this stage it is important that the options should cover a wide range. At the later stages of project development attention may be concentrated on a smaller range but may need to be described in more detail.

The objectives of a rehabilitation scheme have been extensively discussed above and most are familiar with the concept of cost. In urban rehabilitation schemes there may be physical constraints that limit the range of options and may also, in extreme cases, impact on the selection of objectives. It is advisable to consider potential constraints at an early stage. When developing options, it will be necessary to take into account the outcome of the formulation of goals that was defined in Process 1a.

Each rehabilitation option may comprise several techniques and may be small or large in scale and ambition. By proposing a range of options that satisfy the boundaries and constraints of the project, it maximises the potential to achieve an innovative and successful project that meets the project goals as there will be a wider range of options to choose from.

When developing options, the decision maker or technical specialist should consult a range of sources of information to ensure a list of options including a variety of techniques that are appropriate for the situation. This is to say that it is important that the options developed include techniques that will be applicable to the particular case of the project's river catchment and urban community. In the URBEM Framework this information is provided in the Supporting Information covered in modules S2.1 on existing case studies, S2.2 on study site monitoring and S2.3 on rehabilitation techniques. In addition, the URBEM work on aesthetic evaluation and social appraisal may help to generate ideas on improving the aesthetics of the river and the associated social capital. As well as the URBEM outputs, there is a range of wider literature that gives information on river rehabilitation techniques that will help to develop options (e.g. Environment Agency, 1999; Wolters *et. al.*, 2001; FISRWG, 1998; Rutherford *et. al.*, 2000; Vivash, 1999). The sections below provide an introduction to some of the techniques implemented in the case studies and described in manuals, which gives a good starting point for the generation of options for a river rehabilitation project.

Daylighting

This is the term that is used to describe opening up to the daylight a river that has previously been culverted. The advantages of such an option include:

a) improved visual appearance
b) increased habitat
c) improved mobility for fish.
d) reduced risk of channel blockage during floods

See the Case Studies for Woluwe, Brussels; Albisreader Dorfbach, Zurich and Mud Creek, Totonto.

Plan form

The plan form of many urban river channels has been straightened in the past. There is presently a general belief that this reduces the visual interest of the river. Straightening rivers also has the potential for a number of geo-morphological impacts. Straightening a river increases its slope and tends to make the river flow more uniform. The increase in slope has an impact on the flow velocities, depths and sediment transporting capability. There is also a tendency for bank erosion to take place on a river that has been straightened. Thus channel straightening often results in the need for providing bank protection.

The plan form of the river, in terms of the size and shape of meanders is described by geomorphic relationships. For a particular river discharge, sediment concentration and sediment size there is an appropriate plan form. This implies that if a river rehabilitation scheme involves modifications to the plan form of a river the modifications cannot be chosen at random but should comply with the appropriate geo-morphological relationships.

Modifications to the plan form of an urban river often posses enormous problems. There are normally issues to do with:

land ownership,
existing infrastructure built along the existing river banks,
existing services buried in the river bank and
presence of drainage outfalls.

The advantages of restoring the natural plan form of a river include:

a) enhanced visual appearance,
b) reduced channel slope
c) reduced tendency for bank erosion.

If a river channel has been straightened in the past then the issues that arise include:

a) Identify physical constraints to changes in plan form
b) Can one determine pre-modification plan form?
c) Can one re-establish original plan form?
d) If one cannot re-establish the original plan form can one ‘match’ the original plan form, e.g. in terms of sinuosity?
e) Can one increase the sinuosity from existing towards original?
(see Vivash (1999) Manual of River Restoration Techniques – Restoring meanders to straightened rivers, Part 1)
f) Can one carry out in-channel works to create impression of sinuosity
(see Vivash (1999) Manual of River Restoration Techniques – Enhancing straightened river channels, Part 3)

Note that modifications to the plan form may require changes to any outfalls to the river, see Vivash (1999) Manual of River Restoration Techniques, Part 9: Enhancing outfalls to rivers.

See the Case Studies: Pegnitz, Nuremberg; River Skerne, Darlington, UK and the Quaggy Brook, London; White Clay Creek, Delaware.

Bank protection

In many urban areas any risk of bank erosion is unacceptable as this may lead to damage to buildings or infrastructure. In the past this has led to the use of 'hard' engineering such as concrete or sheet-piling for bank protection. In constructing such protected river banks they are often made vertical or near vertical. In general such vertical, hard-engineered banks are thought to be unattractive and they can also pose Health and Safety problems. With improved knowledge of material behaviour and new techniques for bank protection it is sometimes possible to provide the same level of protection but using materials which are not so visually intrusive. The use of other materials may also allow vegetation growth which aids in adding variety to the visual appearance. There is also the potential for placing such materials at lesser slopes so that the bank angle can reflect more closely what it would be in a natural river system. This may reduce the impression of the channel being artificial.

The issues that arise when considering altering the existing bank protection include:

a) Can one remove the bank protection? This will involve checking for the presence of physical constraints, such as services, drainage outlets; determining the flow velocities that the bank protection has to be able to resist and establishing land ownership.
b) Can one use natural materials?
c) Can one make the bank protection appear more natural?
d) Is the bank vertical? – Can one make the bank sloping?
(see Vivash (1999) Manual of River Restoration Techniques – Revetting and supporting river banks, Part 4).

See the Case Studies: Nahon, Chrudim, Czech Republic; La Saone, Lyon; Leine Hannover; Torrente Mugnone, Florence; River Skerne, Darlington, UK; Albisreader Dorfbach, Zurich; Anacostia Basin/ Sligo Creek, Washington DC.

Bed stabilisation

In many urban rivers the bed has been replaced by artificial material such as concrete. This has normally been done to ensure that the river bed does not erode, leading to the failure of the river banks. It is often possible to replace artificial materials such as concrete by more natural-looking materials such as rock or gravel while still ensuring that the bed of the river is not eroded. The advantages of replacing the bed of the channel with more natural materials include:

a) enhanced visual appearance

b) creates a wider range of physical habitats
c) provides refuges for small fish
d) enhanced fish population

In addition the shape of the bed of the river may have been made horizontal or gently V-shaped. Depending upon the overall discharge capacity of the channel, it may be possible to create a two-stage channel within the bed of the river. By meandering the low flow channel within the upper stage it is possible to create the visual appearance of a meandering channel. Depending upon the nature of the floods and the flow velocities it may be possible to allow planting on the upper stage which adds visual interest and provides habitat. The advantages of including a two-stage channel include:

a) enhanced water depths for low flows which can increase fish habitat
b) enhanced visual appearance
c) opportunities for using the upper stage for planting

The issue that arises is, if the bed of the channel is artificial can it be replaced by more natural materials, for example, rock or gravel? One will need to establish the flow velocities that the bed material will need to withstand and to determine the size of bed material that would be stable under these flow conditions.

In many channels with coarse bed material there are naturally occurring bed features such as sequences of pools and riffles. These cause variations in the flow regime with deeper slower flow in the pools and shallower and faster flow over the riffles. This provides habitat diversity and adds to the visual appearance of the channel. In many urban rivers these features have been removed as part of channel maintenance. One option may be to re-introduce such features.

The issues to be considered include:

a) Are pools and riffles appropriate for this type of river?
b) If pools and riffles were re-introduced would the flood risk be affected?
c) If the sediment forming the pools and riffles is mobile then where will the sediment go downstream of the rehabilitated reach – will this cause a problem?
d) If the sediment forming the pools and riffles is mobile then will there be an adequate supply of sediment from upstream of the rehabilitated reach to maintain the system?

See the Case studies: Wienfluss, Vienna; Wandse, Wandsbe; Torrente Mugnone, Florence; Quaggy Brook, London; Albisreader Dorfbach, Zurich; Anacostia Basin/ Sligo Creek, Washington DC; White Clay Creek, Delaware.

Enhance environment

One of the potential achievements of a rehabilitation scheme can be increasing the diversity of the available habitat. There is a belief that providing an increased range of physical habitats encourages bio-diversity. It

is often possible within rehabilitation schemes to increase the range of physical habitats in terms of water velocities and depths. This can be done by making the rehabilitated channel non-uniform in shape and plan.

Where it is appropriate there are a wide range of steps that can be taken to enhance the environment within the riparian zone, which can include plating of vegetation, shrubs and trees, though it is important that any such work should fit in with the character of the area.

See the Case Studies for Alterbachsystem, Salzberg; Wienfluss, Vienna; Isar, Munich; Elbe Harbour Facilities, Hamburg; Torrente Mugnone, Florence and the River Skerne, Darlington, UK; Albisreader Dorfbach, Zurich; Anacostia Basin/ Sligo Creek, Washington DC; White Clay Creek, Delaware.

Water quality

The water quality in a river reach is either dependent upon upstream conditions or dependent upon discharges into the river within the reach. In many cases the upstream effects dominate and so action to improve the water quality often has to take place upstream. In the urban context, problems with water quality are frequently associated with discharges to the river. Typically these may be either discharges of effluent from a factory or may be a combined sewer overflow.

If water quality issues need to be addressed then the causes of the poor water quality need to be determined. It is then necessary to develop a strategy to improve the water quality to the necessary levels. This is likely to involve either preventing the discharge of pollutant to the river or incorporating some form of treatment into the river system. This might include the provision of settling areas and wetland areas that provide biological treatment of the water. A major issue with the provision of wetland areas is the issue of whether the necessary land area is available to provide the required improvement in water quality.

See the Case Studies: La Chaudanne, Grezieu-la-Varenne, France and Torrente Mugnone, Florence; Mud Creek, Toronto.

Public access/amenity

Of the many options for urban river rehabilitation schemes, the one that often has the largest beneficial impact on the public is the improvement of public access and the provision of amenities. It is recommended that any urban river rehabilitation scheme should aim to improve public access wherever possible. The important factors are that the public should be able to see the river and that suitable pathways or walking areas are provided. Ideally any such access should be suitable for pushchairs and disabled access. Within an urban context it is appropriate to consider the provision of public amenities such as areas for sitting, picnicking or playing.

For information on providing urban riverside access see Vivash (1999) Manual of Techniques, Section 8.5. For information on access paths for disabled users see Vivash (1999) Manual of Techniques, Section 8.3.

See the Case Studies Fosso della Bella Monaca Ditch, Rome, River Skerne, Darlington, UK and Quaggy Brook, London.

Aesthetics

Many river restoration schemes that have been carried out have had as their justification a desire to improve biodiversity and habitats. When talking to members of the public who have been affected by such schemes, their overriding impression is the appearance of the river, so that a frequently heard comment is that the river after the scheme looks much nicer. The implication is that, whatever the objectives of the decision makers in selecting a scheme, it is most likely to be judged by the public mainly on how it looks.

There are many options to improve the visual appearance of the water body. These include:

a) re-introducing meanders in a previously straightened river,
b) removing artificial bed and bank materials
c) re-profiling vertical river banks
d) in tidal areas there may be a preference for a maintained water level that removes tidal effects.

Public perception of a water body is affected by signs of water pollution, which may be either visual or odorous. For a water body to be acceptable to the public, minimum standards of water quality normally need to be achieved. This acceptable standard depends upon the nature of the activities that are taking place adjacent to the water.

The setting of the water body also has a strong impact on the public perception. Thus the aesthetics can be addressed by improving the riparian zone. It is difficult to make specific suggestions for such improvements as they should be linked to the character of the area and what is appropriate in one location could be quite inappropriate in another.

All the Case Studies have elements which provide aesthetic improvements and so all of them are relevant to this section.

Re-naturalise flow regime

The urbanisation of an area may have an impact on the flow regime of a river. Urbanisation can lead to:

a) increased peak discharges
b) reduced time to peak
c) reduced low flows

This may have an impact on the river channel. In particular, increased peak discharges resulting from urbanisation may lead to an increased flood risk and

the need to provide flood defences. Re-naturalisation of the flow regime may result in reduced peak discharges and reduce the flood risk.

There are a wide range of options for re-naturalising the flow regime and these are discussed in detail in Work Package 8 (Rocha *et. al.*, 2004b)

See the Case Studies: La Chaudanne, Grezieu-la-Varenne, France; Emscher, Deinhauser Bach, Castrop-Rauxel

3.4.2 Describe the consequences of options (2a.2)

Having developed a number of options for rehabilitating a river, the consequences of each option should then be assessed. In particular an assessment should be made of the impact of the options on the selected criteria. This assessment may be based on some objective method, for example, the use of numerical modelling, or it may be based on a more subjective analysis or perhaps past experience. The degree of detail required will depend upon the stage that the project has reached and the information that is currently available. At the feasibility stage there may be little direct data available and reliance may have to be placed on expert judgement and past experience. At a more detailed stage the results of data collection and studies may be available which could assist in the assessment of the implications of each option.

3.4.3 Score options (2a.3)

Each option should be assessed in terms of the selected criteria. It is normally useful if these ratings can be normalised to a consistent scale. It is suggested that the lowest practical level of a particular criteria is assigned the score 1 while the highest practical level is assigned the score 10. Scores between 1 and 10 can then be assigned to levels between these two extremes.

The decision maker should then check that the criteria scores for all the options are self-consistent.

3.5 Process 2b Assessment of Options

3.5.1 Apply MCDM method (2b.1)

The selected MCDM method should then be applied using the criteria scores that have been determined. This should enable either the selection of a preferred option or the ranking of the options, whichever is required by the decision maker.

3.5.2 Review Assessment (2b.2)

The decision maker should then review the results of the analysis. The issues considered by this review should include:

a) Selection of objectives and criteria – where appropriate ones selected?
b) Method of analysis – was the appropriate MCDM method selected?
c) Selection of weights – were the weights that were selected appropriate?
d) Scoring of criteria – were the criteria scores for each option correct?

On the basis on this review he or she may decide that changes are required. In this case these changes should be carried out and the appropriate elements of the process repeated.

Once any review has been completed the decision maker should have available the final agreed results of the analysis.

3.6 Process 3 Implement, Monitor and Review

This process encapsulates the construction, realisation of outcomes and monitoring phases of the management cycle described in Chapter 2. The implementation phase has the best possible chance of running smoothly if good planning, as promoted by the URBEM Framework, has been carried out. It is often the case, however, that unexpected outcomes or problems arise during implementation and it is only by careful monitoring and project management that construction can be adapted or new measures implemented to gain the most potential from a rehabilitation scheme.

3.6.1 Design Monitoring Programme (3.1)

Select parameters to monitor from indicators of success (1b.1) considering cost, difficulty and value of monitoring

Having completed process 1b.1, the decision maker should already have defined success indicators and acceptability criteria, which can be used to develop the monitoring programme. Process 3.1 looks at the practicalities of carrying out the monitoring to enable calculation of the success indicators.

So, when selecting which parameters to monitor, it is necessary to understand what information is required for the evaluation of the success indicators. The monitoring programme should be designed with the boundaries and controlling factors of the project (see processes 1a.3 and 1a.4) and must take into account the availability of trained personnel and the availability of any required measuring equipment.

Decide where and when to monitor

Deciding where and when to monitor is important as it influences the quality of the data that is collected. Monitoring aims to measure a representative sample of a population, so it is important that the sampling frequency, sample size and sample selection (location) are considered carefully.

In terms of location, different indicators will demand different spatial coverage. Indicators relating to physical attributes of the river may need to be monitored throughout the catchment or just in the reach and downstream and upstream neighbouring reaches of the location of the project. If the indicator relates to a characteristic of the urban environment, it may be necessary to sample over the entire city or, in contrast, just in a small area, depending on the requirement for information from that indicator. Likewise, indicators relating to people may require surveys carried out with organised groups, local residents, local businesses or visitors to the area, depending on what information one is hoping to find from the monitoring.

The frequency of monitoring will also be different for each indicator. In general, it is prudent to carry out monitoring before, during and after a rehabilitation project. The purpose of monitoring before a project is to establish the existing state of the river and the city so that one knows what needs to be improved (and by how much) when assessing potential for rehabilitation and developing options. The 'before' monitoring also establishes a benchmark for measuring the success and achievements of a project. Monitoring during a project enables the decision maker to understand how the physical system and the community reacts to different stages in the project, which ensures that negative impacts are minimised and positive impacts are maximised. The construction phase can be altered and adapted to gain the most from the project. The monitoring carried out after the project has been completed allows decision makers to appraise projects and justify the investment in rehabilitation. For an in depth discussion of post project appraisal, see Tourbier & Gersdorf (2005).

Decide actions in event of not meeting objectives

As discussed above, the monitoring carried out during a rehabilitation project allows the decision maker to adapt the rehabilitation scheme to get the most from the project. It may be that the decision is to not change the planned project implementation if it is felt that the anticipated long term benefits will outweigh any short term negative impacts discovered by the monitoring. If, however, it is found that a particular negative impact is becoming too severe, measures to minimise that impact can be put in place. Contingencies for dealing with changes in the implementation plan should be allowed for in the planning of a project.

3.6.2 Implement option and monitoring (3.2)

This stage sees the realisation of the plan that has been prepared up to this point in the generic approach. Implementation involves a project manager to

run the day to day construction of a rehabilitation scheme and have an overview of all aspects of the project. Implementation and monitoring may involve teams of consultants, local authority planners and environmental authorities working together to achieve the goals of the project.

3.6.3 Review monitoring results (3.3)

As discussed above, there should be monitoring from before, during and after the project which will be processed and analysed by the appropriate technical specialist.

3.6.4 Report and lessons learnt (3.4)

The results from the monitoring, and, more importantly, the implications of these results, must be communicated effectively to the decision maker and project manager (if they are different people) so that the project can be adapted if necessary.

Any lessons learnt from the monitoring should be reported so that future rehabilitation projects can gain from the experience of previous ones.

If the monitoring reveals any information that may change the objectives of the project, it will be necessary to return to the first process in the generic approach.

3.6.5 Review monitoring programme (3.5)

If the monitoring provides acceptable results and there is no information that would change the objectives of the project, the monitoring programme should be reviewed to check that it is still required. If it is, then return to process 3.2, if not, then the project should have been successfully completed.

4. Multi-Criteria Decision Making

4.1 Introduction

This chapter presents the guidance provided for the multi-criteria decision making module in the decision guidance. Multi-criteria decision making (MCDM) is used in the generic approach in order to implement the best scheme for achieving the objectives of a river rehabilitation project. As explained in Chapter 4, a project may have several objectives and there may be several possible scheme options. In order to select the best option, the objectives are measured in terms of specific criteria and MCDM is used to evaluate options in terms of the criteria.

MCDM is concerned, therefore, with the situation in which it is necessary to select from a range of options when each option has multiple criteria and not all the cirteria can be measured using the same unit of measurement. In the context of river rehabilitation a number of options may be identified for rehabilitating a particular reach of urban watercourse. In general the impact of each option on the:

- aesthetics,
- water quality,
- environment and
- society

will be different. MCDM is a structured approach designed to assist decision makers to prioritise a range of options which takes account of the preferences of the decision maker.

In some problems all the criteria can be assessed in terms of monetary value, thus there is a single unit of measurement applicable to all the criteria. In this case monetary value associated with each option can be determined and the preferred option is, presumably, the one that maximises the monetary value. In the work described here it is assumed that not all the criteria can be measured with the same unit of measurement. For example, one may not be prepared to assign a monetary value to the view of a river or the impact on society of a particular river rehabilitation and we cannot measure the view of the river and the impact on the environment using the same unit of measurement. Even in these situations, however, it is necessary to make a decision as to which is the best option to pursue. This decision will have to take account of all the different criteria associated with the options. MCDM is an approach that provides a formal structure with which to analyse such a problem. While the MCDM method provides a rational and systematic approach it relies upon significant inputs from the decision maker. The decision maker has to carry out the processes in the generic approach which include:

a) setting the objectives,

b) specifying the criteria on which the analysis is to be based,
c) specifying how the criteria should be assessed,
d) specifying the analysis method to be adopted,
e) reviewing the results of the analysis.

In addition they may also be involved in:

a) developing different options to be assessed,
b) assessing the different options on the criteria that have been selected.

The issue as to the identity of the decision maker is considered in Chapter 4. The decision maker may be a single person or may be a group, it may involve some or all of the stakeholders or their representatives.

4.2 Methods of Analysis

In arriving at a decision, one has to consider the scores achieved by each option on all the criteria. In carrying out a comparison of different options a distinction may be made between methods in which high scores for one criteria may be traded-off against low scores for another criteria and methods in which such a trade-off is not considered. These are often referred to as compensatory (trade-off) and non-compensatory (without trade-offs) methods.

In a rehabilitation scheme the decision maker may be more concerned about the future visual appearance of the river than they are about bio-diversity. They might thus prefer an option in which visual appearance gets a high score and bio-diversity receives a low score to an option in which both achieve average scores. In this case the decision maker is prepared to trade-off benefits in the visual appearance against poor bio-diversity. There may be cases in which such trade-offs are not acceptable. Thus there may be minimum acceptable levels of water quality and options scoring below this acceptable level may be rejected, however high their scores might be on aesthetics and social attributes.

The distinction between compensatory and non-compensatory methods is in part artificial. It may be possible to combine both methods. Thus one could consider setting minimum acceptable scores for all the criteria and reject any options that do not achieve these minimum scores. Options that do satisfy the minimum constraints could then be judged using a compensatory method.

4.2.1 Non-compensatory methods

Dominance

An option is ‘dominated’ if there is another option that excels it in one or more criteria and equals it in the remaining criteria. An option is ‘non-dominated’ if

there is no option that excels it in all the criteria. Note that a non-dominated option may be excelled by other options on some but not all the criteria.

It is possible, but highly unlikely, that one option will dominate all the other options. In this case this option would be the preferred one.

Though the concept of dominance is rarely useful in selecting a single best option it may be useful in eliminating some options. If one option is dominated by another then it can be eliminated from further consideration. Thus the concept of dominance can be used to reduce the overall number of options to be analysed.

One can determine the set of non-dominated options by carrying out pair-wise comparisons between the options and discarding any dominated options. All the non-dominated options, by definition, excel other options in one or more criteria. The decision maker may then select one of these options, possibly guided by the relative importance attached to the different criteria.

The practical difficulty in applying this method is that simple dominance on only a few or even only one criteria ignores all the remaining criteria. Thus the decision is only being made on a limited set of objectives. Unless there is a belief that these are the only objectives that are important it is unlikely that the selected option will be acceptable.

It has been shown (McAnarney, 1987, as reported by Yoon and Hwang, 1995), however, that with this approach, some of the dominated options that are discarded may be preferable to some of the non-dominated options.

Satisficing methods: Conjunctive method

In this approach the decision maker first has to select minimum acceptable scores for each criterion. Any option is considered to be acceptable provided that the scores on all the criteria exceed the minimum acceptable ones. If the acceptable scores are set too high then no option will satisfy the requirement. In this situation the decision maker may decide to lower one or more of the minimum acceptable scores. Alternatively if the minimum acceptable scores are set too low then many options will considered to be acceptable. In this situation the decision maker may decide to raise one or more of the minimum acceptable scores to reduce the number of options that are considered to be acceptable.

It is rare that this approach comes up with a single acceptable option. The main use of this approach is often to segregate the options into those that are acceptable and those that are unacceptable.

Satisficing methods: Disjunctive method

As for the conjunctive method, the decision maker has to assign minimum acceptable scores for all the criteria. In this approach, however, for an option to be acceptable it need only exceed the minimum score on at least one

criteria. Thus if an option exceeds the minimum acceptable score on one criteria then it will be considered to be acceptable, independent of the scores on the remaining criteria. Most options will be considered to be acceptable unless the minimum acceptable score is set to a high value. If no option is acceptable then the decision maker may reduce the minimum acceptable scores for one or more criteria.

Within the context of river rehabilitation it is unlikely that it would be acceptable to accept an option on the basis of a high score on one attribute and ignore the scores on the remaining criteria.

Sequential elimination methods – Lexicographic method

In some situations a single criterion may dominate all others in the mind of the decision maker. An example of such a criterion might be cost. In some situations the issue of cost may over-ride all other considerations. In this situation one can compare all the options on this one criterion and if there is a single option with the highest score (when cost is being considered this would be equivalent to the lowest cost) then this would be selected. If there are two or more options with the same highest score then these options are then compared on the next most important criterion. The process can then be repeated.

The method thus requires the decision maker to rank the criteria in order of importance. It also assumes that within this order each criterion completely dominates those below them in the order. In the context of river rehabilitation it is unlikely that such an approach would be acceptable as it is unlikely there will be criteria that dominate all others.

Sequential elimination methods – Elimination by aspects

As in the Lexicographic method, in this approach each criterion is considered sequentially but in this case options are eliminated rather than selected at each stage. As above, the decision maker has to assign minimum acceptable scores for each criterion. The decision maker then has to order the criteria in terms of the ability of the criteria to eliminate the greatest number of options. The decision maker eliminates all the options that do not achieve the minimum standard on the first criterion. All the remaining options are then considered on the second criterion and any that do not achieve the minimum standard are eliminated. This procedure is repeated until only one option remains.

The procedure is often most suited to situations where one is considering the presence or absence of some feature rather than in situations where one is considering different levels of attainment.

Attitude oriented methods – maximin

This approach is based on a rather negative approach to the selection of options. The idea is to concentrate on the minimum scores and to select that

option which has the largest minimum score. In essence the method tries to select the best of the worst. The selection procedure is to determine the lowest criterion score for each option and then select the option with the highest value of those minimum scores. Thus each option is represented by the lowest scoring criterion and all other criteria are ignored. This may be an appropriate method if one wants to achieve the highest possible minimum standard, for example, if safety is involved. As the method concentrates on the lowest scored criterion and ignores the more highly rated criteria it may not be appropriate when considering river rehabilitation. As the method treats all the criteria similarly and the decision can be based on any of the criteria it is not an appropriate method where the decision maker considers some criteria to be much more important than others.

Attitude oriented methods – maximax

This approach is based on a positive approach to the selection of options. The idea is to concentrate on the maximum scores and to select the option which has the largest maximum score.

In essence the method tries to pick the best of the best. The selection procedure is to determine the highest criterion score for each option and then select the option with the highest of these maximum scores. As the method treats all the criteria similarly and the decision can be based on any of the criteria it is not an appropriate method where the decision maker considers some criteria to be much more important than others.

4.2.2 Compensatory methods

It may be that one option scores very highly on one criterion but less well on other criteria. The decision maker may decide that he or she would prefer an option that scored less highly on the first criterion but more highly on one or more of the other criteria. In these circumstances one can consider that the decision maker is prepared to trade-off a reduction in the score of the first criterion in return for increases in the scores for other criteria. There are a number of methods of analysis that are based around this concept. The main issue for the decision maker is to determine the relative values of the different criteria; that is, what increase in the scores of other criteria would the decision maker accept in return for a unit reduction in score for the first criteria.

Weighted sum method

In this approach the decision maker has to assign weighting factors to each criterion. The total score for an option is then defined as the sum of the scores for each criterion multiplied by the weighting for each criterion.

This method assumes that the contribution of one criterion to the total score is independent of the scores for the other criteria.

The determination of the appropriate weights depends upon the decision maker's preferences. There are methods available to help the decision maker to derive suitable values. The weights may also need to be subject to revision. Thus a decision maker may assign weights but when he or she sees the results of the analysis they may decide that the weights are not appropriate and decide to modify them.

The assumption that the contribution of one criterion to the total is independent of the scores for the other criteria may be relaxed by the introduction of a value function for one criterion that is dependent upon the scores for the other criteria. Though this generalises the method it is at the cost of having to select suitable value functions.

Weighted product method

In this method the weights are used as an exponent on the score for that criterion while the total score is the product of all the values for the individual criteria. All the comments for the Weighted sum method apply. In addition it is necessary for all the scores for individual criteria to be larger than 1.

4.3 Selection of an appropriate method

As can be seen from the above, there are a wide range of methods that can be used for MCDM. In practice the application of an individual method is often not as complicated as it might appear from the above account.

It should be emphasised that there is no 'correct' method. In general, depending upon the method used, different conclusions will be reached as to the appropriate option. The selection of the method will in part reflect the attitude of the decision maker to the problem under consideration.

It should also be remembered that methods can be used in combination. As indicated above, a decision maker might apply a combination of methods. For example, a decision maker may consider that there are minimum acceptable scores for some criteria. In some cases it may be decided that there are minimum acceptable levels for water quality and environmental aspects. The decision maker may not be prepared to accept a trade-off in which the scores for these criteria are reduced below these minimum acceptable levels. In this case the decision maker may apply a Satisficing method to eliminate all the options with scores below these minimum acceptable ones. When considering the remaining options, however, the decision maker may be prepared to accept trade-offs and a weighted sum method may be used to select the final option.

5. Conclusions

This report has described the URBEM Decision Support Framework for urban river rehabilitation that integrates the suite of tools, methods and information that has been developed on the URBEM project. The Framework aims to support decision makers and technical specialists in improving degraded urban watercourses. The URBEM Framework also promotes public and stakeholder engagement and participation provides methods for achieving this.

Urban river rehabilitation is influenced by a wide range of urban land use planning and water management issues. The report describes the management cycle for river rehabilitation that represents an holistic approach to urban river rehabilitation that feeds the lessons learnt from the outcome of rehabilitation projects into the policies and the planning for the next enhancement initiatives. Planning carried out by land use planners and water managers at national, regional and local scales determines a strategy for urban development and river enhancement. The project stage then involves designing specific schemes to implement the strategy from the planning stage. The construction phase is the implementation of the schemes and options designed by the project. Realisation of outcomes from the project will occur over both short and long time scales. The lessons that are learnt from the outcomes of the projects should be used to inform the policies that will in turn determine future planning; and so the cycle continues. Monitoring should be carried out at each stage of the cycle to record the processes and decisions made and to collect environmental data before, during and after the construction of a scheme.

This management cycle describes an ideal approach to river rehabilitation but, based on the findings from case study research (Schanze *et. al.*, 2003), instances of this being carried out fully are limited. The URBEM Decision Support Framework describes the processes involved in carrying out all stages of the management cycle, except the development of policies. Policy development may be informed by the information and methods developed on this project, but, as explained by the management cycle itself, must also be informed by previous experiences.

Multi-criteria decision making is described as one of the tools in the URBEM Framework and information on this is contained in this report. Various approaches are explained for reference, but it is advised that in most river rehabilitation projects, the weighted sum method is likely to be the most suitable approach.

The URBEM Decision Support Framework includes three main elements. These elements are:

Support Guidance This includes all the information that is available to inform the decisions taken in the generic approach.

Decision Guidance This includes the tools and assessment procedures that elicit a decision.

The Generic Approach for Assessing and Managing River Rehabilitation The generic approach describes the processes of setting up the project, deciding options and implementing the project.

The support guidance in the URBEM framework contains information, guidance, specifications and recommendations to help decision makers and technical specialists assess and manage river rehabilitation. The two parts of the support guidance explain how to navigate the URBEM framework and reference river rehabilitation information.

Included in the support guidance is the URBEM training package, information and monitoring collected on case studies of existing river rehabilitation schemes and design information on river rehabilitation techniques.

The URBEM training package (Maksimovic & Tolic, 2005) has been developed in different versions for the three target groups. Detailed training material on each of the URBEM outputs is available for technical specialists who are likely to be implementing the methods and using the information. Less detailed information is given for decision makers who will not necessarily have to use the URBEM tools themselves, but who will have to have a good understanding of the generic approach and how these are complemented by the other URBEM tools.. Basic level training is given for the public and other stakeholders who have no need to know the technical detail of the URBEM outputs but who will benefit from knowing what issues are involved in assessing and managing river rehabilitation and can have an overview of the approach that is used.

The URBEM project provides information on case studies of existing river rehabilitation projects which can be used as a resource to find out how rehabilitation projects have been managed in the past and what type of schemes have already been completed. The case studies report (Schanze *et. al.*, 2003) gives details of whether rehabilitation schemes fulfilled their objectives, which is useful for future projects to know what techniques can be effective in particular situations. Monitoring data of selected case studies in Europe gives valuable information on how to measure criteria for different objectives of rehabilitation schemes (Tellier, 2004, Tellier & Amezaga, 2004).

The URBEM outputs giving information on river rehabilitation techniques can provide a useful resource, especially at the stage of developing options which is one of the processes in the generic approach in the URBEM framework. The information on rehabilitation techniques gives design criteria, advice on the applicability of techniques to different types of river and cities and case study examples (Rocha *et. al.,* 2004a, 2004b).

The decision guidance in the URBEM framework contains the tools and assessment procedures that elicit answers to the questions posed in the generic approach and will help decision makers and technical specialists assess and manage river rehabilitation.

The outputs from the URBEM project that provide decision guidance for river rehabilitation projects are the aesthetic appraisal methodology, the social participation methodology, the multi-criteria decision making techniques reported and the indicators of success.

The URBEM aesthetic appraisal methodology (Silva *et. al.,* 2003, Silva & Saraiva, 2004) introduces the concept of assessing urban river enhancement in terms of three key elements; river, city and people. The aesthetic appraisal method gives a range of appropriate criteria by which the aesthetics of an urban river can be measured and guides the user in applying appropriate criteria for the situation.

The URBEM social participation tool, ProveIt!, measures social capital as well as providing a means to engage the citizens and stakeholders (Higginson, 2004, Walker, 2005). ProveIt! is a toolkit that includes a storyboard, questionnaire and reporting template and has been tested on a number of case studies (Walker *et. al.,* 2004, Brilly, 2004). The tool aims to measure how the local community value their river and increases community ownership of the project.

Multi-criteria decision making (MCDM) techniques are required when there are several criteria by which one must measure the success of a scheme. MCDM is used to select a scheme based on how it scores against the measured criteria. Several techniques are presented in the URBEM guidance to give decision makers the flexibility to use the most appropriate method for their situation.

In addition to these tools, the decision guidance also includes work on Indicators of Success (Tourbier & Gersdorf, 2005). This promotes both appropriate assessment of projects before they are implemented as well as post project appraisal which allows decision makers to learn from the experiences of successful (and unsuccessful) rehabilitation projects.

The generic approach relates to all of the aspects in the management cycle except to the development of policies. There are three processes in the generic approach, with five sub-processes in total. The first two processes provide a method for assessing the potential for urban watercourse rehabilitation. This assessment process involves a wide range of factors as the objectives of a rehabilitation scheme may include the hydraulic, environmental, water quality, social and aesthetic aspects of a river system and its urban setting but the objectives of individual urban watercourse rehabilitation schemes may vary depending upon both the river and its surroundings. The purpose of the tool is to provide a framework for analysing the problem of assessing the potential for rehabilitation so that the user can:

a) decide whether a proposed rehabilitation scheme is appropriate in the particular circumstances or
b) select the most appropriate scheme from a shortlist of proposed options or
c) select a shortlist from a long list of possible options.

The method can be used to consider a number of different options for the same reach of river or may be used to consider rehabilitation schemes on a number of different river reaches either within the same river basin or in different river basins.

The URBEM decision support framework draws together the multi-disciplinary outputs of the URBEM project. The framework is designed to help decision makers and technical specialists to enhance the urban river environment. The framework recognises the importance of involving stakeholders and the public throughout the decision making process and provides guidance on how this can be achieved. The framework is also applicable throughout Europe and can support planning at a range of spatial scales. The result is an integrated approach to assessing and managing river rehabilitation.

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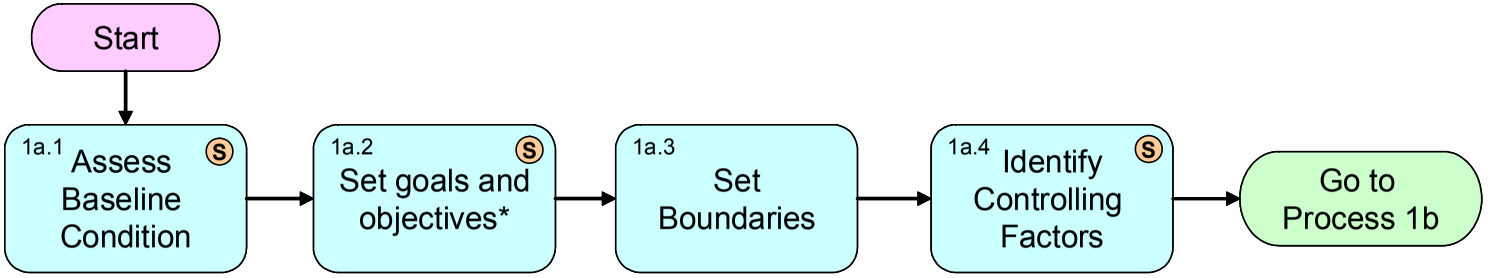
Appendices

Appendix 1
The Complete Activity Chart for the URBEM Decision Support Framework for Assessing and Managing Urban River Rehabiliation

Process 1a – Formulating River Rehabilitation Goals



1. Review information on urban catchment

2. Identify stakeholders

3. Site characterisation: identify issues at catchment, reach and site scales

2, 3, 4, 7

* Can relate to policy, development plan or project

1. Set broad goals

2. Consultation with stakeholders

3. Set specific objectives

5, 2, 4, 7

1. Define time-scale of plan or project

2. Define spatial extent of assessment

3. Define time-scale for assessment

4. Determine resources for assessment

1. Check legislative requirements

2. Determine financial limits

4. Check relevant strategies and plans (including flooding, environmental, landuse planning etc)

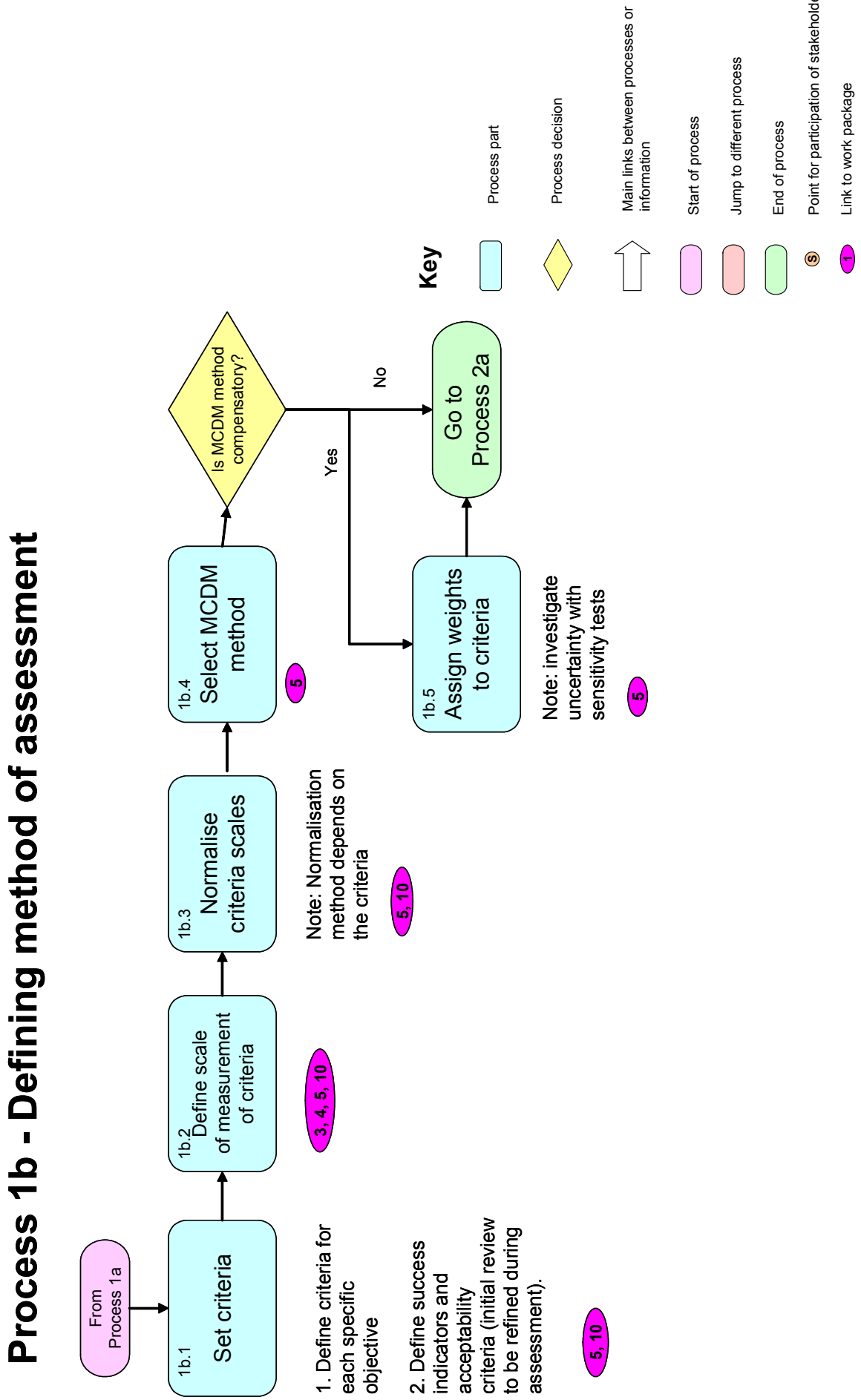
5. Identify stakeholder requirements (including public)

6. Identify physical constraints

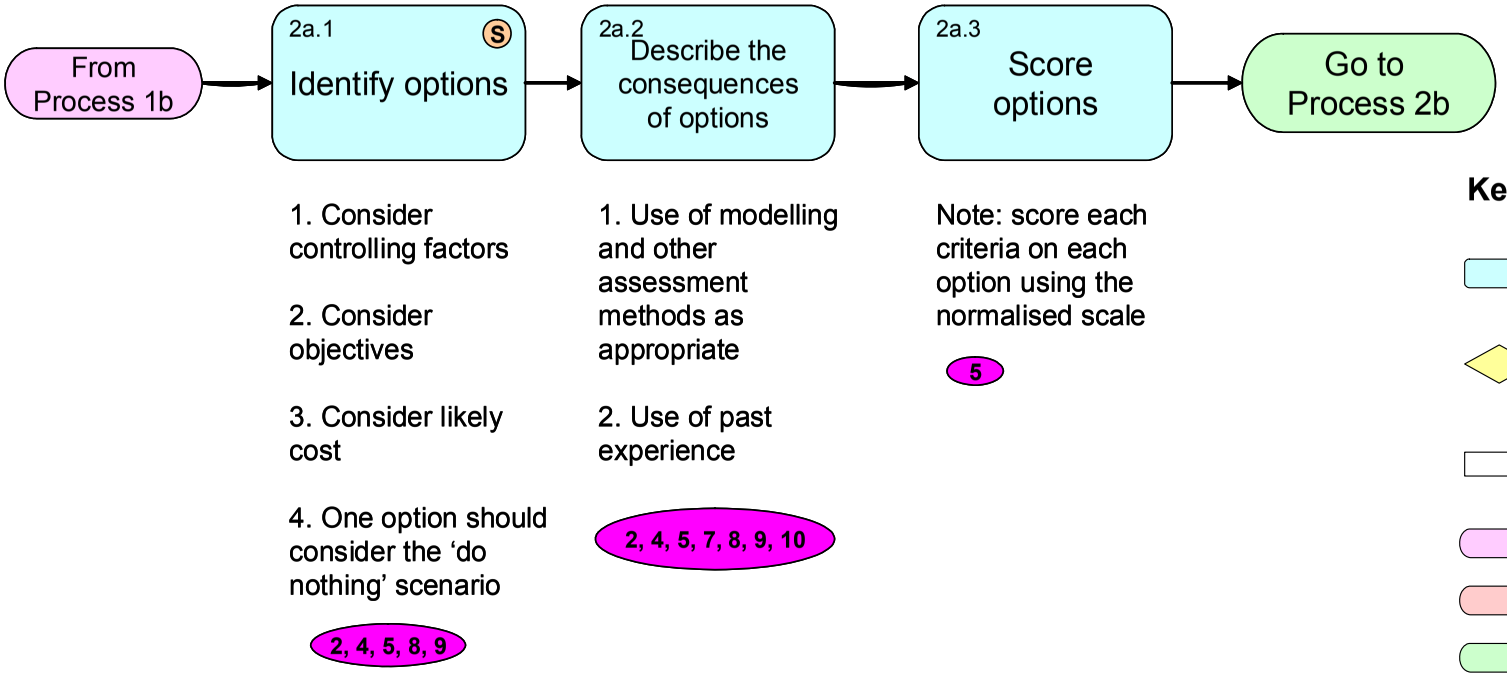
7

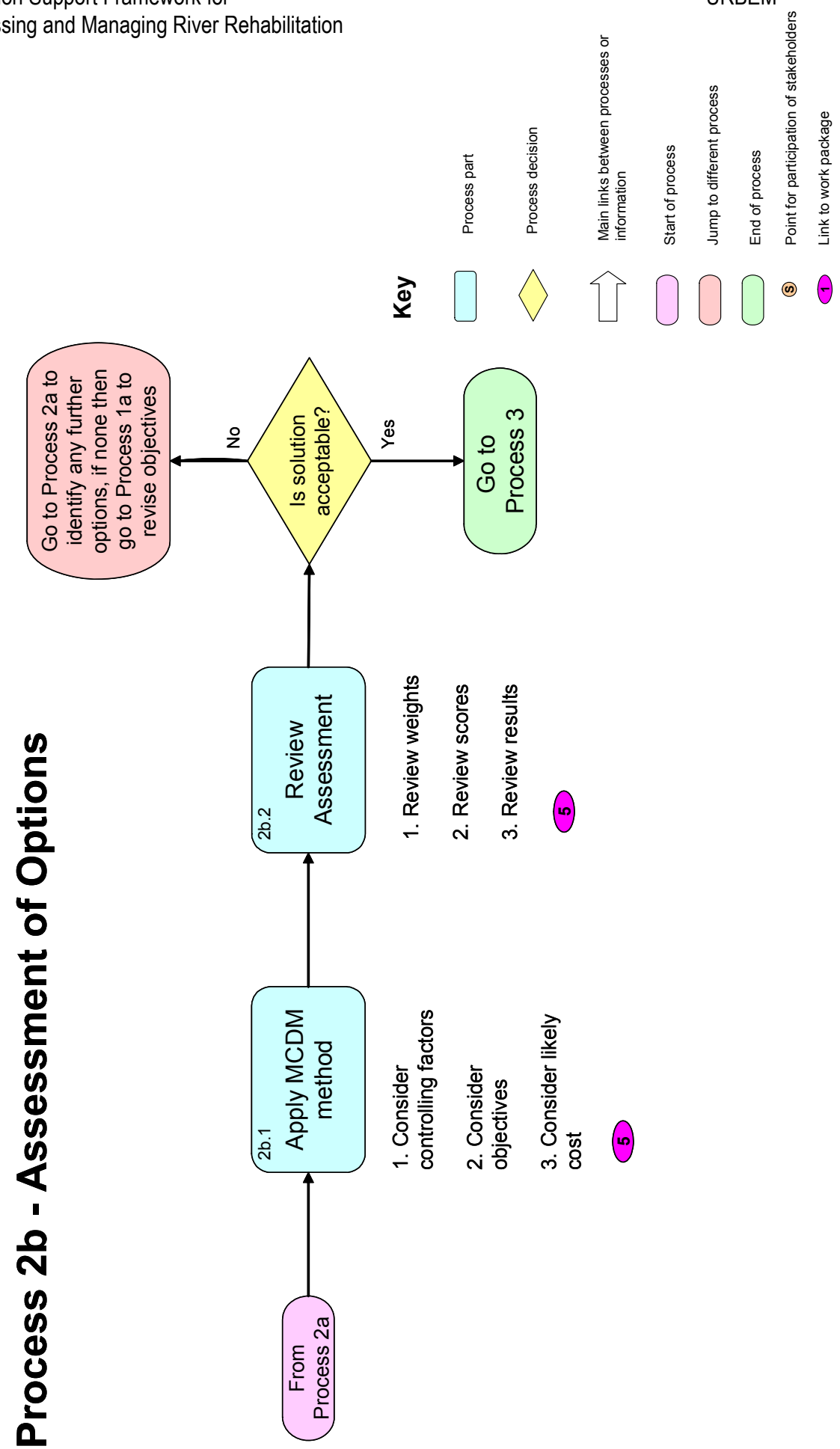
Key

- Process part
- Process decision
- Main links between processes or information
- Start of process
- Jump to different process
- End of process
- S — Point for participation of stakeholders
- 1 — Link to work package


Process 1b - Defining method of assessment
From Process 1a
1b.1 Set criteria
1b.2 Define scale of measurement of criteria
1b.3 Normalise criteria scales
1b.4 Select MCDM method
Is MCDM method compensatory?
Yes
No
Go to Process 2a
1b.5 Assign weights to criteria
1. Define criteria for each specific objective
2. Define success indicators and acceptability criteria (initial review to be refined during assessment).
Note: Normalisation method depends on the criteria
Note: investigate uncertainty with sensitivity tests
5, 10
3, 4, 5, 10
5, 10
5
5
Key
Process part
Process decision
Main links between processes or information
Start of process
Jump to different process
End of process
Point for participation of stakeholders
Link to work package

Process 2a - Development of Options




Process 2b - Assessment of Options
From Process 2a
2b.1 Apply MCDM method
1. Consider controlling factors
2. Consider objectives
3. Consider likely cost
5
2b.2 Review Assessment
1. Review weights
2. Review scores
3. Review results
5
Is solution acceptable?
No
Go to Process 2a to identify any further options, if none then go to Process 1a to revise objectives
Yes
Go to Process 3
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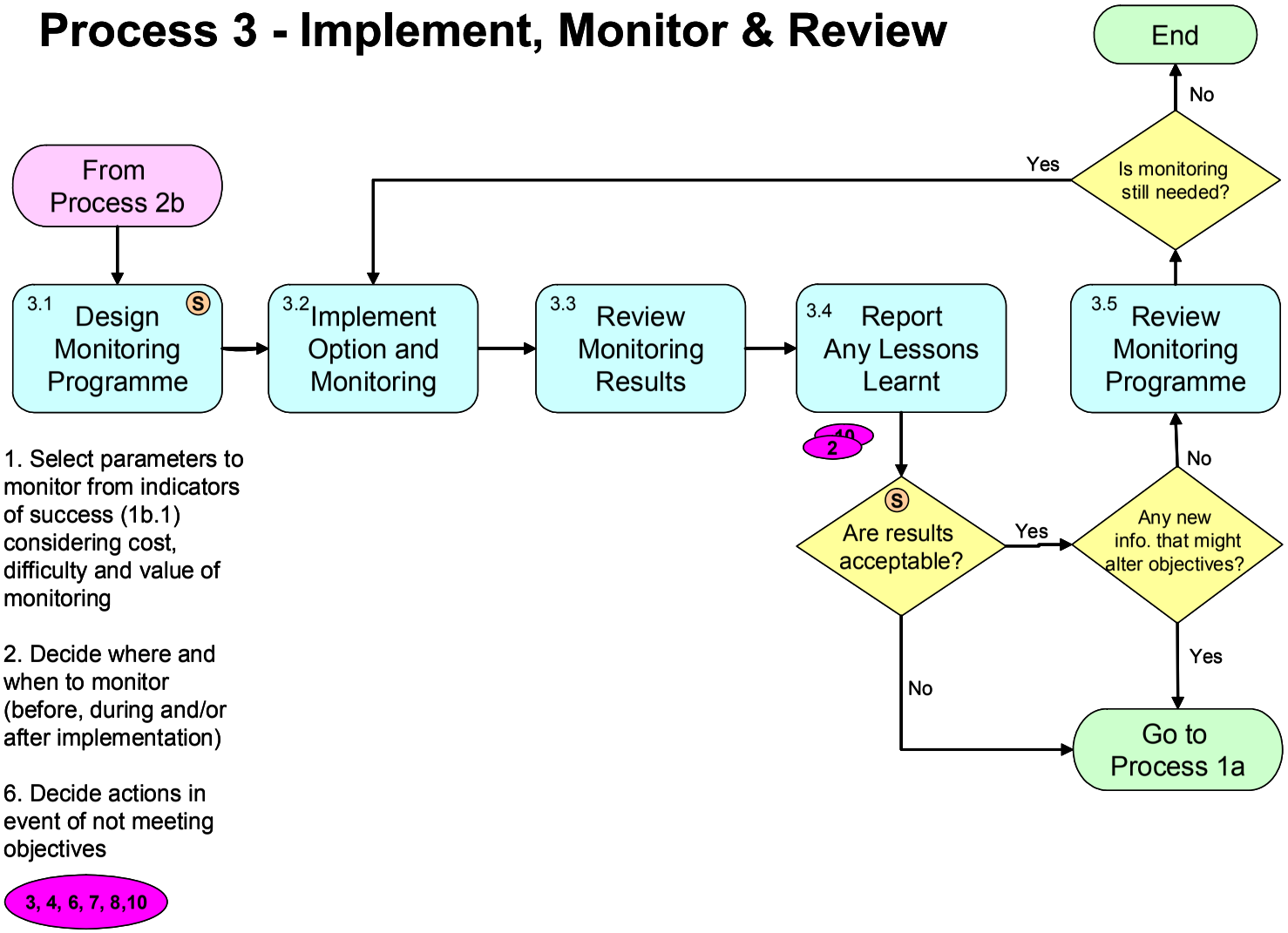
Process 3 - Implement, Monitor & Review



1. Select parameters to monitor from indicators of success (1b.1) considering cost, difficulty and value of monitoring

2. Decide where and when to monitor (before, during and/or after implementation)

6. Decide actions in event of not meeting objectives

3, 4, 6, 7, 8,10

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Appendix 2
Example criteria

Example list of objectives and criteria

1 Water quality
- Water Quality Classification
  - Oxygenation conditions - Dissolved oxygen (DO)
  - BOD
  - Acidification - pH
  - Total ammonia
  - Un-ionised ammonia
  - Hardness
  - Dissolved copper
  - Total zinc
  - Thermal conditions - Temperature
  - Turbidity
  - Pollutants in form of organic and inorganic chemicals
  - Heavy metals

2 Ecology:
- Ecological status (Water Framework Directive)
  - Bio-diversity
  - Species abundance
- Composition and abundance of aquatic flora
  - Composition and abundance of benthic invertebrate fauna
  - Composition and abundance of age structure of fish fauna
  - Macrophytes
  - Channel vegetation
  - Bank vegetation
  - Trees
  - Ornamental and invasive species
  - Nature of surrounding catchment – potential for colonisation

3 Habitats
- Substrate type and distribution
  - Range of habitats
  - Spatial continuity
- Bank materials/protection
- Bank profile
- Hydraulic conditions
  - Nature of flow
    - Flood flows
    - Medium flows
- Low flows

Presence of spawning, nursery and hiding places
Diversity

4 Aesthetics
River
- Natural components

- Width of riparian vegetation
- Shrub density
- Tree density
- Visual obstruction to water course
- Riparian vegetation presence in margins

River morphology

- Channel dimensions
- Sinuosity
- Morphological diversity
- Valley morphology
- Bank shape/irregularities
- Disturbance

Integration in basin

- Size of basin
- Stream order

Natural and technological hazards

- Degree of impervious land
- Bank protection
- Flood vulnerability

City

Cultural heritage

Urban space quality

- Visual permeability
- Contact zones
- Public utility of river watersides
- Quality of bulk space

Pollution

- Dumping and litter on margins
- Dumping and littering in water
- Turbidity
- Water colour

Activities on river front

- Economic activity
- Traditional activities
- Housing
- Recreational use

Accessibility

- River crossings
- Navigation

5 Social

People

Sensory impact

- Odour
- Noise

Landscape perception

- Evaluation of aesthetics
- Public perception

Identity

Capacity for human restoration

Security
Access
Number of people affected – this may need to be broken down into numbers for each type of impact
Potential for acting as a catalyst for further regeneration in area
Impact on property values in area

6 Cost
Capital cost
Annualised maintenance cost

Appendix 3
Example Application of Generic Approach

Example application of generic approach

Description of river system

The river is within an old manufacturing town in the North of England. The river was straightened and canalised during the industrial revolution. The buildings in the area are predominantly industrial buildings which are now mostly derelict. The local authority wants to see the area redeveloped. It is has a limited budget to spend on improvements to the local amenities and infra-structure but the bulk of the funding for the redevelopment will have to come from private sources

The present water quality in the river is poor. This is thought to be due primarily to a number of storm sewer overflows which discharge to the river through the urban area. As a result of the poor water quality the ecology of the river is very badly degraded. At the moment there is virtually no access for the public to the riverbank.

Selection of decision makers

A working party of interested parties has been set up to consider options for improving the area. The members of this working part include:

a) elected representative from the local authority
b) local councillor representing the ward which contains the area
c) representative from the water authority who is responsible for the storm sewer overflows
d) local planning officer
e) representative from local nature conservation organisation.

Setting objectives

The group initially considered the objectives for any proposed scheme. The planning officer and the local authority elected representative considered that the most important aspect was the attraction of additional private investment to the area. the local councillor representing the local population considered the most important aspects were to improve the visual appearance and amenity in the area. The representative from the local nature conservation organisation wanted to see a significant improvement to the ecology of the river. Initially the following high level objectives and corresponding weights were proposed.

High level objectives

a)	Improve visual appearance	0.35
b)	Improve amenity value	0.45
c)	Attract investment to the area	0.1
d)	Improve the ecology of the river	0.1

It was argued that c) is really implied by a) and b) and so is not independent so it was decided to remove Objective c) from the list. The conservationist

complained about the lack of weight attached to the ecology of the river. The planning officer pointed out that improved water quality would lead to improvements in the ecology and claimed that a minimum standard of water quality would be necessary to make the area attractive for development. It was agreed that objective d) should be changed to 'Improve the water quality', the weight should remain the same but there was a minimum acceptable level of water quality and that al options which did not meet this level should be rejected. The conservationist was concerned about the lack of weight given to water quality and ecological issues. It was agreed that during the decision making process the sensitivity of the outcome to this weighting should be explored.

The new objectives and weights were

a) Improve visual appearance 0.40
b) Improve amenity value 0.45
c) Improve the water quality of the river 0.15

Specification of criteria

After some discussion the following criteria and scores were set

Objectives and criteria
Improve visual appearance

Sinuosity	Scale	Sinuosity
	1	1
	2	1.02
	3	1.04
	4	1.06
	5	1.08
	6	1.1
	7	1.12
	8	1.14
	9	1.16
	10	1.18
Natural appearance		
	1	Concrete bed and concrete vertical banks
	4	Natural bed but vertical concrete banks
	6	Concrete bed and semi-natural banks
	10	Natural bed and banks

Improve amenity value

Contact zones		
	1	Existing
	2	1 contact point
	4	2 contact points
	6	3 contact points
	8	4 contact points
	10	5 contact points along reach

Public utilisation of waterside

1 No change
3 Footpaths along bank
4 Footpath along both banks
6 Footpaths with parkland
10 Footpaths with parkland, sitting areas and cafes

Improve water quality of river

Quality expressed in terms of:

1 Bad
2 Poor
8 Moderate
9 Good
10 High

Selection of options

The planner explained that the following elements of work were feasible

Description of rehabilitation scheme

Elements of schemes:

1) In channel works to provide a meandering appearance
2) Removal of storm sewage overflows upstream
3) Provision of public access
4) Removal of concrete bed of channel and replacement by natural substrate
5) Replacement of vertical concrete banks by more natural looking bank materials
6) Provision of footpath along one bank
7) Provision of footpath along both banks
8) Provision of parkland with sitting areas and cafes

The group considered how each of these elements compared against their objectives and the planner gave an indication of the costs for each element.

Criteria	Sinuosity	Natural appearance	Contact zones	Public utilisation	Water quality	Unit costs
1	4	1	1	1	1	100
2	1	1	1	1	8	500
3	1	1	6	1	1	200
4	1	4	1	1	2	100
5	1	6	1	1	2	250
6	1	1	6	3	1	50
7	1	1	8	4	1	100
8	1	1	8	10	1	500

The planners had come up with a number of options as follows:

Option 1

In channel works to provide a meandering appearance
Provision of footpath along one bank

Option 2

In channel works to provide a meandering appearance
Provision of footpath along one bank
Removal of concrete bed of channel and replacement by natural substrate

Option 3

In channel works to provide a meandering appearance
Provision of public access and parkland with sitting and recreational areas
Removal of concrete bed of channel and replacement by natural substrate

Option 4

Remove storm sewage overflows
In channel works to provide a meandering appearance
Provision of public access

These were marked, taking into account the agreed weightings and the costs determined

Options	Sinuosity	Natural appearance	Contact zones	Public utilisation	Water quality status	Total weighted score
1	4	1	6	3	1	6.2
2	4	4	6	3	1	7.4
3	4	4	8	10	1	11.45
4	4	4	6	1	9	7.7

Costs						
1	100		50			150
2	100	100	50			250
3	100	100		500		700
4	100	100	50		500	750

The most highly marked option was Option 3 but this failed to provide the required water quality. Option 4 did provide the required water quality but it was expensive and did not provide the improvements in visual appearance and amenity value that the group wanted to see.

There was some discussion on the storm water overflows and the work that was required to improve the water quality up to Moderate standard. The Water company representative volunteered that it was thought that most of

the quality problems could be attributed to just one storm overflow and modification of this single overflow might provide the required improvement to Moderate. The cost of treating this one overflow would be 250.

Two additional Options were then formulated

Option 5

In channel works to provide a meandering appearance

Provision of public access

Removal of concrete bed of channel and replacement by natural substrate

Removal of one storm sewer overflow

Option 6

In channel works to provide a meandering appearance

Provision of public access and parkland with sitting and recreational areas

Removal of one storm sewer overflow

The markings for the Options were as follows

Options	Sinuosity	Natural appearance	Contact zones	Public utilisation	Ecological status	Total weighted score
1	4	1	6	3	1	6.2
2	4	4	6	3	1	7.4
3	4	4	8	10	1	11.45
4	4	4	6	1	9	7.7
5	4	4	6	3	8	8.45
6	4	1	8	10	8	11.3

Costs						
1	100		50			150
2	100	100	50			250
3	100	100		500		700
4	100	100	50		500	750
5	100	100	50		250	500
6	100			500	250	850

There was general agreement that Options 5 and 6 more closely matched what was thought to be desirable. It was noted that Option 6 was considerably more expensive than Option 5 and so there was a discussion of whether the perceived additional benefits of Options 6 outweighed the additional expense. The local planner considered that Option 6 would be more instrumental in:

a) attracting inward investment to the area and
b) increasing local property prices

and thus thought that the additional benefits were worth the expense. The elected representative from the local authority agreed and said that he would be prepared to recommend Option 6 to the elected council.

The conservationist reminded everyone that they had promised to look at the sensitivity to the assumed weighting for water quality. To satisfy this the weightings were modified as follows:

a) Improve visual appearance 0.35
c) Improve amenity value 0.40
d) Improve the water quality of the river 0.25

With these weighting the revised scores were as follows:

Options	Sinuosity	Natural appearance	Contact zones	Public utilisation	Ecological status	Total weighted score
1	4	1	6	3	1	5.6
2	4	4	6	3	1	6.65
3	4	4	8	10	1	10.25
4	4	4	6	1	9	7.85
5	4	4	6	3	8	8.4
6	4	1	8	10	8	10.95

The change in the weightings narrowed the difference between Options 5 and 6 but it did not change the overall preference for Option 6.