A KNOWLEDGE MAP OF SUSTAINABILITY FOR URBAN REDEVELOPMENT PROJECTS

D Gilmour[1], D Blackwood[1,2], R Falconer[3], J Isaacs[4], A Taylor[5]

[1] *Division of Environment and Forensic Science, School of Contemporary Science, University of Abertay Dundee, Bell Street, Dundee, DD1 1HG*

[3] *SIMBIOS, School of Contemporary Science, University of Abertay Dundee, Bell Street, Dundee, DD1 1HG*

[4] *School of Engineering, Computing and Applied Mathematics, University of Abertay Dundee, Bell Street, Dundee, DD1 1HG*

[5] *Dundee Business School, University of Abertay Dundee, Bell Street, Dundee, DD1 1HG*

This paper presents and evaluates the application of a transparent knowledge elicitation and decision mapping method that has been developed as part of a sustainability assessment and enhancement framework for a major urban redevelopment project. Sustainable Urban Development requires the effective engagement of a wide range of stakeholders such as planners, landscape architects, engineers, policy makers and the members of wider communities. These stakeholders will contribute to different stages of the development process and require information and data in a diverse range of forms to ensure that they are adequately informed and therefore able to make an effective contribution. It is clear therefore that there is a need for a method that enables the identification of key decision points throughout the project development stages. This requires the application of a combination of techniques drawn from the information technology, knowledge management and business process mapping fields to provides a full understanding of the ways in which decisions are made throughout the project and enables the information needs of key decision makers to be determined. This ensures that information on the potential impact of decisions or actions that will influence the overall sustainability of the project can be provided to the right stakeholders, at the right time and in the right form. The paper will explain and justify a three stage method that has been developed and tested on the £1 Billion 30 year Dundee Waterfront redevelopment project. Conclusions are drawn on the effectiveness of the method and on the impact of its application to the Dundee Waterfront development project.

Keywords: decision making processes, decision mapping, knowledge management, sustainable development.

INTRODUCTION

There is a wide awareness of sustainable development in the built environment (Walton et al., 2005) however it is generally accepted that the real challenge lies in understanding how to put it into practice, i.e. to "operationalise" sustainability (Parkin 2000; Lamorgese and Geneletti 2013). This "operationalisation" of the principles of

---

sustainable development within the urban design and development process must be fostered at a number of levels and requires a number of approaches. Tools, techniques and guidance documents have been produced to support decision makers, however decision making in practice is seldom structured and that often "satisfactory" solutions are reached in an ad-hoc basis (Simon 1972). Walton et al., (2005) examined the extent to which current methodologies meet the need for integration. They identified a number of shortcomings including the need for an integrated multi-dimensional tool that could bring existing approaches together.

The SAVE theoretical framework (Blackwood et al., 2012) promotes an integrated and iterative approach to inclusive decision making for Sustainable Development, involving three inter-related components; Assessment, Visualisation and Enhancement. The Enhancement Component identifies opportunities to positively influence the sustainability of developments and to devise and implement appropriate activities and actions. The Enhancement Component requires an understanding of the ways in which decisions are made throughout the project to enable the information needs of key decision makers to be determined. Key decision points in the process, the stakeholders involved in these decisions, their functions and their information needs require to be identified. This is to ensure that information on the potential impact of decisions or actions that will influence the overall sustainability of the project can be provided to the right stakeholders, at the right time and in the right form. A number of authors have effectively used decision mapping or knowledge mapping to document and understand organisation knowledge management and decision making (Snowden 2000; Egbu et al. 2006; Driessen et al. 2007; Yasin & Egbu 2010). A review of literature concluded that an appropriate knowledge a mapping technique needed to do the following:

- To identify key points in the decision process and elicit knowledge used to make decisions
- To be dynamic and represent relationship between knowledge and process flows
- To be simple, transparent, pragmatic and illustrate why, who, what and where of knowledge mapping

A knowledge elicitation and mapping method was therefore developed which addressed the above requirements. This was then tested on the £1 Billion Dundee Waterfront redevelopment project.

METHOD

The method developed enhanced previous work by the researcher and extended the approach used in development of the SAVE Monitoring Framework (Gilmour et al. 2011).The knowledge elicitation and mapping method utilised a combination of techniques drawn from the information technology, knowledge management and business process mapping fields. These were developed into a three stage process:

1. Knowledge Elicitation: Knowledge elicitation and process mapping to identify and classify knowledge
2. Knowledge Map of Sustainability: The creation, through stakeholder workshops, of a verified knowledge map of sustainability
3. Integration of sustainability into decision making: Interviews with key process owners to map existing management systems, identifying opportunities to

ensure the full integration of sustainability issues into the project decision making process

Figure 1 illustrates diagrammatically how each stage in method interconnects. The Knowledge Map of Sustainability draws together the Output of Stage 1 Process Owner Interviews and Stage 2 Workshops.
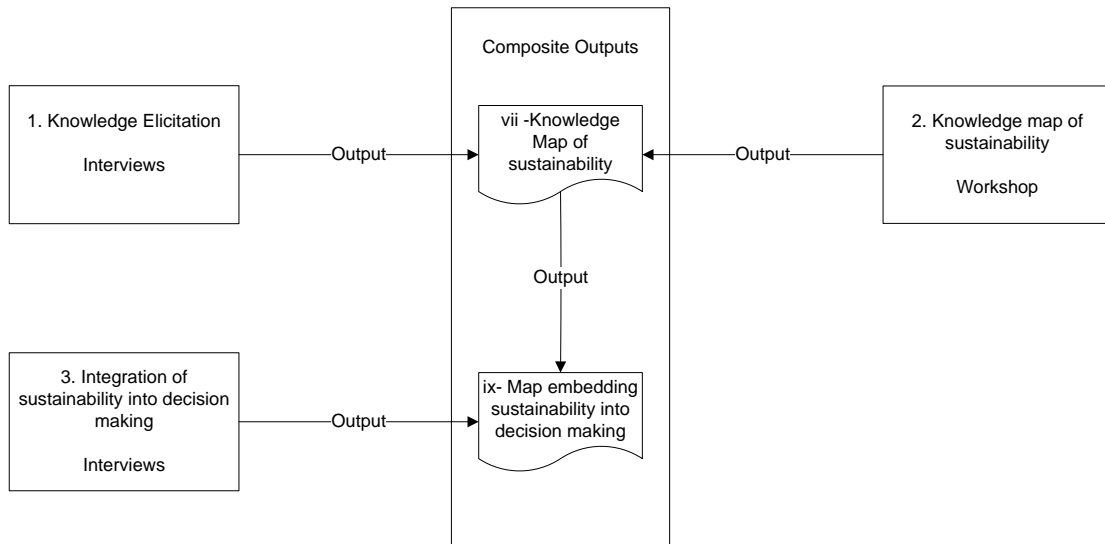

Figure 1 Method

The resulting knowledge map presents the key Knowledge Objects, flows and process in relation to sustainability across infrastructure provision. The third stage (not covered in the scope of this paper) maps existing management systems, identifying opportunities to ensure the full integration of sustainability issues into the project decision making process. The research has been conducted from an interpretive research paradigm (Dainty, 2008), with a non-experimental qualitative research model using semi structured interviews and workshops.

Stage 1 Knowledge Elicitation

Process mapping has been used effectively across many fields. Common to this wide application is that process mapping creates a diagrammatic understanding of the activity, people, data, objects involved in the process. Techniques of representation however vary between process mapping methods and what is represented or captured is bounded by the constructs of the language used for mapping (Biazzo 2002). In this study, an Organic Knowledge Management approach (Snowden 2000) was adopted to elicit and categorise knowledge. The premise to Snowden's approach is that knowledge is only known when it is needed to be known triggered by events and need, therefore you cannot ask someone to list everything they know (Snowden 2000). The human mind needs to be stimulated and therefore recalling the points that we use knowledge, is a method to recollect the use of knowledge. Snowden (2000) terms these as Knowledge Disclosure points (KPDs) such as decisions, judgements, problem resolution or learning. In this study process mapping concepts have been used together with Snowden's Organic Knowledge Management linguistic framework to develop a technique which allows the Knowledge Disclosure Points to be identified during each process, for all stages in infrastructure development. This approach also recognises a key finding of the literature review that you cannot map knowledge without understanding of the process (Egbu et al. 2006).

Process Owner Interviews

Mapping was undertaken by interviewing key individuals responsible for a task or process. These individuals are termed 'process owners' and have a deep understanding of the section of infrastructure or process under investigation. The Interviewees were asked to talk about the design and phasing process for Dundee Waterfront and explain what process was involved, what information used, what knowledge what needed to make judgment or decision. Process Maps were developed with the process owners during 10 interviews which were tape recorded for accuracy of the records. Maps were developed and subsequently verified through a series of further interviews with each participant. Each of the interviews built up a set of Process Maps and associated Knowledge Objects, based on Knowledge Disclosure Points. The method employed a 3 level hierarchy of diagrams which allows process to be mapped at appropriate level of detail. Level 1 which presents high level process and high level Knowledge Objects, Level 2 which present activities within each process and associated Knowledge Objects, Level 3 which present the workflow within the Level 2 diagram processes. The workflow diagrams provided the correct level of detail to allow Knowledge Disclosure Points (decisions) and associated Knowledge Objects used in the process to be identified and catalogued. Knowledge Objects used in the process were then collated for categorisation and analysis.

Knowledge Categorisation

The concepts of Tacit and Explicit knowledge (Nonaka and Takeuchi 1995) are widely recognised in knowledge management. Nonaka and Takeuchi (1995) developed the influential knowledge creation and transfer SECI model, where the four transitions between tacit and explicit, namely socialisation externalisation, combination and internalisation were identified. Snowden (2000) contends that the manager's day to day desire in calm and rational moments is to want information written down, leading to an idealised rational decision making with access to all information required. This is contrasted with real life under pressure decision where the problem moves from "structured explicit, pseudo rational decision making to, simple rules and values, tacit empowerment based on trust and experience" (Snowden 2000, p3). Simon (1972) identifies decision making in practice is seldom structured and that often "satisfactory" solutions are reached in an ad-hoc basis and concludes that most human decision making is concerned with the discovery and selection of satisfactory rather than optimal alternatives and describe this process as "satisficing". An approach was required to identify knowledge used in decision making which recognised the human interaction with process, and the concept of satisficing whilst providing some form of categorisation. Snowden (2000) presents a method of categorising knowledge whilst maintain sense of what information is used in decision making. Knowledge Disclosure Points were identified and mapped in interviews during process map. Knowledge Objects associated with Knowledge Disclosure Points were then collated in tables. The Knowledge Objects were then categorised based on ASHEN categorisation (Snowden 2000) as follows:

- Artefact: the term encompasses all existing explicit knowledge and /or codified information within an organisation e.g. documents, databases, processes.
- Skills are those things we can identify tangible measure of their successful acquisition: expertise, practised ability, dexterity, tact
- Heuristics are the effective way by which decisions are made when the full facts are not known: rules of thumb.

- Experience: actual observation or practical acquaintance with fact or events and the knowledge resulting from this.
- Natural talent: special amplitude, faculty, gift

The nature of the Knowledge Objects associated with each process can be used to inform mechanisms developed to embed sustainability within processes.

Stage 2 Knowledge Map for sustainable decision making

ASHEN workshop
Process Owners who had participated in the Process Owner Interviews were invited to participate in a workshop. The workshop enabled the collective identification of Knowledge Objects based on a number of Knowledge Disclosure Points identified in process mapping. This had two purposes, firstly to confirm Knowledge Objects identified during process mapping and secondly to draw out as a workshop group any clusters of Knowledge Objects used during the Design & Phasing and Construction stages. The workshop was led by the researcher at City Development Offices, Dundee City Council. Following a brief introduction, the workshop was anchored around meaningful questions on the context of the Knowledge Disclosure Points:

- When you made that decision what artefacts did you use or have access to?
- What skills had you acquired that were necessary?
- What heuristics have you developed that enabled you to make that decision quickly on the basis on incomplete or unarticulated inputs?
- What experience have you had which are essential or just plain useful in making that decision?
- What natural talent is necessary and can you give examples of signs that such talent exists as potential in others?

The participants worked as a group to agree what Knowledge Objects where used at Knowledge Disclosure Points during Design & Phasing and Construction phases in the Dundee Waterfront project. The ASHEN Model was presented to workshop participants on flip chart and Knowledge Objects were placed in the categories by the workshop participants. The workshop was tape recorded to give a complete overview of what had been said and the context of the knowledge disclosure and any discussion with the participants around this. In addition to the confirmation of Knowledge Objects identified during Stage 1 Process Mapping, the workshop looked specifically at sustainable development issues. The purpose of this was to draw from the participant's reflection of the sustainability issues relevant to, or contained within, the Knowledge Objects. A portfolio of Sustainability Knowledge Objects were drawn from this and used to create the Knowledge Map.

Creation of the knowledge map
The Knowledge Map for Sustainability draws together the output of Stage 1 Process Owner Interviews and Stage 2 Workshops. The resulting knowledge map presents the key Knowledge Objects, flows and process in relation to sustainability across Design & Phasing and Construction of infrastructure for Dundee Waterfront. Mapping methods for sustainable urban environments were reviewed (Eppler 2001; Egbu et al. 2006; Thomson et al. 2011) and presented a number of mapping techniques and mapping outputs. The review concluded that the important aspect to any map was simplicity, so that the stakeholders or users of these maps understand and can use these outputs. They also need to be able to show key documents, key flows and key

knowledge and to be dynamic to depict information over time. In addition they need to show the why, who, what, where (Egbu et al. 2006). Vail (1999) presents quality criteria to inform the design of knowledge maps as follows:

- Participative- the map is created interactively involving key employees
- Shared - the map represents shared knowledge the all can relate to
- Synergistic- experts contribute their different expertise to the map
- Simple- the map can be overlooked at one glance
- Visual- the map uses a visual framework

Stage 1 produced Process and Workflow Maps for each stage of infrastructure provision under investigation. A challenge in development of the knowledge map was to enable a significant number of processes and Knowledge Objects on to one map without losing the required simplicity and dynamism described above. Buchanan & Gibb (2008) provided comprehensive reviews of commonly cited methodologies from information management fields. Their work concluded that while there is wide commonality within approaches, no method distinguished itself as a preferred approach, therefore emphasis should be on usability of the outputs and organisational requirements (Buchanan and Gibb, 2008).   With this in mind, a representation technique was developed using the project life cycle as the dynamic component (Hunt and Rogers 2005; Thomson, Emmanuel and El-Haram 2011) to integrate process, Knowledge Objects and knowledge flows.

RESULTS

Stage 1 Knowledge Elicitation

Process Owner interviews
Twelve Process Diagrams were developed with the Process Owners to map Design & Phasing and Construction stages of Dundee Waterfront Infrastructure Provision. An example of a Level 2 Design & Phasing Process Diagram is shown in Figure 2. The Level 2 Outline Phasing Process Diagram provides an illustration of the process and associated Knowledge Objects identified and used during Outline Design. The Outline Phasing process is shown as a numbered boxes moving left to right. It starts from 'Splitting the master plan into sections' (5.1) to 'Detailed Phasing' (5.7) following initial drawings, revision and design review. Associated Knowledge Objects are shown in open brackets such as Experience, Engineering Judgement. Document Knowledge Objects (Artefacts) are shown at the bottom of the Process Diagram.
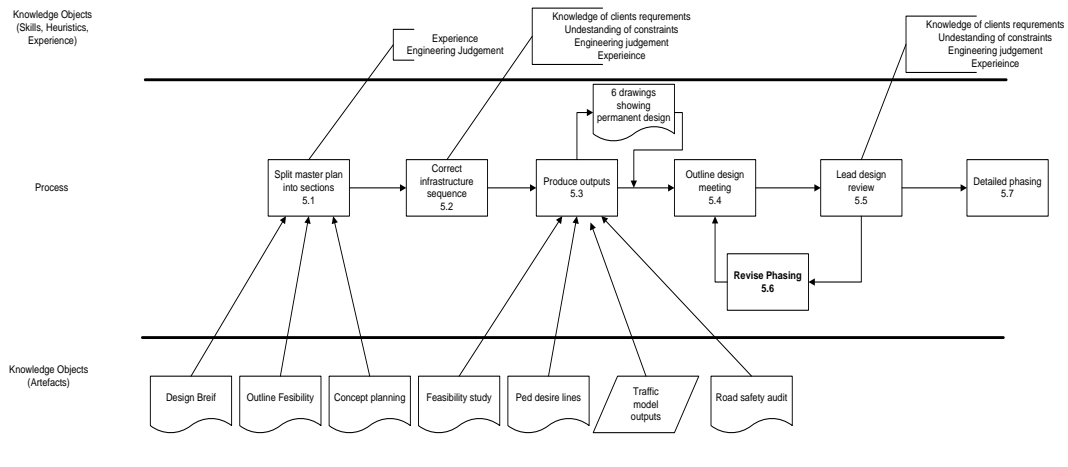
Figure 2 Level 2 Outline Phasing Process Diagram

Knowledge Categorisation
Knowledge Objects associated with Knowledge Disclosure Points were identified during Process Mapping interviews. The Knowledge Objects were then collated into tables and categorised based on ASHEN categorisation (Snowden 2000) as illustrated in Table 1 Outline Phasing Knowledge Objects (extract).

Table 1 Outline Phasing Knowledge Objects (extract)

Artefact object	Skills object	Heuristics	Experience	Natural Talent*
Design brief	Training	H&S implications	Knowledge of the design process	
Outline feasibility	Engineering judgement	Timings	Client constraints	
Concept planning	Knowledge of the requirements	Cost implications	Experience	
Feasibility study	Understanding of constraints	Traffic management implications	Awareness of Previous work	

Natural talent was not identified during categorisation

Stage 2 Knowledge Map of sustainable decision making

Ashen Workshop
The ASHEN workshop was held as described in the method section. Five ASHEN model diagrams were produced collectively by the participants during the workshop. Two diagrams identified Knowledge Objects associated with Design & Phasing and Construction and verified the Knowledge Objects identified in Stage 1. Three diagrams focussed on sustainability issues, identifying Knowledge Objects associated with Sustainability in Design & Phasing, Sustainability in Construction, and Sustainability Opportunities. The Knowledge Objects associated with sustainability identified were then used in the creation of the Knowledge Map for Sustainability. An example of AHSEN workshop output is shown in Figure 3.
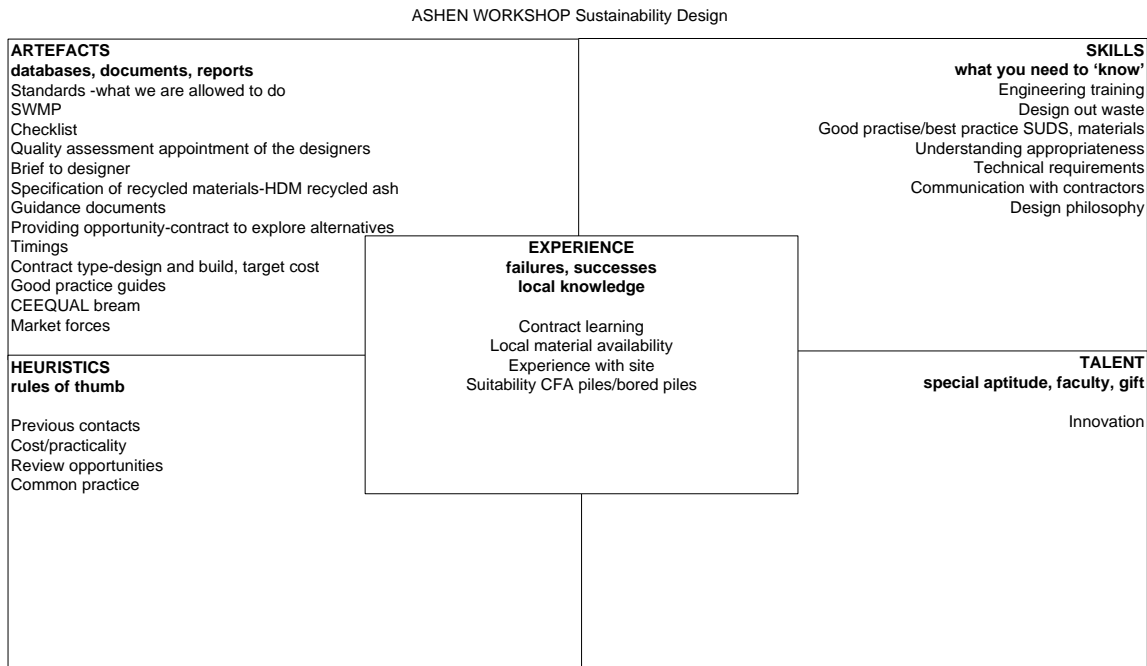
ASHEN WORKSHOP Sustainability Design

ARTEFACTS
databases, documents, reports
Standards -what we are allowed to do
SWMP
Checklist
Quality assessment appointment of the designers
Brief to designer
Specification of recycled materials-HDM recycled ash
Guidance documents
Providing opportunity-contract to explore alternatives
Timings
Contract type-design and build, target cost
Good practice guides
CEEQUAL bream
Market forces

SKILLS
what you need to 'know'
Engineering training
Design out waste
Good practise/best practice SUDS, materials
Understanding appropriateness
Technical requirements
Communication with contractors
Design philosophy

EXPERIENCE
failures, successes
local knowledge

Contract learning
Local material availability
Experience with site
Suitability CFA piles/bored piles

HEURISTICS
rules of thumb

Previous contacts
Cost/practicality
Review opportunities
Common practice

TALENT
special aptitude, faculty, gift

Innovation

Figure 3 ASHEN workshop Sustainability in Design & Phasing

Creation of Knowledge Map for Sustainability

The Knowledge Map for Sustainability is shown in Figure 4 and presents a distillation of output from Process Owner interviews and ASHEN workshops across Design & Phasing and Construction for Dundee Waterfront Infrastructure Provision. In addition, the map has been extended to illustrate Feasibility and Use to present the flow of sustainability knowledge across the project life.
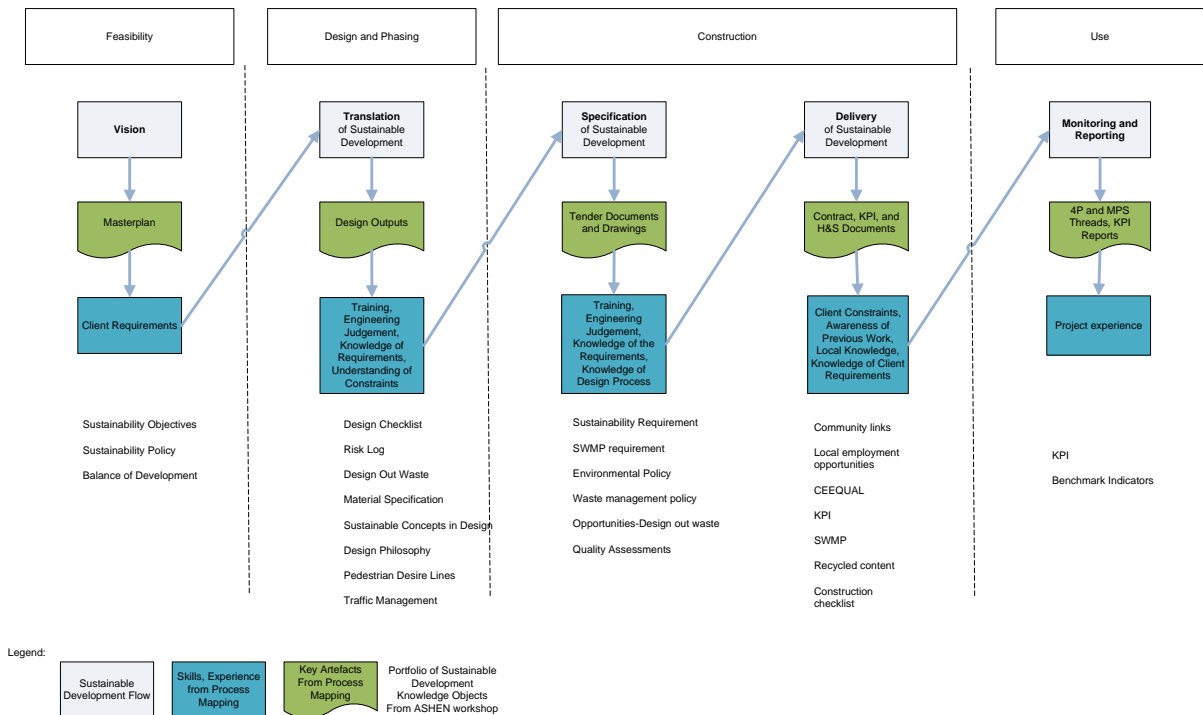
Feasibility	Design and Phasing	Construction		Use
Vision	**Translation** of Sustainable Development	**Specification** of Sustainable Development	**Delivery** of Sustainable Development	**Monitoring and Reporting**
Masterplan	Design Outputs	Tender Documents and Drawings	Contract, KPI, and H&S Documents	4P and MPS Threads, KPI Reports
Client Requirements	Training, Engineering Judgement, Knowledge of Requirements, Understanding of Constraints	Training, Engineering Judgement, Knowledge of the Requirements, Knowledge of Design Process	Client Constraints, Awareness of Previous Work, Local Knowledge, Knowledge of Client Requirements	Project experience
Sustainability Objectives	Design Checklist	Sustainability Requirement	Community links	KPI
Sustainability Policy	Risk Log	SWMP requirement	Local employment opportunities	Benchmark Indicators
Balance of Development	Design Out Waste	Environmental Policy	CEEQUAL	
	Material Specification	Waste management policy	KPI	
	Sustainable Concepts in Design	Opportunities-Design out waste	SWMP	
	Design Philosophy	Quality Assessments	Recycled content	
	Pedestrian Desire Lines		Construction checklist	
	Traffic Management			

Legend:
Sustainable Development Flow
Skills, Experience from Process Mapping
Key Artefacts From Process Mapping
Portfolio of Sustainable Development Knowledge Objects From ASHEN workshop

Figure 4 Knowledge Map for Sustainability

The Knowledge Map for Sustainability describes how the sustainability vision flows and transforms from Feasibility through translation of the vision in Design & Phasing, by specification of the vision in tender documents and appointment of contractors, and the delivery of the vision during Construction. The map also shows where the knowledge resides within each of the project stages. Knowledge Objects (key artefacts, skill and experience) and a portfolio of specific Sustainable Development Knowledge Objects which influence sustainable development are identified for each of the project phases.

One of the key challenges of the map presentation was to capture the dynamism and complexity of the real life process while keeping the simplicity and transparency so much desired in knowledge maps. To this end, the iterative nature of the process has been concealed through categorising Knowledge Objects into phases. It is acknowledged by the researchers that in reality these may be quite indistinct or overlapping. The Knowledge Map was verified by Process Owners at Dundee City Council to ensure usefulness, simplicity of representation and effectiveness to represent a Knowledge Map for Sustainability based on Eppler's (2001) knowledge map quality criteria.

CONCLUSIONS

Simple and transparent decision mapping and knowledge elicitation techniques have been successfully developed and applied to Dundee Waterfront to identify key points in decision process, information decision makers need and knowledge objects that they are using to make decisions. This was achieved through 10 mapping interviews, workshops and further verification interviews. The techniques have mapped the infrastructure provision process to identify knowledge supporting the process. This in turn has allowed a Knowledge Map for Sustainability to be developed to identify what information is currently used to influence sustainability and identify future opportunities to enhance practice. The map has been effective in capturing the role of each stage in process to translating the sustainability vision. This map has been useful to the project team to identify opportunities to influence sustainability within the Dundee Waterfront Infrastructure Provision. This understanding provides an insight on how to operationalise sustainability and will be used in Stage 3 of the Method to identifying opportunities to ensure the full integration of sustainability issues into the project decision making process. The mapping approach has only been tested on one case study, however due to the flexibility of approach it is concluded it should be appropriate for the sustainability enhancement of other infrastructure projects.

REFERENCES

Biazzo, S 2002, Process mapping techniques and organisational analysis: Lessons from sociotechnical system theory, Business Process Management Journal, 8, (1), pp. 42–52.

Blackwood, D, Isaacs, J, Gilmour, D and Falconer, R 2012, Integrating Sustainability in Water Sensitive Urban Design Through Dynamic Visualisation & Modelling, WSUD Conference 2012 Building water Sensitive Community. 7th International Conference on Water Sensitive Urban Design. 21 -23 February 2012.

Buchanan, S and Gibb, F 2008, The information audit: Methodology selection, International Journal of Information Management, 28, (1), pp. 3–11.

Driessen, S, Huijsen, W-O and Grootveld, M 2007, A framework for evaluating knowledge-mapping tools, Journal of Knowledge Management, 11, (2), pp. 109–117.

Egbu, C, Quintas, P and Demaid, A 2006, Knowledge Mapping and Bringing about Change for the Sustainable Urban Environment. A report of Transition Project Research Funded by the EPSRC Sustianble Urban Environment Programme.2006.

Eppler, MJ 2001, Making knowledge visible through intranet knowledge maps: concepts, elements, cases, Proceedings of the 34th Annual Hawaii International Conference on System Sciences, IEEE Comput. Soc, p. 9.

Gilmour, DJ, Blackwood, DJ, Banks, L and Wilson, F 2011, Sustainable development indicators for major infrastructure projects, Proceedings of the ICE Municipal Engineer, 164, (ME1), Thomas Telford, pp. 15–24.

Hunt, D and Rogers, C 2005, Barriers to sustainable infrastructure in urban regeneration, Engineering, (June), pp. 67–81.

Lamorgese, L and Geneletti, D 2013, Sustainability principles in strategic environmental assessment: A framework for analysis and examples from Italian urban planning, Environmental Impact Assessment Review, 26 January, Elsevier Inc.

Nonaka, I and Takeuchi, H 1995, The knowledge-creating company: how Japanese companies create the dynamics, Oxford University Press USA, Oxford University Press, p. 284.

Parkin, S 2000, Contexts and drivers for operationalizing sustainable development, Proceedings of the ICE-Civil Engineering, (November 2000), pp. 9–15.

Simon, H 1972, Theories of bounded rationality, R Radner & C McGuire (eds), Decision and organization, North Holland Publishing.

Snowden, D 2000, The ASHEN Model: an enabler of action Part One of Basics of Organic Knowledge Management The ASHEN Model: an enabler of action Part One of Basics of Organic Knowledge Management, Knowledge Management, 3, (7), pp. 1–8.

Thomson, CS, Emmanuel, R and El-Haram, M a. 2011, Mapping sustainability assessment with the project life cycle, Proceedings of the ICE - Engineering Sustainability, 164, (2), pp. 143–157.

Vail, EF 1999, Knowledge Mapping: Getting Started with Knowledge Management, Information Systems Management, 16, (4), pp. 1–8.

Walton, JS, El-Haram, M, Castillo, NH, Horner, RMW, Price, ADF and Hardcastle, C 2005, Integrated assessment of urban sustainability, Engineering Sustainability, 158, Issue, (June 2005), pp. 57–65.

Yasin, F and Egbu, C 2010, Exploitation of knowledge mapping benefits in the facilities performance evaluation process: a conceptual framework, In: Egbu, C. (Ed) Procs 26th Annual ARCOM Conference, 6-8 September 2010, Leeds, UK, Association of Researchers in Construction Management, 799-808., pp. 799–808.

Yoo, K, Suh, E and Kim, K-Y 2007, Knowledge flow-based business process redesign: applying a knowledge map to redesign a business process, Journal of Knowledge Management, 11, (3), pp. 104–125.