Integrative Design Methods applied to Sustainable Urban Development Research

Thomas S Brinsmead and Cliff A Hooker
University of Newcastle

Keywords: Quality Function Deployment, Integrative Research, Urban Development.

ABSTRACT

Progress in sustainable development is difficult due to the need for integrating competing demands and distinct perspectives. Significant demands required by, and relationships among, distinct perspectives can be identified by means-ends inquiry. To analyse and represent the findings of a collaborative means-ends inquiry, Quality Function Deployment is applied to a case-study involving disparate urban development research projects. The projects were well-defined, relatively narrowly focused, and not closely interacting in their detail. The analysis highlighted this, producing a simple, intuitively accessible and modifiable representation of a common broad urban development triple-bottom-line design problem that each individual project was contributing to solving, albeit indirectly. While not making specific recommendations, the result provides a suitable starting point for a focussed discussion of integrated urban development policy and design: and for identifying related research questions.

1. INTRODUCTION

The apparent complexity of sustainable development problems makes progress, both theoretical and practical, challenging. The requirement to consider multiple potentially conflicting demands (resource efficiency, ecosystem protection, community cohesion, health), and potential interactions among multiple factors (transport networks, natural resources, human aspirations), frequently requires distinct perspectives, often held by distinct individuals. Thus, cross-cultural (eg. cross-disciplinary) collaboration often appears necessary to conceptualise and implement solutions to problems identified as involving sustainability issues. Such collaboration requires the integration of distinct perspectives that may not be straightforwardly compatible. But it is not well understood how to ensure a satisfactory integration, or to establish where it is impossible or unnecessary (Dovers 2005).

Analogously to a well-integrated engineering design, an integrated sustainability solution integrates within five distinct design domains (Brinsmead 2005). It integrates (a) design techniques & features, system components, and tactics (ie. “means”, eg. public open space and recreation infrastructure), and (b) partial objectives, and design & process principles (ie. “ends”, eg. social cohesion, storm flow reduction) informed by (c) integrated understanding of causal principles governing the solution components, overall behaviour and operating environment (demographics, aspirations). The three domains: means, ends understanding; themselves d) must be appropriately integrated, ie. the understanding [c] is of the relationship between solution component means [a] and objective ends [b]. Ideally, the process of solution development is (e) integrated with its social-institutional context. Previously applied to integrated sustainability assessment, the general applicability of this five (design) domain integration framework motivates its normative application (cf Bridgman and Davis’ 2004 policy model) to integrated research more generally.

A procedure deriving from this framework is integrative “means-ends inquiry” (MEI). An extension of value inquiry (eg. Nelson 1974), this is a solution-oriented process for constructing a coherent, well-defined problem from a partially understood one, and is an elementary instance of a self-directed anticipative learning process (Christensen and Hooker 2000). It generalises straightforwardly from two domains (means, ends) to five as “integrated MEI” and from individual to collaborative mode, as a “collaborative MEI”. Quality Function Deployment (QFD, Clausing 1994) is an engineering design method that assists a multi-disciplinary engineering team find collaborative solutions to well-defined integrated design problems. Although advocated for application to engineering design, many elements of QFD are functionally equivalent to the less specifically prescriptive MEI. It was hypothesised that,

applied to practically-oriented, closely related, research problems, 1) a means-ends inquiry would assist articulating an overarching, coherently integrated, practical research problem and 2) QFD procedures might be applied, with minor modification, to guide and document MEI, in a context broader than engineering design.

To test this, three “means-ends inquiry” workshops were conducted with participants researching various urban development projects, aiming to characterise a common problem highlighting the relevance of - and interrelationships among - each project involved, and to motivate research collaboration. The MEI results were analysed with QFD methods. Because the component research projects were not extremely closely interrelated in their detail, the MEI relied significantly on the participants’ broader disciplinary (interpreted loosely) knowledge, rather than the details of their ongoing projects. Thus, rather than integrating the research project results, it produced an integrated representation of their motivating contextual perspectives on urban development, a common design problem towards which each project was contributing to solving, albeit indirectly. The resulting representation (Brinsmead 2007) is simple and intuitively accessible, and suited to focussing discussion, further elaboration and identifying useful collaborative research projects.

This methodological paper describes the workshops, “means-ends inquiry” (MEI), and QFD tools. It discusses the ability of the QFD integrative engineering design tool for guiding an integrated multi-disciplinary MEI, and of collaborative MEI for motivating integrated research, in the particular case where the participants research projects sharing a common theme but do not closely interact. First, means-ends inquiry is briefly described, followed by the case-study application and reflections on integrated MEI. Next, the QFD methods applied to the integrated MEI are described, followed by reflective discussion.

2. MEANS-ENDS INQUIRY and INTEGRATED MEANS-ENDS INQUIRY

Within any particular field of inquiry, improved understanding is especially valuable when it is applicable to solving human problems, ie. supports some improvement capability. For example, urban development research can support energy efficiency, structural strength, cost reduction, community spirit, or approvals process reliability. The practical value of knowledge can be articulated in the range of “ends” that it can help achieve and the “means” to meet them (eg. advanced building materials, insulation, public space), that it helps to understand. Conversely, given a particular problem, improved understanding may be needed for a solution to be found. What need to be understood depends on the range of ends that a satisfactory solution must meet, and means under consideration for its construction. To tackle the general problem of promoting sustainable housing, requisite understanding depends on those aspects of sustainability addressed and the alternatives permitted explored. Reducing embodied energy by building material selection requires understanding manufacturing lifecycles. Economically reducing mains water demand by rainfall harvesting requires understanding rainfall patterns, water consumption patterns, harvesting options and storage dynamics. Reducing water demand by behaviour change requires understanding attitudes, beliefs, and communication processes.

Means-ends inquiry is explicitly articulating the range of ends sought, means considered and relevant intervening factors. Given a particular knowledge area, it can articulate its practical relevance. Given a particular problem, it can direct attention towards understanding that may solve it. However, MEI can be open-ended. Articulating ends (reduced mains water demand) can suggest alternative means (rainwater and stormwater harvesting, greywater re-use, water efficient appliances) which suggest new ends (meeting water services demand, convenience, cost, safety, social acceptability).

Within a particular (eg. disciplinary) perspective, many of the ends, the typical means to meet them, and thus the type of understanding required, are implicitly understood. However when multiple perspectives are applied to a problem, making them explicit is often required, because the means to address some ends will typically make others more or less difficult to address, eg. increasing dwelling density to reduce land use and transport requirements makes it makes it easier to achieve adequate insulation but harder to satisfy lighting demands from solar radiation, and increases building bulk and overshadowing.

Applying multiple perspectives within MEI invariably results in a multi-parameter multi-objective MEI. Integration tasks within each design domain are clearly identifiable. Integrated understanding (c) is that of the possibly complex causal interrelationships among factors in the problem situation. Integration (d) of that understanding with tactics and objectives is that of the means-factor-ends relationship sufficient to find a satisfactory solution. Integration of tactics (a) is finding a suitable combination of available means, and integrated evaluation of multiple objectives (b) is entailed in any judgement that the ends expected to be met by a proposed solution is satisfactory. Only (e) integration of the process (ie. of constructing an integrated solution) within its social-institutional context is not satisfied automatically. Note: only integration (c) is necessary within a purely investigative integrative task, whereas integration (d) is required if the investigation is to be practically relevant, and the practical task (a) of integrated design and/or policy entails integration (b).

2.1 Integrated Means-Ends Inquiry Case Study

A series of three workshops was held with representatives from seven independently formulated research projects from various disciplines covering the sciences, engineering, and social sciences, but within a single University institution, and with a common research theme – urban development, and timetable - a concurrent twelve months. Each project had a claim to practical relevance, being motivated by environmental and/or socio-economic considerations, each of which is arguably relevant to a triple-bottom line conception of sustainability, understood broadly. In particular, they were relevant to fauna welfare, water management, community health, leisure and recreation, visual character, regional transport and financial flows, and development policy. The first workshop took a full day, one month into the research programme. The second and third workshops were shorter at a half-day each, and occurred at months five and eleven. Brief reports outlining the main issues raised in the workshops were circulated after each one.

The first workshop introduced the participants to means-ends inquiry, and identified the various ends that each project was motivated by, or likely to contribute to. At the early stages, only a crude characterisation was possible. A major component of some research projects was to articulate the most important those of ends. For example, the community health project was to develop, for a range of stakeholders, a clarified definition of health, ie. to elaborate the general end of “satisfactory community health” into more specific components (even if only crude proxies) such as adequate social cohesion, nutrition and physical wellbeing. The policy process project investigated which aspects of urban development were most responsible for generating conflict. This information suggested which particular ends local communities, regulatory authorities and developers found significant. Following the first workshop, the main factors to be investigated by each research project, and also initially prospective means that might be considered or suggested by them, were identified in individual interview.

At the second workshop, discussions focussed on the main factors being investigated within each research project and on potentially significant cross-project interactions among important factors. This involved explicitly articulating which factors were believed likely to be most significant. In some cases this proved difficult because there were many potentially significant factors and no apparent structure to them. In other cases, much clarification was - from the perspective of those from the projects under discussion - simply stating the obvious, although it was frequently non-obvious to others. Following the second workshop, some causal links among these factors were identified in general terms, and the characterisation of relevant means was refined. For some projects this was difficult because such links were only to be confirmed subsequent to the detailed data analysis.

The third and final workshop focussed on more precisely identifying the main means that might be suggested by each research project. Following the third workshop, the findings from the means-ends inquiry were analysed using Quality Function Deployment methods, which assisted in integrations (a), (b), (c) and (d). Those findings are reported in Brinsmead (2007) and *briefly* here in *italics* in *Section 3*. The immediate following reflects on the appropriateness of MEI for encouraging integrative research, such as multi-disciplinary sustainability research. The QFD analysis tools are described later.

2.2 Means-Ends Inquiry: Discussion

For this particular application, the detailed issues addressed by the contributing research projects were not closely interacting. Three of the seven projects: recreation, water systems (subdivision and local government area scale), and socioeconomic flows (regional scale); were directly focussed on the urban environment itself. Two projects, visual character (streetscape scale) and fauna tracking, were improving measurement tool reliability. The remaining two, policy conflicts and community health, focussed on the design and approval processes that shape the urban environment. The projects investigated phenomena at different (though nearby) scales. As to be expected for state-of-the-art research, most focussed on tightly defined questions within a narrow partial component of a broader (though intra-disciplinary) picture. Many of the interactions among factors investigated were indirect and/or quite complicated (eg. the impact of water sensitive urban design on visual character), and some were so simple as to be almost trivial (even if hard to articulate, eg. the impact of residential development location on transport energy). Most of the challenges of conducting the MEI resulted from this interaction indirectness.

In order to show the relationship among research projects and to integrate the perspectives informing each, a common scale (subdivision) and degree of resolution was selected. For many projects this was not ideal for showcasing the contribution to their particular disciplinary area. Consequently the resulting integrated description proved only indirectly relevant to the specific findings of many, though not all, the contributing projects (and conversely). Nevertheless, the integrated description resulted in a (multi-disciplinary) overview context that showed a clear relationship among some of the broader (but intra-disciplinary) questions motivating the specific questions addressed by each project, and thereby the extent of their interrelationship. It also suggested potentially fruitful collaborative projects (eg. a focus on open space, since it contributes to multiple ends and impacts on multiple stakeholders) and highlighted significant design parameters that were not directly investigated in the projects (building dimensions and spatial density, population density).

Social context. It is important to address the participants' motivation in participating and ensure their expectations are met. Initially some of the motivation for participation was the prospect of collaborating directly with other researchers, and learning how other disciplinary perspectives might impact upon their projects. However it provide impossible to satisfy the original aim of the workshops to develop an integrated account of the participants' research projects. Consequently, although the participants had the opportunity to learn about other urban development issues, the means-ends inquiry did not impact significantly on the conduct of the research projects themselves. Significant effort by the participants was needed to educate each other about background information very fundamental to their expertise. While some enjoyed playing this educative role, others found it rather tedious and unilluminating. The limited time available for fuller explanation contributed to the frustration.

From the viewpoint of the integrated perspective, the relevance of some of the individual contributing projects was quite indirect. The integrated perspective raised broader and/or fundamental questions that were not necessarily addressed by the contributing research projects, and went somewhat beyond the detailed knowledge of the participants (though still within their general areas of interest). Exploring the integrated perspective was a distraction from the participants' more focussed project tasks, and could be seen as of limited interest, or worse, a competitor project looking at an essentially different problem contesting for legitimacy. Maintaining interest thus required a commitment to an integrated perspective, not for its immediate implications for each project, but for its contextualising promise, whence it had to be accepted that comprehensible integration can require much finessing of detail. It should be clarified that quite general, rather than specific detailed, characterisations of means, factors and ends is acceptable, particularly in the initial stages.

Some participants were initially uncomfortable with the language of means-ends inquiry. There is a twin danger here. Firstly, while the basic concepts are reasonably straightforward, they are also somewhat abstract. Plenty of examples help communicate the ideas. Nevertheless, although the basic concepts are superficially simple, they are not yet precise enough to prevent misapplication – some interpretation is required. For example, nominally purely investigative research may serve no unique particular "ends", nor therefore

imply particular means to achieve them. Nevertheless there may be a range of ends which it could, or will likely, serve. Research on travel statistics could support economic growth, access to social services, or reduced demand for oil imports, travel times or traffic congestion, by siting transport infrastructure or development, or improving public transport or road standards. The project may not be motivated by, nor may the researchers advocate, any particular such ends or means, which are only indirectly related to the research. It should not be implied that the research projects ought to be directly practically applicable or focussed on developing a more elaborated characterisation of means and ends.

Initialisation. Finding an appropriate starting point for integrated MEI can be quite difficult. For any given single perspective it is relatively easy to identify a related set of means, factors, and ends. However, it can be hard to identify those that are most relevant in the context of the other perspectives. The development of a common contextual perspective requires sufficient “distance” from each component perspective, and selecting which particular coarsely resolved features to include from each can require significant insight. It is thus useful to distinguish between a detailed means-factor-ends account of each individual research project, and its contribution to the means-factor-ends account of an integrated research problem. That contribution may in fact represent a means-factor-ends account of the (mono-disciplinary) motivating context for, or a restricted portion of, the individual research project, an account which more easily integrates into the coherent perspective.

Ensuring that an appropriate common scale and resolution (degree of specificity) are selected for the focus of an integrated MEI can be very helpful, though challenging. For example, means to improve visual character could be described as the design of building profiles, as generally as the design of building exteriors, or as specifically as height limitations or height limitations to six stories. If the component perspectives are at significantly varying scales and resolutions, their detailed means-factor-ends accounts should not be integrated directly. Rather, the scale and resolution of their contributions to the integrated perspective should accommodate those of several projects, even though those contributions can appear only indirectly related to the original component perspectives.

A reasonable candidate initial scale is one near the median of the component perspectives. A reasonable initial resolution is one resulting in no more than half a dozen factor categories, where each factor resolved is of similar order of importance (according to some proxy criterion, single or compound) and specificity. It is reasonable to incorporate factors from one, perhaps two, orders of magnitude above and below the selected scale (and resolution) of focus. Starting somewhere rather than being indecisive is important, evolutionary changes can always be made later. Nevertheless, unconditional commitment to the initial selection can also be counterproductive, so that exploring several initial scales and resolutions can be useful. Especially early on in MEI, scope comprehensiveness is more important than resolution precision, although specific example possibilities can be given when describing very coarsely resolved and very general, factor characterisations.

If the given component perspectives are quite disparate, consider elaborating several integrated (sub-)perspectives concurrently. For example, two important categories of factors were distinguished in the case-study, those in the urban environment itself and those in the design, decision making and policy processes that indirectly shape it (ie. outcome versus process). However, they are causally closely related, since intentional process regulates (Hooker 1995) outcome, ie. it shapes outcome and is directed by anticipated outcome ends.

Limitations. The time required for discussion is commensurate with how distantly related are the component perspectives. If participants need to communicate fundamental background that informs their particular perspective, this requires some commitment to educating the others. Construction of an integrated perspective requires sometimes detailed informational input. However, if its scale is sufficiently different from those of its component perspectives, it may not provide detailed information in return, but only an alternative contextual perspective. In the case-study, for example, the integrated perspective was reasonably relevant to the community health project, being at a similar scale and resolution, but was less directly relevant to the others. Any integrated account will mostly reflect the issues believed to be most important by the participants. Thus, where the component perspectives are fairly disparate, the initial integrated MEI account may not be comprehensive. If the problem

situation is sufficiently complex, a simple, comprehensive account may be impossible, and even the final account will be limited in scope.

The rate of progress in integrated MEI can be variable– several alternative integrated initial perspectives might be explored with limited progress before one yields sufficient purchase to grow into a reasonably elaborated, yet coherent, integrated perspective. Progress may then slow as continued elaboration expands requirements for systematic investigation. Some research projects may be quite tightly defined with the subject matter initially well-understood, their means-factor-ends characterisations relatively static. The characterisations of more open-ended, opportunistic research may evolve significantly.

It is overly time consuming to explore differences among participants in fundamental philosophical assumptions - eg. regarding adequacy of evidence for belief (epistemology) or the reality status (ontology) of investigated factors, particularly those implicit in disciplinary specific methodology. The development of discipline-specific cross-disciplinary methods will generally require dedicated attention. In the interests of timeliness it is reasonable to simply presume that a claim is *prima facie* acceptable if is valid under any component perspective.

Benefits. Collaborative MEI is useful because it encourages consideration of more than simply narrow mono-disciplinary issues by explicitly articulating ends, and of practical relevance by articulating means. Analysis of factor interactions can reveal which in particular are significant, and encourages precision about their nature - eg. their dependence upon diverse contextual factors. It can thus reveal how interrelated or separate are the areas of research inquiry. Unless the research projects are already practically oriented and quite closely related - ie. are at similar scales and have either common, or strongly interacting, factors of interest - MEI is not suited to integrating the research results, nor even merely guiding research towards an integrated research output. However, it is well suited to placing existing investigative projects that share a common theme within a wider context, and this context, explicitly articulated, would make a suitable starting point for framing a coherent, practically oriented, integrated research programme. Whether it would assist in guiding such an integrated programme is still an open question.

3. QUALITY FUNCTION DEPLOYMENT: TOOLS for MEANS-ENDS INQUIRY

Quality Function Deployment (QFD, Clausing 1994) is a methodology for guiding a multi-disciplinary engineering design process, consisting of a set of closely related tools. Some of these were used to analyse and document the MEI described above.

Ends. A large number of ends were identified by the participant group, though only some thirty or so of the most important were selected for more detailed analysis as “evaluation criteria” for the urban environment, and approximately fifteen for the design and approvals process. While these were not exhaustive, this number approaches the upper limit of what can be reasonably comprehended (ibid. p134), provided they are appropriately organised. In this case they were organised into a hierarchical taxonomy (to a tree depth of three levels). *The main categories were physical wellbeing, psycho-social wellbeing, services access, ecological impact, and economic benefit.*

More precise articulation of ends can direct the proposal of solution candidates. For example, distinguishing among water supply, reduced stormwater flow and groundwater infiltration allows the recognition that rainwater tanks support the first and second goals, but not the third. Criteria analysis involves identifying them as “must-have” versus “nice-to-have” features, and as “more-“, “less-” or “close-to-target-” is-better criteria. Crudely establishing the relative significance of each criterion, by providing numerical importance scores, assists evaluative integration (a), helping prioritise urban development factors for further investigation. Criteria correlation analysis evaluates pairs of criteria as either mutually conflicting or supporting, highlighting opportunities or the need for creative solutions.

Means. Articulating means highlights those factors (components) that most significantly influence the selected evaluation criteria. Again only a limited number (twenty or so) were selected for detailed analysis and were also organised into a hierarchical taxonomy for ease of manipulation. *The main categories were public space, public infrastructure, public services*

and private space. Means integration was not attempted – this would amount to urban development design, or a development approvals process policy recommendation.

Understanding. Integrated understanding (b) of the means-ends relationship was summarised in a QFD component-criteria interaction matrix. This records simply how significant (nil, low, medium, high) is each component in influencing each criterion, rather than specifying a more precise quantitative relationship. Even this can be difficult because it may be contingent, but it is reasonable to assume those circumstances where maximum significance occurs. A simple weighted summation (interaction weights by criteria importance) assists more precise estimation of component relative importance, for directing further inquiry. *For a subdivision, important components were identified as 1) lot and building dimensions and orientation, 2) transport routes (low and high speed), public transport and local commercial services and 3) open space (parkland and bushland).* Coherence analysis (d) is achieved by checking that each component is significant for some criterion, and that all significant factors for each criterion are included. Relatively independent component-criteria subsets can be identified by the few, weak interactions between them (Shin and Kim 2000).

Context. Awareness of some aspects of the wider context was provided by analysis of which stakeholders would regard which particular criteria are the most important. This reveals distinctions within stakeholder groups and unavoidable conflict among their first order preferences (eg. for residents there may be interest conflicts between existing and future prospective ones). Awareness of the process itself is provided by this methodological paper, but evaluation of its fit with its social and institutional context (eg. addressing the interests of the participants) was not undertaken explicitly in the workshops. For this, a separate MEI is appropriate. Relevant ends include timeliness, participant enthusiasm, and producing an integrated perspective that is coherent, simple, accessible, flexible, relevant, representable. Means include encouraging realistic participant expectations, a simple practice MEI as an early exercise, participant mutual education opportunities, detailed MEI for contributing projects distinguished from the wider integrated MEI, tailoring the timetable to the closeness of component perspectives, deliberate selection of scale and resolution, developing several distinct integrated perspectives, and monitoring metrics of elaboration progress.

3.1 Reflection on Quality Function Deployment

Quality Function Deployment provides methodically systematic, but tedious processes for analysing the results of integrated MEI. It produces a straightforward, though crude, representation of a practical multidisciplinary problem, making the practical relevance of related investigative research explicit. It provides a prescriptively tight framework for organising relevant means-ends data, although the data itself must be provided by MEI. For the analysis to be informative, the selected means and ends must be at similar scales and resolutions. The selected criteria must be directional and the means-relevant components non-directional. The quantitative guidelines for the number of factors analysed (several dozen only) usefully balances timeliness against comprehensiveness.

QFD analysis has proved partially informative applied to integrated MEI involving perspectives at multiple scales. However, because of its coarseness of resolution, its precision – and thus confidence in its accuracy – is limited. Absent more reliable data, component significance analysis depends strongly on participant judgement, which may be inaccurate - particularly if they are unfamiliar with the scale of focus. QFD analysis would likely be more illuminating, and practically relevant, for integrating multiple perspectives of more closely interacting factors, and more easily applied if they were at similar scales. Nevertheless, it usefully invites critical analysis of, and justification for, claims that particular factors are significant and highlights some inevitable tensions among aspirational criteria (eg. in a free market, housing desirability and affordability).

Although the QFD tools result in a simple representation, its accuracy is limited by its crudeness. The means-ends relationship is represented as essentially independent (of both other recognised components and unrecognised contextual parameters). Similarly, the implicit assumption that pairwise criteria correlation is independent may not be valid. Contrariwise, exhaustively checking cross-correlation (among criteria, and between components and criteria) may be unwarranted if significant interactions are few, and the two

dimensional matrix doesn't allow explicit representation of indirect causal means-ends relationships – an influence diagramme graph may be superior. Categorisation of means and ends into hierarchical taxonomies makes them easier to comprehend, and is reasonably flexible, but the hierarchical framework doesn't easily permit simultaneous representation of alternative categorisations (eg. subdivision factors could usefully be categorised by decision process stage, decision making actor or functional subsystem). Flexibility to change categorisation schemes as the integrated perspective is elaborated should be exploited.

4. CONCLUSION

Collaborative means-ends inquiry can be applied to disparate investigative research projects on a common theme, to result in a characterisation of a common practical (action-oriented) problem to which those projects are contributing, thereby showing the relationship among them. However, the more disparate are the projects (in scale, resolution, and directness of interacting factors), the more time is required for the participants to understand each others' projects, the more the process will draw on the participants broader knowledge rather than that of their initial focus of interest, and the less directly and practically relevant will be the common problem final representation to those projects. Thus, the factors of interest must be checked to ensure they are sufficiently significantly directly interacting such that an integrated perspective is appropriate, lest the effort required not be justified.

Means-ends inquiry is harder to apply to nominally investigative research than more directly practically oriented research, though this can be ameliorated by seeking only general and/or provisional characterisations of means and ends. Since MEI is an iterative process, more progress is likely by starting somewhere (or several places) rather than delaying by indecision. A reasonable start is to identify the scale and resolution of each contributing project and to then characterise a closely related practical problem for each at a common scale. Resolution should be limited to twenty-to-thirty distinctions, fewer for earlier iterations. Continued participant interest will likely be contingent on the closeness of the relationship between the resulting problem description and their self-identities as researchers, time pressures, how well communicated are the characterisations of the other projects, and how well the process challenges have been foreseen.

Quality Function Deployment methods are ideally suited for organising and representing the results of MEI, given a sufficiently similar scale and resolution. In fact, a problem representation resulting from "lean" QFD analyses, perhaps one for each project as well as a common integrated one, would have made good initial focal points for workshop discussions. QFD methods are also useful for precisely identifying interactive links between factors, or recognising their absence. However, they remain less time consuming and more practically relevant when applied to practical problems at a common scale and when participant domain knowledge is reliable, though implicit.

7. REFERENCES

Bridgman, P and G Davis (2004), *The Australian policy handbook* (3rd ed), Allen & Unwin, Crows Nest

Brinsmead TS (2005), Integrated Sustainability Assessment: Identifying Methodological Options, ISBN: 0 85847 222 8, http://pandora.nla.gov.au/pan/53596/20051027/www.naf-forum.org.au/papers/Methodology-Brinsmead.pdf

Brinsmead, TS and CA Hooker (2007), Means-Ends Inquiry: A strategy for directing inter-disciplinary research conversation, *W092 Procurement Systems Conference*, Hunter Valley, September

Christensen, WD and CA Hooker (2000), An interactivist-constructivist approach to intelligence: self-directed anticipative learning. *Philosophical Psychology*, 13(1), 5-45.

Clausing D (1994), *Total Quality Development: A step-by-step guide to world class concurrent engineering*, The American Society of Mechanical Engineers, New York

Dovers S (2005), Clarifying the Imperative of Integration Research for Sustainable Environmental Management, *Journal of Research Practice* 1(2), ICAAP

Hooker CA (1995), *Reason, Regulation and Realism*, State University of New York, Albany

Nelson JL (1974), *Introduction to value inquiry: a student process book*, Hayden Books, New Jersey

Shin, J-S and K-J Kim (2000), Complexity reduction of a design problem in QFD using decomposition, *Journal of Intelligent Manufacturing*, 11, p339-354