Proceedings of the Institution of Civil Engineers
Engineering Sustainability 159
December 2006 Issue ES4
Pages 169–177

Paper 14765
Received 29/03/2006
Accepted 26/10/2006

Keywords:
environment/municipal & public service engineering/social impact

T. K. K. B. Morgan
Senior Lecturer, Faculty of Engineering, University of Auckland, New Zealand

ice
Institution of Civil Engineers

Decision-support tools and the indigenous paradigm

T. K. K. B. Morgan BE, MBA, MIPENZ CPEng, IntPE

Sustainability legislation in New Zealand (NZ) provides an interesting challenge for decision-makers such as planners, architects and engineers. NZ's Action Plan for Sustainable Development requires 'taking account of the social, economic, environmental and cultural effects of our decisions'. The assessment of sustainability in NZ thus occurs in four dimensions. Internationally, cultural effects are generally considered within the analysis of societal effects. The separate consideration of cultural effects is necessary in NZ to acknowledge the status of the indigenous people, the *Tāngata Whenua*. The requirement for separate consideration of cultural effects was created in NZ's founding document, the 1840 Treaty of Waitangi. Although the addition of a cultural criterion to decision-support tools (DSTs) could be considered a viable solution to accommodate the partnership obligations created by the Treaty, the extension of international sustainability DSTs in this way has not worked in practice. The acknowledgement of a specific cultural dimension in the definition of sustainable development seems to accept that NZ's prevalent societal values and beliefs are not representative of its indigenous people. Therefore, in order to incorporate effectively indigenous values and beliefs into sustainability decision-making in NZ, an approach based on indigenous concepts is essential. The indigenous concept of *mauri* (binding force) has been identified for inclusion in a new DST that provides a culturally consistent measure of sustainability. The NZ context is used to identify and illustrate the requirements of a culturally consistent model for including sustainability in decision-making. A preliminary ranking of the four dimensions of sustainability assessment is presented using an established hierarchy definition process. The result is a methodology for sustainability assessment, developed specifically for the NZ context, but which may also have wider international applications where decision-makers have limited knowledge and understanding of the indigenous people's culture, values and beliefs.

1. INTRODUCTION

Contingent with sharing indigenous knowledge (IK), the traditions of the Maori people require that the context for the perspective provided here is explained. The context for this paper is provided in the *pepeha* in Fig. 1. The phrases are also defined, with other indigenous words, in the glossary. The *pepeha* establish the temporal location in terms of genealogy, the geographic location in terms of the mountains and waters of the Maori people and their standing as the *Tāngata Whenua* (people of the land). It is therefore important to understand the need for anyone involved in sustainability assessment to follow the tradition of acknowledging the mountains, the waters and those that came before from the beginning of time.

It is evident from papers in this journal that a transition from the theory of sustainable development to 'real world' action and outcomes is a significant challenge in the UK and Europe. The introduction of sustainable development principles into legislation in New Zealand (NZ) has similarly resulted in increased pressure on decision-makers to integrate concepts that have not featured in the historical approaches used in their organisations. Ashley *et al.* [1] comment that decision-mapping exercises in the UK revealed that a relatively narrow set of economic and technical criteria are used, and that decision-making is mainly driven by consideration of costs, risk, environmental impact and maintaining flexibility and build quality. Decision-making in NZ in the engineering profession has been strongly influenced by UK practice and strongly parallels this general approach.

The increasing demand for transparent and stakeholder-sensitive decision-making processes experienced in Europe and the UK is also evident in NZ. Furthermore, the opportunity that this shift in the decision-making paradigm represents allows discussion of a sustainable future for the planetary ecosystem and consideration of more holistic approaches to decision-making worldwide.

Identifying appropriate actions for sustainable development in NZ involves understanding a problem of significant complexity due to its multi-faceted and dynamic nature. NZ's sustainable development policy requires 'taking account of the social, economic, environmental and cultural effects of our decisions'.[2] The assessment of sustainability in NZ thus occurs in four dimensions and is characterised by strong dimensional interdependencies and intra-dimensional considerations that are broader than the constrained interpretation usually prescribed by conventional scientific analysis.[3]

In the late 1950s, the system dynamics approach to solving industrial manufacturing problems was developed using

Fig. 1. The *pepeha* outlining the context of this paper

concepts drawn from feedback control theory to organise available information related to the problem into computer simulation models.[3] Systems thinking has its origins in Forrester's industrial-based application of feedback control theory and perceives people as interacting parts of a larger system. In this regard, it follows that the decision-making behaviour of people is strongly influenced by the societal system within which they exist. Maani and Cavana[4] have defined systems thinking as the ability to see the whole, while understanding internal dependencies, in order to explain its complexity. It is not surprising that systems thinking is considered a useful approach from which to address the challenges of achieving sustainability.

Indigenous thinking also has a valuable contribution to make and, interestingly, the definition of systems thinking has parallels in the IK of Maori. An ancient Maori proverb, shared with the author in 1989 by a tribal elder discussing the engineering process, demonstrates these similarities: '*Kimihia katoa nga putake o te kaupapa, ingia, I kitea, kimihia te rongoa*'. A literal translation provided in a paper titled using the proverb is: 'In searching out all the relevant facets of an issue, there-in will lie the understanding that can provide the solution'.[5]

Sustainability, while being a global challenge, necessarily requires local actions and regional solutions. Regional approaches are consistent with indigenous thinking in NZ. Indigenous management of the environment is carried out for a water catchment by the *hapū* (clan group).[6] The importance of regional approaches for water management has been acknowledged in the system dynamics field by Simonovic,[7] who identified the significance of water pollution at a global level, but noted that solutions for water problems are on a regional level.

The indigenous people in NZ consider themselves an integral part of the ecosystem within which they exist. This relationship is an identification with the landscape in terms of *pepeha*, and it is reinforced when questioning strangers '*No wai koe*?'[8] 'Of what waters are you?' At the regional level, the indigenous people have an intimate understanding of the ecosystem characteristics specific to that place and over time. The IK of the Maori has been repetitively verified by historic testing whose success was often essential for continued survival. An example is the traditional management of the *kumara* or sweet potato, brought to NZ via French Polynesia from South America by Tawhaki more than a millennium ago. *Kumara* is one of the traditional names used for the sweet potato in Peru. The first European explorers to land in NZ, Hawaii and Rapanui (Easter Island), the most outlying island groups of Polynesia, noted that the *kumara* was the staple food source and very important economically at that time, the late eighteenth century.[9] The *kumara* is a perennial except in NZ where the tuber must be stored in excavated caves located to optimise passive solar gain from the winter sun. The cultivation of *kumara* in NZ occurs at a latitude 12° greater than its limit in the northern hemisphere. Traditional Maori developed the storage practice that is peculiar to NZ, because the sweet potato tuber could not survive the colder sub-tropical winter experienced in NZ and geographic isolation in the Pacific Ocean precluded replenishment of stocks on an annual basis from further north. The development of this approach was essential to sustain the staple food source from one growing season to another and provides an example of the essential nature of IK in pre-European NZ.

The characteristics of indigeneity are identified as: unity with the environment (holistic); geographic relationship that reinforces belonging (place); endurance over many generations (time); development of a distinctive culture (identity); a system of knowledge; sustainability; and a unique language. All of these characteristics are underpinned by the primary characteristic of the enduring relationship between peoples, their territories and the natural environment.[10]

Many indigenous peoples use the tree's dendritic structure to symbolise the interconnectedness, interdependence and intertwined nature of the universe[11] and, in this way, IK provides theoretical structures for understanding and prioritising knowledge and the relationships of all things in the environment. In Maori IK, genealogy is used to explain the structural relationships within the ecosystem. Furthermore, the holistic approach strongly parallels the objectives of systems thinking, and IK therefore has much to offer in striving for sustainability.

While the potential contribution of Maori IK could be challenged on the basis of the historic consequences for the Moa and Huia (bird species indigenous to NZ that are now extinct), it should not be forgotten that science developed in different parts of the world has also had some spectacular failures. The impacts of these failures have often been global, systemic and complex, both in time and space, and have exposed a lack of understanding of the

underlying cause-and-effect relationships of scientific applications.[12] Therefore, with regard to the relative merits of western science and Maori IK, comparison of these knowledge systems to establish superiority of one over another is not useful when the planetary sustainability solution being sought does not seem able to be provided by either knowledge system on its own.

NZ has struggled to progress the concept of an approach to sustainability that combines the strengths of western science and Maori IK. The concept of a Treaty-based environmental audit framework for NZ has previously been explored by the Parliamentary Commissioner for the Environment; however, there was no clear consensus for the framework, its desirability or the processes for its development.[13] While the report[13] did confirm that an audit framework at local and regional levels would be more appropriate, it was considered that a piecemeal approach to the challenge of sustainable development was unlikely to capture the potential benefits available from the successful combination of the two knowledge systems, western science and Maori IK, at the theoretical level.

The work presented in this paper describes a decision-support tool (DST) that aims to integrate and enable social, economic, environmental and cultural well-being (sustainability) by virtue of its holistic approach. This tool is intended to significantly improve the quality of decision-making within and outside the engineering profession. There are currently no decision-making tools in mainstream use that achieve the effective integration of cultural effects from the perspective of the *Tāngata Whenua* (Maori people), and therefore this successfully implemented research will result in a movement to a new paradigm for decision-making in NZ. The identification of DST characteristics relevant in the NZ context is the first step towards this goal.

2. CHARACTERISTICS OF A USEFUL DECISION-SUPPORT TOOL

The NZ context is differentiated from other international contexts by the existence of, and adherence to, the 1840 Treaty of Waitangi, NZ's founding document and first resource management legislation. Therefore any DST must effectively incorporate and represent Maori perspectives to the satisfaction of *Tāngata Whenua* and be consistent with the Treaty of Waitangi. This means that the DST will need to use a conceptual approach that incorporates appropriate IK and concepts.

Based on international best-practice, the DST should embody 'strong sustainability'[14] and therefore demonstrate ecological integrity, acknowledge the interdependence of all life and deliver intra- and inter-generational equity. These concepts are inclusive as they are common to both indigenous people and brought by the European settlers' thinking as well as the beliefs of many other ethnicities. System dynamics models have little impact unless they change the way people perceive a situation. However, to be effective, the model must communicate with and modify prior mental models as people's beliefs determine action.[15]

Another characteristic of a good DST will be strong alignment with the approach identified in predominant NZ legislation. The DST must therefore be effects focused and must promote social, economic, environmental and cultural well-being.

Finally, the DST should be accessible by all parts of society to ensure informed and effective participation by all involved in the decision-making process. For this reason the DST must be easy to understand, simple to use and, to an extent, intuitive. The DST should be able to determine whether a practice is not sustainable. It should be capable of adapting to different priority settings by users but should also clearly identify the bias applied in each case. These characteristics are summarised in Table 1.

3. MODEL CONCEPTUAL BASIS

3.1. *Mauri*

Mauri is a concept that permeates all Maori thinking and earlier work has established the potential suitability of the *mauri* principle as a measure of sustainability.[16] The land, forests, waters, and all the life they support, together with natural phenomena such as mist, wind and rocks, possess *mauri*.[17] *Mauri* is the binding force between the physical and the spiritual[18] and is a holistic concept central to Maori thinking due to its representation in the genealogy of creation.

The creation story narrative refers to *mauri* existing in the original seed, pulsing as the life principle[19] impelling the shoot to emerge in its quest for being. *Mauri* is the force that interpenetrates all things to bind and knit them together; and as the various elements diversify *mauri* acts as the bonding element creating unity in diversity.[20]

The central proposition of this analysis is that *mauri* is the binding force, the power of the gods,[21] the glue that makes it possible for everything to exist, by holding the physical and spiritual elements of a being or thing together in unison. When actions impact negatively upon the *mauri* of something, this essential bond is weakened, and can potentially result in the separation of the physical and spiritual elements resulting in the death of a living thing or alternatively the loss of a thing's capacity to support other life. Therefore *mauri* has been chosen as the conceptual basis for the DST, called the *Mauri* Model.

Characteristic	Description
Inclusive	effectively incorporate and represent Maori perspectives
Indigenous	adopt a sustainability measure from indigenous thinking
Eco-centric	demonstrate ecological integrity
Holistic	acknowledge the interdependence of all life
Equitable	deliver intra- and inter-generational equity
Legal relevance	be effects-focused and promote social, economic, environmental and cultural well-being
Integrated	demonstrate interconnectedness between the criteria chosen
User friendly	be flexible yet easy to understand in its application
Definitive	clearly determine whether a practice is or is not sustainable
Transparent	be transparent and clearly identify applied bias

Table 1. Characteristics for a DST relevant to the NZ context

3.2. The *Mauri* Model

New Zealand legislation indicates that sustainable development should be holistic and promote social, economic, environmental and cultural well-being. To assess each of these well-being dimensions using *mauri* as the measure of sustainability, it is necessary to identify physical representations of those dimensions for which the impact upon *mauri* can be evaluated. These representations have been chosen as the *mauri* of the community (social), *whanau* or family unit (economic), ecosystem (environmental) and *hapū* or clan group (cultural).

It is also necessary for the DST users to apply relative weightings to each of these four dimensions. Weightings reflect the relative importance given to social, economic, environmental and cultural well-being. The allocation of equal weighting to each dimension has little validity as the lack of bias between them assumes that these dimensions have equal importance in the real world. This is not a valid assumption in this context.

The term sustainable development has been given many definitions that have created confusion regarding its exact meaning.[22] The IUCN/UNEP/WWF[23] definition is: 'Improving the quality of human life within the carrying capacity of supporting ecosystems'. This definition identifies the need to focus on the fundamental practice of sustainable development as without this any economy or society can not be truly sustainable.

Following international best-practice, a non-anthropocentric model hierarchy that reflects strong sustainability would be expected to have the economy as a subset of society, and society as a subset of the environment.[24] This hierarchy is logical as ultimately the human economy depends on the acceptance of the people and the existence of a physical environment within which to operate. However, this hierarchy does not incorporate the cultural dimension specifically.

Both social and cultural well-being are components of society and in many countries where the dominant culture is also that of the indigenous people there is less potential for conflicting views. The NZ context, however, requires that the hierarchy of these two dimensions within the *Mauri* Model be determined. The order used to discuss this hierarchy is based below on the order consistent with the knowledge base from which the *mauri* concept is derived.

All *whanau* are part of the community, and a community occupies a specific area by virtue of the *manakitanga* (prestige associated with caring for visitors) of the *hapū* who have authority in a particular region. The *hapū* identity is entirely dependent upon their environment of origin. This hierarchy has been examined further using the analytic hierarchy process (AHP).[25] The AHP has been used to determine the actual weightings of dimensions relative to each other, in effect determining the hierarchy. To apply the AHP it has been necessary to identify the characteristics of the four dimensions, in terms of *mauri*, in more detail. The metrics chosen as sustainability indicators for each dimension of well-being require further analysis to ensure completeness and appropriateness for the option being assessed or for trend analysis over time.

As noted previously, *mauri* is pervasive. *Mauri* is evident throughout the environment, it is an intrinsic quality of water and people, it is within groups of people like *hapū* and communities, and it involves the close interaction of individuals and groups with both the inner being and the external world. *Mauri* is not unlike the idea of a life force or 'the living daylights' as in the English expression 'you scared the living daylights out of me'. The following discussion attempts to capture the major life contexts of *mauri* in a manner that highlights key themes that underpin the principles upon which each of the well-being dimensions in the *Mauri* Model are based.

3.3. *Mauri* of the ecosystem

The *Tāngata Whenua* believe that the physical and spiritual integrity of the ecosystem is reflected by its *mauri* and the state of the environment. This includes all land, air, flora and fauna, and water. Consideration of the *mauri* in terms of environmental well-being is related to the geographic boundaries established by a water catchment, the region of a specific *hapū*, and the related impacts on estuaries, harbours and the ocean. Metrics relevant to the *mauri* of the ecosystem include threats to or loss of air quality and quantity, water quality and quantity, native species diversity (flora and fauna), land quality and quantity, and measures or outcomes as mitigation. Other relevant metrics are the consumption of energy, water, renewable and non-renewable materials, and emissions to the air, water and land. The state of the environment that is passed onto future generations is most important and in this regard principle 3 of Agenda 21 (inter-generational equity) is acknowledged.[26]

3.4. *Mauri* of the *hapū*

The well-being of a particular environment, in particular the qualities of water within a catchment and how well managed it is, impacts on the identity, standing and authority of the *hapū* in a variety of ways. These include: reinforcing the ability to continue in a guardianship role; the prestige associated with caring for visitors; maintenance of the *hapū* knowledge base through active reinforcement; the effective dissemination of knowledge to successive generations; and the integrity of all of these practices. These metrics, among others, impact directly on the *mauri* of the *hapū* and are relevant in any assessment of cultural well-being as a dimension of sustainability. Relevant metrics depend on those already noted for the *mauri* of the ecosystem but with specific attention to the maintenance of *hapū* practices and their continued relevance for future generations.

3.5. *Mauri* of the community

The community at large includes non-Maori, Maori from other regions and the *Tāngata Whenua*. The community well-being dimension includes their general health and safety and includes the ability to accommodate future community needs such as land and water resources to satisfy housing demand or the creation of employment opportunities. Community well-being also includes most aspects of day-to-day life such as recreational access to parks, forests, beaches, reserves, rivers, lakes, estuaries and the ocean or opportunities for employment. Relevant metrics include threats to (or increased) public health or loss of life, public safety, public recreational access, amenity value of public space and measures or outcomes as mitigation.

3.6. *Mauri* of the *whanau*

Economic well-being is assessed in terms of the impact upon the *mauri* of the *whanau* (family unit). The family unit is chosen

because ultimately it is at this level that economic decisions impact upon people. The impact upon the *mauri* of the *whanau* is a measure of the direct personal effect that accrues to a *whanau* as a result of a choice of action. The impact upon *mauri* varies from *whanau* to *whanau* and is primarily measured in economic terms or a reduction in levels of service. The economic impact is the financial consequence and may be experienced as a direct fee, a portion of rates or taxation revenue. In the majority of instances, there is little discretion on the part of *whanau* to allocate these financial resources to other priorities such as sustenance, warmth or accommodation. Economic well-being tends to be the level of analysis best understood by engineering practitioners when considering choices for technological solutions.

3.7. Weighting of dimensions

The relative importance of these four contexts of *mauri* can be assessed independently by allocating a weighting bias before measurement of impact upon *mauri* is carried out. As an example, the *Mauri* Model was adopted by the Combined Tāngata Whenua Forum (CTWF) to carry out a parallel assessment of technology options for a 50-year regional planning strategy called SmartGrowth.[27] The weightings adopted by the CTWF, by the consultant engineers involved and the potential 'middle ground' compromise are provided in Table 2. Note that the consulting engineers used a modified version of the Hellstrom model[28] for their sustainability analysis and their weightings have been derived from that analysis.

Other weightings are also possible and, provided the model user clearly identifies the rationale for a specific weighting set, the model ensures any bias applied is transparent. That is, the model user can determine the relative importance of the four well-being dimensions with various stakeholder groups before completing any engineering assessment or analysis.

3.8. *Mauri* assessment

The *Mauri* Model can be visualised as the Venn diagram shown in Fig. 2. The cultural, economic and social dimensions are shown as successive subsets of environmental well-being, which is consistent with the weightings and prioritisation determined by the indigenous perspective (CTWF).

An alternative visualisation of the *Mauri* Model is the *koru* (spiral) shown in Fig. 3. The *koru* was the original concept for the model; however, the nesting of dimensions in this representation is not as readily explained. The *koru* uses a similar hierarchy to that shown in Fig. 2 but with less distinct boundaries between dimensions. The blurring of dimensional boundaries better aligns the model with the holistic approach that is intrinsic to IK.

	CTWF	Consulting engineers	Compromise
Ecosystem (environmental)	40%	20%	30%
Hapū (cultural)	30%	10%	20%
Community (social)	20%	20%	20%
Whānau (economic)	10%	50%	30%

Table 2. *Mauri* (well-being) weightings adopted for the SmartGrowth project

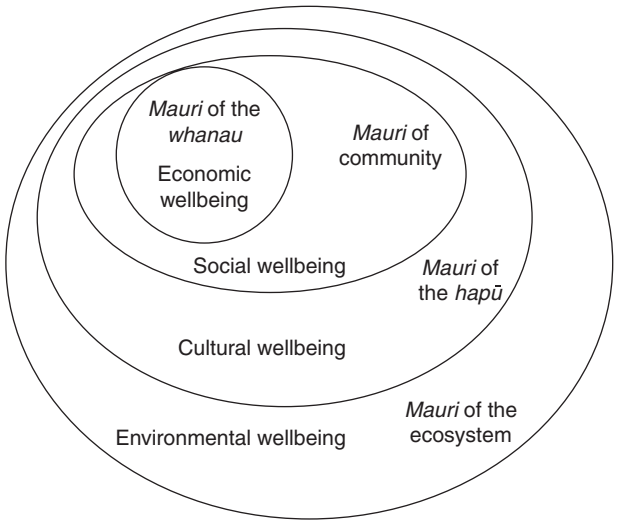

Fig. 2. Venn diagram representation of the *Mauri* Model (nested dimensions of well-being)

Sustainability assessment can now be carried out using the model, based on whether a technology is identified as enhancing, maintaining, neutral, diminishing or destroying the *mauri* of the dimension being considered. As *mauri* is an indicator of life force, how the *mauri* is affected is a direct indication of an option's long-term viability and sustainability. Five ratings have been defined for the *mauri* of each well-being dimension. For each dimension, the effect on *mauri* of a development, project or process option is given a rating from Fig. 4.

The rating for each dimension is multiplied by the predetermined weighting to give a final score resulting in an overall sustainability rating in the range −2 to +2. It should be noted that there are a wide range of metrics that determine the impacts on *mauri*. The metrics that should be used and their relative importance are determined and established, using the AHP, by the practitioner and stakeholders at the outset. The selection of metrics, their relative importance for the assessment of the cultural well-being dimension and the impact upon the *mauri*

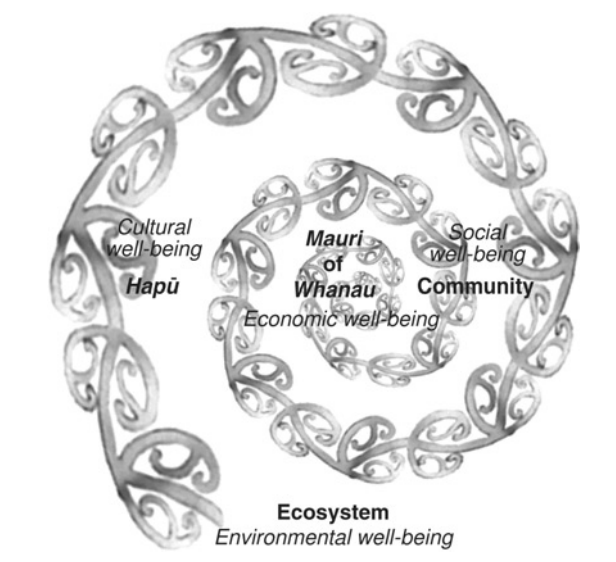

Fig. 3. *Koru* representation of the *Mauri* Model as a series of inter-related dimensions of well-being

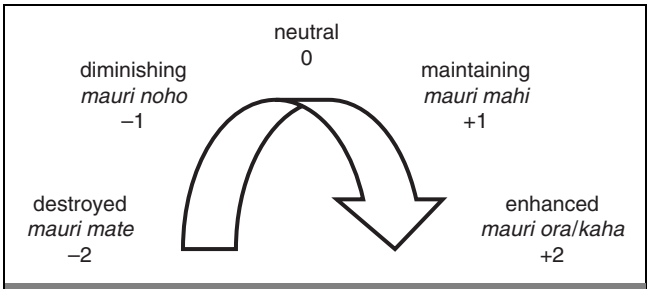

Fig. 4. Sustainability barometer for *mauri*

of the *hapū* should all be the sole prerogative of the *hapū* affected.

4. DISCUSSION

So what does the *Mauri* Model do that is different? The *Mauri* Model is an expert-weighted decision matrix that provides a culturally-based template within which indigenous values are explicitly empowered alongside 'western' thinking. The template facilitates several stages of deliberation in sustainability assessment

(*a*) determination of a heirarchy of dimensions (*whanau*, community, *hapū*, ecosystem) and their weights using *mauri* as the yardstick
(*b*) selection of significant indicators for each dimension that are organised into a sub-heirarchy and given relative weights
(*c*) analysis of potential options by measuring the impact upon *mauri* (barometer) for each indicator
(*d*) arithmetic combination of all indicators, proportionally weighted within each dimension
(*e*) arithmetic combination of all dimensions, proportionally weighted.

Both stages (*d*) and (*e*) can be carried out using computer spreadsheets in Microsoft Excel or higher level programming software. As the model can be used in parallel by groups with differing perspectives, each group's results can be readily compared and any divergence identified. The comparison then provides a framework for discussion and collaboration towards the most favourable option or, alternatively, the identification of appropriate mitigation measures.

Sahota and Jeffrey[29] provide a useful perspective on the realities of DST 'real world' application based on an evaluation of the drivers for and barriers to DST adoption. Their study identifies the importance of the decision-making context and the need to move beyond a purely technical orientation. They conclude that a holistic approach to the development of a newer breed of DSTs is necessary in the context of sustainability.

In this regard, the *Mauri* Model could be considered one of the newer breed. The economic, social, environmental and technical criteria used by Sahota and Jeffery would require to be supplemented in the NZ context with a strong sense of place. This strong sense of place is provided by the cultural well-being dimension in the *Mauri* Model based on the Maori understanding of the place and relevance of culture and importance to indigenous identity. A technical criterion group is not identified specifically in the *Mauri* Model, as technical considerations are typically accommodated within the economic well-being dimension as this is also an intellectual construct of society.

Kapelan *et al.*[30] developed a description of a perceived ideal DST. Their description identifies 14 criteria used to define strong and weak characteristics of DSTs. Progress with development of the *Mauri* Model is at an early stage compared with many of the DSTs considered, and the level of detail incorporated into the *Mauri* Model is not as sophisticated. Analysis of the *Mauri* Model measured against the 14 criteria was carried out to determine potential deficiencies. The analysis identified that eight of the 14 criteria were considered in the development of the *Mauri* Model. As the focus for the *Mauri* Model was to achieve higher level relationships that determine decision quality and defensibility, the criteria considered most relevant were those that determine whether the *Mauri* Model would be effective and inclusive. Effectiveness and inclusivity are essential to overcome historical barriers to participation in the NZ context, as the indigenous perspective is rarely integrated into decision-making.

Table 3 lists the eight common criteria identified as drivers here and by Kapelan *et al.*[30] Several of the other criteria were acknowledged in the *Mauri* Model development, but because these criteria are associated with the effectiveness of the DST, the need for this level of complexity was avoided at this early stage of development. It is interesting that Kapelan *et al.* identify the majority (5 out of 7) of these common criteria as their seven primary areas for further improvement in DSTs.

The actual value of the *Mauri* Model is yet to be fully demonstrated. The model was used by CTWF in the Smartgrowth project, and is currently being used by Ngati Pikiao practitioners (a tribal group with at least 18 000 descendants) involved in local government working parties, as well as both *hapū* in the

Characteristic	Kapelan *et al.*[30] criteria description	Identified for improvement
Inclusive transparent	support for group decision-making and communications	intuitive basis of model
Inclusive eco-centric transparent	risk/uncertainty modelling	systematic approach to risk and uncertainty
Indigenous legal relevance/holistic	sustainability criteria/indicators/impact assessment	provides framework for chains of linked interdisciplinary needs
Uses AHP	ranking and optimisation techniques	wider use of ranking between and across dimensions
Equitable user friendly	flexible spatial and temporal scales	not identified
Integrated holistic	level of integration	achieves high level of integration across dimensions
User friendly definitive	how easy/difficult is it to use the DST?	not identified

Table 3. The seven criteria identified as common for a DST for the NZ context and by Kapelan *et al.*[30]

greater Auckland region. Work to date suggests it will work in tandem with legislative requirements to better define the opportunity for indigenous (Maori) input during design and consultation. The DST does this by taking an indigenous concept (*mauri*) that is central to the indigenous paradigm and categorising the impacts on *mauri* in terms of legislative requirements. This approach allows enhanced identification of the priorities from an indigenous viewpoint and enhanced understanding from the practitioner's viewpoint.

In this regard, the power of the *Mauri* Model is similar to Geldof's concept of interactive implementation.[31] Both approaches require the cooperation of historically separated parties and achieve this through a shift in focus to values. This focus shift to values requires involvement and the commitment that comes with involvement builds trust. However, the parties have different preferences based on their differing values; to accommodate these differences and work together takes negotiation.

Geldof's discussion of coping with uncertainty is useful here. Fig. 5 shows the relationship between complexity and uncertainties to be accepted. Geldof suggests that in complex processes, coping with uncertainty such as sustainability analysis, it is best to set an appropriate level of uncertainty in order to achieve change. However, a situation between absolute certainty and chaos is necessary for manageable change to occur.

The analogy is made to the NZ context, in that the status quo is almost entirely reliant on a western scientific perspective while a total shift to the indigenous perspective would result in an unmanageable situation due to the majority's relative ignorance of the indigenous minority's perspective. The *Mauri* Model, while based on a concept from IK, is applied within a DST aligned to the existing sustainability framework conceived from a western scientific perspective. This creates a situation where the parties involved feel that uncertainties are manageable and there are enough opportunities to reduce uncertainties through further investigation. The situation at the apex of the parabola in Fig. 5 is most complex because here choices must be made. Choices

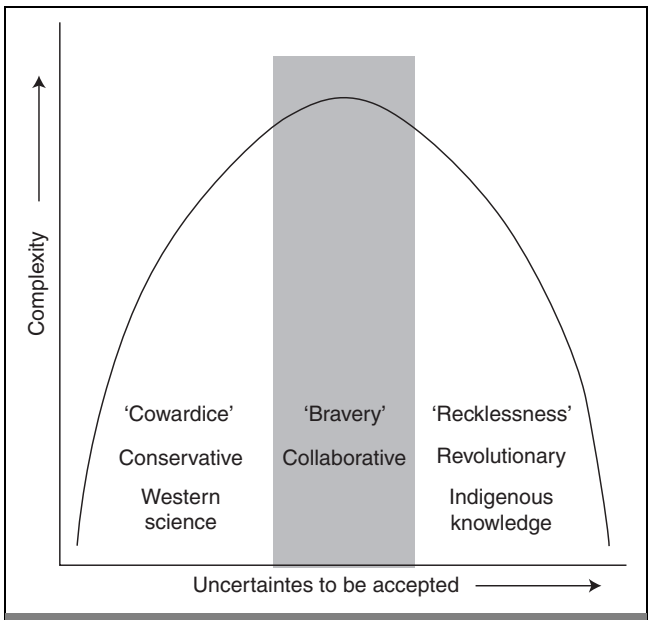

Fig. 5. Relationship between complexity and uncertainties to be accepted (after Geldof[31])

anchor the process and must be made to focus the effort, but not so much so that contact with the context is lost.

The *Mauri* Model as a DST has further advantages in that it also allows the indigenous paradigm to express the relationships between the dimensions that in the practitioner's engineering paradigm are treated as separate considerations that are not interdependent. The practitioner's analysis and credibility is further compromised when their cultural background has an influence on the ranking of the dimensions, which is subjective, and hence incorporates relative importance based on the practitioner's expertise and background. This phenomenon has already been identified in relation to water management, where water professionals struggle to gain acceptance for their preferences in a broader societal context. Geldof describes this as an attitude of rather doing something wrong and being certain about it than doing something that might actually be right. The *Mauri* Model avoids this by specifically identifying weightings at the outset, before options are ranked. At a more specific level the *Mauri* Model relates historic examples of indigenous values within the categories and thus provides an opportunity for vicarious understanding by the practitioner, with real examples the engineer can use as justification.

Sustainability and the achieved long-term enhancement of *mauri* are one and the same thing. The holistic context created within the traditional Maori paradigm elevates the importance of environmental, social and cultural well-being within the limits of sustainability above more narrowly focused economic realities. The capacity to present an alternative hierarchy of value that is reinforced in the cultural paradigm of traditional Maori thinking is a strength of the *Mauri* Model. The advantages of the *Mauri* Model over other approaches are that the process emphasises connections between levels, uses the concept of *mauri* as the binding force indicative of long-term sustainability, includes spiritual and physical aspects, and analogous western scientific definitions allow easy interpretation.

Ongoing evaluation by a range of end users (including *Tāngata Whenua*, consulting engineers, local government administrators and politicians) is allowing weightings to be determined for the different potential applications. Evaluation of the *Mauri* Model is currently being carried out for decision-making supporting effectiveness at the policy, feasibility, design, implementation and monitoring stages of solution development.

5. CONCLUSIONS

The cultural reality of the indigenous people of NZ reinforces the sustainability catchphrase 'think globally—act locally'. The guardianship ethic, essentially the maintenance of the *mauri* of all things, is based on the genealogy of creation, which links all things with humankind, providing the basis to think globally. Application of these guardianship rights is associated with a specific geographic relationship that reinforces the cultural identity of the hapū and requires local action. The use of *mauri* as the common yardstick simplifies the relationships between the dimensions of sustainability (*whanau*, community, *hapū*, ecosystem) and provides the basis for consistent prioritisation of well-being.

Indigenous knowledge is holistic in nature and it is this characteristic that reinforces the sustainability ethic. The Second

International Indigenous Peoples Forum on Climate Change[32] stated

> Our traditional knowledge on sustainable use, conservation and protection of our territories has allowed us to maintain our ecosystems in equilibrium. This role has been recognised at the Earth Summit and is and has been our contribution to the planet's economy and sustainability for future and present generations.

Based on the contribution that IK has made to the development of the *Mauri* Model, the indigenous peoples' perspective has further contributions to make in achieving sustainability, and IK continues to be of value in addressing this challenge.

Galileo proved Copernicus's theory of a heliocentric universe showing that the Earth did indeed revolve around the Sun.[33] This was the first work to outwardly challenge the established authority of religion, debunking the Ptolemaic ideal of the Earth as the centre of the universe. The concept of a heliocentric universe was developed solely from a scientific standpoint, breaking away from religious and cultural constraints. This allowed western science to freely explore the universe, leading to an unprecedented level of detailed knowledge and technological innovation. However, as a consequence, social, cultural, spiritual and environmental knowledge lost their relevance.

Thus, prior to the sixteenth century, the western world had a holistic view of nature as God's plan. That holistic worldview interconnected knowledge of the environment, the spiritual world and culture.[34] With Copernicus and Galileo came the reign of scientific thought with specialised branches of knowledge and, as each branch became separate from the others, the whole body of knowledge became fragmented. Present-day integration of the social, economic, environmental and cultural dimensions of sustainability is therefore a difficult goal for western scientific approaches that treat knowledge as compartmentalised, isolating or ignoring information that other knowledge systems would consider highly relevant and indeed essential for a truly holistic approach.

Newton followed the work of Galileo, introducing the concept of gravity to explain the forces of attraction between planets in the solar system. As a result western science was able to develop an understanding of the lunar influence on tides and plant growth. What remains to be seen is whether the introduction of the concept of *mauri* can provide the basis to better understand sustainability in a similar way?

The *Mauri* Model seeks to integrate the complex and interactive dimensions of social, economic, environmental and cultural well-being that define sustainability in NZ. While the *Mauri* Model requires further development and refinement to be sufficiently robust for broad application, the potential that is necessary to address sustainability challenges with a higher probability of acceptance in the NZ context has been identified. The *Mauri* Model therefore clarifies the complex and multi-faceted analysis necessary to achieve consistency with the holistic perspective demanded by the NZ context. Future potential applications of the model may occur in situations where the indigenous culture of a region is not that of the practitioner. In these situations the *Mauri* Model, in conjunction with an indigenous concept akin to *mauri*, may provide a process that empowers the perspective of indigenous people and provides enhanced understanding for all involved.

REFERENCES

1. Ashley R., Blackwood D., Butler D., Davies J., Jowitt P. and Smith H. Sustainable decision making for the UK water industry. *Proceedings of the Institution of Civil Engineers, Engineering Sustainability*, 2003, **156**, No. 1, 41–49.
2. New Zealand Government. *Sustainable Development for New Zealand. Programme of Action*. NZ Government Print, 2003, ISBN 0478-263260.
3. Forrester J. W. System dynamics and the lessons of 35 years. In *The Systemic Basis of Policy Making in the 1990s* (De Greene K. B. (ed.)), Massachusetts Institute of Technology, MA, 1991, pp. 5–6.
4. Maani K. E. and Cavana R. Y. *Systems Thinking and Modelling: Understanding Change and Complexity*. Prentice Hall, Auckland, 2000.
5. Morgan K. K. B. Kimihia katoa nga putake o te kaupapa . . . in the problem lies the answer. *Pacific Ecologist*, 2002, **4**, No. 4, 12–15.
6. Morgan K. K. B. Waiora, the waters of life. Whose water, whose life, whose identity? *Proceedings of Environment Summit*. New Zealand Water and Waste Association, Auckland, 2005.
7. Simonovic S. P. Assessment of water resources through system dynamics simulation: from global issues to regional solutions. *Proceedings of the 36th Hawaii International Conference on System Sciences, Hawaii*, 2002, 9 pp.
8. Love M. T. Maori issues and water—going into the future with a clear view of the past. In *Maori Issues and Engineering*. Institution of Professional Engineers, Wellington, 1990, pp. 4–6.
9. O'Brien P. J. The sweet potato: its origin and dispersal. *American Anthropologist: New Series*, 1972, **74**, No. 3, 342–365.
10. Durie M. *Nga Tai Matatu, Tides of Maori Endurance*. Oxford University Press, Melbourne, 2005, pp. 10–16.
11. Haami B. Te Rakautumuao: the tree of the universe. *Indigenous Knowledge and Western Science: Perspectives from the Pacific*. Lecture delivered at the University of Auckland, 2003.
12. Parliamentary Commissioner for the Environment. *Key Lessons from the History of Science and Technology: Knowns and Unknowns, Breakthroughs and Cautions*. Government Print, 2001.
13. Parliamentary Commissioner for the Environment. *He rangahau kit e aria ko te Tiriti te uptake e whakatuturutia ai nga tikanga mo te taiao: Exploring the Concept of a Treaty Based Environmental Audit Framework*. Government Print, 2002.
14. O'Riordan T. The new environmentalism and sustainable development. *The Science of Total Environment*, 1991. Cited in Bosselmann K. The concept of sustainable development. *Environmental Law for a Sustainable Society: New Zealand Centre for Environmental Law Monograph Series*, Volume 1.
15. Forrester J. W. System dynamics and the lessons of 35 years. In *The Systemic Basis of Policy Making in the 1990s* (De Greene K. B. (ed.)), Massachusetts Institute of Technology, MA, 1991, pp. 20–21.
16. Morgan T. K. K. B. A *Tāngata Whenua* perspective on sustainability using the *Mauri* Model. *Proceedings of the 1st NZ Society of Science and Engineering Sustainability Conference, Auckland*, 2004, CD-ROM, abstract 36.

17. Marsden M. God, man and universe: a Maori view. In *Te AoHurihuri* (King M. (ed.)). Reed, Auckland, 1975, pp. 196–197.
18. Durie M. *Te Mana, Te Kawanatanga, The Politics of Maori Self-Determination*. Oxford University Press, Auckland, 1998, ch. 2, pp. 23–24.
19. Marsden M. The natural world and natural resources: Maori value systems and perspectives. In *The Woven Universe* (Royal C. (ed.)). The Estate of Rev. Maori Marsden, Masterton, 2003.
20. Marsden M. A. and Henare T. A. Kaitiakitanga: a definitive introduction to the holistic world view of the *Maori*. The Estate of Rev. Maori Marsden, Masterton, 2003.
21. Barlow C. *Tikanga Whakaaro: Key Concepts in Maori Culture*. Oxford University Press, Auckland, 1991.
22. Tunks A. One indigenous vision for sustainable development Law? Tensions and prospects. *Environmental Law for a Sustainable Society: New Zealand Centre for Environmental Law Monograph Series*, Volume 1, 2002.
23. IUCN, UNEP, WWF. *Caring for the Earth: A Strategy for Sustainable Living*, 1991.
24. Bosselmann K. The concept of sustainable development. *Environmental Law for a Sustainable Society: New Zealand Centre for Environmental Law Monograph Series*, Volume 1, 2002.
25. Saaty T. L. *Analytical Heirarchy Process: Planning, Priority Setting, Resource Allocation*. McGraw-Hill, New York, 1980.
26. United Nations Commission on Environment and Development. *Agenda 21*. UN, Paris, 1992.
27. Morgan T. K. K. B. *The Sustainable Evaluation of the Provision of Urban Infrastructure Alternatives using the Tāngata Whenua Mauri Model within the SmartGrowth Sub-region*. Mahi Maioro Professionals, Engineering Consultancy Report, 2003.
28. Hellstrom D. J. and Karrman U. *A Framework for Systems Analysis of Sustainable Urban Water Management*. Environmental Impact Assessment Review 20, 2000.
29. Sahota P. S. and Jeffrey P. Decision-support tools: moving beyond a technical orientation. *Proceedings of the Institution of Civil Engineers, Engineering Sustainability*, 2005, **158**, No. 3, 127–134.
30. Kapelan *et al.* (2005) Decision-support tools for sustainable urban development. *Proceedings of the Institution of Civil Engineers, Engineering Sustainability*, 2005, **158**, No. 3, 135–142.
31. Geldof G. D. Coping with complexity in integrated water management. In *On the Road to Interactive Implementation*. Tauw, Deventer, 2005.
32. Second International Indigenous Peoples Forum on Climate Change. *Final Report*. The Hague, 2000.
33. Galileo G. *Dialogues Concerning Two New Sciences*. Running Press, Philadelphia, 2005.
34. Roberts M. Indigenous knowledge and western science: perspectives from the Pacific. In *Science, Technology, Education, Ethnicity: An Aotearoa/New Zealand Perspective*. The Royal Society of New Zealand, Wellington, 1998, pp. 59–75.