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STEEP PROJECT

Systems Thinking for Comprehensive City Efficient Energy Planning

Seventh Framework Programme

Theme Energy

D2.1 Energy Master Plan Process Model

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1. Introduction

The methodology outlined in this document describes a systemic problem structuring method presented for district energy master planning. The methods described in this document facilitate the elicitation, sharing, capturing and transformation of pluralistic perspectives, knowledge claims and values about the problem situation in a collaborative process. The methodology is based upon the deliberative concept of discursive decision making with the objective to find the best possible consensus. Its overarching aim is thus to enhance moral legitimacy of decisions for intervention and to reflect social and cultural values in collective decision-making.

The application of the methodology builds capacity for problem structuring in a multi-agency setting in the participating cities in the specific context of this project. Furthermore, it equips project participants with the transferable skills of collaborative sensemaking using hierarchical process modelling to structure the group model building process. The consequential ability to apply this methodology iteratively enables 'learning towards actions' in multi-stakeholder contexts that are characteristic of future city development challenges.

Results from the group model building workshops held in Bristol, San Sebastián and Florence are presented. Formal methodology evaluation is presented in STEEP deliverable D2.5 where we document our reflections on how the methodology is working in the project in the spirit of Ormerod (2014) and using formal evaluation techniques appropriate to PSM use described by Midgley et al. (2013). The effectiveness of the group model building activity has been analysed from theoretical perspectives by White, Yearworth, and Burger (2015), using the "Mangle of Practice" lens from (Pickering, 1993, 1995), and by White, Burger, and Yearworth (forthcoming) using Activity Theory. Scale-up of the methodology for use in citywide future city planning is presented in STEEP deliverables D4.1 and D4.2. Training material for using the methodology is available online in the resources section of the STEEP project website.

The first section of this deliverable presents final reflections on the overall performance of the methodology in the STEEP project from the perspective of making recommendations for future use and developments for prospective users in the future city context.

2. Developing the STEEP methodology

2.1 Updated literature review

An updated literature review was motivated by the vicissitudes of using Problem Structuring Methods (PSM) in a multi-agency setting. This use is epitomised by the STEEP project where energy planning in city districts involves a wide range of

stakeholders represent different organisations and where evaluation of the methodology in STEEP deliverable D2.5 revealed some areas for development.

The long-term increase in multi-organisational partnerships and the associated "*collaborative advantage*" also brings with it complexities and challenges (Ackermann, Franco, Gallupe, & Parent, 2005; Franco, 2008). However, despite increased use of PSMs in this type of problem context the goals of collaboration are difficult to achieve, and ventures can end in frustration at failure to achieve agreed goals (Ackermann et al., 2005).

PSMs such as developed and used in the STEEP project do offer the potential to support effective attention to the substantive nature of the problem (in this case energy planning) as well as achieving procedural justice (Franco, 2008). However, little work has been done as yet. Most reported work on PSMs in use focuses on actors from single organisations and it is not immediately clear how well the methods transfer to groups working across/between organisations (Franco, 2007). Despite some evidence for their use in energy planning as reported in the initial literature review (e.g. work of (Coelho, Antunes, & Martins, 2010; Neves, Martins, Antunes, & Dias, 2004; Sheffield, 2004, 2009a, 2009b)) there is still the need for more studies to be carried out in order to clarify the effectiveness, impact and potential of range of PSMs in the multi-agency setting (Franco, 2008).

Key issues with multi-organisational work include

i) Lack of clear accountability structure (Franco, 2007),
ii) Lack of direct 'power to act', i.e. actors (often) have limited authority to commit their organisations to a decision (Franco, 2007) or "*do not exhibit an overall framework of authority and power*" (Franco, 2009),
iii) Lack of clear 'client' or process owner (Ackermann et al., 2005),
iv) The complex politics and power in operation (Ackermann et al., 2005),
v) Parties have different perspectives on a problem domain (Franco, 2008), and
vi) There are conflicting goals (Ackermann et al., 2005) with the 'traditional adversarial stance' between stakeholders (Franco, 2009).

On the other hand, positive effects of PSMs in a partnership context include

i) Rich open exchanges leading to increased mutual understanding of the problem domain and of each other,
ii) They can contribute to a high level of ownership to agreements and implementation,
iii) Support for a 'balanced dialogue' amongst partners, and
iv) Facilitation of positive adjustments/accommodations in the partnership though integration and dissemination of learning among partners (Franco, 2008).

An important development has been the exploration of how PSMs can be implemented without workshops, or at least workshops that require the physical presence of the stakeholders.

As Morton, Ackermann, and Belton (2007) point out – reflecting our experience on STEEP – "*PSMs have been widely and successfully used in many organisations, but the reliance on face-to-face meetings and workshops makes a typical PSM project difficult and time-consuming to organise …*" and that this means "*…that the process may only involve a narrow cross-section of the organisation. Yet much interaction in organisations is neither face-to-face nor even synchronous*". More broadly, "*PSMs can be very costly in terms of participant time, as well as in financial terms if the organisation is not physically collocated…*", which is the case in the context of multi-organisational teams/groups, inter-organisation partnerships. They also point out "*patterns of organisational communication have been transformed by the arrival of e-mail and the Internet, which allow remote [including geographically distributed], asynchronous interaction*". From this they then raise an important question *"…how it might be possible to use such technologies to reduce the overall cost and broaden the catchment of a PSM intervention?*"

Considerable issues arise with respect to facilitating and moderating asynchronous and distributed modes of interaction in PSMs. Not least the difficult question of original motivation to use an online platform if there isn't the prompting action of attending a workshop. This need for *animating* the methodology is anticipated in the full description of the STEEP methodology captured in Figure 1.

Key research questions raised by Morton et al. (2007) are

1. To explore how the issues which arise in moderating such distributed interaction differ from the issues involved in facilitating a workshop
2. To identify the circumstances under which it makes sense to consider using the distributed mode of interaction within a PSM process.

In previous work cited by Morton et al. (2007) there are already elements of distributed and asynchronous working in existing PSM implementations. For example

i) *"… Some PSM applications do partially incorporate a distributed component ((Best, Parston, & Rosenhead, 1986; Vennix, 1996) use a Delphi-like process in their System Dynamics and Robustness Analysis modelling respectively)*"

ii) *"… Within the Group Support Systems (GSS) tradition … considerable interest in the distributed work.*" e.g. (Hiltz et al., 2013)

iii) "*Policy Delphi*" (Turoff, 1975). Policy Delphi refers to an application of the Delphi process where the motivating problem is a decision problem, rather than simply a question of assessment.

However, "*neither the Policy Delphi nor the distributed GSS programs use the sort of qualitative modelling techniques which are the bread and butter of a PSM intervention*

… another, perhaps deeper reason is that there is, we would contest, a distinctively PSM view of the decision making process which focuses on organisational decision making as the negotiation of interpretive frames" (Morton et al., 2007). They used a series of case studies to begin to investigate their research questions use of a modified version of the "*SODA process, …, but relying largely or exclusively on asynchronous communication*" using a Delphi-like process. Their work raised many questions and opportunities for investigation within the context of non-collocated and asynchronous settings, including:

i) Issues over motivating participants
ii) The need for a modelling approach that is "*sufficiently transparent or familiar that participants can 'read' the model without real-time coaching*"
iii) Issues with sequencing and co-ordination of interactions
iv) How facilitators can intervene appropriately
v) What kinds of tasks and groups might be appropriate in different contexts and with particular technologies

Such findings highlight both the potential and range of issues associated with a non-synchronous and distributed approach.

2.2 Integration of hard systems and soft systems approaches

Taking a 'systems thinking' perspective and considering both hard systems and soft systems paradigms (summarised in Annex B) is a very powerful starting position to problem structuring. This assists in developing a rapid appreciation of the 'big picture' and identifying the most beneficial approach to intervention. It also makes available a wide range of formal modelling techniques and tools. Whilst the STEEP methodology mainly focuses on presenting a soft systems approach it is important to consider how the hard systems viewpoint can be integrated. The STEEP methodology fully describes and *argumentation* phase that can be carried with the stakeholders based on ideas of dialogue mapping and Issue Based Information Systems (IBIS) (Conklin, 2003, 2006; De Liddo, 2010; Kunz & Rittel, 1970). Processes that have been identified as having poor performance or there is a high degree of uncertainty about performance are further resolved into *Issues*, *Options* and *Arguments*. Issues are perceived as the primary cause of poor or unknown performance. Stakeholders then discuss Options for resolution, and the Arguments for and against. Ideally arguments are supported by appropriate expert/specialist models (evidence) presented as scenarios or answers to specific 'what-if' questions about the future performance of an implementation. This method of incorporation of expert opinion enables the integration of arguments for specific actions across widely disparate stakeholder groups. For example, in the development of the Climate and Energy Security Framework (CESF) for Bristol a "mini-Stern" review was conducted by the University of Bristol to develop an expert model that would answer specific "what if" questions about possible interventions. These

"evidential" statements then provide arguments for and against taking possible actions to resolve an issue identified by the STEEP modelling approach.

2.3 Final version of the STEEP methodology

Annex D includes an original model of the STEEP methodology expressed in its own modelling language. Such 'recursive' presentation of methodology is not new, Checkland modelled SSM using its own purposeful activity system modelling language in (Checkland, 1981). As the project has developed this view of the STEEP methodology has developed to the point where it has been used to document itself on the STEEP collaborative stakeholder engagement platform, which is linked via the STEEP project website. The complete methodology as a Hierarchical Process Model (HPM) is shown in Figure 1.

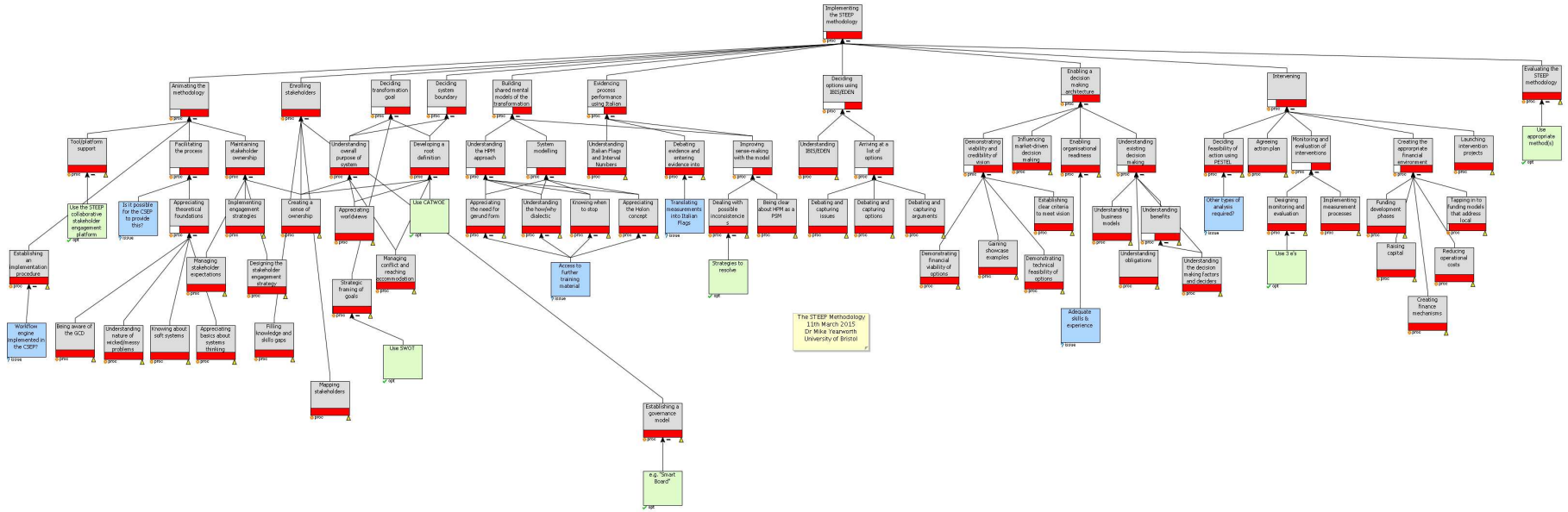

Figure 1. The STEEP Methodology expressed in its own modelling language and evidenced at its initialisation stage where none of the processes have been implemented and thus are performing badly

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A useful descriptive summary of the methodology is presented in **Figure 2.**

Hierarchical Process Modelling (HPM) begins with stakeholders agreeing a top-level *transformational* process analogous to the construction of a root definition in Soft Systems Methodology (SSM). This process is similar to the Transformation of a root definition in SSM although in HPM this would be considered the *purpose* of the system to be modelled. The modelling paradigm is consistent with the soft systems view of (Checkland & Holwell, 2004).

Once stakeholders have agreed the transformational goal or purpose of the system, modelling is conducted in facilitated group model building sessions. The facilitator leads the participants through a language game of answering 'how' questions in order to *decompose* the top-level process into more detail as stakeholders build a shared understanding of how the transformation is to be achieved. At any time the *dual* of the 'how' question – 'why' – can be asked by participants to move back up the hierarchy to understand context.

Challenging the top-level process is also allowable in the language game enabling questions about system boundary. Synergies across system boundary can thus be explored by further 'how' exploration of processes outside the original system being modelled.

Part of the language game entails imposing a strict grammatical form for process descriptions; they must be *gerunds* to enforce both a sense of *doing* and of a *continuous present*. A significant benefit from this rule is that it allows objects to enter the system model as processes. For example a vehicle such as a car could be modelled as the process <transporting passenger>, deferring the fulfilment of 'how' (a car or alternative mode of transport) to later in the modelling process or even postponed indefinitely if it does not really matter.

Whilst the visual representation of an HPM is, as the name states, hierarchical, the 'how' branches descending from a process are better thought of as being '*part-of*' the higher-level process. A process in HPM can thus be thought of as a *holon*.

Once participants in the modelling process have sufficient understanding of their transformational system the facilitator leads them into a new phase of modelling, that of assessing performance. Having modelled a transformational system as an HPM it is possible to ask the question "how well are the processes performing?" HPM uses a novel method of expressing beliefs about process performance as interval numbers, which can express tri-valued statements of i) performing well (green), ii) don't know (white), and iii) not performing well (red). The inclusion of a don't know representation enables explicit capture of epistemic uncertainty (Helton & Burmaster, 1996). These assessments of process performance by stakeholders are colloquially known as "Italian Flags". Whilst the original design of HPM used strict mathematical propagation of evidence to ascertain overall process performance (Hall, Blockley, & Davis, 1998; Marashi, Davis, & Hall, 2008) in this use of HPM as a PSM the Italian Flag is only used as a means to identify processes that are performing badly (flags that are mostly red), or there is a high degree of uncertainty (flags that are mostly white). The movement towards agreeing action to improve is thus one of identifying processes to *fix* (red) or *find-out* (white).

An extra stage that can be carried with the stakeholders is to use an argumentation phase based on ideas of dialogue mapping and Issue Based Information Systems (IBIS) (Conklin, 2003, 2006; De Liddo, 2010; Kunz & Rittel, 1970), where processes with poor performance or high uncertainty are further resolved into the *Issues* causing such, the possible *Options* for resolution, and the *Arguments* for and against. Ideally arguments are supported by appropriate expert/specialist models (evidence) presented as scenarios or answers to specific 'what-if' questions about future performance of an implementation. This method of incorporation of expert opinion enables the integration of arguments for specific actions across widely disparate stakeholder groups.

Naturally, these steps can be broken arbitrarily into a number of different workshops as time and stakeholder availability allow.

Figure 2. Descriptive summary of the STEEP methodology citing (Checkland & Holwell, 2004; Conklin, 2003, 2006; De Liddo, 2010; Hall, Blockley, & Davis, 1998; Helton & Burmaster, 1996; Kunz & Rittel, 1970; Marashi, Davis, & Hall, 2008) and adapted from Lowe, Martingale, and Yearworth (submitted).

2.4 Main recommendations for successful implementation

The development of the STEEP methodology to scale-up to citywide future city planning is documented in STEEP deliverables D4.1 and D4.2. The main points are summarised here:

1. Ownership and definition of any transformation is co-dependent with the membership of the stakeholder group; the two co-create each other
2. Current PSM practice assumes a plural problem context and that there is sufficient commitment amongst the stakeholders for them to want to work collectively to arrive at a shared understanding and agreement on actions
3. Without the requisite power/control to enforce a specific transformational goal it is probable that either commitment will be weakened, or likelihood of success will be considerably reduced, or both
4. Transformational processes need constant reviewing and renegotiation of goals

2.5 Future developments

Recent work by Yearworth (2015); (Yearworth, forthcoming) based in part on the experience of the STEEP project and incorporating ideas of "Super Wicked" problems[1] (Bernstein, Cashore, Levin, & Auld, 2007; Lazarus, 2009), and ideas about workshop-less PSMs as discussed in the revised literature review has led to the following observations about the development requirements for a PSM in a messy multi-agency problem context such as STEEP:

1. Setting transformational goals, owning stakeholder engagement, and dealing with goal erosion are interdependent problems that when combined with multi-agency working suggests that conventional workshop-style facilitator-led settings are no longer appropriate alone. They are still likely to have a place but as part of an augmented process that helps deal with multi-agency related issues
2. Dealing with worldviews, subjectivity and the fact that we are the cause of the problem suggests that we need to extend existing methods to deal with more inclusive and widespread participation
3. The fact that time is running out suggests that we need to move to PSM implementations that are quick and inexpensive to deploy, iterate quickly, and persist over time
4. Overcoming cognitive biases require specialist behavioural modelling approaches

Moving towards ICT-supported non co-located group model building workshops is a promising direction of travel for this type of work (Morton et al., 2007; Shaw,

[1] No single authority is in control, we are the cause of the problem anyway, time is running out, and we inherently discount the future in our everyday decision-making.

Westcombe, Hodgkin, & Montibeller, 2004), particularly where these encourage the widest possible stakeholder participation and suitable integration of expert and non-expert opinions. We have summarised these requirements into three key concepts: "Open Platform", "Evidence" and "Glue" as follows:

1. Making use of the ubiquity and inclusivity of all forms of social media and open source software tools ➔ **Open Platform**
2. Inclusion of specialised expert hard-systems modelling into the process that can be debated ➔ **Evidence**
3. The STEEP Problem structuring methodology that enables accommodation to be found across disparate views of development ➔ **Glue**

The STEEP stakeholder engagement platform as at the end of the project represents the beginnings of development in this direction.

3. Systems methodology for master planning

The systems methodology used for the STEEP project is based on an interpretation of Soft Systems Methodology (SSM) (Checkland & Scholes, 1999) using Hierarchical Process Modelling (HPM) as an almost direct replacement for Purposeful Activity Systems (PAS) modelling in SSM. The following sources were also central for methodology development:

a) Original work of, amongst others, Blockley, Davis, Godfrey and Hall at the University of Bristol (Blockley & Godfrey, 2000; Davis & Hall, 2003; Hall et al., 1998),

b) The Yearworth & White generic constitutive definition of Problem Structuring Methods (PSMs) was used to guide the interpretation and development[2] (Yearworth & White, 2014)

c) Approaches originating from the group model-building community centred on the work of Vennix, Rouwette, Andersen and Richardson (Andersen, Vennix, Richardson, & Rouwette, 2007; Andersen & Richardson, 1997; Vennix, 1996).

For comparison, the originally conceived way of using of HPM is described fully in (Blockley & Godfrey, 2000; Dias, 2013).

The HPM Methodology was initially socialised within the STEEP project to familiarise the project partners with some of the basic ideas of Problem Structuring Methods, systems thinking, hierarchical process modelling, and assessing process performance. The objectives at the start of the project were set out as the following learning outcomes:

At the end of the training workshop the Project partners were expected to:

a) Have gained an appreciation of systems thinking and its application to wicked/messy problems using Problem Structuring Methods (PSMs). Also understood the difference between the hard and soft systems traditions and the advantages/disadvantages of each

b) Be able to express a messy problem situation as a desired transformation using language of purpose and process

c) Use a hierarchical process model as a conceptual system to achieve the transformation

d) Understand how system performance can be assessed based on theories of evidence and used to direct attention for interventions

e) Appreciate the role that necessity and sufficiency conditions play in determining overall system performance in hierarchical process modelling

[2] The generic constitutive definition of a PSM is presented in Annex C.

f) Use argumentation to identify issues associated with poor performance, elicit options to resolve, and capture arguments for and against interventions.

3.1 Justification for HPM as a PSM and the use of PSMs

The hard and soft system traditions were explained in terms of Checkland's epistemic shift, making use of Table 3.1 in (Checkland & Holwell, 2004, p. 56), and Figure 1 of (Kotiadis & Mingers, 2006, p. 858) ex (Brown, Cooper, & Pidd, 2006, p. 667) and (Pidd, 2004, p. 18) to discuss the different ways of thinking about the relationship between these two paradigms. The intention was move the project team towards an understanding that systems can be thought of as conceptualisations that can be used to structure problems and guide interventions, as well as the more conventional view of real systems in the world. The latter realist/functionalist approach tends to eliminate creative scenario planning and leads to jumping to technological fixes (Jackson & Klobas, 2008; Nuno & Pidd, 2000; Slaughter, 2002). The key features of these two views are summarised in Annex B.

The nature of the project and the participants' backgrounds as revealed during the STEEP systems training event (details can be found in (STEEP, 2013a)) demonstrated the prevalent functionalist, realist view of systems. In fact, the approach to engineering of energy systems to achieve low CE development could be characterised as an exemplar of what Bevan calls the pervasive, implicit, pragmatic realist stance of expert modellers working in the domain of sustainability (Beven, 2002).

The project partners were introduced to the original Rittel and Webber of wicked and messy problems using a slight adaptation of their original description of such problems as follows (Rittel & Webber, 1973):

a) The aim is intervention in a problem situation, not knowledge gathering for its own sake
b) No definitive formulation of the problem situation is possible
c) There is no stopping rule, the problem situation is on-going
d) Interventions are not right or wrong, there is no immediate/ultimate test of an intervention, but they can only be viewed as good/bad
e) Interventions are 'one-shot', no trial-and-error (experiments), every intervention counts significantly, they are essentially unique
f) No enumerable, exhaustively describable, set of interventions
g) Problem situations can be considered as symptoms of other problems
h) Interventions can be contested at the level of explanation, there is likely to be conflicting evidence/data

The application of these criteria to the conceptual modelling process using HPM and SSM seems to have been novel to the project participants in the problem situation of energy efficient district planning. Energy Efficient City District Planning exhibits these criteria of a wicked and messy problem situation and the use of a problem structuring method was therefore considered necessary and appropriate in the STEEP project design (STEEP, 2011).

We also used a slightly adapted form of Mingers' description of wicked/messy problem situations to provide further emphasis on the difficulty of interventions (Mingers, 2011):

a) Aim is intervention in a problem situation, not knowledge gathering for its own sake
b) No definitive formulation of the problem situation
c) There is no stopping rule, the problem situation is on-going
d) Interventions are not right or wrong, there is no immediate/ultimate test of an intervention, but only viewed as good/bad
e) Interventions are 'one-shot', no trial-and-error (experiments), every intervention counts significantly, they are essentially unique
f) No enumerable, exhaustively describable, set of interventions
g) Problem situations can be considered as symptoms of other problems
h) Interventions can be contested at the level of explanation, there is likely to be conflicting evidence/data

We integrated the characterisation of PSMs from descriptions originating from Mingers and Rosenhead (Mingers, 2011; Mingers & Rosenhead, 2004; Rosenhead, 1996) as follows: PSMs have a number of distinctive characteristics which include i) these are methods that are not mathematical, but structured and rigorous and based on qualitative, diagrammatic modelling, ii) they allow for a range of distinctive views to be expressed/explored/accommodated and allow for multiple and conflicting objectives, iii) they encourage active participation of stakeholders in the modelling process, through facilitated workshops and cognitive accessibility, iv) they can facilitate negotiating a joint agenda and ownership of implications of action, v) they operate where significant uncertainty is expected and tolerated and also operate iteratively, and perhaps most importantly vi) the aim is for exploration, learning, and commitment from stakeholders to taking desirable and feasible intervention in the problem situation.

Table 1 of the Yearworth & White framework was used as a justification for the design of the HPM as a PSM methodology and was briefly presented in the STEEP systems training event (STEEP, 2013a; Yearworth & White, 2014). This table is also reproduced in Annex C.

3.2 From root definition to a purposeful process

The actual development of a hierarchical process model in the HPM methodology requires a single 'top level' process to act as a descriptor for the *purpose* of the system. There is a direct correspondence with the root definition in SSM (Dias, 2013, p. 227). Having decided to adopt an SSM-like process we used a slightly modified version of Hindle's description of the SSM process, shown in Figure 3, to convey how HPM could support an iterative engagement with intervention in a messy problem situation (Hindle, 2011).

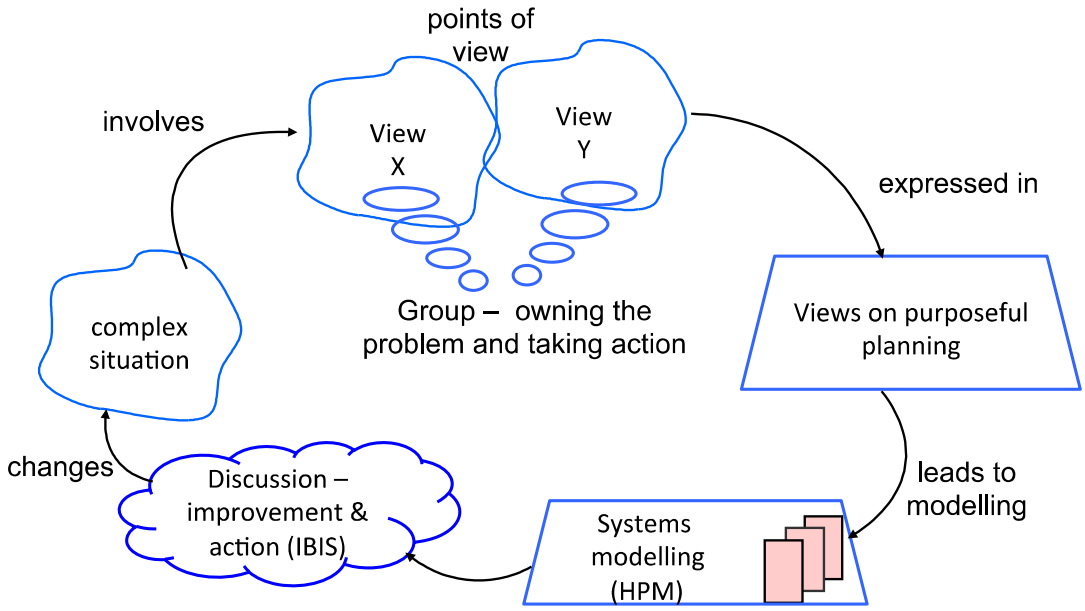

Figure 3. Diagrammatic view of the problem structuring method. Adapted from (Hindle, 2011).

We used the SSM approach to developing a root definition by introducing the notion of verb models first. In SSM, verb models are constructed in order to explore perspectives that are relevant to a situation, in order to ask questions of a real world situation (Checkland & Poulter, 2006). They do not claim to provide a simplified version of reality, but instead to model a particular way of looking at it. The value of doing this is that different models can be constructed and compared, surfacing different understandings and perspectives. Verb models are sentences describing a process or activity relevant to the problem situation. At their most basic, they describe an activity in the form (A system to do P by means of Q in order for R). A number of elements are likely to be present in a useful verb model, including an activity or transformation (T), a worldview that makes sense of this (W) and an environment in which the transformation takes place (E). Alongside these three elements, three types of Stakeholding are distinguished: stakeholders as actors (A), as owners (O) and as customers (C). Thus given an activity or transformation (T), the actors (A) are the doers, the ones whose actions directly constitute or result in the activity in question.

The customers (C) are the victims or beneficiaries – the ones whose fortunes are changed for good or ill by the activity. The owners (O) are those responsible for the activity, the usual test for which is that they can cause the system to cease to exist. The collection of parts in a root definition is collectively known by their acronym CATWOE.

A hypothetical example of a root definition suitable for the STEEP project might be:[3]

> *"A system for the Smart City Group (A) at Bristol City Council (O) to achieve energy efficient development of the TQEZ (T) for the Bristol community at large (C) by promoting a set of practices around open data and GIS modelling (W) and which is seen as essential activity for the City to meet commitments to 2050 emission targets (E)"*

From this the transformational process (T) would be adapted slightly into a gerund[4] form suitable for HPM i.e. the statement "achieve energy efficient development of the TQEZ" could become:

- Achiev*ing* energy efficient development of the TQEZ

As well as any number of related process descriptions of system purpose e.g.

- Master-planning for district energy
- Accelerating interventions for greater energy efficiency
- Transitioning to a smart city
- Achieving deployment of low carbon technology

None of these would be the *right* statement to use. We go on to show that the process of systems modelling enables this statement to be challenged by a group to find a *more useful* (in the sense of meeting purpose) transformational process description.

In the soft systems tradition, the system model (holon[5]) is thus an intellectual device that is used to decide how to intervene in a messy problem situation. This system has a purpose, which needs to be articulated as the starting point for the modelling process. The resultant hierarchical process model is thus a conceptual model that consist of processes, described by gerunds, structured into a hierarchical arrangement by decomposition and representing the minimum processes in a system required to achieve the stated purpose.

The notion of building a purposeful activity model resembles a process:

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[3] Further examples from the STEEP systems training workshop are given in (STEEP, 2013a).

[4] Originating from the Latin gerund can be translated as "*(which is) to be carried out*" using the active present (or continuous) form. We believe the gerund construct translates well into other languages, at least if they share the same Latin grammar roots.

[5] During the systems training event for the STEEP project an attempt was made to socialise the term holon as an alternative to soft system (or conceptual model of a system) in order to break the link with the hard systems viewpoint. A holon is a philosophical concept coined by Koestler and refers to something that is both a whole and also a part (Koestler, 1967). We go on to argue that both the processes in our process modelling and the whole process model need to be thought of as holons.

- In SSM: a human is acting purposefully, from a specific world-view
- In general: an agent is acting meaningfully, in a specific context

SSM may benefit from process modelling techniques during root definition and conceptual model building.

"*Process modelling can augment the notion of Checkland's purposeful activity systems by introducing a multi-level, inter-connected set of processes which is more manageable and industry-oriented. The ACT model also generalises the CATWOE notation in SSM to a form that is more flexible and intuitive to use.*" (Marashi, 2006)

The ACT Model of a process:

- Agent (subject of the sentence): those who are involved affected or concerned about the transformation
- Transformation (the verb): the conversion of a state or entity to another state or entity
- Context (the adverbials): the situation in which the transition is meaningfully acting on the state of the object

"*The main difference between a purposeful activity model and the classical view of a process is that the former is more focused on an abstract, mental set of activities that realises a transformation, whether these activities exist in the real-world or not, while the latter is more concerned about what actually happens in the real-world. These two complementary views of activity models are essential to debate the problem situation by comparing a model of ideal world with what happens in reality.*" (Marashi & Davis, 2006; Marashi, 2006, p. 61)

3.3 The process of modelling

We make use of Sowa's generic description that all systems can be represented as models consisting of "blobs" and "links" (Sowa, 1984). In HPM the links represent hierarchical decomposition. The blob is conceived as a transformational entity, a process. Anything can be thought of as a process and described by gerunds. The top-level process describes the enacting of a transformation. In relation to the top-level process (purpose), we can challenge system boundaries[6] by asking 'why' questions, and elicit system structure through repeated questioning of 'how'. We can view this as a dialectical process, the combined questioning of why and how over a process description leading to its meaningful refinement by the participants of the group. This is at the heart of how mental models are surfaced from group participants and debated in order to bring about a shared understanding. We can use layering as required in order to provide meaningful groupings of processes, proceeding until there is no

[6] The effect of questioning *why* the group is using its agreed purpose (transformational statement) description would be to challenge the boundary of the system. However, other approaches, e.g. Critical Systems Heuristics (Ulrich, 2003; Ulrich & Reynolds, 2010), may be more appropriate to use.

longer a process answer to the how question. A snippet of a model is shown in Figure 4 illustrating the process.

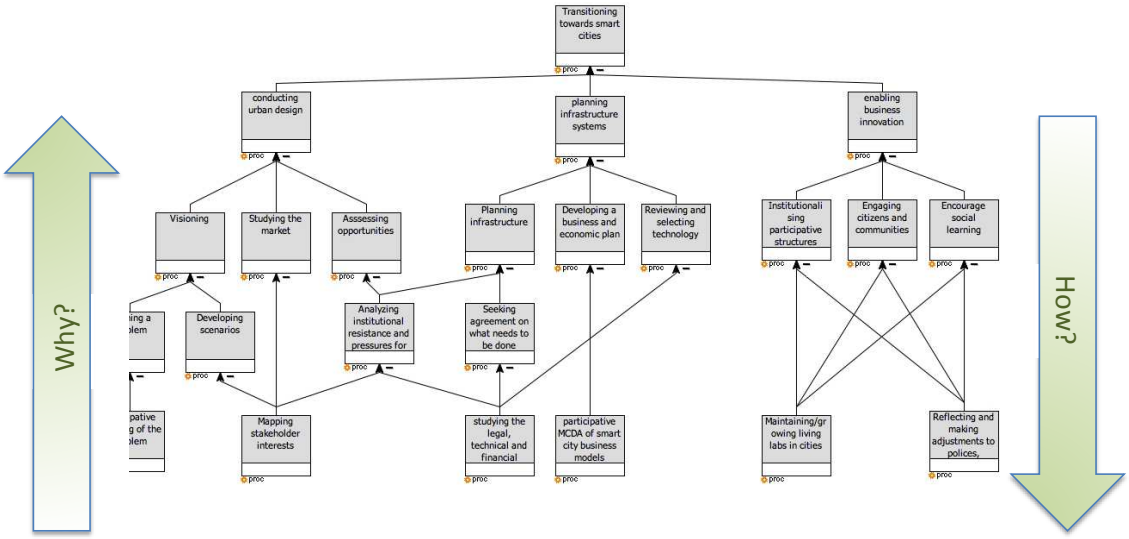


Figure 4. An example HPM based on the transformational process "Transitioning towards smart cities". The process questions How? and Why? illustrate how the model is both constructed and read.

A more developed example can be seen in Figure 4 of (Marashi & Davis, 2007, p. 521).

3.4 From models to evidence of performance

We have so far described the process of developing conceptual models which consist of processes, described by gerunds, and structured into a hierarchical arrangement by decomposition, and representing the minimum processes in a system required to achieve the transformational purpose we have agreed for our problem situation. The HPM method requires us to ask the following question: how well are we doing in achieving the purpose? The early development of HPM focussed strongly on suitable and appropriate theories of evidence to characterise process performance (Davis & Hall, 2003; Hall et al., 1998). This needed a means to express the likelihood of an event – 'success being achieved'. Many techniques rely on probability theory for this and hence express uncertainty. Limitations of classical probability lead to Theories of Evidence using probabilities that do not sum to 1.0, but consider the possibility of uncertainty in our knowledge.

HPM is able to support the clear distinction between

a) Aleatory uncertainty – which is an intrinsic property of a system, which can behave in many different ways e.g. stochastic, type A, irreducible, variability
b) Epistemic uncertainty – which arises from our lack of knowledge of the system, or is a property of the analysis of the system e.g. subjective, type B, reducible, state of knowledge (Helton & Burmaster, 1996).

HPM makes use of interval numbers to express knowledge about process performance. If E is a proposition, an interval number is used as a probability measure such that

P(E)=[Sn(E),Sp(E)], where Sn(E) is the lower bound and Sp(E) the upper bound of probability of P(E) e.g.

P(E)=[0,0] – indicates belief that E is certainly false

P(E)=[1,1] – indicates belief that E is certainly true

P(E)=[0,1] – indicates belief that E is unknown

This notation is summarised graphically in Figure 5 in a form, which has, for obvious reasons, been labelled the "Italian Flag" notation.

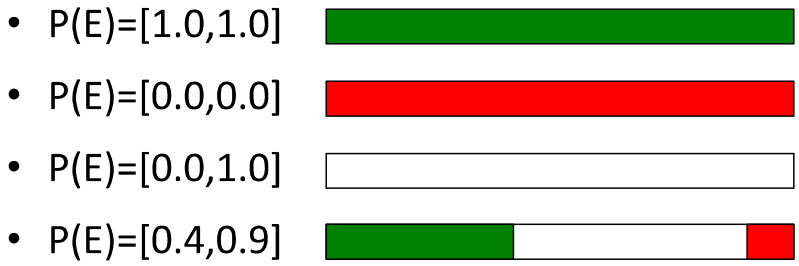


Figure 5. The interval numbers used in HPM presented graphically as so called "Italian Flags". The evidence values in sequence correspond to process performance as follows, i) good, ii) poor, iii) unknown, iv) mixed.

In the use of HPM for the STEEP project we use the HPM to scaffold discourse about evidence for and against process performance. The method enables prioritisation of actions incorporating factual knowledge, perspectives, and value judgements. Whilst HPM has several alternative algorithms for the propagation of (IPT) that groups may chose from (Davis & Hall, 2003; Marashi et al., 2008), we emphasize the role of HPM as a PSM and thereby focus on its ability to structure a process of consensus finding for action prioritisation in situations of uncertainty. We do this by highlighting processes, which, in the estimation of the participants in the group model building, have poor performance (mostly red in the Italian Flag notation), or where the participants have little knowledge (mostly white). These can be used to direct attention for *fixes* (interventions) and *find out more* respectively.

Use of IPT is made by the facilitator to make sure there are no glaring inconsistencies between the participants' view of the performance of the processes, or knowledge thereof, and the way in which they structurally combine into describing the performance of a system. The software used to capture the models makes use of sufficiency, necessity and dependency conditions. A full description can be found in (Marashi et al., 2008). Here we make use of the following definitions

- Sufficiency – How much of the evidence is directly relevant to the parent process?
- Necessity – Will the parent fail if the sub-process fails? Takes over if evidence against is large
- Dependency – How much overlap of evidence is there between the sub-processes?

A truth table illustrating the effect of extreme values of necessity and dependency for independent processes is shown in Figure 6.

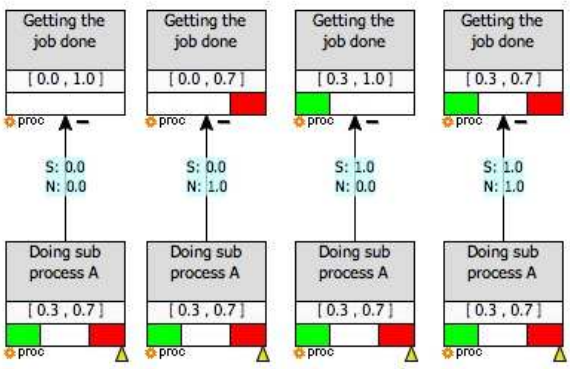


Figure 6. Simple truth-table style presentation of how necessity and sufficiency conditions affect the propagation of evidence in a model.

We can read Figure 6 as follows:

1. [S: 0.0, N: 0.0] – the process "Doing sub-process A" is neither necessary or sufficient to determine the success of the process "Getting the job done". The link between them is thus redundant, it is shown here only for completeness; the system "Getting the job done" does not include "Doing sub process A".
2. [S: 0.0, N: 1.0] – the process "Doing sub-process A" is necessary but not sufficient to determine the success of the process "Getting the job done". Poor performance of "Doing sub-process A" will impact the performance of "Getting the job done" but good performance will not.
3. [S: 1.0, N: 0.0] – the process "Doing sub-process A" is sufficient but not necessary to determine the success of the process "Getting the job done". Good performance of "Doing sub-process A" will impact the performance of "Getting the job done" but poor performance will not.
4. [S: 1.0, N: 1.0] – the process "Doing sub-process A" is both necessary and sufficient to determine the success of the process "Getting the job done". Unless there are other sub processes in the system "Getting the job done" the sub process is to all intents the same as the top-level process; its presence in the model contributes no further understanding about the system.

Experience has shown that participants in group model building sessions report that estimating necessity, sufficiency, and dependency conditions is difficult. In practice the software to support the modelling is used in in a way that assumes that the number of processes per level is >2 and usually ~5±2 (cf Checkland's suggestions for number of processes when PAS modelling). Using default parameters of Necessity=0.3, Sufficiency=0.4, Dependency=0 (independent sub-processes) tends to produce results for estimates of system performance that are intuitive. However, the point of using HPM is problem structuring with the aim of intervention, not prediction. Therefore, we are less concerned with the meaning of evidence propagation than we are identifying where the participants in the group model-building workshop should focus attention.

3.5 Towards desirable and feasible intervention

The natural limit of modelling is reached as processes no longer yield further process decompositions to the how/why question dialectic, the participants are confronting intractable issues in answering the how questions for processes identified as performing poorly or where there is inadequate knowledge about performance. The HPM as a PSM method uses argumentation to resolve these issues and steer the participants in the group model-building workshop towards desirable and feasible interventions. HPM uses a simple argumentation scheme based on issues, options and arguments. The origins for this are based on Issue Based Information Systems (Kunz & Rittel, 1970). These are types of information system designed to support cooperatives confronted by complex problems and needing to arrive at a plan of action. They rest on a model of problem solving by cooperatives as an argumentative process and start from an unstructured problem situation or topic, named as a trigger phrase, from which a discourse develops. Issues are brought up and disputed, and arguments are constructed for/against until the issue is settled. Different types of information exchanges occur between participants, with experts specifically consulted, using factual literature and outputs from modelling, and further sub-cooperatives. The IBIS approach makes the argumentation visible i.e. provides documentation/reporting. Systems that support this type of approach have been reported (Buckingham Shum, 2008; Buckingham Shum, 2006; Conklin, 2003; Marashi & Davis, 2006). PeriMeta supports

- Issues: a point of discussion to be resolved about the performance or state of knowledge about a process
- Options: a possible intervention to resolve the issue
- Arguments: support or refute an option

and they appear as elements in the process map under processes in the order

Process←Issues←Options←Arguments.

An example argumentation map is shown in Figure 7 and Figure 8.

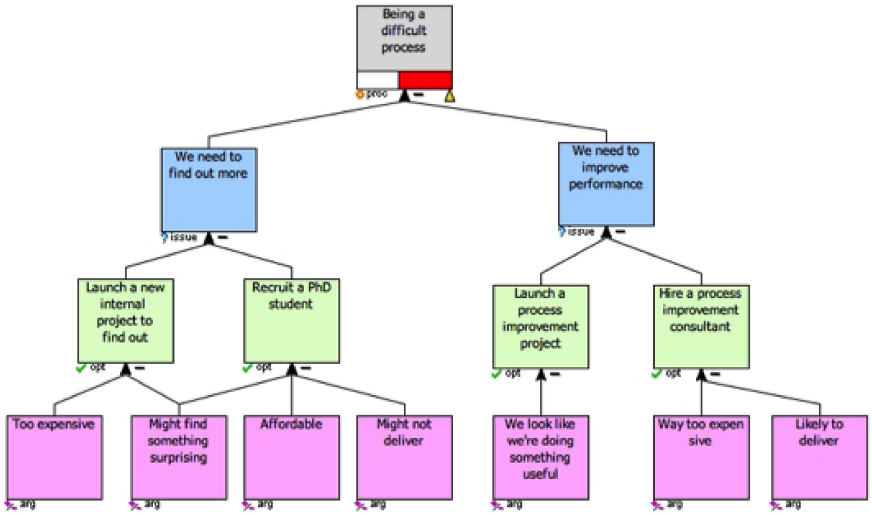


Figure 7. Example argumentation map of issues, options, and arguments intervene to resolve a problem with a process where we have mixed evidence of poor performance and uncertainty, and no evidence of good performance.

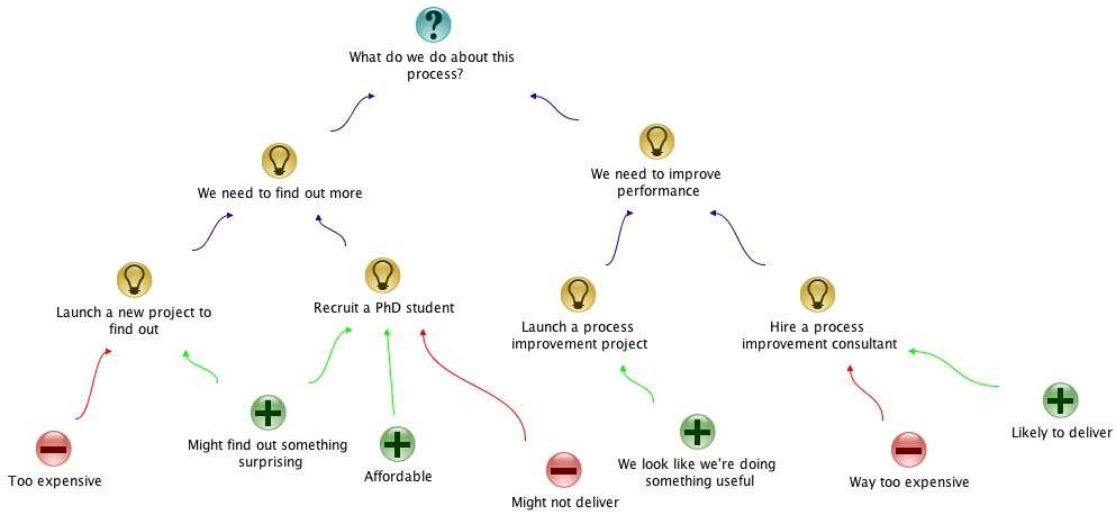


Figure 8. The same argumentation map as in Figure 7 but produced using the Compendium software from the Open University (Compendium Institute Open University 2014).

A more detailed example of argumentation from modelling electricity supply risks can be found in (Marashi & Davis, 2007).

3.6 Closing the loop

At this point the use of the PSM has led us to discuss desirable and feasible interventions in the problem situation. The question of evaluating effectiveness is addressed in workpackage T2.5 in the STEEP project and is based on approaches

outlined in (Midgley et al., 2013; Pawson & Tilley, 1997; White, 2006), as well as capturing personal reflections of the implementation of the process as narrative accounts (Ormerod, 2014).

The intention is that the use of the PSM is iterative i.e. the project returns to the question of transformational process and further group model building according the schema summarised in Figure 1.

For completeness the use of HPM as a PSM is also described in terms of its own system modelling language in Annex D.

4. Group model building workshop design

There is no single, right way of designing a group model-building workshop to implement the methodology described above. An essential element of all Problem Structuring Methods (PSMs) is the creativity brought to the specific implementation. This is one of the nine elements in the generic constitutive definition of PSMs – see row 4 in Annex C (Yearworth & White, 2014). The design presented here is for the two workshops held in Bristol with the BTQEZ/STEEP stakeholder group on the 19th March and 11th June 2014.

4.1 Objectives

The objectives of group model building are as follows (Bristol example shown):

1. Socialising the stakeholder group for the Bristol Temple Quarter Enterprise Zone (BTQEZ)
2. Explaining the purpose of the STEEP project and the purpose for the series of workshops that will be held with this stakeholder group
3. Introducing the STEEP methodology to the stakeholder group at a level of detail necessary to
    a. Justifying its use
    b. Getting stakeholder buy-in
    c. Understanding how it will be used during the workshop
4. Developing a shared understanding within the stakeholder group of a transformational process description that captures the objectives of the STEEP project that can be used to drive the model building process
5. Developing a preliminary hierarchical process model (HPM) that represents the shared view of the stakeholder group of how the transformational process could be achieved
6. Identifying processes within the HPM which are not performing well/at all ('red processes' – *fix*), or where the stakeholders have little/no knowledge about performance ('white processes' – *find out more*)

7. Eliciting issues associated with the sub-processes within the model that will have to be resolved in order for the transformational process to be successful
8. Developing Options and eliciting arguments to resolve issues i.e. developing desirable and feasible interventions
9. Communicating what will happen next, how we plan to keep the stakeholder group involved

4.2 Preliminary work

Vennix, in his pioneering work on group model building, suggests a schema for planning a workshop (Vennix, 1996). This has been adapted for use for HPM and is shown in Figure 9.

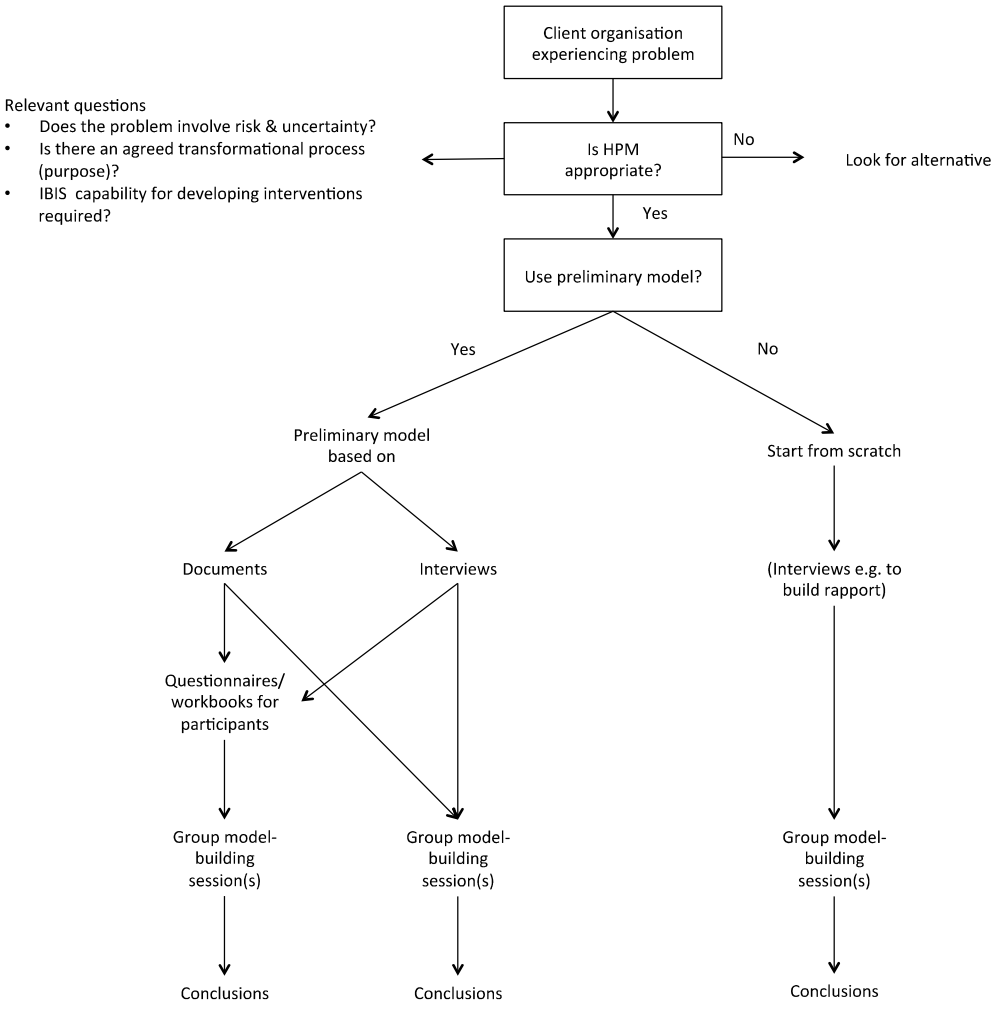


Figure 9. Schema for designing a group model building workshop adapted from (Vennix, 1996).

4.3 Example use of a preliminary model

For the Bristol group model building workshops it was decided to use a preliminary model based on the Sustainability Context Study for the Temple Quarter Enterprise Zone published by the City Design Group, Planning and Sustainable Development Division at Bristol City Council in May 2013. The model is shown in Figure 10.

Figure 10. Preliminary model used for the Bristol group model building workshops.

4.4 Developing the group model-building script

Note that for the purpose of illustrating how a group model-building workshop can be planned we have included the actual planning scripts for first two workshops in Bristol and are shown in Appendix E and F respectively. These are written in first person to describe what it is that the facilitator will be doing/thinking-about during the workshops at every stage. The detailed timetable is given at the end of each workshop description. The duration of the workshop was limited to 4 hours based on the following considerations:

1. Reduced likelihood of attracting senior stakeholders to a day-long workshop
2. Avoidance of ¾ day workshop which would necessarily loose time to a lunch break
3. Maintaining concentration over a long period of time for what is likely to be for many stakeholders a quite demanding task

4.5 Implementing the methodology

The scripts in Appendices E and F provide details of how the methodology was actually implemented at the two Bristol group model-building workshops.

5. Preliminary review of literature

The systems modelling approach described in the methodology section and elaborated in the workshop design script assumes that no preliminary modelling was undertaken. However, the methodology is iterative as shown in Figure 1 and thus subsequent group model building workshops may start with existing models or process descriptions. In order to facilitate Task 1.4 and deliverable 1.4 (STEEP, 2013b) a preliminary review of the academic literature was undertaken to provide concepts relating to the more social aspects of energy planning as revealed by similar problem structuring method interventions (Bhatt, Friley, & Lee, 2010; Coelho et al., 2010; Elias, 2008; Gezelius & Refsgaard, 2007; Neves et al., 2004; Pohekar & Ramachandran, 2004; Sheffield, 2004).

The texts were analysed using a basic qualitative data analysis technique. Documents were loaded into NVivo v10 software and in-vivo concepts were extracted from the text. These concepts were then classified according to the top-level data categories identified in Task 1.4 and supplied to CSE. Subsequent to this initial analysis and in preparation for the first group model building exercise in Bristol the in-vivo concepts were re-analysed with a view to possible process descriptions. These descriptions, in gerund form to be compatible with HPM, are presented in column 4 of Annex A. These form the basis of a crib-sheet for the facilitator of the group model building exercise.

6. Systems Models

The systems models from the group model building workshops held by project partners will be available, in various stages of development, shortly after the workshops take place. In this version of the deliverable (Revision [1]) we present in the following sections the preliminary versions of the models developed during workshops held in the three cities.

6.1 Bristol Modelling

In the first Bristol group model building workshop 5 sub groups were formed. The preliminary model shown in Figure 8 was enhanced by the addition of 8 further sub-processes to the top-level process. These processes are listed in Table 1.

Process Number	Process Name
1	Establishing infrastructure planning
2	Driving resilience and flexibility
3	Engaging existing sites/owners
4	Understanding technical feasibility
5	Understanding commercial feasibility
6	Achieving connectivity and convenience
7	Greening the arena
8	Moving people

Table 1. New processes developed in the first Bristol group model building workshop

The models corresponding to these processes are shown in Figures 11-18.

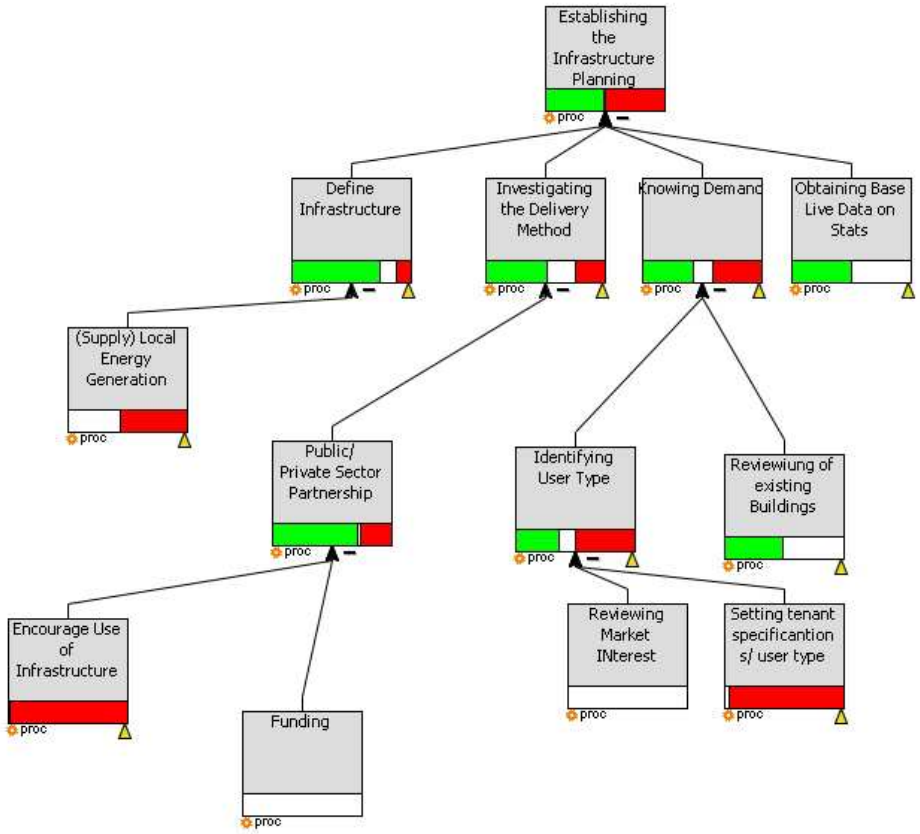


Figure 11. Process 1 – Establishing Infrastructure Planning

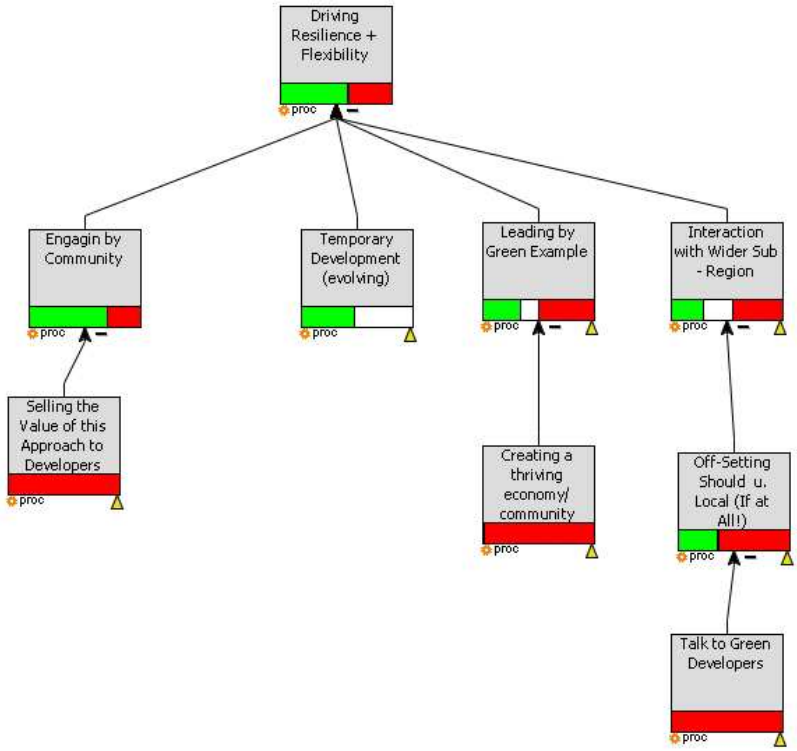


Figure 12. Process 2 – Driving resilience and flexibility

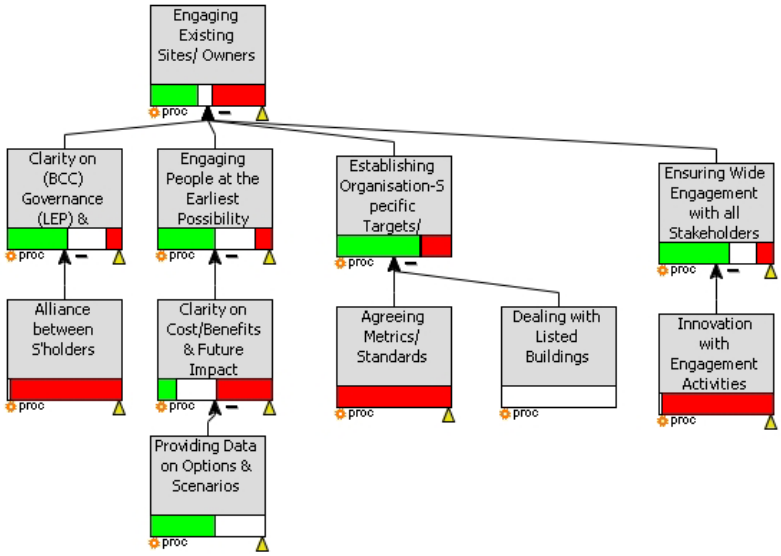


Figure 13. Process 3 – Engaging existing sites/owners

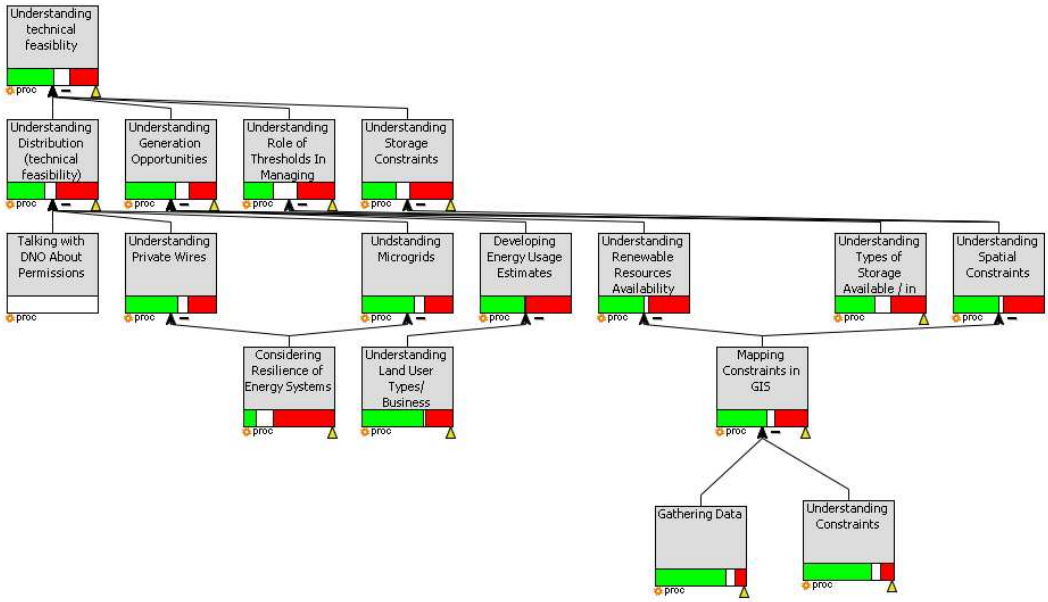


Figure 14. Process 4 – Understanding technical feasibility

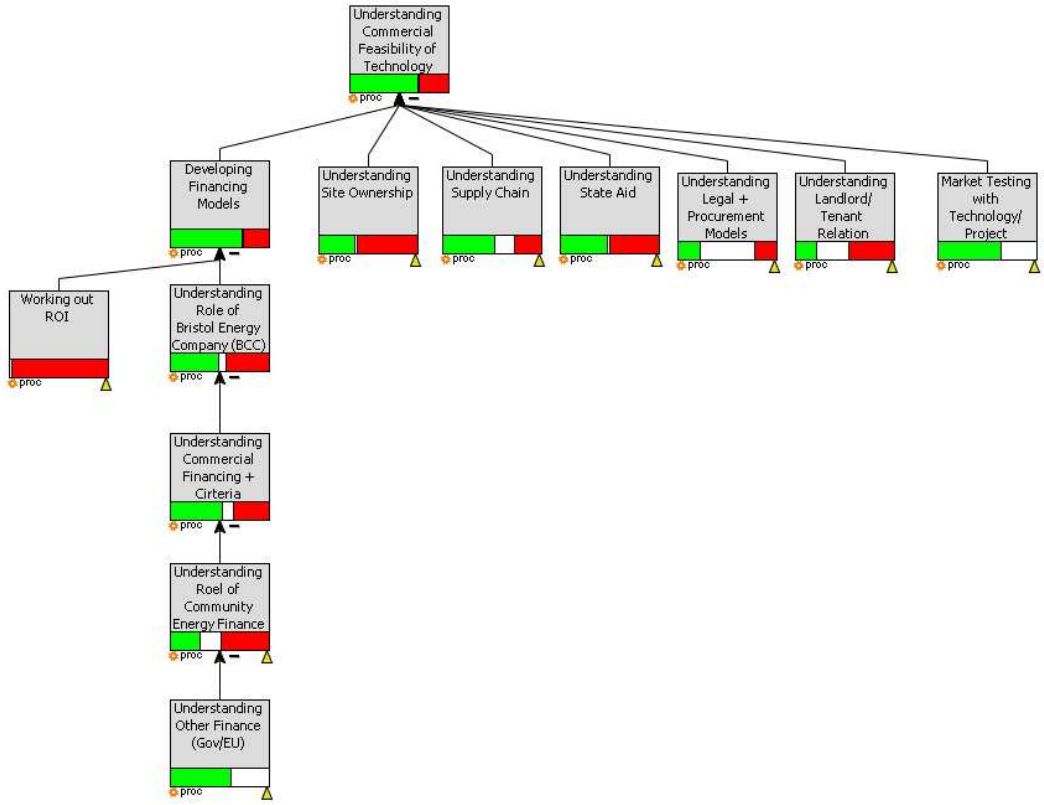


Figure 15. Process 5 – Understanding commercial feasibility

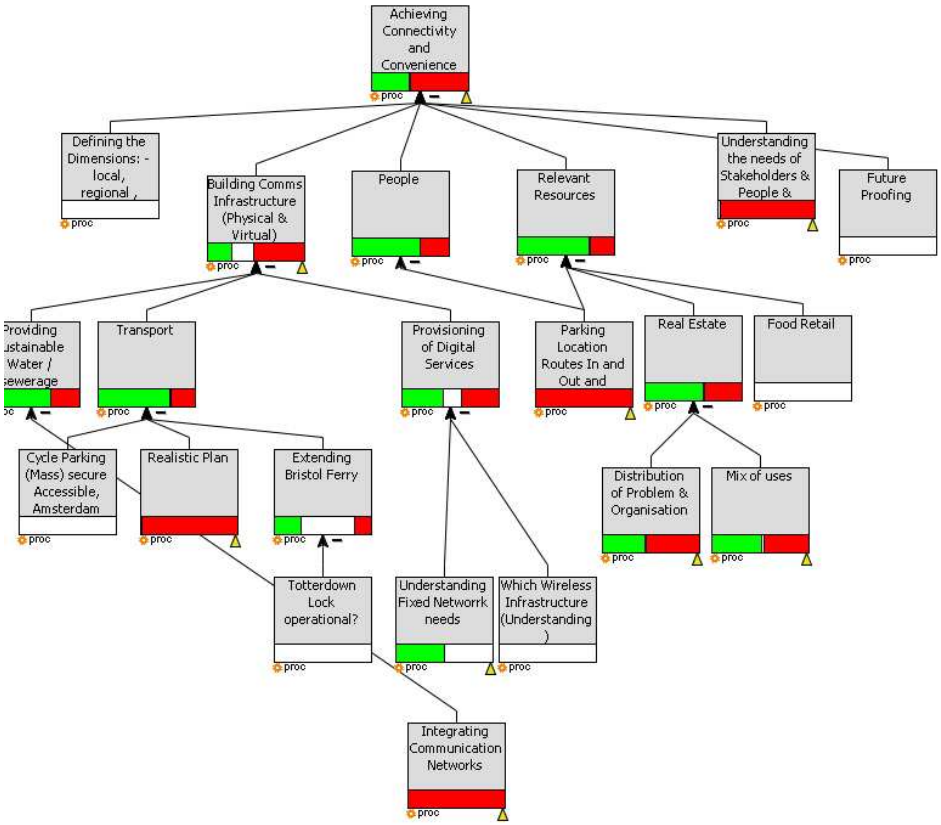


Figure 16. Process 6 – Achieving connectivity and convenience

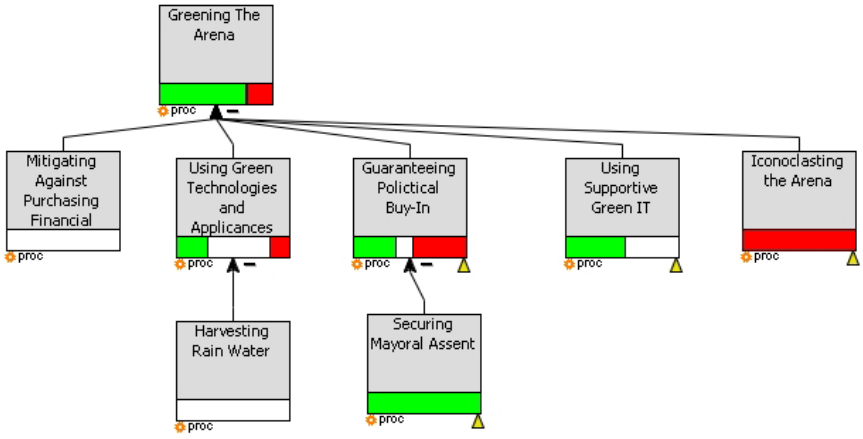


Figure 17. Process 7 – Greening the arena

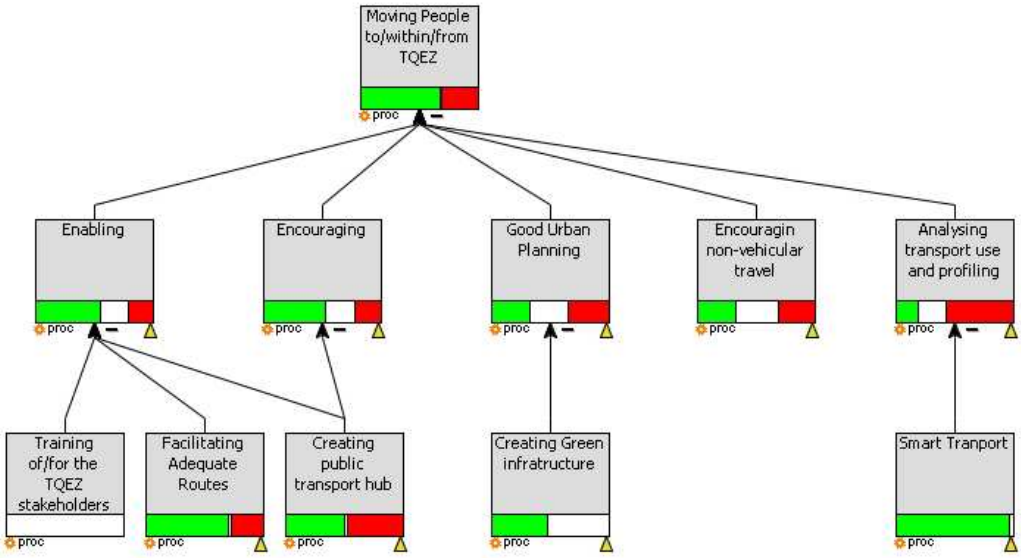


Figure 18. Process 8 – Moving people

After the first group model building workshop the Bristol team held a meeting on the 29th June 2014 to review the models. This meeting determined that the best use of the second group model building workshop could be made by collating the eight sub models into a new preliminary model that would be used as the starting point for the new groups. The preliminary top level model and sub models are shown below in Figure 19–Figure 26.

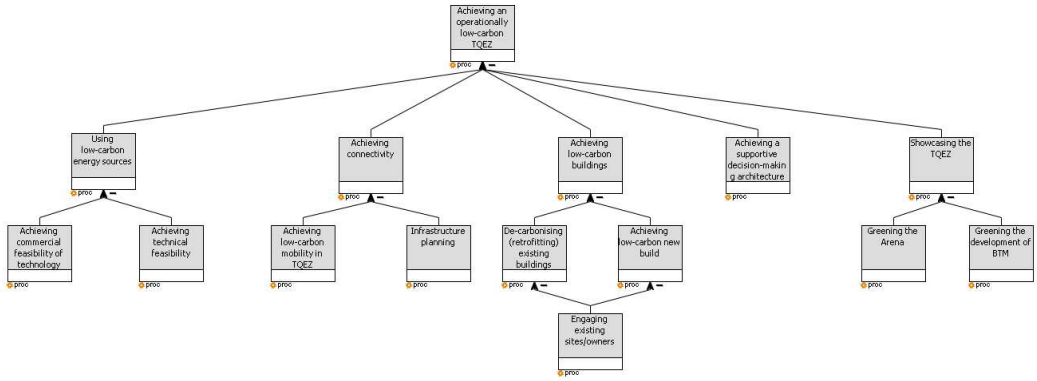


Figure 19 Achieving operationally low-carbon TQEZ

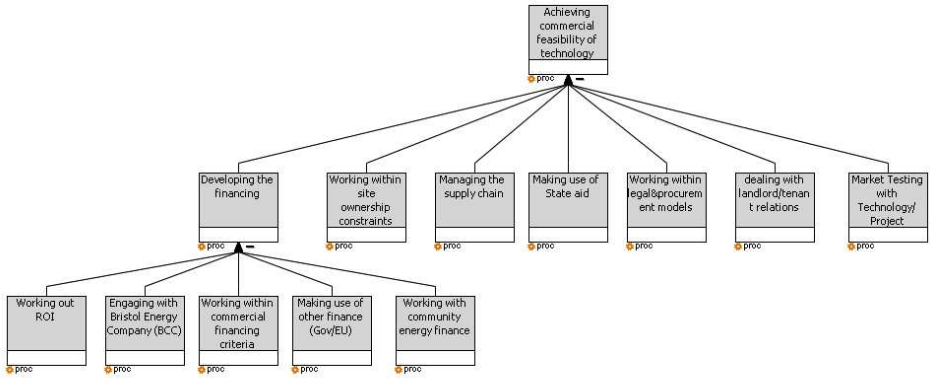


Figure 20 Achieving commercial feasibility of technology

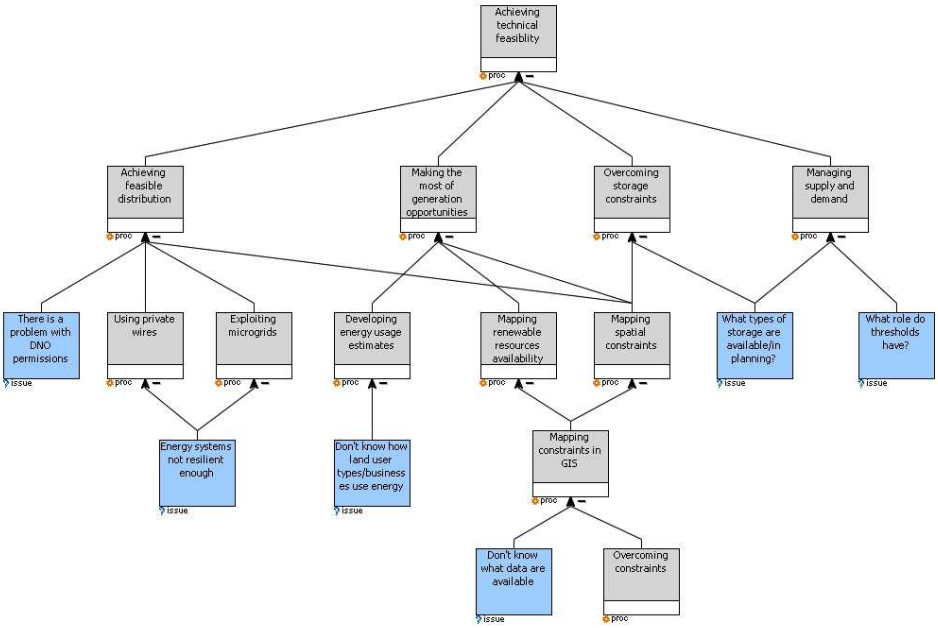


Figure 21 Achieving technical feasibility

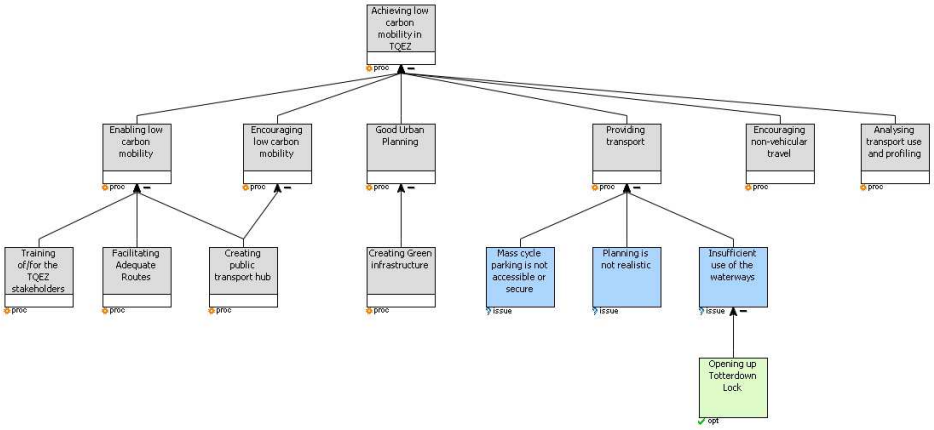


Figure 22 Achieving low-carbon mobility in TQEZ

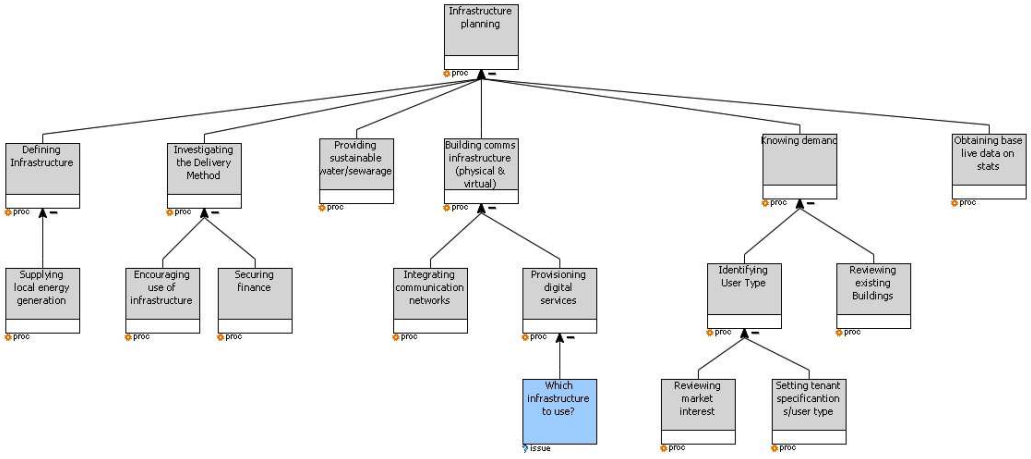


Figure 23 Infrastructure planning

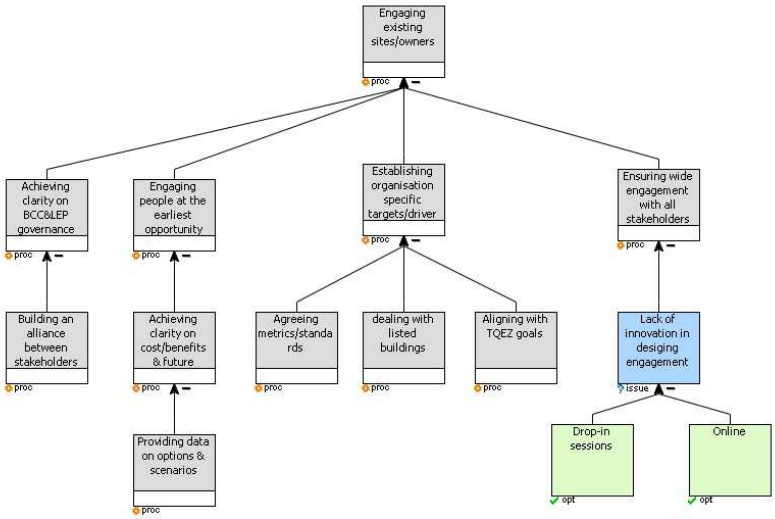


Figure 24 Engaging existing sites/owners

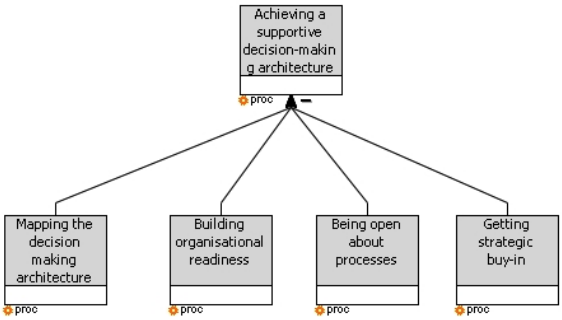


Figure 25 Achieving a supportive decision making architecture

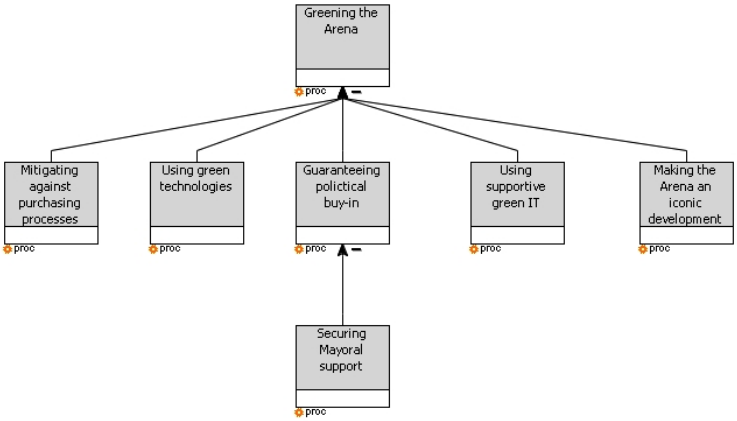


Figure 26 Greening the Arena

Preliminary models from the second Bristol workshop are shown in Figure 27 to Figure 31. These models were reviewed on the 4th September 2014 with a view to deciding which options to pursue. These are discussed below in §6.1.1.

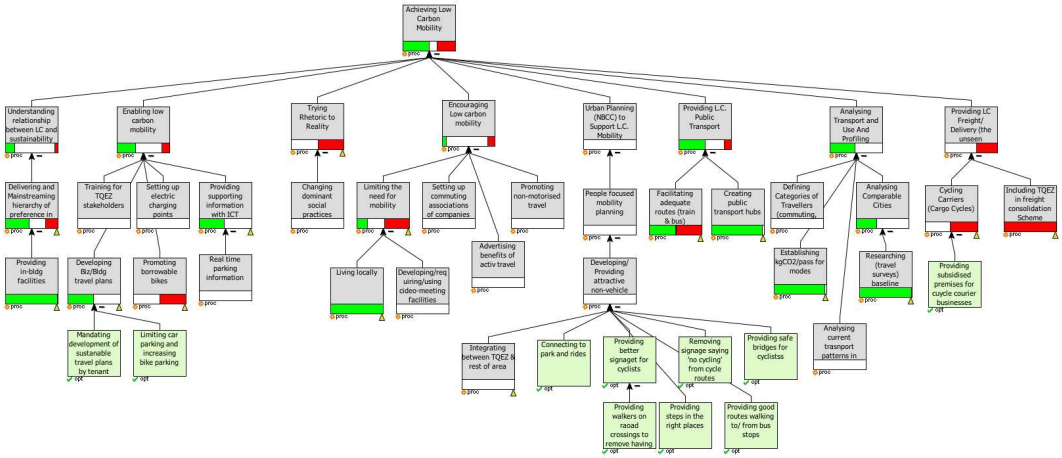


Figure 27 Achieving low carbon mobility

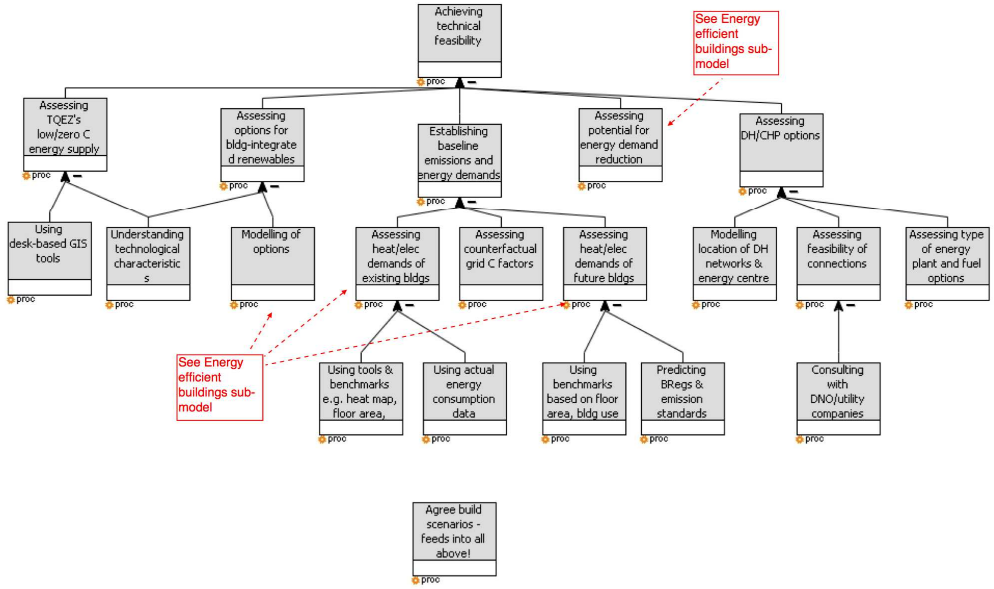


Figure 28 Achieving technical feasibility

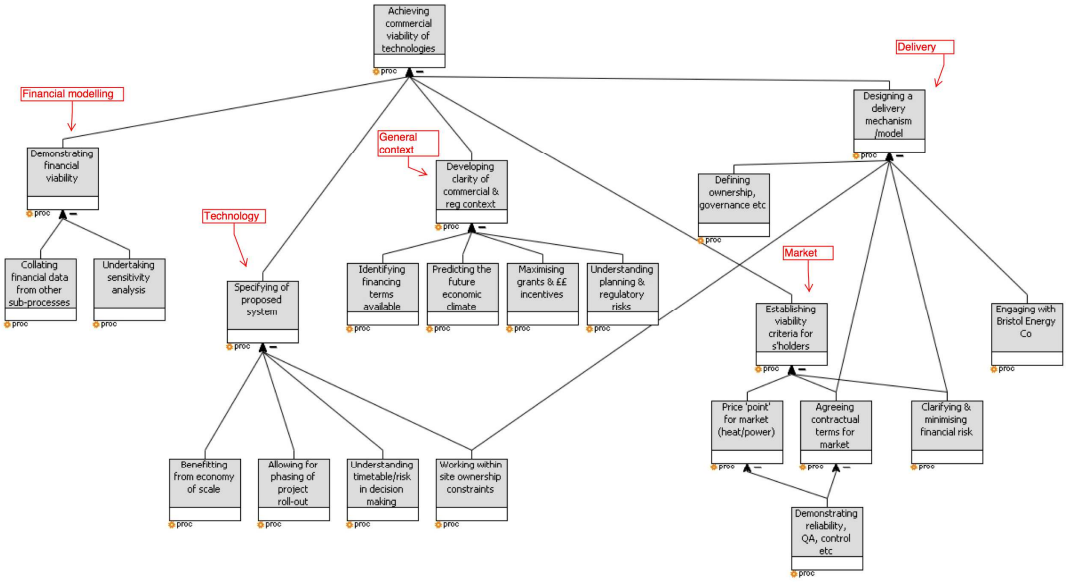


Figure 29 Achieving commercial feasibility

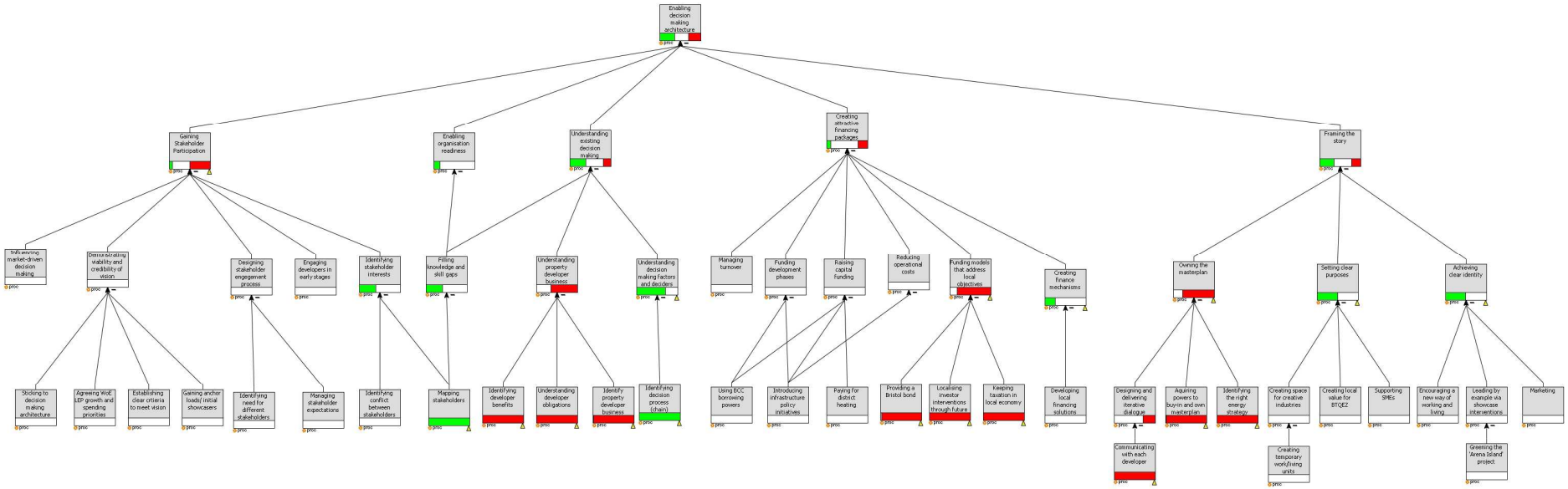


Figure 30 Enabling decision making architecture

6.1.1 Developing options in Bristol

There exists a complex pattern of decision making between Bristol City Council (BCC), the Local Enterprise Partnership (LEP), the Homes and Community Agency (HCA), Network Rail (NR) and a number of site owners and developers. This originally led to the need for a sub group in the second Bristol workshop to specifically address the purposeful transformation of <Achieving a supportive decision making architecture> as shown in Figure 25. This sub group developed the model shown in Figure 30 to address the transformation <Enabling a decision making architecture>. The review on the 4th September identified a number of processes that were either performing so poorly or there was such a high degree of uncertainty that unless these were addressed there would be little point in spending more time looking for options to develop through PESTEL analysis using SPeAR. In the language of necessity and sufficiency, *whilst achieving technical and commercial feasibility and low carbon mobility are* ***necessary*** *to achieve the goal of an operationally low carbon development in the TQEZ, failure to enable a decision making architecture that performs well is* ***sufficient*** *by itself to undermine overall success*. This is a crucial finding. The process modelling has thus identified actionable options but these are *processes* that must be made to work, rather than actionable technical solutions that can be evaluated using the PESTEL tool for viability. The situation is not too dissimilar from the findings that emerged from the preliminary literature where a lot of attention was placed on the problem structuring method itself. This is reflected in the process analysis shown in Annex A, where about half of the processes identified concern the methodology itself. The <Enabling decision making architecture> sub model is reminiscent of work by Checkland and Winter which drew a distinction between Soft Systems Methodology (SSM) focussed on content i.e. SSM_C; and SSM focussed on its own processes i.e. SSM_P; (Checkland & Winter, 2006). Here <Enabling decision making architecture> addresses the problem structuring process itself, whereas achieving technical and commercial feasibility and low carbon mobility are very much about content.

The key processes (including identified sub-processes) to be addressed with priority and urgency are as follows

1. <Understanding property developer business models>
2. <Funding models that address local objectives>
3. <Mapping stakeholders>
4. <Framing the story>
5. <Gaining stakeholder participation>

6.2 San Sebastián modelling

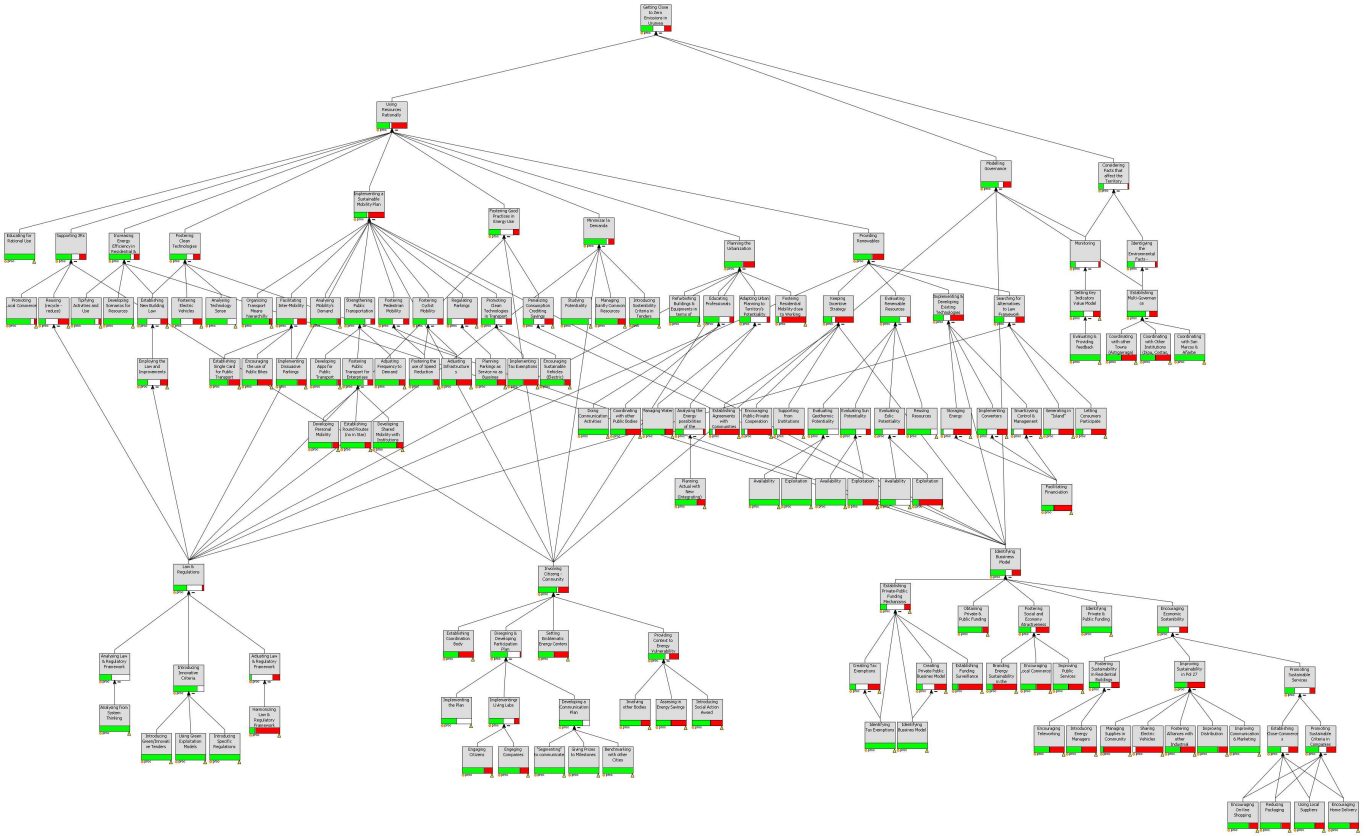


Figure 31 Getting close to zero emissions in Urumea

6.2.1 Developing options in San Sebastián

22 processes have been identified as critical arising from the modelling in San Sebastián and will be taken forward into PESTEL analysis using the SPeAR tool to prioritize the interventions that must be developed in Urumea Riverside. These processes are as follows:

1. Adjusting infrastructures
2. Regulating parkings
3. Establishing New Build Law
4. Fostering the use of electric Vehicles
5. Implementing Tax Exemptions
6. Penalizing Consumption Crediting Savings
7. Fostering Residential Mobility
8. Adapting Urban Planning to Territory
9. Keeping the Incentive Strategy
10. Implementing & Developing Known Technologies
11. Searching alternatives to Regulatory Framework (renewables)
12. Harmonising Law & Regulatory Framework
13. Creating Tax Exemptions
14. Creating Public-Private Business Model
15. Branding the Neighbourhood
16. Improving Public Services
17. Fostering Sustainability in Residential field
18. Improving Sustainability in Poligono 27 (industrial park)
19. Fostering Sustainable Services
20. Implementing "Living Labs"
21. Governance
22. Implementing Monitoring & Evaluation System

6.3 Florence modelling

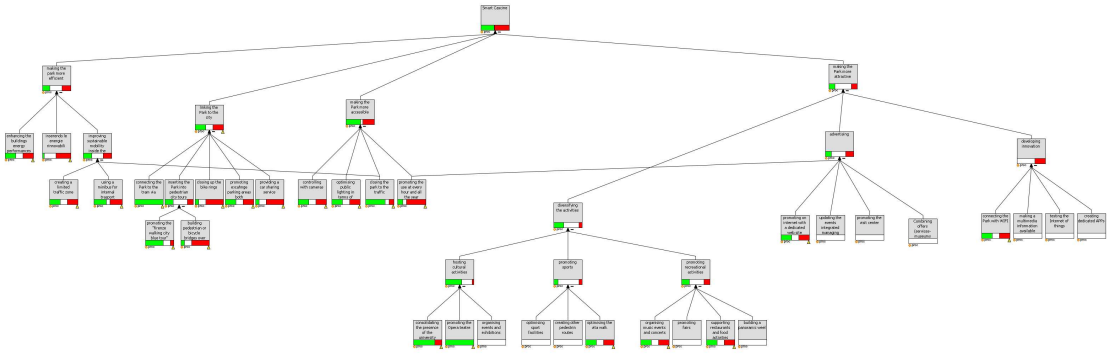


Figure 32 Smart Cascine – making the Park more attractive, green and Smart

6.3.1 Developing options in Florence

So far, option development has not been reported.

7. Summary

As of September 2014 we have achieved a number of milestones in the development of the STEEP methodology. We have

1. A strong methodological asset in the STEEP Problem Structuring Method (based on HPM, argumentation and the generic constitutive definition of PSMs), which is publicly available via the STEEP website at http://smartsteep.eu/resources,
2. The results from STEEP platform work from CSE and available at http://tools.smartsteep.eu/process-model/index.html, which provides an open source environment for energy systems modelling,
3. The PESTEL tool "SPeAR" from Arup,
4. Material currently being prepared for STEEP deliverable D2.3, which describes a means for integrating 1-3 into a coherent framework that can be owned by cities generally, and
5. Material being developed for evaluating the methodology in the STEEP project and reported in D2.5

8. Development of this deliverable

This deliverable was subject to revisions throughout the duration of the STEEP project as more group model building exercises took place. Note that examples developed during the training exercise held in December 2013 are available in the deliverable document for task T1.3 (STEEP, 2013a). Note that the training workshop itself, which is

based on the methodology described in this document, is documented on the STEEP project website at http://www.smartsteep.eu/resources/.

9. Annexes

Annex A – In Vivo concepts in the literature as process descriptions

Top Level Data Category	Indicative Data Required	In Vivo Concept from Task 2.1 Analysis	Process Description	
Building characteristics and energy water demand and consumption	Details of any initiatives undertaken to require or encourage demand-side measures to reduce energy use e.g. smart-meters	demand-side management (DSM) programmes	Managing demand side energy use	[1]
Building characteristics and energy water demand and consumption	Details of any initiatives undertaken to require or encourage demand-side measures to reduce energy use e.g. smart-meters	demand-side management (DSM) programmes	Managing demand side energy use	[2]
Building characteristics and energy water demand and consumption	Details of any initiatives undertaken to require or encourage demand-side measures to reduce energy use e.g. smart-meters	encouraging mitigation measures	Encouraging mitigation measures	[1]
Digital infrastructure & communications	Details of any initiatives undertaken to require or encourage demand-side measures to reduce energy use e.g. smart-meters	displacing and decreasing peak demand	Displacing and decreasing peak demand	[1]
Economics and finance	Policy measures (local, regional or national) and including incentives (if any) to promote economic development which have a bearing on energy efficiency	economic development	Developing the economy	[1]
Economics and finance	Policy measures (local, regional or national) and including incentives (if any) to promote economic development which have a bearing on energy efficiency	economic impacts of energy-efficiency investments	Promoting economic development which has a bearing on energy efficiency	[1]

Economics and finance	Details of qualitative measures of impact arising from implementation of policy measures (local, regional or national) and including incentives (if any) to promote economic development which have a bearing on energy efficiency	Non-monetary and nonquantifiable impacts	Evaluating non-monetary and nonquantifiable impacts	[2]
Governance and local authority structure management	Any effectiveness measurements, both qualitative and quantitative	Effectiveness. Do initiatives well classified by the system actually get implemented	Measuring effectiveness	[3]
Governance and local authority structure management	Any effectiveness measurements, both qualitative and quantitative	Effectiveness. Do initiatives well classified by the system actually get implemented	Measuring effectiveness	[2]
Governance and local authority structure management	Any efficacy measurements, both qualitative and quantitative	Efficacy. Does the system identify correctly a valid energy efficiency initiative	Measuring efficacy	[3]
Governance and local authority structure management	Any efficacy measurements, both qualitative and quantitative	Efficacy. Does the system identify correctly a valid energy efficiency initiative	Measuring efficacy	[2]
Governance and local authority structure management	Any efficiency measurements, both qualitative and quantitative	Efficiency. Does the system work with the minimum resources	Measuring efficiency	[3]
Governance and local authority structure management	Any efficiency measurements, both qualitative and quantitative	Efficiency. Does the system work with the minimum resources	Measuring efficiency	[2]
National local policy	Details of policies with impact on energy consumption patterns	environmental regulatory regime	Evaluating policies with impact on energy consumption patterns	[1]

National local policy	Details of policies with impact on energy consumption patterns	policies with impact on energy consumption patterns	Evaluating policies with impact on energy consumption patterns	[3]
National local policy	Details of policies with impact on energy consumption patterns	policy measures	Evaluating policies with impact on energy consumption patterns	[2]
National local policy	Details of policies with impact on energy consumption patterns	regulatory and policy framework within which the other stakeholders in local energy planning must operate	Evaluating policies with impact on energy consumption patterns	[3]
National local policy	set of legislative rules for eligibility of financing through sources or programs	set of legislative rules for eligibility of financing through sources or programs	Setting rules for eligibility for financing	[3]
National local policy	Details of policies with impact on energy consumption patterns	transport policies	Setting transport policies	[3]
Social and demographic	What resources are available for energy efficient measures?	Capital and human resources are scarce and must be directed toward the most effective measures	Allocating human resources Allocating capital resources	[1]
Social and demographic	Demographic data with a bearing on planning and energy efficiency	Changing demographics	Changing demographics	[1]
Social and demographic	Job data relevant to planning and energy efficiency	Creating jobs	Creating jobs	[1]
Social and demographic	Demographic data with a bearing on planning and energy efficiency	shrinking households	Changing size of households	[1]
Stakeholder identification and community engagement	List of stakeholders qualified by roles, interests, power, opinion, salience, and expectations of the role	social roles and the norms of behaviour that are expected of these roles	Identifying stakeholders Engaging stakeholders§	[3]

Stakeholder identification and community engagement	List of stakeholders qualified by roles, interests, power, opinion, salience, and expectations of the role	An energy agency whose role is to manage public funds aimed at fostering energy efficiency through its own initiatives or financing third parties	Identifying stakeholders Engaging stakeholders§	[2]
Stakeholder identification and community engagement	List of stakeholders qualified by roles, interests, power, opinion, salience, and expectations of the role	changing positions and interests of stakeholders	Identifying stakeholders Engaging stakeholders§	[4]
Stakeholder identification and community engagement	List of stakeholders qualified by roles, interests, power, opinion, salience, and expectations of the role	chart of specific stakeholders	Identifying stakeholders Engaging stakeholders§	[4]
Stakeholder identification and community engagement	List of stakeholders qualified by roles, interests, power, opinion, salience, and expectations of the role	Consumers are concerned with energy costs the protection of the environment and reliability of supply; react to new infrastructures and technologies; have enough power to influence the decisions of all the stakeholders	Identifying stakeholders Engaging stakeholders§	[3]
Stakeholder identification and community engagement	List of stakeholders qualified by roles, interests, power, opinion, salience, and expectations of the role	Energy agency demands the involvement in the planning process; provides information; promotes initiatives and oversees the implementation of measures	Identifying stakeholders Engaging stakeholders§	[3]

Stakeholder identification and community engagement	List of stakeholders qualified by roles, interests, power, opinion, salience, and expectations of the role	Environmentalist groups analyse impacts from alternatives on environmental and social welfare; although they do not have a role in the legislation they exert an increasing pressure in this setting	Identifying stakeholders Engaging stakeholders§	[3]
Stakeholder identification and community engagement	List of stakeholders qualified by roles, interests, power, opinion, salience, and expectations of the role	identifying the stakes or interests of stakeholders	Identifying stakeholders Engaging stakeholders§	[4]
Stakeholder identification and community engagement	List of stakeholders qualified by roles, interests, power, opinion, salience, and expectations of the role	Local government demands for energy supply security energy savings and rational use of energy and conservation of the environment; can stop any project; demands more responsibility in the planning process; provides rules and specific legislation; ensure and conservation of the environment; can stop any project; demands more responsibility in the planning process; provides rules and specific legislation	Identifying stakeholders Engaging stakeholders§	[3]
Stakeholder identification and community engagement	List of stakeholders qualified by roles, interests, power, opinion, salience, and expectations of the role	Local interest groups may have different opinions concerning the optimal energy supply system.	Identifying stakeholders Engaging stakeholders§	[1]

Stakeholder identification and community engagement	List of stakeholders qualified by roles, interests, power, opinion, salience, and expectations of the role	Local producers demand a role in the energy supply system; aim long life and an easy control of production systems	Identifying stakeholders Engaging stakeholders§	[3]
Stakeholder identification and community engagement	List of stakeholders qualified by roles, interests, power, opinion, salience, and expectations of the role	Manufacturers provide technical assistance; usually support the implementation of some consumption reduction measures; aim to maximize sales; can be forced to bring efficiency to the market through standards or mandatory labelling	Identifying stakeholders Engaging stakeholders§	[3]
Stakeholder identification and community engagement	List of stakeholders qualified by roles, interests, power, opinion, salience, and expectations of the role	role of participants in decision making processes	Identifying stakeholders Engaging stakeholders§	[5]
Stakeholder identification and community engagement	List of stakeholders qualified by roles, interests, power, opinion, salience, and expectations of the role	salience of stakeholders	Identifying stakeholders Engaging stakeholders§	[4]
Stakeholder identification and community engagement	List of stakeholders qualified by roles, interests, power, opinion, salience, and expectations of the role	stake holders i.e. who have an interest in or who are likely to be affected by the situation	Identifying stakeholders Engaging stakeholders§	[3]
Stakeholder identification and community engagement	List of stakeholders qualified by roles, interests, power, opinion, salience, and expectations of the role	stakeholder analysis	Analysing stakeholders' needs	[4]
Stakeholder identification and community engagement	List of stakeholders qualified by roles, interests, power, opinion, salience, and expectations of the role	stakeholder management capability	Managing stakeholders§	[4]

Stakeholder identification and community engagement	List of stakeholders qualified by roles, interests, power, opinion, salience, and expectations of the role	stakeholder map of the problem situation	Mapping stakeholders§	[4]
Stakeholder identification and community engagement	List of stakeholders qualified by roles, interests, power, opinion, salience, and expectations of the role	stakeholders or participants can understand and hence ultimately participate in the planning and decision making processes	Engaging stakeholders§	[3]
Stakeholder identification and community engagement	List of stakeholders qualified by roles, interests, power, opinion, salience, and expectations of the role	stakeholders role in the urban energy planning	Engaging stakeholders§	[3]
Stakeholder identification and community engagement	List of stakeholders qualified by roles, interests, power, opinion, salience, and expectations of the role	Technical officers act as sources of information and consultants of decision makers; are forced to observe...	Incorporating expert opinion	[3]
Stakeholder identification and community engagement	List of stakeholders qualified by roles, interests, power, opinion, salience, and expectations of the role	The end-use equipment manufacturers	Engaging OEMs	[2]
Stakeholder identification and community engagement	List of stakeholders qualified by roles, interests, power, opinion, salience, and expectations of the role	The energy companies	Engaging energy companies	[2]
Stakeholder identification and community engagement	List of stakeholders qualified by roles, interests, power, opinion, salience, and expectations of the role	The energy market regulator if energy efficiency is a key issue in the regulatory framework	Engaging the energy market regulator	[2]
Stakeholder identification and community engagement	List of stakeholders qualified by roles, interests, power, opinion, salience, and expectations of the role	The energy service companies (ESCOs). Their business is energy efficiency	Engaging with ESCOs	[2]
Stakeholder identification and community	List of stakeholders qualified by roles, interests, power, opinion, salience, and expectations of the role	transactional-level stakeholder analysis	Analysing stakeholders at a transactional level	[4]

engagement				
Planning – also processes associated with planning	Details of all measures, both quantitative and qualitative, which are use to score performance of energy planning interventions	choose measures and units for all the indicators and determine scores on the indicators	Choosing measures and units for all the indicators	[3]
Planning – also processes associated with planning	Data about situations where there have been competing solutions for energy planning and how decisions were made including trade-offs	comparison of competing solutions	Comparing competing solutions	[3]
Planning – also processes associated with planning	Details of long-term strategies which have an impact on energy planning but are not policies	comprehensive long-term planning	Comprehensive long-term planning	[1]
Planning – also processes associated with planning	Data about situations where there have been competing solutions for energy planning and how decisions were made including trade-offs	conflicting and multiple objectives	Resolving conflicting and multiple objectives§	[5]
Planning – also processes associated with planning	Data about situations where there have been competing solutions for energy planning and how decisions were made including trade-offs	conflict among criteria	Resolving conflict between criteria§	[5]
Planning – also processes associated with planning	Data about situations where there have been competing solutions for energy planning and how decisions were made including trade-offs	consider trade-offs between the various tests'	Considering trade-offs§	[2]
Planning – also processes associated with planning	Details of mechanisms (e.g. stakeholder workshops, consultations) which have been used to reconcile conflicting stakeholder views/needs	create a consensus after sufficient deliberation and contrasting of viewpoints has taken place	Creating consensus§	[4]
Planning – also processes associated with planning	Details of long-term strategies which have an impact on energy planning but are not policies	Energy system planning interacts with strategic planning in other fields	Interacting with strategic planning in other fields	[1]

Planning – also processes associated with planning	Details of mechanisms (e.g. stakeholder workshops, consultations) which have been used to reconcile conflicting stakeholder views/needs	environment where participants or stakeholders are properly guided and discussions or debates are adequately channelled	Guiding and channelling discussion§	[3]
Planning – also processes associated with planning	Data about stakeholder satisfaction in implementation of energy policy	estimation of initiative success (potential adherence of end-users	Estimating success	[2]
Planning – also processes associated with planning	Details of mechanisms (e.g. stakeholder workshops, consultations) which have been used to reconcile conflicting stakeholder views/needs	facilitate communication among participants and improve people's role component to identify opportunities to change	Facilitating communication among participants§	[3]
Planning – also processes associated with planning	Details of mechanisms (e.g. stakeholder workshops, consultations) which have been used to reconcile conflicting stakeholder views/needs	facilitate decision making	Facilitating decision making§	[3]
Planning – also processes associated with planning	List of stakeholders qualified by roles, interests, power, opinion, salience, and expectations of the role	formal structures of power as well as the informal leadership that is accepted and given	Identifying formal power structures	[3]
Planning – also processes associated with planning	Details of mechanisms (e.g. stakeholder workshops, consultations) which have been used to reconcile conflicting stakeholder views/needs	group model building	Group model building§	[4]
Planning – also processes associated with planning	Data about stakeholder satisfaction in implementation of energy policy	initiative success	Measuring success	[2]
Planning – also processes associated with planning	Details of long-term strategies which have an impact on energy planning but are not policies	integrate urban planning and energy planning	Integrating urban planning and energy planning	[1]

Planning – also processes associated with planning	Details of long-term strategies which have an impact on energy planning but are not policies	Integrated Urban Energy Planning (IUEP) problems	Achieving IUEP	[3]
Planning – also processes associated with planning	Details of long-term strategies which have an impact on energy planning but are not policies	long-term solutions	Identifying impact of long-term strategies Evaluating impact of long-term strategies	[1]
Planning – also processes associated with planning	Details of long-term strategies which have an impact on energy planning but are not policies	long-term strategic planning	Identifying impact of long-term strategies Evaluating impact of long-term strategies	[1]
Planning – also processes associated with planning	Data about stakeholder satisfaction in implementation of energy policy	maintain an observation process to evaluate constraints	Measuring stakeholder satisfaction	[3]
Planning – also processes associated with planning	Data about situations where there have been competing solutions for energy planning and how decisions were made including trade-offs	multicriteria approaches.	Implementing MCDA Analysing effect of MCDA	[5]
Planning – also processes associated with planning	Data about situations where there have been competing solutions for energy planning and how decisions were made including trade-offs	Multi-criteria decision making applications in energy planning	Implementing MCDA Analysing effect of MCDA	[5]
Planning – also processes associated with planning	Data about situations where there have been competing solutions for energy planning and how decisions were made including trade-offs	Multi-criteria decision making methods	Learning about situations where there have been competing solutions for energy planning and how decisions were made including trade-offs	[5]
Planning – also processes associated with planning	Data about situations where there have been competing solutions for energy planning and how decisions were made including trade-offs	Multi-objective optimization	Learning about situations where there have been competing solutions for	[5]

			energy planning and how decisions were made including trade-offs	
Planning – also processes associated with planning	Data about situations where there have been competing solutions for energy planning and how decisions were made including trade-offs	multiple conflicting criteria	Learning about situations where there have been competing solutions for energy planning and how decisions were made including trade-offs	[3]
Planning – also processes associated with planning	Details of mechanisms (e.g. stakeholder workshops, consultations) which have been used to reconcile conflicting stakeholder views/needs	Negotiating quantifying and communicating the priorities	Learning about other PSM approaches that have been used§	[5]
Planning – also processes associated with planning	Details of mechanisms (e.g. stakeholder workshops, consultations) which have been used to reconcile conflicting stakeholder views/needs	participatory environment accommodates the involvement and participation of multiple experts and stakeholders	Learning about other PSM approaches that have been used§	[3]
Planning – also processes associated with planning	Details of mechanisms (e.g. stakeholder workshops, consultations) which have been used to reconcile conflicting stakeholder views/needs	Planning and operation of the energy system is generally carried out by different actors with sometimes conflicting goals	Learning about other PSM approaches§	[1]
Planning – also processes associated with planning	Details of long-term strategies which have an impact on energy planning but are not policies	Planning tasks such as environmental planning urban planning or transportation system planning may affect the energy system.	Understanding impact of other planning activities e.g. urban, environmental, transport	[1]

Planning – also processes associated with planning	Details of mechanisms (e.g. stakeholder workshops, consultations) which have been used to reconcile conflicting stakeholder views/needs	political process involving negotiations and trade-offs among key stakeholder groups	Engaging in political processes	[3]
Planning – also processes associated with planning	List of stakeholders qualified by roles, interests, power, opinion, salience, and expectations of the role	power relationships in the situation i.e. how power is manifested spread used obtained delegated	Understanding power relationships Enhancing PSM techniques to deal with power relationships e.g. CSH§	[3]
Planning – also processes associated with planning	List of stakeholders qualified by roles, interests, power, opinion, salience, and expectations of the role	power versus stake grid	Mapping power relationships§	[4]
Planning – also processes associated with planning	Details of long-term strategies which have an impact on energy planning but are not policies	strategy	Understanding impact of other long-term strategies Developing strategy	[4]
Planning – also processes associated with planning	Details of long-term strategies which have an impact on energy planning but are not policies	strategy options	Understanding impact of other long-term strategies Developing options§	[1]
Planning – also processes associated with planning	Data about situations where there have been competing solutions for energy planning and how decisions were made including trade-offs	trade-offs among criteria	Learning about other PSM approaches§	[3]
Planning – also processes associated with planning	Details of models that have been used to support stakeholder engagement in energy planning activities	understanding the perception of models and analysts in a realistic scenario	Understanding the perception of models and analysts in a realistic scenario	[5]

Planning – also processes associated with planning	Details of mechanisms (e.g. stakeholder workshops, consultations) which have been used to reconcile conflicting stakeholder views/needs – and data specifically about conflicts between stakeholders and conflicts of interest	climate for rational consideration and negotiation was subverted by a deadlocked conflict	Developing mechanisms to resolve deadlocks§	[6]
Planning – also processes associated with planning	Details of mechanisms (e.g. stakeholder workshops, consultations) which have been used to reconcile conflicting stakeholder views/needs – and data specifically about conflicts between stakeholders and conflicts of interest	conflict among stakeholders is inevitable in planning processes	Developing mechanisms to resolve deadlocks§	[6]
Planning – also processes associated with planning	Details of mechanisms (e.g. stakeholder workshops, consultations) which have been used to reconcile conflicting stakeholder views/needs – and data specifically about conflicts between stakeholders and conflicts of interest	conflict of interest	Developing mechanisms to resolve conflicts of interest§	[6]
Planning – also processes associated with planning	Details of mechanisms (e.g. stakeholder workshops, consultations) which have been used to reconcile conflicting stakeholder views/needs – and data specifically about conflicts between stakeholders and conflicts of interest	conflict over claims of correct empirical knowledge	Resolving knowledge claims§	[6]
Planning – also processes associated with planning	Details of mechanisms (e.g. stakeholder workshops, consultations) which have been used to reconcile conflicting stakeholder views/needs – and data specifically about conflicts between stakeholders and conflicts of interest	conflicts of interest	Resolving conflicts of interest§	[6]

Planning – also processes associated with planning	Data about costs of planning processes, mechanisms, initiatives with an impact on energy planning	costs of this decision-making process.	Measuring the costs of planning processes	[6]
Planning – also processes associated with planning	Details of mechanisms (e.g. stakeholder workshops, consultations) which have been used to reconcile conflicting stakeholder views/needs	greater degree of consensus,	Achieving consensus§	[6]
Planning – also processes associated with planning	Data about incentives directed at stakeholder interests	incentives	Understanding stakeholder incentives§	[6]
Planning – also processes associated with planning	Data about incentives directed at stakeholder interests	incentives for the actors	Understanding stakeholder incentives§	[6]
Planning – also processes associated with planning	Data about incentives directed at stakeholder interests	incentives to clarify decision criteria	Understanding stakeholder incentives§	[6]
Planning – also processes associated with planning	Data about incentives directed at stakeholder interests	incentives to express sincere concerns	Understanding stakeholder incentives§	[6]
Planning – also processes associated with planning	Data about expert consultants that have been employed to produce definitive data used in planning processes	inherent power of expert knowledge	Understanding the power of expert knowledge Managing the power of expert knowledge	[6]
Planning – also processes associated with planning	Details of mechanisms (e.g. stakeholder workshops, consultations) which have been used to reconcile conflicting stakeholder views/needs – and data specifically about conflicts between stakeholders and conflicts of interest	legitimation of sincere concerns	Legitimising sincere concerns§	[6]
Planning – also processes associated with planning	List of stakeholders qualified by roles, interests, power, opinion, salience, and expectations of the role	means of domination	Dealing with power structures§	[6]

Planning – also processes associated with planning	Details of mechanisms (e.g. stakeholder workshops, consultations) which have been used to reconcile conflicting stakeholder views/needs – specific data about issues of trust	mutual trust can be considered a condition for communicative action	Achieving a state of mutual trust§	[6]
Planning – also processes associated with planning	Details of mechanisms (e.g. stakeholder workshops, consultations) which have been used to reconcile conflicting stakeholder views/needs – specific data about issues of trust	necessary level of mutual trust in terms of sincerity	Achieving sincere relationships§	[6]
Planning – also processes associated with planning	Details of mechanisms (e.g. stakeholder workshops, consultations) which have been used to reconcile conflicting stakeholder views/needs	open dialogue	Achieving open dialogue§	[6]
Planning – also processes associated with planning	Details of mechanisms (e.g. stakeholder workshops, consultations) which have been used to reconcile conflicting stakeholder views/needs	reconcile divergent values and interests	Reconciling divergent values§	[6]
Planning – also processes associated with planning	What reflections have been conducted into the performance of past initiatives, specifically in the performance of the process, as well as impact	reflection and decision develop intentions	Reflecting on outcomes	[7]
Planning – also processes associated with planning	What reflections have been conducted into the performance of past initiatives, specifically in the performance of the process, as well as impact	reflection and experience reduce conceptual confusion (equivocality)	Reflecting on the performance of processes of past initiatives	[7]
Planning – also processes associated with planning	What reflections have been conducted into the performance of past initiatives, specifically in the performance of the process, as well as impact	reflection reduces equivocality about the multiple ways in which an idea may be approached, stabilized and framed	Reflecting on the impact of past initiatives	[7]

Planning – also processes associated with planning	Details of mechanisms (e.g. stakeholder workshops, consultations) which have been used to reconcile conflicting stakeholder views/needs – specific data about issues of trust	rejected the validity of their counterparts' statements by questioning their sincerity	Achieving sincere relationships§	[6]
Planning – also processes associated with planning	Details of mechanisms (e.g. stakeholder workshops, consultations) which have been used to reconcile conflicting stakeholder views/needs – specific data about issues of trust	removed, or at least reduced, suspicions of hidden agendas	Understanding other mechanisms (e.g. stakeholder workshops, consultations) which have been used to reconcile conflicting stakeholder views/needs – specific data about issues of trust	[6]
Planning – also processes associated with planning	Details of mechanisms (e.g. stakeholder workshops, consultations) which have been used to reconcile conflicting stakeholder views/needs	social consensus (validated by rightness)	Understanding other mechanisms (e.g. stakeholder workshops, consultations) which have been used to reconcile conflicting stakeholder views/needs – specific data about issues of trust	[7]
Planning – also processes associated with planning	Data about expert consultants that have been employed to produce definitive data used in planning processes	taking the time necessary to present the data in readable form to the laymen	Engaging non-experts Translating data from experts into forms that can be understood by non-experts	[6]

[1] (Bhatt et al., 2010)

[2] (Neves et al., 2004)
[3] (Coelho et al., 2010)
[4] (Elias, 2008)
[5] (Pohekar & Ramachandran, 2004)
[6] (Gezelius & Refsgaard, 2007)
[7] (Sheffield, 2004)

§ – Although these are valid process descriptions they are unlikely to feature in any specific process model since they describe processes which the PSM in use *is itself trying to bring about*. However, they may appear in group model-building if specific emphasis is required. There is no reason why the process description of the PSM we are using, as shown in Annex D, could not appear as a sub process of the transformational processes developed by the project and in fact has happened in the Bristol modelling, see §6.1 and §6.1.1. This perhaps illustrates the full importance of the use of a holon description.

Annex B – Comparison of hard and soft systems traditions

Description of the hard and soft systems traditions adapted from (Checkland & Holwell, 2004).

Hard systems tradition	Soft systems tradition
Assumes the world contains systems that can be engineered	Assumes the world is problematical but can be explored with systems models
Assumes systems models to be models of the world (ontologies)	Assumes systems models to be intellectual, conceptual constructs (epistemologies)
Modelling is oriented to goal seeking, optimisation, and prediction	Modelling is oriented to learning, exploration, and commitment
Talks the language of "solutions"	Talks the language of "issues"
Philosophically: positivistic Sociologically: functionalist Systemicity: lies in the world	Philosophically: phenomenological Sociologically: interpretive Systemicity: lies in the process of inquiry into the world
Advantages	
Allows use of powerful quantitative techniques (simulation, visualisation…)	Is open to all stakeholders and keeps in touch with human interests
Disadvantages	
May loose touch with the actual problem situation; ownership and control issues	Does not produce final answers, accepts that inquiry is never ending

Annex C – Characteristics of Problem Structuring Methods (PSMs)

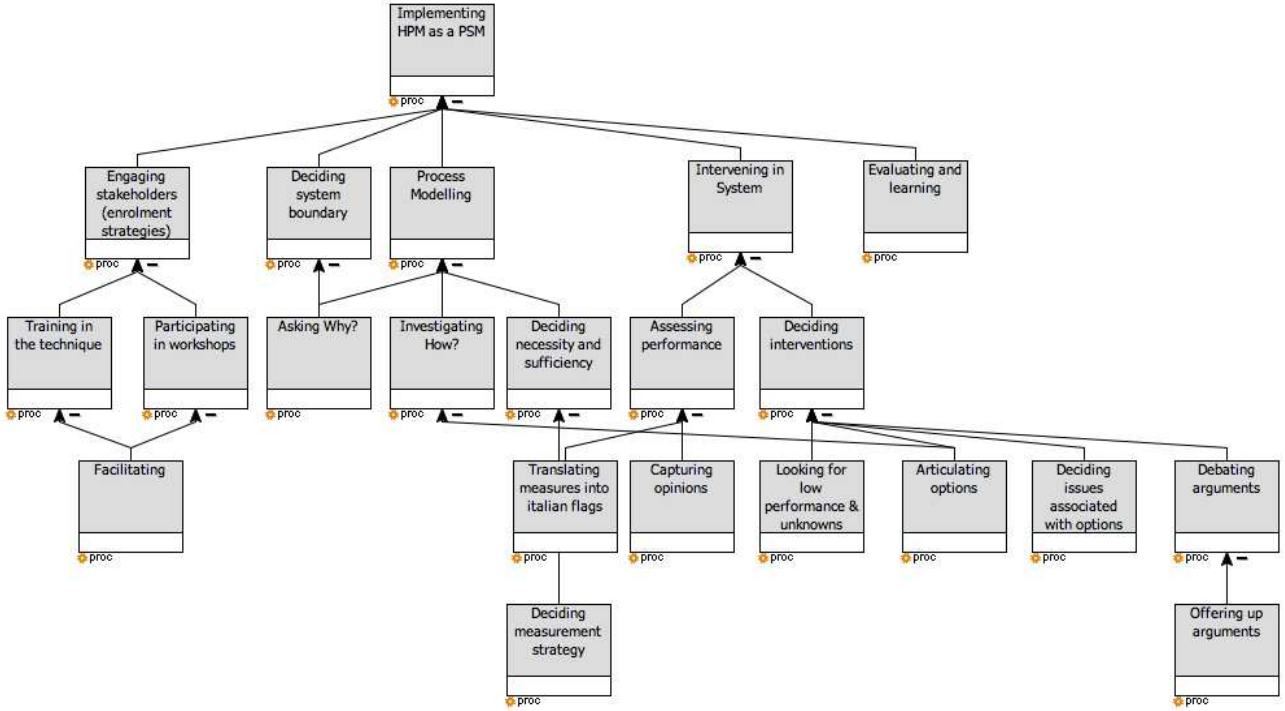
Characteristics of Problem Structuring Methods (PSMs) adapted from (Yearworth & White, 2014)

Aspect	Definition
Improvement Activity	A structured way of approaching systemic intervention has been taken, which was *designed* to lead to improvements in a problematic real-world situation through a set of purposeful activities
Systemic Approach	The problem structuring approach used systems ideas (including boundary, hierarchy, communication and control), which i) are appropriate to context, ii) theoretically adequate, and iii) supported by appropriate systems modelling
Adaptation/ Creativity	Conscious thought and creativity must have gone into how the problem structuring approach was adapted or elements combined for the particular problem situation
Methodological Lessons	Use of the problem structuring approach yielded methodological lessons, extracted by conscious reflection
Worldviews	The process of problematisation recognised that problems are construct of an individual's mind; they do not exist independently of human thought. These constructs are defined by an individual's "worldview", the problem structuring approach acknowledged these and worked with them
Messiness	The problem context in which the problem structuring approach was used was recognised as *messy/wicked/swampy* following definitions such as contained in (Ackoff, 1979, 1981; Rittel & Webber, 1973; Rosenhead, 1992; Vennix, 1999).
Interactive/ Iterative/ Therapeutic	The intervention in the problem situation has come about through sharing of "*perceptions, persuasion and debate"* in a participative group setting using an interactive and iterative approach. The facilitator or owner of the problem structuring approach adopted a stance that was "*interactive/therapeutic, not expert*"
Subjectivity	In the approach taken it has been recognised that the stakeholders of the problem situation are not *"divorced from the problem*" and that they could not act as objective "*outsiders*" as in the 'hard' systems tradition

Limits	Approaches to problem structuring might unwittingly suffer from *inter alia* bounded rationality, inadequacy of organizational language to supply adequate conceptual terminology, application of non-appropriate methodology, "*spurious saliency*" etc. The approach used demonstrated that it dealt with such conceptual limitations including building expertise in the use of problem structuring methods

Annex D – Process description of the PSM as used

Process description of the PSM described in §3.



Annex E – Planning for the first Bristol workshop

Welcome: Introductions will need to be made. For the first section I need to clearly establish the purpose of the STEEP project, the purpose behind the series of workshops, and finally the purpose for the day. I need to make sure that the stakeholder group know why they are there and what is expected from them. I will also make clear that the modelling process is itself under scrutiny/evaluation and request that participants complete a short questionnaire. The purpose is to help us improve the methodology. I will also point out that the modelling will be videoed, again for the purpose of improving methodology. I will have to ask if anyone wants to opt out of being filmed, in which case I will have to designate one or more groups as no data collection groups.

Introducing the STEEP Methodology: I will then take no more than about 30 minutes to describe the methodology that is being used by the STEEP project. This will have to include enough background to justify it and get buy-in i.e. the methodology needs to be made meaningful for the stakeholders. I need to make sure that everyone is happy with the ideas of i) a transformational process expressed as the purpose of a system (including CATWOE), ii) conceptual modelling using process and decomposition (how/why questioning), and iii) that processes need to be described using gerunds. I will also explain the purpose for eliciting evidence about process performance. I will introduce the Italian flag notation and how the stakeholders can vote within their sub-groups in order to come up with a (rough) interval number for each process and how this will be used in the second workshop to direct attention for taking desirable and feasible action to improve performance of the transformational process. I will use less technical language than I used during the training session to improve cognitive accessibility. For example, HPM will be called 'conceptual modelling'.

1st Exercise: The first group activity will take about 45 minutes and will be focussed on i) making sure that each sub-group understands the transformational process that will be the focus of our systems model, ii) understanding the preliminary model, and iii) starting the process of modelling by asking why questions of the top-level transformational process and adding any further layer 1 processes they feel are missing from the preliminary model. Getting the sub-groups to discuss the transformational process and reviewing CATWOE will be important – do we have missing Owners, Customers, Actors? Are there any missing, or new, prevailing assumptions? Are there any Environment considerations that have been missed? The end of the first exercise will involve reporting back to the whole group explaining their first review of the starting model and describing additions to the first layer of the process model.

2nd Exercise: I will then call the whole group to together and remind the workshop of the method of developing a HPM. I will emphasise the how/why questioning, the nature of the decomposition relationship, and using gerunds to describe the

processes. I will also emphasise that we want to see 'rich' process decompositions i.e. aiming for 5±2 process decompositions rather than long/skinny chains, or fat layers. This was less clear in the training and was apparent in the models developed. I will stress that whilst we all have our mental models of what this transformational process (expressed as a conceptual system model) is about, the purpose of group model building is to surface these models, and make them explicit and shared. The modelling approach is designed to elicit a structural, hierarchical account of system behaviour with specific focus on the rich decomposition descriptions. Given some of the behaviours observed during training I will encourage the sub-groups to be more orderly in approach, and working at the decomposition layer by layer. I will allow 10 minutes for the description of the exercise and then 45 minutes for the modelling and 15 minutes for reporting back.

3rd Exercise: Having had the first experience of modelling and also seen what the other groups have done I believe that it would be useful for the sub-groups to spend some more time refining their models. I will be picking up on problems that the sub-groups have experienced in trying to model, guessing that some will be about using gerunds and rich 5±2 decompositions, but there may be other problems with engagement and arguments, and also with challenging the transformational process (the why? questioning). Some groups may already be finding issues after how? questioning. The third exercise will be a chance to refine the models and take 30 minutes, with a 5-minute introduction. I will give the participants red/white/green stickers and ask them to quickly label processes with their assessment of performance and whilst reporting back comment on any processes that are labelled mainly white or red. I will ask participants to freely comment (briefly) on issues arsing from poor performance/unknowns and we will capture this as audio or video. The final reporting back session will be twice as long at 30 minutes to cover this.

1st Group Model Building Workshop

Session	Who	Objectives	T Start	T End	Duration (mins)
Arrival			12:45:00	13:00:00	0:15:00
Welcome and Introduction	MY	1,2	13:00:00	13:15:00	0:15:00
STEEP Methodology, transformational statement, CATWOE	MY	3,4	13:15:00	13:45:00	0:30:00
Break - chance for stakeholders to talk	omnes		13:45:00	13:55:00	0:10:00
1st Exercise - introduction	MY	5	13:55:00	14:00:00	0:05:00
1st Exercise - conceptual modelling (1)	omnes	5	14:00:00	14:30:00	0:30:00
1st Exercise - report back to group	omnes	5	14:30:00	14:40:00	0:10:00
2nd Exercise - introduction	MY	5	14:40:00	14:50:00	0:10:00
2nd Exercise - conceptual modelling (2)	omnes	5	14:50:00	15:35:00	0:45:00
2nd Exercise - report back to group	omnes	5	15:35:00	15:50:00	0:15:00
3rd Exercise - introduction	MY	6	15:50:00	15:55:00	0:05:00
3rd Exercise - process performance	omnes	6	15:55:00	16:25:00	0:30:00
3rd Exercise - reporting back	omnes	6	16:25:00	16:55:00	0:30:00
Wrap-up session	MY	9	16:55:00	17:00:00	0:05:00

Table 1. Timings for the First Bristol Group Model-Building Workshop

The following slides were used to introduce the methodology to the group and structure the 4-hour workshop.

STEEP

Welcome and Introduction
Lorraine Hudson
Bristol City Council

STEEP Overview

- STEEP - FP7 smart energy project
- Bristol, Florence & San Sebastian
- Energy, transport & ICT
- Energy process model (Yr 1) & Smart City Plan (Yr 2)
- Achieving a carbon neutral Temple Quarter Enterprise Zone
- Open innovation
- Workshop 2 and stakeholder engagement platform
- Part of Smart City Bristol Programme

City Vision and Planning Framework

- European Green Capital 2015
- Signatory of Covenant of Mayors
- 40% reduction in CO_2 emissions by 2020
- Climate Change & Energy Security Framework 2012-2015
- Bristol Development Framework
- Planning in TQEZ – Spatial Framework, Development Management and LDOs

STEEP

The STEEP Project Methodology
Dr Mike Yearworth

Purpose for today

1. Introduction to the STEEP project
2. Understand the purpose of systems modelling and how this helps BCC in developing the BTQEZ
3. Elicit your expert contribution to developing a conceptual systems model of the transformation that BCC are trying to achieve for the BTQEZ
4. Perform an assessment on the performance of the processes identified in the systems model
5. Outline on-going engagement and 2nd Workshop (11th June)

Permissions and data collection

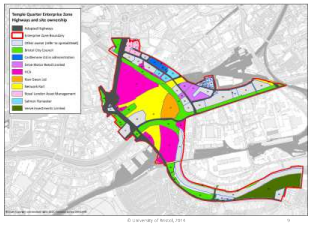
- STEEP is an EU funded research project
  - unded by the FU FP7 Energy - Smart Cities programme involving San Sebastián, Bristol and Florence
  - http://wordpress.smartsteep.eu
- We have a duty to report on our work through the agreed deliverable schedule
- We must also evaluate our methods and our results
- We have two requests. We would like you to
  - Permit us to use video recordings of the workshop process (opt-out)
  - Complete a short questionnaire

Timetable

Session'	Time'
Welcome and Introduction	13:00 – 13:15
Overview' of 'workshop' purpose' and 'the' STEEP' project' methodology'	13:15 – 13:45
Stakeholder group introductions over coffee	13:45 – 14:00
Developing the high level conceptual systems view of the processes needed to achieve the transformation	14:00 – 14:45
Detailed conceptual modelling of the transformation	14:45 – 15:45
Refining the conceptual model and investigating process performance	15:45 – 16:45
Wrap-up session, on-going engagement, and plans for the 2nd Workshop	16:45 – 17:00

The STEEP Project

Systems' Thinking' for Comprehensive City Efficient ***Energy Planning'***



The STEEP Project

- A **systems' thinking'** approach to creating a digital Energy Master Plan Process Model which takes into consideration all of the systems and infrastructure within an urban environment which impact on energy use
- This **conceptual' representa=on'** will be used to model the impact of different possible interventions that will help achieve greater efficiency of energy flows, be these standalone or in combination with others, and will help to select the best mix of measures to implement

The STEEP Project

- Modelling will be done within a single district of each city, in this case the BTQEZ.
- The conceptual Energy Master Plan Process Model of the district will be developed with project partners and stakeholders
- Leading to creation of a digital map for each district which can be navigated interactively and where the possible interventions, and their impacts, can be reviewed…
- Key stakeholders of the district will be involved in the modelling, review and validation, and in every iteration of the process model

What are Systems?

(Elliott & Deasley, 2007)

- "A system is a set of parts which, when combined, have qualities that are not present in any of the parts themselves. Those qualities are the emergent properties of the system."
- "We are increasingly concerned with complex systems, in which the parts interact with each other and with the outside world in many ways"
- "The relationships between the parts determine how the system behaves."
- "Intuition rarely predicts the behaviour of complex systems."

What is Systems Thinking?

(Mingers & White 2010)

- "Viewing situations holistically, as opposed to reductionistically, as a set of diverse interacting elements within an environment
- Recognising that the relationships or interactions between elements are more important than the elements themselves in determining the behaviour of the system
- Recognising a hierarchy of levels of systems and the consequent ideas of properties emerging at different levels, and mutual causality both within and between levels
- Accepting, especially in social systems, that people will act in accordance with differing purposes or rationalities"

What is Systems Thinking?

(Senge, 1990)

"a discipline for seeing wholes. It is a framework for seeing interrelationships rather than things, for seeing patterns of change rather than static snapshots… systems thinking is a discipline for seeing the '*structures*' that underlie complex situations, and for discerning high and low leverage change"

Energy planning as a wicked and messy problem

- Problem situations involving many interested parties with different perspectives (worldviews)
- Problem situations that are not well defined
- There is difficulty in agreeing objectives of interventions
- Success of interventions requires creating agreement amongst parties involved
- There are many uncertainties and lack of reliable (or any) data
- Almost certainly trying to work across the boundary between human activity and the artefacts of engineering

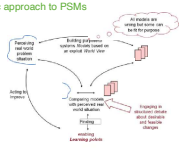
Adapted from (Mingers 2011, Rittel & Webber 1973)

Taking Action – Problem Structuring Methods (PSMs)

- Structured and rigorous methods based on diagrammatic modelling
- Allow for a range of distinctive views to be expressed/explored/ accommodated and allow for multiple and conflicting objectives
- Encourage active participation of stakeholders in the modelling process, through facilitated workshops and cognitive accessibility
- Can facilitate negotiating a joint agenda and ownership of implications of action
- Significant uncertainty is expected and tolerated
- Operate iteratively
- Aim is for exploration, learning, and commitment from stakeholders

Adapted from (Mingers, 2011; Mingers & Rosenhead, 2004; Rosenhead, 1996)

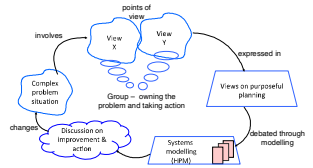
A generic approach to PSMs



Adapted by John Davis from (Checkland & Scholes 1999)

The "Hard" and "Soft" systems traditions compared

Hard systems tradition	Soft systems tradition
Assumes the world contains systems that can be engineered	Assumes the world is problematical but can be explored with systems models
Assumes systems models to be models of the world	Assumes systems models to be conceptual constructs
Modelling is oriented to goal seeking, optimisation, and prediction	Modelling is oriented to learning, exploration, and commitment
Talks the language of "solutions"	Talks the language of "issues"
Advantages	**Advantages**
Allows use of powerful quantitative techniques (simulation, visualisation…)	Is open to all stakeholders and keeps in touch with human interests
Disadvantages	**Disadvantages**
May loose touch with the actual problem situation; ownership and control issues	Does not produce final answers, accepts that inquiry is never ending



Purposeful transformations

- Using the soft systems tradition our system model is an conceptual device that will be used to help stakeholders decide how to intervene in a messy problem situation
- This system has a *purpose*, which needs to be articulated as the starting point for our modelling process
- We will be using conceptual models that consist of processes, described by gerunds, structured into a hierarchical arrangement by decomposition and representing the minimum processes in a system required to achieve purpose

How to develop HPM idea #1 – Hierarchy

- A conceptual model of a system can represented by a network of "blobs" and "links"
- Hierarchy offers us a way of managing complexity
- Each level the same but expressed in more detail – *decomposi, on.*
- *Decomposi, on* is the simple link

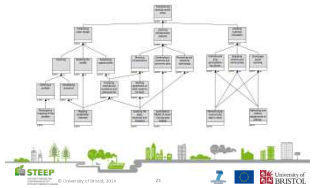
Step 1 in the modelling language we will use. There is only one kind of link – a *decomposi, on.*

How to develop HPM idea #2 – Process

- A conceptual model of a system can represented by a network of "blobs" and "links"
- The "blob" is conceived as a transformational entity, a process
- Anything can be a process
- Described by gerunds – originating from Latin, gerund can be translated as "*(which.is).to.be.carried.out*" using the active present (or continuous) form

Step 2 in the modelling language we will use. There is only one form of blob - a *process.*

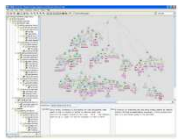
Example of a process hierarchy



Examples… modelling electricity supply risk in the UK

(Marashi & Davis, 2007)

…modelling MACs for the Highways Agency



Purposeful Transformation – arriving at the root definition

- We use verb models describe an activity in the form: "A system to do P by means of Q in order for R"
  - Example: "A system to carry out community programmes (P) by providing corporate sponsorship (Q) in order to foster sustainable development (R)."
- Useful verb models include a number of elements:
  - an activity or Transformation (T), a Worldview that makes sense of this (W) and an Environment in which the transformation takes place (E)
  - three types of stakeholders are distinguished: Actors (A), Owners (O), Customers (C)

Purposeful Transformation

- A system for the Smart City Group (A) at Bristol City Council (O) to achieve energy efficient development of the TQEZ (T) for the Bristol community at large (C) by promoting a set of practices around open data and GIS modelling (W) and which is seen as essential activity to meet commitments to 2050 emission targets (E)
- The transformation (T) is then expressed as a process

"Achieving a carbon neutral BTQEZ development"

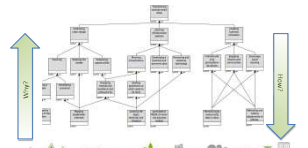
Deciding interventions

- Developing/reviewing the Hierarchical Process Model
- Capturing *evidence* of process performance
- Eliciting *issues* relating to poor/unknown performance
- Investigating and capturing possible *op, ons* to intervene in the problem situation
- Capturing *arguments* for and against the options
- Agreeing an *Ac, on.Plan*.that is i) Desirable, ii) Feasible, iii) Ethical
- Reflecting, documenting, evaluating important

Process of model building

- The top level process enacts a transformation
- Challenging system boundary by asking *why*?
- Eliciting system structure through repeated questioning of how?
- Layering as required in order to provide meaningful groupings of processes
- Proceeding until there is no longer a process answer to the *how?* question (we are hitting unresolved issues)

Process of model building

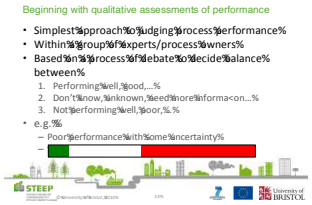


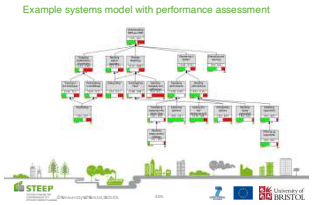
Assessing performance of system

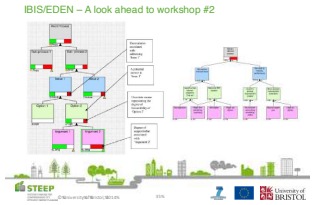
- We have conceptual models…
- Consisting of processes,
- Described by verbal nouns,
- Structured into a hierarchical arrangement by decomposition, and
- Representing the minimum processes in a system required to achieve the transformational purpose we have agreed for our problem situation.
- Suggests we can ask the following question:

How well are we doing in achieving the purpose?

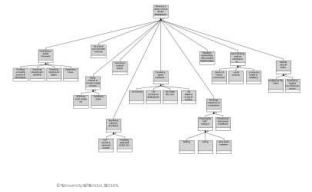
Performance measures with explicit uncertainty

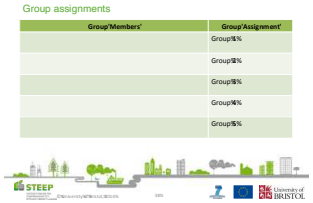

Beginning with qualitative assessments of performance
Simplest approach to judging process performance
Within a group of experts/process owners
Based on a process of debate to decide balance between
1. Performing well, good,...
2. Don't know, unknown, need more informa<on...
3. Not performing well, poor,...
e.g.
Poor performance with some uncertainty


Example systems model with performance assessment

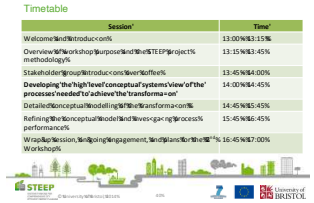

IBIS/EDEN – A look ahead to workshop #2

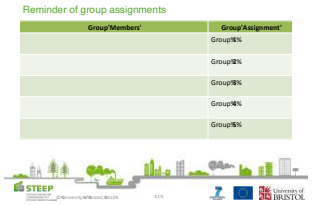

Sustainability Context Study
Temple Quarter Enterprise Zone
A Sustainable Urban Quarter by Design

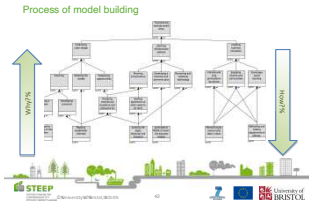



Group assignments
Group 'Members'
Group 'Assignment'
Group 1
Group 2
Group 3
Group 4
Group 5


STEEP
Developing the high level conceptual systems view
Dr Mike Yearworth

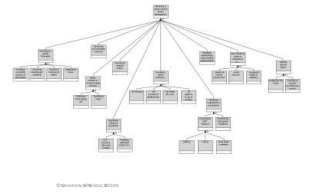

Timetable
Session
Time
Welcome and Introduc<on 13:00 - 13:15
Overview of workshop purpose and the STEEP project methodology 13:15 - 13:45
Stakeholder group Introduc<ons over coffee 13:45 - 14:00
Developing 'the high level conceptual systems view of the' processes 'needed to' achieve 'the transforma<on' 14:00 - 14:45
Detailed conceptual modelling of the transforma<on 14:45 - 15:45
Refining the conceptual model and views <gathering process performance 15:45 - 16:45
Wrap up session, ongoing engagement, and plans for the 2nd Workshop 16:45 - 17:00


Reminder of group assignments
Group 'Members'
Group 'Assignment'
Group 1
Group 2
Group 3
Group 4
Group 5

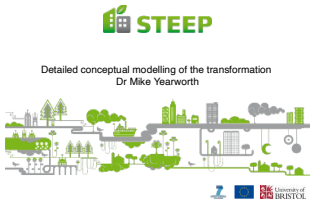

Process of model building
Why?
How?

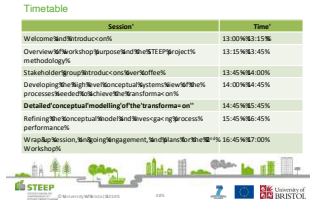

Sustainability Context Study
Temple Quarter Enterprise Zone
A Sustainable Urban Quarter by Design


Purposeful Transformation
A system for the smart City Group (A) at Bristol City Council (O) to achieve energy efficient development of the TQEZ (P) for the Bristol community at large (C) by promo<ng the use of prac<ces round open data and GIS modelling (W) and which is seen as essen<al ac<vity to meet commitments to 2050 emission targets (E)
The transforma<on (T) is then expressed as a process
"Achieving a carbon neutral BTQEZ development"




Group Model Building: Exercise #1
Working with the process model given in the and out
Focussing on the top level process descrip<on
"Achieving a carbon neutral BTQEZ development"
Discuss the model in your group to understand what it is saying and then answer the following...
1. What is missing from this model by asking the ques<on "how" is this transforma<on to be achieved?
2. What do you disagree with in the model?
At the end of the session present your group view


STEEP
Detailed conceptual modelling of the transformation
Dr Mike Yearworth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Refining the conceptual model and views <gathering process performance 15:45 - 16:45
Wrap up session, ongoing engagement, and plans for the 2nd Workshop 16:45 - 17:00

Group Model Building: Exercise #2

- Working with the original process model given in the hand-out **plus** the additional top level processes from exercise #1 (if any)
- Develop the model further by focussing on asking "how" questions of each process in the model
- Try to aim for roughly 5-7 sub-processes per process
  - Try to avoid long skinny chains of sub-processes
  - Also try to avoid >10 sub processes
- At the end of the session present your revised model to the whole group

STEEP

Refining the conceptual model and investigating process performance
Dr Mike Yearworth

Timetable

Session'	Time'
Welcome and Introduction	13:00 – 13:15
Overview of workshop purpose and the STEEP project methodology	13:15 – 13:45
Stakeholder group introductions over coffee	13:45 – 14:00
Developing the high level conceptual systems view of the processes needed to achieve the transformation	14:00 – 14:45
Detailed conceptual modelling of the transformation	14:45 – 15:45
Refining 'the'conceptual'model'and'inves=ga=ng'process' performance'	15:45 – 16:45
Wrap-up session, on-going engagement, and plans for the 2nd Workshop	16:45 – 17:00

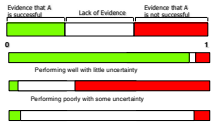
Group Model Building: Exercise #3

- Working with the process model at the end of Exercise #2
- Continue to develop the model further by focussing on asking "how" questions of each process in the model
- If there are not roughly 5-7 sub-processes per process attempt to rationalise the model by using grouping activities
- Assess the performance of the processes by using the coloured stickers to indicate your judgement
- On a separate flipchart list issues with why a process is assessed as either
  - White, or predominately white (don't know), or
  - Red, or predominately red (performing badly)

Beginning with qualitative assessments of performance

- Simplest approach to judging process performance
- Within a group of experts/process owners
- Based on a process of debate to decide balance between
  1. Performing well, good,...
  2. Don't know, unknown, need more information...
  3. Not performing well, poor, ...
- e.g.
  - Poor performance with some uncertainty
  -

Performance measures with explicit uncertainty



Beginning with qualitative assessments of performance

STEEP

Wrap-up Session
Dr Mike Yearworth

Review – Purpose for today

1. Introduction to the STEEP project
2. Understand the purpose of systems modelling and how this helps BCC in developing the BTQEZ
3. Elicit your expert contribution to developing a conceptual systems model of the transformation that BCC are trying to achieve for the BTQEZ
4. Perform an assessment on the performance of the processes identified in the systems model
5. On-going engagement and 2nd Workshop

2nd Stakeholder Workshop

- Wednesday 11th June, here!
- We would like to maintain the integrity of the modelling process and continuity of engagement
  - Ideally we would like you to be present at the next workshop, else appoint a substitute from your organisation
- Further information about the modelling process
  - http://wordpress.smartsteep.eu

Stakeholder Engagement Platform

- An opportunity to provide input on an open-source online tool for stakeholders to collaborate on smart city/energy masterplanning.
- Further information on the Stakeholder Engagement Platform at the next workshop, in the meantime engage with this process by contacting CSE directly

Annex F – Planning for the second Bristol workshop

Welcome: Introductions will need to be re-made, based on previous experience there is no guarantee of a consistent group. I need to 'remind' participants about the purpose of the STEEP project, the purpose behind the series of workshops, and finally the purpose for the day. Again, I need to make sure that the stakeholder group know why they are there and what is expected from them.

Reminder of the STEEP Methodology: I will then take no more than about 20 minutes to remind the participants about the methodology that is being used by the STEEP project. The focus will be on a refresh about conceptual modelling using process and decomposition (how/why questioning), and that processes need to be described using gerunds. I will also explain the purpose for eliciting evidence about process performance. I will then explain the technique of argumentation based on the IBIS principles of issues←options←arguments.

1st Exercise: I will focus on reviewing the model(s) developed from the first workshop and re-asking questions about process performance. I will be directing the attention of the group towards mainly towards 'leaf' processes but will also be on the lookout for inconsistencies between evaluation of higher level processes and what the propagation algorithm in PeriMeta would calculate assuming we have roughly 5 ± 2 decompositions and default necessity and sufficiency conditions. This shouldn't take too long, so will spend 5 minutes introducing and 20 minutes on the exercise, plus 15 minutes for reporting back.

2nd Exercise: This exercise will be a preliminary look at issues arising from poor performance and/or lack of knowledge about process performance i.e. focussing on the red and the white. This will take the form of a brainstorming exercise and I will ask the sub-groups to build a table with rows labelled by the process name and without too much discussion get the participants to list issues for each process that 'explain' either the poor performance or lack of knowledge. I will get the sub-groups to flag any issues that they feel are major and need action else the transformational process will fail.

3rd Exercise: The final session will focus on eliciting options and arguments for the issues identified in the 2nd exercise. This exercise will take a total of 75 minutes.

Session	Who	Objectives	T Start	T End	Duration (mins)
Arrival			12:45:00	13:00:00	0:15:00
Welcome and Introduction	MY	1,2	13:00:00	13:15:00	0:15:00
STEEP Methodology	MY	3	13:15:00	13:45:00	0:30:00
Break - chance for stakeholders to talk	omnes		13:45:00	13:55:00	0:10:00
1st Exercise - introduction	MY	4,5,6	13:55:00	14:00:00	0:05:00
1st Exercise - review conceptual models from workshop 1	omnes	4,5,6	14:00:00	14:30:00	0:30:00
1st Exercise - report back to group	omnes	4,5,6	14:30:00	14:45:00	0:15:00
2nd Exercise - introduction	MY	7	14:45:00	14:55:00	0:10:00
2nd Exercise - process performance and identifying issues	omnes	7	14:55:00	15:25:00	0:30:00
2nd Exercise - report back to group	omnes	7	15:25:00	15:40:00	0:15:00
3rd Exercise - introduction	MY	8	15:40:00	15:45:00	0:05:00
3rd Exercise - developing options and arguments for intervention	omnes	8	15:45:00	16:25:00	0:40:00
3rd Exercise - reporting back	omnes	8	16:25:00	16:55:00	0:30:00
Wrap-up session	MY	9	16:55:00	17:00:00	0:05:00

Table 2. Timings for the Second Bristol Group Model-Building Workshop

References

Ackermann, F., Franco, L.A., Gallupe, B., & Parent, M. (2005). GSS for multi-organizational collaboration: Reflections on process and content. *Group Decision and Negotiation, 14*(4), 307-331.

Andersen, D., Vennix, J., Richardson, G., & Rouwette, E. (2007). Group model building: problem structuring, policy simulation and decision support. *Journal of the Operational Research Society, 58*(5), 691-694. doi: 10.1057/palgrave.jors.2602339

Andersen, D.F., & Richardson, G.P. (1997). Scripts for group model building. *System Dynamics Review, 13*(2), 107-129.

Bernstein, S., Cashore, B., Levin, K., & Auld, G. (2007). *Playing it Forward: Path Dependency, Progressive Incrementalism, and the Super Wicked Problem of Global Climate Change*. Paper presented at the 48th Annual Meeting of the International Studies Association, Chicago, IL., USA.

Best, G., Parston, G., & Rosenhead, J. (1986). Robustness in Practice-The Regional Planning of Health Services. *Journal of the Operational Research Society, 37*(5), 463-478. doi: 10.2307/2582669.

Beven, K. (2002). Towards a coherent philosophy for modelling the environment. *Proceedings of the Royal Society A - Mathematical Physical and Engineering Sciences, 458*(2026), 2465-2484. doi: 10.1098/rspa.2002.0986

Bhatt, V., Friley, P., & Lee, J. (2010). Integrated energy and environmental systems analysis methodology for achieving low carbon cities. *Journal of Renewable and Sustainable Energy, 2*(3). doi: 10.1063/1.3456367

Blockley, D., & Godfrey, P.S. (2000). *Doing it differently : systems for rethinking construction*. London: Thomas Telford.

Brown, J., Cooper, C., & Pidd, M. (2006). A taxing problem: The complementary use of hard and soft OR in the public sector. *European Journal of Operational Research, 172*(2), 666-679. doi: 10.1016/j.ejor.2004.10.016

Buckingham Shum, S. (2008). *Cohere: Towards Web 2.0 Argumentation*. Paper presented at the 2nd International Conference on Computational Models of Argument, Toulouse, France.

Buckingham Shum, S.J., Selvin, A.M., Sierhuis, M., Conklin, J., Haley, C.B., Bashar Nuseibeh, B. . (2006). Hypermedia Support for Argumentation-Based Rationale. In A. H. Dutoit, McCall, R., Mistrík, I., Paech, B. (Ed.), *Rationale Management in Software Engineering*. Berlin: Springer.

Checkland, P. (1981). *Systems thinking, systems practice*. Chichester: John Wiley.

Checkland, P., & Holwell, S. (2004). "Classic" OR and "soft" OR - an asymmetric complementarity. In M. Pidd (Ed.), *Systems Modelling: Theory and Practice*. Chichester: John Wiley & Sons, Ltd.

Checkland, P., & Poulter, J. (2006). *Learning for action : a short definitive account of soft systems methodology, and its use for practitioner, teachers and students*. Hoboken, N.J.: Wiley ; Chichester : John Wiley [distributor].

Checkland, P., & Scholes, J. (1999). *Soft Systems Methodology in Action: Including a 30-year retrospective*. Chichester: Wiley.

Checkland, P., & Winter, M. (2006). Process and content: two ways of using SSM. *Journal of the Operational Research Society, 57*(12), 1435-1441. doi: 10.1057/palgrave.jors.2602118

Coelho, D., Antunes, C.H., & Martins, A.G. (2010). Using SSM for Structuring Decision Support in Urban Energy Planning. *Technological and Economic Development of Economy, 16*(4), 641-653. doi: 10.3846/tede.2010.39

Compendium Institute Open University (2014). Retrieved 3rd March 2014, from http://compendium.open.ac.uk/institute/

Conklin, J. (2003). Dialogue Mapping: Reflections on an Industrial Strength Case Study. In P. A. Kirschner, Buckingham Shum, S., Carr, C. (Ed.), *Visualizing Argumentation*. London: Springer-Verlag.

Conklin, J. (2006). *Dialogue mapping : building shared understanding of wicked problems*. Chichester, England ; Hoboken, NJ: Wiley.

Davis, J.P., & Hall, J.W. (2003). A software-supported process for assembling evidence and handling uncertainty in decision-making. *Decision Support Systems, 35*(3), 415-433. doi: 10.1016/s0167-9236(02)00117-3

De Liddo, A., Buckingham Shum, S. (2010). *Cohere: A Prototype for Contested Collective Intelligence*. Paper presented at the Workshop on Collective Intelligence In Organizations: Toward a Research Agenda. ACM Conference on Computer-Supported Cooperative Work, Savannah, GA, USA.

Dias, W.P.S. (2013). Comparing the systems approaches of Checkland and Blockley. *Civil Engineering and Environmental Systems, 30*(3-4), 221-230. doi: 10.1080/10286608.2013.853749

Elias, A.A. (2008). Energy efficiency in New Zealand's residential sector: A systemic analysis. *Energy Policy, 36*(9), 3278-3285. doi: 10.1016/j.enpol.2008.05.005

Franco, L.A. (2007). Assessing the impact of problem structuring methods in multi-organizational settings: An empirical investigation. *Journal of the Operational Research Society, 58*(6), 760-768.

Franco, L.A. (2008). Facilitating collaboration with problem structuring methods: A case study of an inter-organisational construction partnership. *Group Decision and Negotiation, 17*(4), 267-286.

Franco, L.A. (2009). Problem structuring methods as intervention tools: Reflections from their use with multi-organisational teams. *Omega, 37*(1), 193-203.

Gezelius, S.S., & Refsgaard, K. (2007). Barriers to rational decision-making in environmental planning. *Land Use Policy, 24*(2), 338-348. doi: 10.1016/j.landusepol.2006.04.002

Hall, J.W., Blockley, D.I., & Davis, J.P. (1998). Uncertain inference using interval probability theory. *International Journal of Approximate Reasoning, 19*(3-4), 247-264.

Helton, J.C., & Burmaster, D.E. (1996). Guest editorial: Treatment of aleatory and epistemic uncertainty in performance assessments for complex systems. *Reliability Engineering & System Safety, 54*(2-3), 91-94. doi: 10.1016/s0951-8320(96)00066-x

Hiltz, S.R., Dufner, D., Fjermestad, J., Kim, Y., Ocker, R., Rana, A., & Turoff, M. (2013). Distributed Group Support Systems: Theory Development and Experimentation. In G. M. Olson, T. W. Malone & J. B. Smith (Eds.), *Coordination Theory and Collaboration Technology*: Psychology Press.

Hindle, G.A. (2011). Case Article—Teaching soft systems methodology and a blueprint for a module. *INFORMS Transactions on Education, 12*(1), 31-42.

Jackson, P., & Klobas, J. (2008). Building knowledge in projects: A practical application of social constructivism to information systems development. *International Journal of Project Management, 26*(4), 329-337.

Koestler, A. (1967). *The Ghost in the machine*. London: Hutchinson.

Kotiadis, K., & Mingers, J. (2006). Combining PSMs with hard OR methods: the philosophical and practical challenges. *Journal of the Operational Research Society, 57*(7), 856-867. doi: 10.1057/palgrave.jors.2602147

Kunz, W., & Rittel, H.W.J. (1970). Issues as Elements of Information Systems: Studiengruppe für Systemforschung, Heidelberg, Germany.

Lazarus, R.J. (2009). Super wicked problems and climate change: restraining the present to liberate the future. *Cornell Law Review, 94*(5), 1153-1234.

Lowe, D.A., Martingale, L., & Yearworth, M. (submitted). Combining the Viable System Model and Hierarchical Process Modelling in a Multi- Methodology for use as a Problem Structuring Method. *Journal of the Operational Research Society*.

Marashi, E., & Davis, J. (2007). A Systems-Based Approach for Supporting Discourse in Decision Making. *Computer-Aided Civil and Infrastructure Engineering, 22*, 511-526.

Marashi, E., & Davis, J.P. (2006). An argumentation-based method for managing complex issues in design of infrastructural systems. *Reliability Engineering & System Safety, 91*(12), 1535-1545. doi: 10.1016/j.ress.2006.01.013

Marashi, S.E. (2006). *Managing Discourse and Uncertainty for Decision-making in Civil and Infrastructure Engineering Systems.* (PhD), University of Bristol.

Marashi, S.E., Davis, J.P., & Hall, J.W. (2008). Combination methods and conflict handling in evidential theories. *International Journal of Uncertainty Fuzziness and Knowledge-Based Systems, 16*(3), 337-369. doi: 10.1142/s0218488508005315

Midgley, G., Cavana, R.Y., Brocklesby, J., Foote, J.L., Wood, D.R.R., & Ahuriri-Driscoll, A. (2013). Towards a new framework for evaluating systemic problem structuring

methods. *European Journal of Operational Research, 229*(1), 143-154. doi: 10.1016/j.ejor.2013.01.047

Mingers, J. (2011). Soft OR comes of age-but not everywhere! *Omega-International Journal of Management Science, 39*(6), 729-741. doi: 10.1016/j.omega.2011.01.005

Mingers, J., & Rosenhead, J. (2004). Problem structuring methods in action. *European Journal of Operational Research, 152*(3), 530-554. doi: 10.1016/s0377-2217(03)00056-0

Morton, A., Ackermann, F., & Belton, V. (2007). Problem structuring without workshops? Experiences with distributed interaction within a PSM process. *Journal of the Operational Research Society, 58*(5), 547-556. doi: 10.1057/palgrave.jors.2602210

Neves, L.M.P., Martins, A.G., Antunes, C.H., & Dias, L.C. (2004). Using SSM to rethink the analysis of energy efficiency initiatives. *Journal of the Operational Research Society, 55*(9), 968-975. doi: 10.1057/palgrave.jors.2601763

Nuno, M., & Pidd, M. (2000). A conceptual framework for understanding business processes and business process modelling. *Information Systems Journal, 10*(2), 105-129.

Ormerod, R. (2014). The mangle of OR practice: towards more informative case studies of 'technical' projects. *Journal of the Operational Research Society, 65*, 1245-1260. doi: doi:10.1057/jors.2013.78

Pawson, R., & Tilley, N. (1997). *Realistic Evaluation*. London: Sage.

Pickering, A. (1993). The mangle of practice - agency and emergence in the sociology of science. *American Journal of Sociology, 99*(3), 559-589. doi: 10.1086/230316

Pickering, A. (1995). *The mangle of practice : time, agency, and science*. Chicago ; London: University of Chicago Press.

Pidd, M. (2004). Complementarity in systems modelling. In M. Pidd (Ed.), *Systems Modelling: Theory and Practice*. Chichester: John Wiley & Sons Ltd.

Pohekar, S.D., & Ramachandran, M. (2004). Application of multi-criteria decision making to sustainable energy planning - A review. *Renewable & Sustainable Energy Reviews, 8*(4), 365-381. doi: 10.1016/j.rser.2003.12.007

Rittel, H.W.J., & Webber, M.M. (1973). Dilemmas in a General Theory of Planning. *Policy Sciences, 4*(2), 155-169.

Rosenhead, J. (1996). What's the problem? An introduction to problem structuring methods. *Interfaces, 26*(6), 117-131. doi: 10.1287/inte.26.6.117

Shaw, D., Westcombe, M., Hodgkin, J., & Montibeller, G. (2004). Problem structuring methods for large group interventions. *Journal of the Operational Research Society, 55*(5), 453-463. doi: 10.1057/palgrave.jors.2601712

Sheffield, J. (2004). The design of GSS-enabled interventions: A Habermasian perspective. *Group Decision and Negotiation, 13*(5), 415-435. doi: 10.1023/B:GRUP.0000045750.48336.f7

Sheffield, J. (2009a). *Design theory for collaborative technologies: Electronic discourse in group decision.* Paper presented at the 53rd Annual Conference of the International Society for the Systems Sciences 2009: Making Liveable, Sustainable Systems Unremarkable.

Sheffield, J. (2009b). *Towards a design theory for collaborative technologies: Habermasian analysis of comprehensive urban planning.* Paper presented at the Proceedings of the 42nd Annual Hawaii International Conference on System Sciences, HICSS.

Slaughter, R.A. (2002). From forecasting and scenarios to social construction: changing methodological paradigms in futures studies. *Foresight, 4*(3), 26-31.

Sowa, J.F. (1984). *Conceptual structures : information processing in mind and machine*. Reading, Mass. ; London: Addison-Wesley.

STEEP. (2011). Systems Thinking for Comprehensive City Efficient Energy Planning (Proposal) *STEEP PROJECT (314277) - Systems Thinking for Comprehensive City Efficient Energy Planning* (pp. 125).

STEEP. (2013a). D1.3 Training material for cities about methodology concepts *STEEP PROJECT (314277) - Systems Thinking for Comprehensive City Efficient Energy Planning* (pp. 125): Bristol City Council.

STEEP. (2013b). D1.4 Data Harmonized for the WP2 *STEEP PROJECT (314277) - Systems Thinking for Comprehensive City Efficient Energy Planning* (pp. 9): Centre for Sustainable Energy

Turoff, M. (1975). The Policy Delphi. In H. A. Linstone & M. Turoff (Eds.), *Delphi Method: Techniques and Applications*: Addison-Wesley Educational Publishers Inc.

Ulrich, W. (2003). Beyond methodology choice: critical systems thinking as critically systemic discourse. *Journal of the Operational Research Society, 54*(4), 325-342. doi: 10.1057/palgrave.jors.2601518

Ulrich, W., & Reynolds, M. (2010). *Critical Systems Heuristics*. New York: Springer.

Vennix, J. (1996). *Group Model Building: Facilitating Team Learning Using System Dynamics*. Chichester: Wiley.

White, L. (2006). Evaluating problem-structuring methods: developing an approach to show the value and effectiveness of PSMs. *Journal of the Operational Research Society, 57*(7), 842-855. doi: 10.1057/palgrave.jors.2602149

White, L., Burger, K., & Yearworth, M. (forthcoming). Understanding behaviour in problem structuring methods interventions with activity theory. *European Journal of Operational Research*. doi: http://dx.doi.org/10.1016/j.ejor.2015.07.044

White, L., Yearworth, M., & Burger, K. (2015) Understanding PSM interventions through sense-making and the mangle of practice lens. *Vol. 218. Lecture Notes in Business Information Processing* (pp. 13-27).

Yearworth, M. (2015). *Sustainability as a "super wicked" problem; opportunities and limits for engineering methodology*. Paper presented at the 7th International

Conference on Sustainable Development in Building and Environment (SuDBE 2015), Reading, UK.

Yearworth, M. (forthcoming). Sustainability as a "super wicked" problem; opportunities and limits for engineering methodology. *Intelligent Buildings International*.

Yearworth, M., & White, L. (2014). The non-codified use of problem structuring methods and the need for a generic constitutive definition. *European Journal of Operational Research, 237*(3), 932-945. doi: 10.1016/j.ejor.2014.02.015