The Influence Matrix Methodology: a technical report

Anthony Cole

Landcare Research
Private Bag 11052, Palmerston North
New Zealand

Landcare Research Contract Report: LC0506/175

PREPARED FOR:
Foundation for Research, Science and Technology (FRST)

DATE: July 2006

ISO 14001

Reviewed by:	*Approved for release by:*
Andrew Fenemor Scientist Landcare Research	Bob Frame Science Leader Sustainability and Society

Contents

List of tables and figures

Summary

This report provides a full documentation of technical and theoretical developments that have emerged from the use of an influence matrix as a participatory modelling tool at catchment scale in New Zealand. The participatory modelling trial involved a group of researchers and community members in the Motueka Catchment of New Zealand. This Motueka Community Reference Group (CRG) – a stakeholder group in the Motueka Integrated Catchment Management (ICM) research programme[1] – trialled both the development of an influence matrix[2] and a participatory process designed to build and interpret the matrix.

The influence matrix was applied to the task of calculating whole-of-system sustainability values used: (i) as a qualitative pre-cursor to quantitative system dynamic modelling; (ii) for identifying those highly influential critical, active, passive and buffering factors that constitute the governing dynamics of this Catchment system; and (iii) as a contribution towards both research design and resource management plan and policy development. The challenge of achieving whole-of-system sustainability must include consideration of ecosystem services. The influence matrix developed and evaluated using the methods outlined in this report was not intentionally framed by researchers from an ecosystem services view of the world, but provides a number of important insights in this area.

This report provides the theoretical basis for this joint problem solving method and describes in stepwise manner the methods used in its construction and evaluation. The reason for producing this separate technical report is to ensure these developments have been fully documented. Because of the amount of technical and theoretical background, that detail was not included in the partner report (Cole et al., 2006) that documented: (a) the methodology and logic of the matrix calculations to identify and prioritise four fundamental classes of influence factors: critical, active, buffer and passive factors; (b) the participatory model, strengths, weaknesses and repeatability; and (c) commented on how the results could be applied in a practical planning context, for example, by territorial or regional councils.

The exploratory ideas presented here were first presented for peer review to a gathering of international researchers in the area of ecosystem services research at a conference symposium on *Theory and Practice in the Study of Ecosystem Services.* This special session was organised by Dr Steven Cork of CSIRO Sustainable Ecosystem in Canberra as part of the Ecological Society of Australia 'Ecology 2002 Conference' in Cairns, Australia, 2–6 December 2002. The production of this report documents the contents of this presentation and the refinements to it that emerged in response to questions and ideas put forward by conference participants.

[1] http://icm.landcareresearch.co.nz/

[2] The influence matrix methodology referred to in this paper has emerged from initial research in the development of cross impact matrix forecasting (Gordon & Hayward, 1968). This initial research was then further developed by Godet (1979) and Vester and von Hesler (1982) who both use the term impact matrix. However, Vester as early as 1976 introduced the term 'paper-computer' and later 'influence matrix' (Vester, 2004) while numerous applications of this method are published under the names such as impact matrix, networked thinking method (Fried & Volker, 2005); and sensitivity model (Ulrich, 2005). Quite separately, the name influence matrix is also used in statistics as a diagnostic tool for regression and other statistical inference (Ko & Chang, 1997). This diversity of names and meanings is confusing. In the remainder of this paper we consistently use the name influence matrix (influence matrix) to designate our use of the impact matrix in a way that extends earlier work by Vester and von Hesler (1982).

1. Introduction

The influence matrix is a mathematical modelling tool generally used to analyse complex problems and provide insights into complex system structure, function and behaviour. Despite its mathematical and scientific origins this tool has been effectively used in numerous international participatory modelling studies to mediate group dialogue processes. In 2003, as a part of the Motueka Integrated Catchment Management research programme[3], the influence matrix was trailed as a participatory modelling tool. The results of this study were published in a co-authored report that provided a brief outline of the influence matrix method, the participatory process and its evaluation (Cole et al., 2006). However, a number of important theoretical insights and methodological refinements developed during the course of this study were not included in this earlier report.

This present report provides a full technical documentation of the influence matrix methodology, its theoretical underpinning, and previous applications. The reason for producing an additional technical report is to ensure important technical and theoretical developments associated with the application of the influence matrix in the Motueka Integrated Catchment Management research programme have been fully documented as a basis for future research and development of this important methodology. To achieve this aim, the remainder of this report is divided into two main parts. First, the remainder of this introduction section provides a historical account of the theoretical development of the influence matrix methodology and its application in this New Zealand based Catchment research context to assist in the calculation of what we have called sustainability values. Second, the methodology section of this report provides a step by step account of: (i) the routine analytical methods associated with the construction and evaluation of an influence matrix; (ii) mathematical refinements made to the standard evaluation techniques; and (iii) the development of new evaluation techniques.

1.1 Theoretical underpinning

The influence matrix emerged from research in the area of cross impact analysis that attempted to extend and address weaknesses in the forecasting techniques of the Delphi method developed by the RAND Corporation at the beginning of the Cold War.

At UCLA in 1968, Gordon and Hayward published their computer-based approach to cross-impact analysis in the first volume of the Futures journal (Gordon & Hayward, 1968). Their method employed an orthogonal matrix and at each row/column intersection asked the question, if the event in the row was to occur, how would it affect the probability of occurrence of the event in the column? The scoring strategy involved a quite complicated set of symbols that were coded to indicate: (i) influence strength (scale 1–10); (ii) inhibition or enhancement (-ve or +ve sign); and (iii) predecessor status (0=immaterial, 1=likely, 2=necessary). The matrix was mathematically evaluated to produce a ranking of factors based on the conditional probability of other events occurring or not occurring. In connection with this paper, two further developments emerged from this initial research.

[3] http://icm.landcareresearch.co.nz/

In 1979 Godet published a book on the crisis in forecasting in which he attempted to correct short comings in the cross impact matrix methodology through the development of MICMAC (Godet, 1979). The initial impact matrix developed by Gordon and Hayward (1968) and later simplified by Frederic Vester (1976) was only capable of measuring the direct[4] effects of one system factor on another. Godet attempted to address the indirect impacts problem by (i) a modified scoring strategy based on 0, 1 (0=no impact, 1=impact) and (ii) by raising the power of the matrix. New impact matrices are added as required until appropriate coverage of indirect affects is obtained, with each new matrix contributing towards the active sum used as a measure of total system-wide influence. The MICMAC solution algorithm is continued until there is a stable order of the impact factors, although recent research now suggests this objective function is unlikely to be universally applicable to every system (Fried & Volker, 2005).

The Networked Thinking methodology of Vester and von Hesler (1982) also made a number of modifications (Vester & Hesler, 1982) to the initial cross impact matrix methodology of Gordon and Hayward (1968). First, they developed a simplified scoring strategy that quantified influence or impact on a scale of 0, 1, 2, and 3 (no impact, weak impact, medium impact and strong impact). Second, a simplified scoring strategy then implied changes to the solution algorithm. Both the MICMAC and Networked Thinking approaches attempt to quantify the system wide importance of each factor. In the Networked Thinking approach this was achieved by ranking active[5] and passive[6] sums as Gordon and Hayward had attempted to do with their probability indices. Third, in addition to this Vester and von Hesler mathematically combined these indices as a basis for developing a functional factor typology (Figure 1) that characterises each factor in terms of its downstream and upstream system-wide influences.

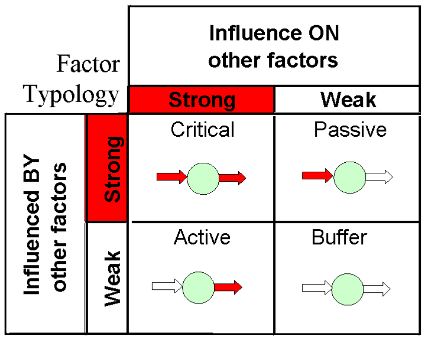


Figure 1 *Influence matrix factor typology*

Although mathematically simple and elegant, the algorithm on which the factor typology is based is not powerful enough to discriminate completely between active/critical and passive/buffer functional types in the case of those factors that have intermediate active and passive sums (Brenner, 1999). However, this is not a necessity as it is also possible to use the product and quotient of the active and passive sum to define a continuous typology classification rather than distinctive typological groupings (Schlange, 1995; Vester, 2002).

---

[4] An indirect impact is the influence of one system factor upon another even if there is no direct effect.
[5] The total sum of all row influences for a given factor which provides a measurement of the relative influence that factor has on all other system factors.
[6] The total sum of all column influence for a given factor provides a measure of the extent to which that factor is influenced by all other factors.

In the years following the initial publication of Vester and von Hesler (1982), Vester in particular continued to develop and refine the theoretical underpinning and application of the Networked Thinking approach (Vester, 2004; Vester & Guntrum, 1993; Vester, 1988), while the method itself was applied in a diversity of research contexts including: cost benefit analysis (Wenzel & Igenbergs, 2001), risk analysis (Swiss Federal Office of Civil Defence, 1995), the integration of transport and urban form (Transformes, 2002), improving slash and burn agricultural practices (Messerli, 2000), the management of ecological reserves (Iron Curtain Consortium, 2004), environmentally sustainable transport (Environment Directorate (OECD), 2000), regional landuse modelling (Walz, 2006), and planning sustainable settlements (Coplak & Raksanyi, 2003) and city regions (Wiek & Binder, 2005; Vester, 1976).

1.2 Calculation of sustainability values

Frederic Vester's himself clearly viewed the influence or impact matrix, as a preliminary step (Vester, 2004; Ulrich, 2005) towards system dynamic modelling because it helped to focus attention *and limited research resources* on those critical, active, passive and buffer factors that wield the greatest governing influence over the system. If we are not explicitly including and modelling these broader governing influences in our system dynamics models of sustainability then it must follow that the first requisite for achieving sustainable futures cannot be upheld.

The influence matrix can make an important contribution towards the goal of achieving sustainable futures. Having established the existence of a collectively held sustainability goal, it is important that we have some way of measuring the value of different system factors in making progress toward that goal. System values are clearly context dependent. If we choose the factors for building an influence matrix with the future goal of sustainability in mind then the analytic power of the influence matrix provides a way of calculating sustainability-values.

There is a slight semantic point of clarification needed here. Our use of the term "sustainability-value" is not an attempt to view the *concept of sustainability* from the perspective of theories of value. Our use of the technical term "sustainability-value" refers to those factors of a complex social system that have a relatively large system-wide influence in terms of achieving the goal of sustainability in the context in which it is defined. Hence, we use the term sustainability-value in a much broader sense than implying a focus on just ecological sustainability, which Costanza and Folke (1997) have attempted to do. However, we maintain the ecosystem services focus of Costanza and Folke (1997) in our application of the influence matrix methodology. This simply involves framing the system being studied (a catchment) and the model being developed (an influence matrix) from an ecosystem services view of the world. This framework is explained more fully later in the methodology sections of this report.

In the influence matrix methodology, the active sum, passive sum and critical, active, passive and buffer factors provide us with a range of sustainability values that define the upstream, downstream and total influence that each system factor *contributes* to the entire system. As such, the use of these influence matrix indices as a proxy for sustainability value may be considered as the articulation of a whole-of-system contributory theory of sustainability-value. A useful feature of the influence matrix is that it provides a means of whole-of-system depiction based on a qualitative metric (system-wide influence) that avoids the theoretical and methodological equivalence problems associated with trying to measure and model whole-of-system factors using mixed units (Costanza & Hannon, 1989).

Furthermore, there seems no obvious mathematical reason why the analytic power of the influence matrix solution algorithm could not be extended and applied quantitatively to the economic, biophysical and social accounting matrices routinely used by ecological economists. The main limitation of this approach would be that none of these quantitative models constitutes a whole-of-system depiction. However, there are times when it is appropriate to focus on parts of the whole system, and here the analytic power of the influence matrix maybe advantageous. The remainder of the report provides an outline of the technical steps associated with (i) the construction of an influence matrix in a participatory research context, and (ii) its evaluation in a manner that provides deeper insight into whole-of-system function and the aim of sustaining ecosystem services.

2. Methodology

The method used in building an influence model is generally designed based on the size of the problem being explored. Influence matrix size is determined by the number of system factors selected and this in turn determines the amount of work involved in constructing an influence matrix. The Motueka CRG members involved in this project found that an influence matrix of 28 rows by 28 columns (784 cells) took about 3–3.5 hours to score. Their choice of 28 factors came as a result of aggregating a much larger group of 171 factors. Aggregation is one simple way of reducing the number of factors chosen to a more manageable number. The four main steps involved in building an influence matrix are outlined in Figure 1. This process is portrayed as cyclical because the completion of an influence matrix model itself opens new opportunities for further inquiry using the same tool. The above four steps are briefly outlined below to provide a methodological context for closer evaluation of the technical steps used to build and evaluate an influence matrix later in this method section. Cole et al. (2006) provide a more detailed outline and evaluation of how these four main steps were adapted for use in a participatory process in the Motueka case study.

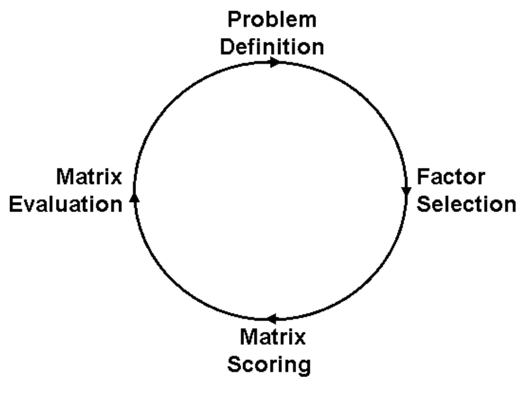


Figure 2 *The influence matrix development cycle*

Defining the problem – the community reference group was given the opportunity to define the research problem related to the needs of their local Catchment community. This was achieved with the use of an introductory sentence aimed at focusing the ideas of group members on the long-term management outcomes they would like to see in their Catchment:

The residents of the Motueka Catchment want to manage their Catchment so as to ensure that they continue to enjoy…

The introductory sentence was completed with the aid of contributions from participating group members obtained during a brainstorming session in which ideas were written on a whiteboard. Some refinements were necessary to this participatory method. Then the various ideas and issues raised during the brainstorming session were collectively re-worded and organised into a goal statement.

Choosing influence factors – a goal statement helps guide the selection of influence model factors thought to be related in some way to the achievement of preferred goals. After two brainstorming sessions the group identified 171 factors. An influence matrix comprised of 171 factors would contain 29 241 cells. A matrix of this size would take a very long time to score[7]. To overcome this problem, the 171 factors were aggregated to a set of 28 key factors (Appendix 1).

It is possible to disaggregate an influence matrix, if necessary, by inserting additional columns and rows into an existing influence matrix. Once extra factors have been inserted into an existing model it is necessary to score the new columns and rows. Once this is done, the matrix needs to be re-evaluated. The ability to aggregate and disaggregate an influence matrix provides a lot of scope for adjusting a table without having to build it again from the beginning. A computer spreadsheet is a good tool for building, adjusting and evaluating influence matrix models.

Scoring the influence matrix – the influence matrix contains numbers that represent a qualitative assessment of the strength of the influence that exists between a given factor and every other factor in the matrix. System-wide influence is estimated qualitatively using the score strategy shown in Table 1. A scoring strategy of 0–5 provides (i) a score of zero for no influence, (ii) low, average and high influence scores. and (iii) the option to score either side of and average system influence of 3 (Table 1).

Table 1 *Scoring strategy*

No influence	0
Has an influence but its only weak	1
The influence is stronger than 1 but less than 3	2
Has an average sized influence	3
The influence is stronger than 3 but less than 4	4
Has a strong influence	5

As a time-saving measure the influence matrix was primarily scored by individuals producing their own fully scored matrix. These individual matrices were then combined mathematically

[7] From experience we have estimated that it takes approximately 40–60 hours to work through an influence table containing 10 000 cells.

to produce an average matrix. Participatory approaches to scoring an influence matrix were also tried but found to be very time consuming.

Evaluation – the evaluation of the influence matrix typically involves (i) the calculation of influence indices, (ii) the sorting of system factors based on influence scores or indices, and (iii) the determination of a factor typology. These various lines of information can be used to produce a system dynamics model and also form the empirical basis of what was referred to earlier in this report as sustainability values. In addition to these more routine analytical methods developed and used by Vester and von Hesler (1982), this report explores (a) the use of visual colour coding of influence matrix scores as a means of evaluation of patterns in the influence Matrix, (b) the evaluation of group influence scores, and (c) some mathematical refinements to the earlier method developed by Vester and von Hesler (1982). The remainder of this report provides an outline of each of the evaluation methods mentioned above.

2.1 Calculation of influence indices

In building on the mathematical methodology of Vester (1976) and Vester and von Hesler (1982) we have not attempted to differentiate between direct and indirect factors as Godet (1979) and others have done.

An influence matrix is a square matrix with identical factors in the same rank order in rows and columns. The matrix is constructed by using a scoring strategy to quantify the strength of influence of row factors on individual column factors on an element by element scoring basis. It is possible to rank the row and column factors using row (1) and column (2) sum scores as derived below. By contrast the factor typology is produced by mathematically combining the row and column sum scores to produce multiplier (5) and quotient scores (4).

Assume that we have an influence matrix (M_{ij}) of dimensions 15 rows by 15 columns. To evaluate this matrix we sum the rows (i) and columns (j) of the influence matrix to calculate the row (active) (1) and column (passive) sums (2).

Row (or active) sum (RS) = $\sum_{i=1}^{i=15} M_{ij}$ (1)

Column (or passive) sum (CS) = $\sum_{j=1}^{j=15} M_{ij}$ (2)

As a refinement of the solution method of Vester (1976), the factor typology is calculated using three lines of numerical information. First, we calculate the absolute numerical difference (AND) between the RS and CS scores for each factor. This additional step is not included in the method of Vester (1976, 2002) or Vester and von Hesler (1982) who have concentrated on interpreting a factor typology continuum rather than being concerned with factor typology groupings. Both these approaches have their merits. We place more importance on grouping to decide on functional character as a basis for system dynamic modelling. The *AND* score helps discriminate between buffer/critical and passive/active factors with intermediate passive and active sum scores.

Absolute Numerical Difference (AND) = $RS - CS$ (3)

For a particular factor, if AND is close to zero, the functional character of that factor tends towards critical or buffer. In contrast, a higher AND score indicates the functional character of that factor tends towards passive or active (Appendix 3).

The quotient score is used to identify whether a particular factor is active or passive:

Quotient Score (QS) = AS / PS (4)

High quotient scores (i.e. where the row sum is much larger than the column sum for that factor) indicate active functional character, meaning a strong influence on other factors. A low quotient score indicates passive functional character in which the factor is relatively more strongly influenced by other factors compared with the strength of its influence on other factors. Factors with intermediate quotient scores will tend to be more critical or buffering in functional character.

The multiplier score is used to identify whether a factor is critical or buffer:

Multiplier Score (MS) = $AS \times PS$ (5)

High multiplier scores indicate critical functional character, meaning a strong influence on other factors and strongly influenced by other factors. Low multiplier scores indicate buffering functional character in which the factor is weakly influenced by other factors and has a weak influence on other factors. Factors with intermediate multiplier scores will tend to be more passive and active in functional character. In both cases, we use the AND score to decide borderline cases.

2.2 Ranking factors based on influence indices

The row (active) (1) and column (passive) sums (2) mathematically defined above also have conceptual meaning. The active sum is a measure of the influence of an individual factor on other factors in the matrix or model system (Figure 2).

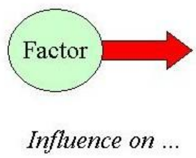
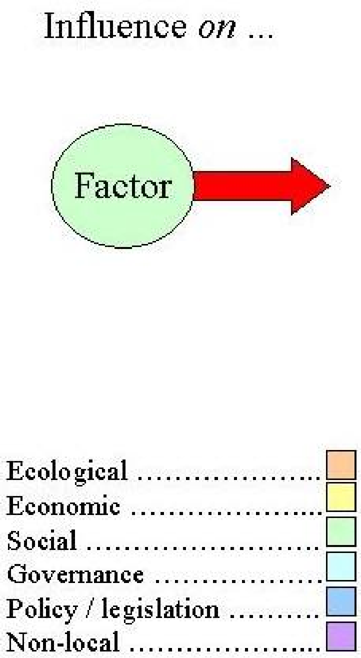


Figure 3 *The active sum and its influence on other factors*

It is possible to rank all the factors according to their active sum scores. This provides a measurement of the extent to which each factor is able to influence all other system factors (Table 2). Colour coding helps us visually assess Table 2 for the clustering of common factors. A quick visual assessment of Table 2 indicates the main clustering of factors are those ecological/science factors (brown) in the centre of the Table (maintain soil health, maintain biodiversity, scientific research and maintain the integrity of ecological processes). There is also a clustering of economic factors (yellow) with lower influence scores at the top of Table 2. It is interesting to note that those factors with higher influence scores include representative factors from the six main factor groupings (ecological, economic, social, institutional, regulatory and non-local). No one grouping holds a monopoly on active influence in the Catchment.

Table 2 *The 28 key factors ranked by active sum (AS) scores*



	Influence
Customary Use	43
Landscape Change Processes	54
Tertiary Sector	55
Natural Assimilation & Purification	56
Community Services	56
Property Valuation	57
Income Tax & GST	57
Labour Market	59
Human Health	60
Pest Management	61
Tourism, Leisure, Recreation, Sport	62
Economic Drivers	63
Participation in Economic Life	64
Family & Community Wellbeing	65
Maintain Soil Health	65
Maintain Biodiversity	66
Scientific Research	67
Maintain Integrity of Ecological Processes	68
Secondary Industry	71
Population Dynamics	72
Climate & Atmosphere	73
Public Life - Governance	73
Non-Local Influences	73
Water Quality & Supply	75
Economic Inputs	75
Governance of Social Institutions	82
Policy, plans, rules, legislation	83
Primary Industries	85

It is not surprising to find that primary industries have the greatest influence on other factors in the Catchment, especially given that the Catchment is organised around horticulture, agriculture and forestry activities. It would be interesting to disaggregate this single factor and build another influence matrix to be able to see which primary industries or industry have the highest influence in the Catchment. It is also interesting to note that *water quality and supply* and *climate and atmosphere* are included with the factors that have higher active influences in the Catchment as these are both factors of current concern in the Catchment. It would be interesting to compare this ranking of factors with an assessment of current policy priorities for the local regional authority[8].

The passive sum is a measure of how much an individual factor is influenced *by* all factors in the matrix or model system (Figure 3).

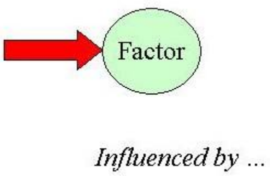


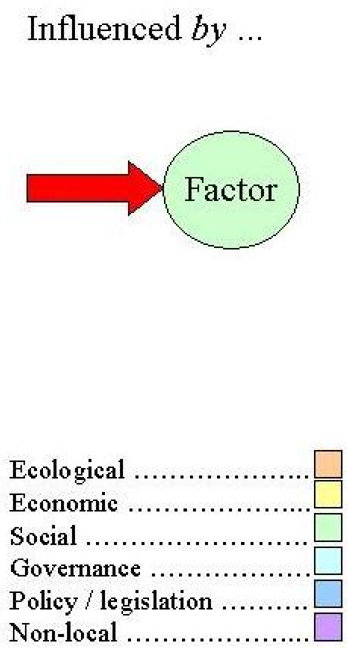
Figure 4 *The passive sum showing influence by other factors*

It is possible to rank all the factors according to their passive sum scores. This provides a measurement of the relative extent to which each factor is influenced by other system factors (Table 3). Colour coding helps us visually assess Table 3 for the clustering of common factors. A quick visual assessment of Table 3 indicates the main clustering of factors are those ecological/science factors (brown) at the top of Table 3 and a clustering of economic and social factors in the lower part of Table 3. This indicates ecological factors overall are

[8] Tasman District Council

less sensitive to change in other parts of the Catchment system than economic and social factors. Table 3 shows economic and social factors tend to hold a monopoly on backward (or passive) influence in the Catchment. This point can be more clearly seen in the group passive scores of Table 4.

Table 3 *The 28 key factors ranked by passive sum (PS) scores*



	Influence
Climate & Atmosphere	48.71
Customary Use	50.00
Natural Assimilation & Purification	51.57
Non-Local Influences	51.86
Economic Drivers	57.43
Landscape Change Processes	57.57
Pest Management	58.14
Public Life - Governance	58.29
Governance of Social Institutions	59.43
Income Tax & GST	59.57
Scientific Research	62.86
Maintain Soil Health	64.00
Maintain Integrity of Ecological Processes	65.14
Labour Market	67.00
Participation in Economic Life	67.00
Economic Inputs	67.14
Community Services	67.14
Maintain Biodiversity	67.71
Tertiary Sector	68.86
Population Dynamics	69.14
Tourism, Leisure, Recreation, Sport	71.00
Property Valuation	71.86
Water Quality & Supply	74.43
Human Health	77.86
Secondary Industry	78.00
Policy, plans, rules, legislation	79.00
Family & Community Wellbeing	79.86
Primary Industries	88.00

Influence indices can also provide insight into the role of group factor influence in the Catchment. Column 1 of Table 4 provides a list of the factor groups. Column 2 of Table 4 gives the total influence score for each factor grouping. This score represents the extent to which each factor group is influenced by all of the other factors in the Catchment. In column 3 of Table 4 the factor group scores are converted into percentages of the total system-wide influence accounted for in the influence matrix (GS%). However, interpretation of these scores needs to account for any bias introduced by the number of factors in a particular group. To overcome this bias problem each group factor score is divided by the number of factors in that group (column 4) and converted into a percentage weighted score (column 5). By comparing the GS% scores in columns 3 and the Wtd% scores in column 5 it is possible to see how weighting has helped normalise the group scores.

Table 4 *Passive scores by factor grouping*

Factor group	Group Score	GS%	Weighted	Wtd%
Ecological	349.14	21	43.6	12
Social	490.29	30	70.0	19
Economic	607.86	37	67.5	18
Governance	59.43	4	59.4	16
Policy/Legislation	79.00	5	79.0	21
Non-local	51.86	3	51.9	14
Total	1637.57	100.0	371.5	100.0

Of the first 3 factor groups listed in Table 4, the social group of factors are most strongly influenced by other groups of factors with a weighted group score of 70 representing 19% of the total system-wide backward weighted influence. Only 1% of the total system-wide backward weighted influence score separates social and economic group factors. Ecological group factors have a lower weighted group score of 43.5 representing 12% of the total backward weighted influence.

Table 4 also indicates that the last 3 factors listed in rows 4–6 (governance, policy/legislation and non-local influences) account for a combined weighted group score of 190.3, representing 51% of the system-wide backward weighted influence. Policy/legislation receive the strongest weighted backward influence. The backward influence score for Policy/legislation represents an informational flow. Given its high score, it would be interesting to know if the Reference Group Members consider this aggregated factor to be responsive to current local community needs.

The relative distribution of group influence helps us to get a sense of the relative importance of different groups of factors to the overall functioning of the system. Weighting the factor group scores helps to normalise the high or low influence of individual factors. For example, rankings of the individual factors (Tables 2 and 3) consistently showed that primary industries had the strongest forward and backward system-wide influence. This could lead to the conclusion that the economic group of factors will have the strongest system-wide influence; however, Table 5 shows this is not the case. The results of Tables 2 and 3 would seem to indicate individual factors influence changes *as a function of organisational scale* (high individual influence scores does not necessarily mean high group scores).

Table 5 contains a list of the main factor groupings sorted according to group active sum scores. From these results it is possible to see that governance and policy/legislation currently exert the largest weighted system-wide influence on all other factors in the Catchment accounting for 38% of total weighted influence. Surprisingly, the ecological group of factors have a higher weighted group score and weighted percentage score than social and economic factor groups.

Table 5 *Active scores by factor grouping*

Factor group	Group Score	GS%	Weighted	Wtd%
Ecological	583	32	73	17
Social	452	25	65	15
Economic	565	31	63	14
Governance	82	4	82	19
Policy/Legislation	83	5	83	19
Non-local	73	4	73	17
Total	1839	100	438	100

Despite the high score for the ecological group of factors, governance, policy/legislation and non-local influences also have high scores that, combined, account for 55% or more than half of the weighted system-wide influence. This suggests that for all that can be done to manage ecological and economic dimensions of the Catchment, non-local drivers, institutional arrangements (including political processes), policy and legislation effectively require an equal level of consideration. The importance of this perception/hypothesis should not be missed as it highlights the system-wide importance of the institutional/political/legal dimension in addressing future management goals.

2.3 The determination of a factor typology

In addition to the calculation of indices which characterise each factor in terms of its downstream and upstream system-wide influences, Vester and von Hesler mathematically combined these indices as a basis for developing a functional factor typology (Figure 1). If asked directly, most stakeholders would not be able to identify factors in their catchment or local community according to differing function roles. This is because the average person does not have the mental ability to evaluate complex influence interactions of the type portrayed in the influence matrix. The influence matrix provides a solution to this problem. From the row and column scores of the influence matrix it is possible calculate the functional roles of different factors based on the relative size of forward and backward influences (Table 6).

Table 6 *Influence indices used to determine functional character*

Factors	**Type**	**RS**	**CS**	*AND*	**Quotient**	**Multiplier**
Climate & Atmosphere	Active	73	49	24	1.49	3577
Non-local Influences	Active	73	52	21	1.40	3796
Governance of Social	Active	82	59	23	1.39	4838
Public Life – Governance	Active	73	58	15	1.26	4234
Scientific Research	Active	73	63	10	1.16	4599
Economic Drivers	Active	63	57	6	1.11	3591

Factors	**Type**	**RS**	**CS**	*AND*	**Multiplier**	**Quotient**
Pest Management	Buffer	61	58	3	3538	1.05
Income Tax & GST	Buffer	57	60	3	3420	0.95
Landscape Change Processes	Buffer	54	58	4	3132	0.93
Natural Assimilation &	Buffer	56	52	4	2912	1.08

Factors	**Type**	**RS**	**CS**	*AND*	**Multiplier**	**Quotient**
Primary Industries	Critical	85	88	3	7480	0.97
Policy, plans, rules, legislation	Critical	83	79	4	6557	1.05
Water Quality & Supply	Critical	75	74	1	5550	1.01
Secondary Industry	Critical	71	78	7	5538	0.91
Economic Inputs	Critical	75	67	8	5025	1.12
Population Dynamics	Critical	72	69	3	4968	1.04
Maintain Biodiversity	Critical	66	68	2	4488	0.97
Maintain Integrity of	Critical	68	65	3	4420	1.05
Participation in Economic Life	Critical	64	67	3	4288	0.96
Maintain Soil Health	Critical	65	64	1	4160	1.02

Factors	**Type**	**RS**	**CS**	*AND*	**Quotient**	**Multiplier**
Human Health	Passive	60	78	18	0.77	4680
Property Valuation	Passive	57	72	15	0.79	4104
Tertiary Sector	Passive	55	69	14	0.80	3795
Family & Community	Passive	65	80	15	0.81	5200
Community Services	Passive	56	67	11	0.84	3752
Labour Market	Passive	57	67	10	0.85	3819
Tourism, Leisure, Recreation,	Passive	62	71	9	0.87	4402
Customary Use	Passive	43	50	7	0.86	2150

Although mathematically simple and elegant, the algorithm on which the factor typology is based is not powerful enough to discriminate completely between active/critical and passive/buffer functional types in the case of those factors that have intermediate active and passive sums (Brenner, 1999). One solution to this problem is to use the product and quotient of the active and passive sum to define a continuous typology classification rather than distinctive typological groupings (Schlange, 1995; Vester, 2002). However, it is not always desirable to clump and group factors together. An alternative way of addressing this problem was therefore developed in this research project based on the absolute numerical difference score (AND, equation 3). As mentioned above, the *AND* score helps discriminate between buffer/critical and passive/active factors with intermediate passive and active sum scores.

In operational terms, the factor typology can be calculated with the aid of a spreadsheet program to automate the column and row operations and the sorting of factors based on influence indices. Table 7 shows how the calculations are set out in a spreadsheet program with: (i) factor names in column 1; (ii) active sum (AS) scores for each factor in column 2; (iii) passive sum (PS) scores for each factor in column 3; and (iv) the multiplier score (MS) in column 4. Multiplication has a dual effect. For factors that have a weak active and passive sum it produces a small score. During sorting[9], these factors will be ranked at the top of the calculation table as buffer elements; those factors that have a weak influence on other factors and are weakly influenced by them (Figure 1).

Table 7 The calculation of critical and buffer factors

Factor Names	Active Sum (AS)	Passive Sum (PS)	AS x PS	
Customary Use	43	50	2157	*Buffer*
Natural Assimilation & Purification	56	52	2873	
Landscape Change Processes	54	58	3084	
Income Tax & GST	57	60	3396	
Climate & Atmosphere	73	49	3542	
Pest Management	61	58	3572	
Economic Drivers	63	57	3643	
Community Services	56	67	3741	
Non-Local Influences	73	52	3800	
Tertiary Sector	55	69	3807	
Labour Market	59	67	3972	
Property Valuation	57	72	4065	
Maintain Soil Health	65	64	4187	
Scientific Research	67	63	4193	
Public Life - Governance	73	58	4263	
Participation in Economic Life	64	67	4307	
Maintain Integrity of Ecological Processes	68	65	4402	
Tourism, Leisure, Recreation, Sport	62	71	4402	
Maintain Biodiversity	66	68	4450	
Human Health	60	78	4683	
Governance of Social Institutions	82	59	4865	
Population Dynamics	72	69	4949	
Economic Inputs	75	67	5017	
Family & Community Wellbeing	65	80	5202	
Secondary Industry	71	78	5516	
Water Quality & Supply	75	74	5550	
Policy, plans, rules, legislation	83	79	6546	
Primary Industries	85	88	7480	*Critical*

Multiplication will tend to produce a high score for factors that have a relatively strong active and passive sum. Sorting the results of this multiplication operation will position factors with higher multiplier scores towards the bottom of Table 7 as critical factors (i.e. factors that are strongly influenced by, and have a strong influence on other factors).

The ordering of the scores shown in Table 7 indicates there is not just one critical factor that has the highest multiplier score, but a group of factors that tend to be critical in character because they have relatively higher active and passive sums. Likewise, there is not just one buffer factor, but a group of factors that tend to be buffers in character because they have relatively lower active and passive scores. Table 4 is an example of a continuous typology.

[9] Assumes sorting based on ascending numerical order.

Table 6, shows how the absolute numerical difference (AND) score is used to differentiate between those marginal factors in Table 8 that have intermediate multiplier scores.

The method described above for the calculation of the critical and buffer factors is also used to calculate the active and passive factors (Figure 1). Table 8 shows how the calculations are set out in a spreadsheet program with: (i) factor names in column 1; (ii) active sum (AS) scores for each factor in column 2; (iii) passive sum (PS) scores for each factor in column 3; and (iv) the quotient score (QS) in column 4. The order of the division operation in column 4 of Table 8 is important. The active sum is the reference point for the identification of active factors. The division of the active sum by the passive sum ensures factors having a high active sum will also have a high quotient score (i.e. the division of a large number by a small number). During sorting, these factors will be ranked at the bottom of the calculation table as active elements (Table 8), i.e. factors that have a strong influence on other factors but are weakly influenced by them (Figure 1).

For factors that have a weak active sum, division produces a small score (i.e. the division of a small number by a relatively large number). During sorting, these factors will be ranked at the top of the calculation table as passive elements (Table 8), i.e. factors that have a weak influence on other factors but are strongly influenced by them (Figure 1).

Table 8 The calculation of passive and active factors

Factor Names	Active Sum (AS)	Passive Sum (PS)	AS/PS	
Human Health	60	78	0.77	*Passive*
Property Valuation	57	72	0.79	
Tertiary Sector	55	69	0.80	
Family & Community Wellbeing	65	80	0.82	
Community Services	56	67	0.83	
Customary Use	43	50	0.86	
Tourism, Leisure, Recreation, Sport	62	71	0.87	
Labour Market	59	67	0.88	
Secondary Industry	71	78	0.91	
Landscape Change Processes	54	58	0.93	
Income Tax & GST	57	60	0.96	
Participation in Economic Life	64	67	0.96	
Primary Industries	85	88	0.97	
Maintain Biodiversity	66	68	0.97	
Water Quality & Supply	75	74	1.00	
Maintain Soil Health	65	64	1.02	
Population Dynamics	72	69	1.04	
Maintain Integrity of Ecological Processes	68	65	1.04	
Policy, plans, rules, legislation	83	79	1.05	
Pest Management	61	58	1.06	
Scientific Research	67	63	1.06	
Natural Assimilation & Purification	56	52	1.08	
Economic Drivers	63	57	1.10	
Economic Inputs	75	67	1.11	
Public Life - Governance	73	58	1.25	
Governance of Social Institutions	82	59	1.38	
Non-Local Influences	73	52	1.41	
Climate & Atmosphere	73	49	1.49	*Active*

Table 8 shows how the factors in column 1 have been ranked into ascending numerical order based on their quotient scores as listed in column 4. Those factors that tend to be more active in character are ranked at the bottom of the Table. The most active factor is climate and atmosphere. Those factors that tend to be more passive in character have been ranked at the top of Table 8. The Human health factor is most passive in character. Those factors in the centre of the Table 9 are more critical or buffer than active or passive, as shown by their quotient score approximating 1. The upper and lower quotient values determine active and passive character. Likewise, the upper and lower multiplier scores determine critical and buffer character. The AND score is used to differentiate between factors with quotient scores at the margins.

The factor typology provides insight into those governing factors that wield the greatest overall influence on the system as defined by participants. The results of the factor typology calculations are shown in Table 9.

Table 9 *The GRC factor typology*

Factors	Type	Factors	Type
Primary Industries	Critical	Scientific Research	Active
Policy, plans, rules, legislation	Critical	Economic Drivers	Active
Water Quality & Supply	Critical	Human Health	Passive
Secondary Industry	Critical	Property Valuation	Passive
Economic Inputs	Critical	Tertiary Sector	Passive
Population Dynamics	Critical	Family & Community Wellbeing	Passive
Maintain Biodiversity	Critical	Community Services	Passive
Maintain Integrity of Eco Processes	Critical	Labour Market	Passive
Participation in Economic Life	Critical	Tourism, Leisure, Recreation	Passive
Maintain Soil Health	Critical	Customary Use	Passive
Climate & Atmosphere	Active	Pest Management	Buffer
Non-local Influences	Active	Income Tax & GST	Buffer
Governance of Social Institutions	Active	Landscape Change Processes	Buffer
Public Life – Governance	Active	Natural Assimilation & Purification	Buffer

Evaluation of the CRG influence matrix has produced the factor typology shown in Figure 9. The factor types listed in Table 9 have been sorted in descending order from the strongest to weakest influence scores. For example, the most critical factor of all is primary industries, and the most active factor is climate and atmosphere. We comment on the significance of these factors below.

Critical Factors – have a system-wide influence on other factors and a high level of sensitivity to change in the system. Critical factors are important operational processes in the system, usually associated with growth and development, and closely coupled with the function of active, passive and buffer factors. For this reason it is difficult to consider critical factors in isolation from other system-wide factors. The CRG influence matrix has identified 10 critical factors listed here in order of highest to lowest multiplier scores: *primary industries, policy, plans, rules, legislation, water quality and supply, secondary industries, economic inputs, population dynamics, maintaining biodiversity, maintaining the integrity of ecological processes, participation in economic life, maintaining soil health.*

Given that primary industries in the Motueka Catchment are the backbone of the local economy (contribution to Catchment GDP $27.9M$_{2001}$) next to forestry (contribution to Catchment GDP $23.6M$_{2001}$), it is not surprising to discover that primary industries are the most critical factor. However, it is interesting to discover that *policy, plans, rules, legislation* take second place, a fact that underscores the critical role played by regional government in the eyes of the CRG members. It is also not surprising to find that *water quality and supply* is the third most critical factor, given the central role of primary industries in the Catchment and the history of water allocation issues that the community has had to deal with collectively. It is also important to note the number of ecosystem services that have turned out to be critical factors in this analysis.

Active Factors – are responsible for driving change and development in the system. They have a strong influence on other system factors. From a simple cause and effect perspective, the identification of these system drivers helps us understand much about the behavioural characteristics of a system from the type of resource base and disturbance regime that drives it. For example, is the system primarily growth or disturbance driven? The CRG influence matrix has identified 6 active factors listed here in order of highest to lowest quotient scores: *climate and atmosphere, non-local influences, governance of social institutions, public life – governance, scientific research, economic drivers.*

Given that the Catchment economy is so strongly based on primary industries it is not surprising to discover that the Catchment system as a whole is strongly influenced by *climate and atmosphere* as a driver. Because of the dependence of the Catchment economy on external markets for the sale of primary produce, we would expect *non-local influences* such as exchange rates, interest rates and the degree of foreign ownership would be an important driver, and in this analysis it is the second most active factor.

Passive Factors – are highly sensitive to change and we call these factors indicator variables because of the manner in which they respond to strong influences. Passive factors can perform different roles in the system. For example, a passive factor could be a stock, the state of which performs an important feedback function for the system. Typically, we would expect to find passive factors in the final-demand or consumption end of the economy as they have weak forward influence and thus are not associated with growth processes in the same way that critical and active factors are. Passive factors can also play important signal damping functions for the system. The CRG influence matrix has identified 8 passive factors listed here in order of highest to lowest quotient scores: *human health, property valuation, tertiary sector, family and community wellbeing, community services, labour market, tourism, leisure, recreation and sport, customary use.*

Buffer Factors – have the capacity to absorb change without drastically altering their own state or that of other factors in the system. All complex systems go through stages of growth, development and state change that adjust in extent and frequency. System buffers provide room for sudden growth and change shocks on the one hand, and compensation for lack of growth and change on the other hand. The CRG influence matrix has identified four buffer factors listed here in order of highest to lowest multiplier scores: *pest management, income tax and GST, landscape change processes, natural assimilation and purification.*

The factor typology from the CRG influence matrix does seem to be lacking in its range of passive and buffer factors identified through this analysis. For example, the passive factors are mainly social in nature, while we would expect there also to be important ecological and economic passive factors. However, those passive factors that are chosen provide a very useful indication of what the CRG members consider as indicator variables for the social (*human health, property valuation, family and community wellbeing, community services, customary use)* and economic (*community services, labour market, tourism, leisure, recreation and sport, property valuation*) wellbeing of the Catchment. It would also have been useful to see some ecological indicators. Their absence is probably related to aspects of our participatory process design, especially the factor selection and aggregation stages, since both these process stages determine the final selection of factors that go into the influence matrix structure. Further research is needed to better understand the extent to which the results of the influence matrix model are dependent on our process design.

2.4 Evaluation of the influence matrix colour map

Before seeking to evaluate the visual properties of the influence matrix it is important to outline how it was developed and organised in practical terms.

The first step in building the Motueka CRG influence model involved an attempt to define system goals. The Community Reference group members decided on the following goal statement. The text in italics was developed by the community group members.

The residents of the Motueka Catchment want to manage their Catchment so as to ensure they continue to enjoy … *a safe place to play and live, its pristine character and beauty, its identity, economic and ecological balance, its economic viability for business development, its exceptional climate, biological, community and landscape diversity and coastal integrity.*

The above statement shows that the goals of the Motueka CRG are far broader than simply economic efficiency. This implies the management of the Catchment is a multiple goal problem, and the influence matrix is ideally suited to challenges of this kind.

The Motueka CRG identified 171 factors (Appendix 1) they felt influenced the long-term management of the Motueka Catchment toward the goals mentioned above. An influence matrix based on 171 factors would take a long time to score. To overcome this problem the 171 factors were aggregated to form a group of 28 key factors (Appendix 2). This list of key factors was used to name the columns and rows of our influence matrix (Table 10). These rows and columns have been colour coded to assist identification of the different groups of factors: ecological (brown), economic (yellow), social (green), governance of social institutions (blue), policy, plans, rules and legislation (dark blue), and non-local influences (purple).

Table 10 shows the completed average influence matrix produced by the group. It was produced from seven individually scored influence matrices. The influence scores in each cell of the matrix provide a qualitative estimate of how different matrix factors influence each other. It is very difficult to draw useful conclusions from the matrix in this form. One of the easiest ways to evaluate the matrix is to use colour coding to produce an influence matrix colour map.

Table 10 *The influence matrix*

	Climate & Atmosphere	Pest Management	Maintain Biodiversity	Maintain Integrity of Ecological Processes	Maintain Soil Health	Natural Assimilation & Purification	Landscape Change Processes	Water Quality & Supply	Scientific Research	Customary Use	Economic Drivers	Economic Inputs	Income Tax & GST	Labour Market	Primary Industries	Property Valuation	Secondary Industry	Tertiary Sector	Family & Community Wellbeing	Human Health	Participation in Economic Life	Population Dynamics	Public Life - Governance	Community Services	Tourism, Leisure, Recreation, Sport	Governance of Social Institutions	Policy, plans, rules, legislation	Non-Local Influences
Climate & Atmosphere	2	3	3	3	4	3	3	4	3	2	2	2	2	2	4	3	2	2	3	3	2	3	2	2	4	1	2	1
Pest Management	0	3	4	3	3	2	3	3	2	2	2	3	2	1	3	3	2	1	2	3	2	2	1	1	2	2	3	2
Maintain Biodiversity	2	2	2	4	3	2	3	3	3	3	2	2	2	2	3	3	2	2	2	2	2	2	2	1	3	2	3	2
Maintain Integrity of Ecological Processes	3	2	3	3	4	3	2	4	3	3	2	2	1	1	3	2	2	2	3	3	2	2	2	1	3	2	3	2
Maintain Soil Health	2	2	3	3	3	3	3	4	3	2	2	2	1	2	4	3	2	1	3	3	2	2	1	2	2	1	3	2
Natural Assimilation & Purification	4	2	3	3	4	2	2	3	2	2	1	1	1	1	2	2	2	1	2	3	1	1	1	1	2	1	3	2
Landscape Change Processes	2	2	2	2	3	2	2	2	2	2	2	2	1	1	2	3	2	2	1	1	2	2	1	2	2	1	3	2
Water Quality & Supply	3	1	3	4	3	3	2	3	3	3	3	3	2	3	4	4	4	2	3	3	2	2	2	2	3	2	3	2
Scientific Research	2	4	3	3	3	2	2	3	2	1	1	3	1	2	4	3	4	3	2	3	1	1	1	2	2	2	4	2
Customary Use	0	1	2	2	1	2	2	2	3	3	1	1	0	1	1	1	2	2	2	2	2	1	2	1	2	1	2	1
Economic Drivers	2	2	2	2	2	1	1	2	2	1	3	3	3	3	3	3	3	2	2	2	2	2	2	2	3	2	2	3
Economic Inputs	2	2	2	2	3	1	3	3	2	2	3	2	3	3	4	4	4	3	3	2	3	3	3	3	3	2	2	2
Income Tax & GST	1	2	1	1	1	1	1	1	2	1	3	3	1	3	4	2	3	3	3	2	2	2	2	3	2	3	3	2
Labour Market	1	2	2	1	1	1	1	1	1	1	2	3	3	2	4	2	3	3	3	2	3	3	2	3	3	2	3	1
Primary Industries	3	4	4	3	4	3	3	4	4	2	2	4	3	3	2	4	4	3	4	2	3	3	3	3	3	2	3	2
Property Valuation	1	2	2	1	1	1	2	2	1	1	2	2	2	2	3	2	2	3	3	2	3	2	2	2	2	2	3	2
Secondary Industry	2	1	2	2	2	2	2	3	3	1	2	3	3	4	3	3	2	3	3	3	3	3	3	3	3	2	3	2
Tertiary Sector	1	1	1	1	1	0	1	2	2	1	1	2	2	3	3	2	3	2	3	4	2	3	2	3	3	2	2	2
Family & Community Wellbeing	1	2	2	2	2	2	2	3	2	1	2	3	2	3	3	2	3	2	2	4	3	3	2	3	3	2	3	2
Human Health	1	2	2	2	1	1	2	2	2	1	1	2	2	3	3	2	3	3	4	3	3	3	2	3	2	2	2	1
Participation in Economic Life	1	1	2	2	1	1	2	2	2	2	2	3	3	4	3	2	3	3	3	3	2	4	3	3	2	2	3	2
Population Dynamics	2	2	2	2	2	2	2	2	2	2	2	2	2	4	3	3	3	3	4	3	3	2	3	3	3	2	2	2
Public Life - Governance	2	3	3	2	2	2	2	3	2	1	2	2	2	3	3	3	3	3	3	4	3	3	2	3	3	3	3	2
Community Services	1	1	1	1	1	1	1	1	1	1	1	2	2	3	3	2	2	3	3	4	3	3	3	3	3	3	3	1
Tourism, Leisure, Recreation, Sport	1	2	2	2	1	1	2	3	1	1	2	2	3	3	3	3	2	3	3	3	3	3	2	3	2	2	3	2
Governance of Social Institutions	2	3	3	4	2	3	3	4	3	2	2	3	2	3	3	3	3	3	3	3	3	3	4	3	2	3	4	2
Policy, plans, rules, legislation	3	4	3	3	3	3	3	4	3	2	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3	2
Non-Local Influences	2	3	3	2	2	2	2	2	2	1	3	3	3	3	4	3	3	3	3	3	2	3	2	3	3	3	3	3

A colour map makes it possible to look for patterns or trends in the data recorded in the influence matrix. There are different types of colour maps that can be built from the data in an influence matrix. The simplest approach is to take the influence matrix shown in Table 10 and assign a common colour to each of the six influence scores (Table 2). Table 11 provides a colour key that shows which colour is assigned to each of the six influence scores that were used in Table 2.

Table 11 *The colour score key used to interpret Table12*

Influence Description	*Score*	*Colour*
No influence	0	
Weak influence	1	
Influence is stronger than weak	2	
Average Influence	3	
Infuence is stronger than average	4	
Strong Influence	5	

The scores in Table 12 have not been sorted in anyway, therefore the order of the column and row factor names is identical to those in Table 10. A visual inspection of the Table shows that a couple of dominant colour patterns exist and have been defined with the aid of black borders. What do these patterns mean? It is possible to interpret these patterns by seeking to understand what the various parts of the influence matrix shown in Table 10 represent theoretically.

Table 12 *An influence matrix colour map*

	Climate & Atmosphere	Pest Management	Maintain Biodiversity	Maintain Integrity of Ecological Processes	Maintain Soil Health	Natural Assimilation & Purification	Landscape Change Processes	Water Quality & Supply	Scientific Research	Customary Use	Economic Drivers	Economic Inputs	Income Tax & GST	Labour Market	Primary Industries	Property Valuation	Secondary Industry	Tertiary Sector	Family & Community Wellbeing	Human Health	Participation in Economic Life	Population Dynamics	Public Life - Governance	Community Services	Tourism, Leisure, Recreation, Sport	Governance of Social Institutions	Policy, plans, rules, legislation	Non-Local Influences
Climate & Atmosphere	2	3	3	3	4	3	3	4	3	2	2	2	2	2	4	3	2	2	3	3	2	3	2	2	4	1	2	1
Pest Management	0	3	4	3	3	2	3	3	2	2	2	3	2	1	3	3	2	1	2	3	2	2	1	1	2	2	3	2
Maintain Biodiversity	2	2	2	4	3	2	3	3	3	3	2	2	2	2	3	3	2	2	2	2	2	2	2	1	3	2	3	2
Maintain Integrity of Ecological Processes	3	2	3	3	4	3	2	4	3	3	2	2	1	1	3	2	2	2	3	3	2	2	2	1	3	2	3	2
Maintain Soil Health	2	2	3	3	3	3	3	4	3	2	2	2	1	2	4	3	2	1	3	3	2	2	1	2	2	1	3	2
Natural Assimilation & Purification	4	2	3	3	4	2	2	3	2	2	1	1	1	1	2	2	2	1	2	3	1	1	1	1	2	1	3	2
Landscape Change Processes	2	2	2	2	3	2	2	2	2	2	2	2	1	1	2	3	2	2	1	1	2	2	1	2	2	1	3	2
Water Quality & Supply	3	1	3	4	3	3	2	3	3	3	3	3	2	3	4	4	4	2	3	3	2	2	2	2	3	2	3	2
Scientific Research	2	4	3	3	3	2	2	3	2	1	1	3	1	2	4	3	4	3	2	3	1	1	1	2	2	2	4	2
Customary Use	0	1	2	2	1	2	2	2	3	3	1	1	0	1	1	1	2	2	2	2	2	1	2	1	2	1	2	1
Economic Drivers	2	2	2	2	2	1	1	2	2	1	3	3	3	3	3	3	3	2	2	2	2	2	2	2	3	2	2	3
Economic Inputs	2	2	2	2	3	1	3	3	2	2	3	2	3	3	4	4	4	3	3	2	3	3	3	3	3	2	2	2
Income Tax & GST	1	2	1	1	1	1	1	1	2	1	3	3	1	3	4	2	3	3	3	2	2	2	2	3	2	3	3	2
Labour Market	1	2	2	1	1	1	1	1	1	1	2	3	3	2	4	2	3	3	3	2	3	3	2	3	3	2	3	1
Primary Industries	3	4	4	3	4	3	3	4	4	2	2	4	3	3	2	4	4	3	4	2	3	3	3	3	3	2	3	2
Property Valuation	1	2	2	1	1	1	2	2	1	1	2	2	2	2	3	2	2	3	3	2	3	2	2	2	2	2	3	2
Secondary Industry	2	1	2	2	2	2	2	3	3	1	2	3	3	4	3	3	2	3	3	3	3	3	3	3	3	2	3	2
Tertiary Sector	1	1	1	1	1	0	1	2	2	1	1	2	2	3	3	2	3	2	3	4	2	3	2	3	3	2	2	2
Family & Community Wellbeing	1	2	2	2	2	2	2	3	2	1	2	3	2	3	3	2	3	2	2	4	3	3	2	3	3	2	3	2
Human Health	1	2	2	2	1	1	2	2	2	1	1	2	2	3	3	2	3	3	4	3	3	3	2	3	2	2	2	1
Participation in Economic Life	1	1	2	2	1	1	2	2	2	2	2	3	3	4	3	2	3	3	3	3	2	4	3	3	2	2	3	2
Population Dynamics	2	2	2	2	2	2	2	2	2	2	2	2	2	4	3	3	3	3	4	3	3	2	3	3	3	2	2	2
Public Life - Governance	2	3	3	2	2	2	2	3	2	1	2	2	2	3	3	3	3	3	3	4	3	3	2	3	3	3	3	2
Community Services	1	1	1	1	1	1	1	1	1	1	1	2	2	3	3	2	2	3	3	4	3	3	3	3	3	3	3	1
Tourism, Leisure, Recreation, Sport	1	2	2	2	1	1	2	3	1	1	2	2	3	3	3	3	2	3	3	3	3	3	2	3	2	2	3	2
Governance of Social Institutions	2	3	3	4	2	3	3	4	3	2	2	3	2	3	3	3	3	3	3	3	3	3	4	3	2	3	4	2
Policy, plans, rules, legislation	3	4	3	3	3	3	3	4	3	2	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3	2
Non-Local Influences	2	3	3	2	2	2	2	2	2	1	3	3	3	3	4	3	3	3	3	3	2	3	2	3	3	3	3	3

The influence matrix is composed of three main groups of factors: ecological, economic and social. It is possible to build a model that illustrates how these three entities are interrelated together. The model in Figure 5 contains social, economic and ecological groups of factors. The social and economic factors have been grouped together into one combined group called social-economic systems. The remaining ecological factors have been placed into one group called ecological systems. These two spheres symbolise the ecological/ecological and social-economic/social-economic quadrants of the influence matrix portrayed in Tables 10 and 12.

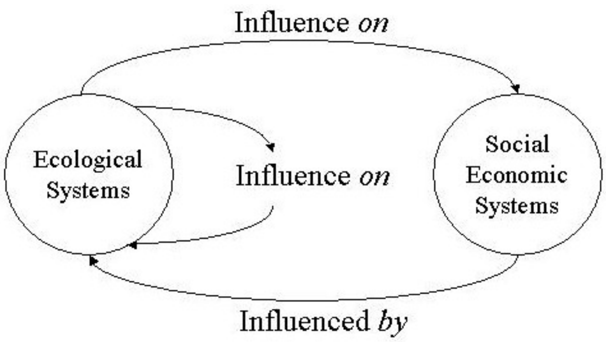


Figure 5 *An influence model for a social-economic-ecological system*

The model in Figure 5 shows that ecological systems have an influence *on* social economic systems and in turn they are also influenced *by* social-economic systems. This model also shows that ecological systems have an influence *on* themselves. This simplified view of the world is captured in the influence matrix show in Table 12. In order to illustrate this point Table 12 has been re-drawn (Table 13) with Figure 5 superimposed on top of it.

Table 13 *The quadrants of an influence matrix and what they represent as shown in Figure 4*

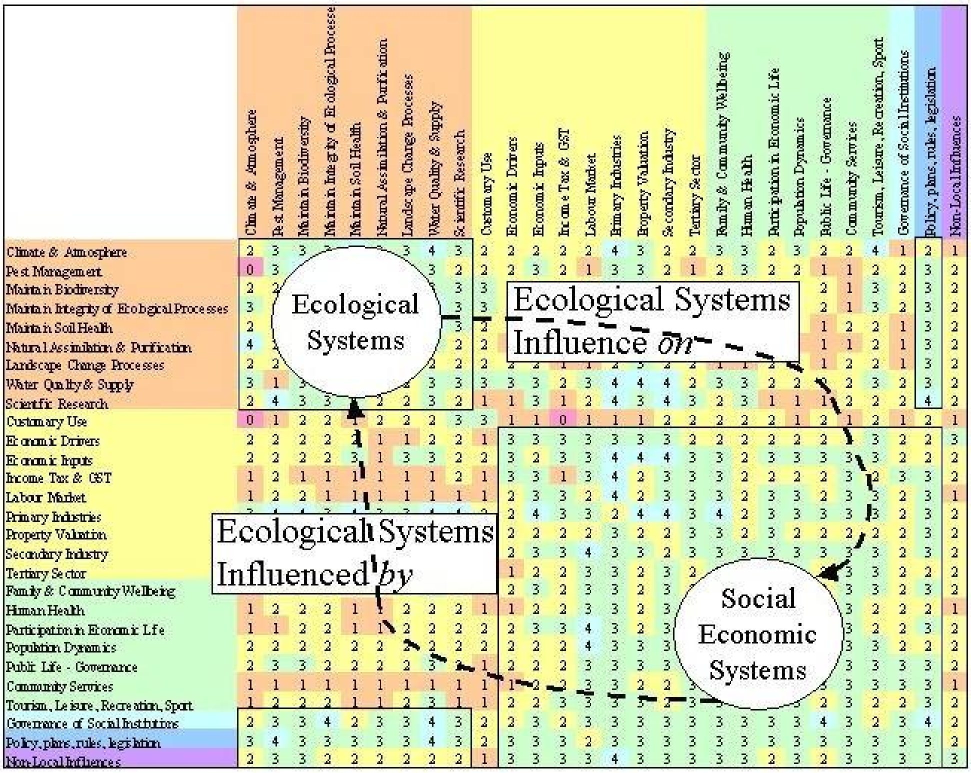


Table 13 shows that the influence matrix is composed of four main areas or quadrants that represent the simplified view of the world presented in Figure 5. The influence matrix has a quadrant in which ecological factors influence each other; representing ecological systems. Ecological systems have an influence *on* the social economic quadrant of the influence matrix. These influences are recorded by the influence scores contained in the part of the influence matrix labelled with the words “Ecological Systems Influence *on*”. The dashed black line that passes through this part of the influence matrix represents a flow of influence from ecological systems to social economic systems (Table 13).

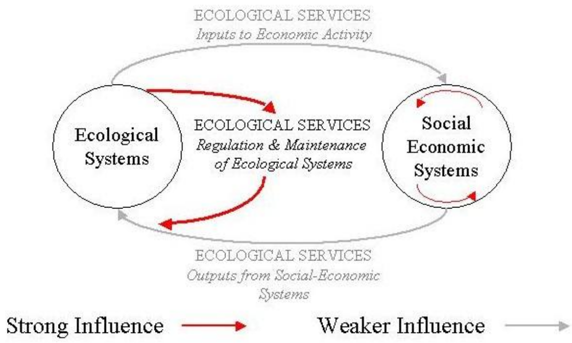


Figure 6 *The flow of system-wide influence based on Binning et al. (2001)*

Likewise, the social economic quadrant of the influence matrix produces a flow of influence that affects ecological systems. These influences are recorded by the influence scores contained in the part of the influence matrix labelled with the words “Ecological Systems Influenced *by*”. The dashed black line that passes through this part of the influence matrix represents a flow of influence from social-economic systems to ecological systems (Table 13).

Now that the various parts of the influence matrix have been defined it is possible to interpret the patterns. The influence matrix colour map indicates the Motueka CRG members have scored the influence matrix in such a way that the ecological and social-economic quadrants of the influence matrix have the overall highest scores as seen by the higher concentration of green and blue pattern in this area of the influence matrix (Table 12).

In contrast, the quadrants of the influence matrix that represent the flows of influence from ecological systems to the social-economic system and from the social-economic system to the ecological system have a lower influence score (as seen by the higher concentration of yellow and brown colour in these parts of the influence matrix). There are two possible reasons why the influence matrix shows patterns of this kind. First, it could be that the flow of influences from the ecological to the social-economic system and from the social-economic system to the ecological system is indeed weak. There are obviously exceptions to this trend as seen in the case of water quality and supply[10] (Table 12).

Another possible explanation is that these flows have an intermediate to strong influence that is currently not perceived by the members of the Motueka Community Reference group.

The model shown in Figure 6 is slightly different to the model shown in Figure 5. Figure 6 provides a summary of the flow of influences in the influence matrix based on Table 13. In Figure 6, red arrows symbolise a strong influence and grey arrows symbolise a weak influence. The summary model in Figure 6 shows that the members of the Motueka Community Reference group have identified the existence of stronger influences within the social-economic system and ecological systems compared with the strength of those influence flows that link the two systems. Current scientific understanding about the importance of ecosystem services to human economic activity suggests this is unlikely to be an accurate perception of reality.

It would be possible to test this hypothesis by conducting research aimed at documenting the nature and monetary value of the flows of ecosystem goods and services present in the Motueka Catchment. This would help document and quantify the level of dependence of the local Motueka community on ecological services. It would then be possible to document any changes in perception by building another influence model. It would also be interesting to build influence models with other stakeholder groups from within the local Motueka community – different groups might have different perceptions.

[10] As a scarce resource, water is currently allocated in the Waimea Catchment using a transferable water-right permit system (Fenemor A. & Kearney M. 1997, Zuur B. & Fenemor A. 2000).

3. Discussion of Results

The aim of this report has been to provide a more detailed outline of the theory and methodological developments that have emerged from the use of the influence matrix as a participatory tool in Integrated Catchment Management research in New Zealand. To make the nature of these methodological refinements and theoretical developments clearer, the introduction section to this report provides a review of the key stages in the historical development of the influence matrix methodology. Furthermore, the standard method developed by Vester (1976) and Vester and von Hesler (1982) has also been outlined in the method section. Against this theoretical and methodological baseline, this New Zealand influence matrix research has added the following developments.

First, this research has extended the use of the influence matrix into the theoretical realm of calculating whole-of-system sustainability values and linking the concept of flows of system influence with flows of ecosystem services (Figure 5 & 6). The use of the influence matrix as a participatory tool for the calculation of sustainability values provides a working solution to the sustainability methodological challenge that has been recognised by ecological economists (Wilson & Howarth, 2002; Costanza & Folke, 1997). The extension of the influence matrix methodology into the realm of ecosystem services research is a unique development in terms of the range of documented applications of the influence matrix outlined earlier in this report. The value of this theoretical and methodological development lies in the ability to explore the role of ecosystem services in a whole-of-system context using a modelling tool that is accessible to non-scientific stakeholders.

This report has not attempted to provide a systematic and thorough coverage of the results of the Motueka influence matrix modelling trial. However, it is already evident from the material presented here that the use of the influence matrix method to investigate ecosystem services has yielded results that challenge many conventional economic assumptions. These insights have emerged because the influence matrix provides a method for exploring management issues at a whole-of-system scale in a participatory manner. As a tool, it provides a means to extend the intellectual and mental capabilities of modelling participants into the realm of complex problem solving.

The mathematical steps involved in calculating influence indices have been outlined in this report to provide a methodological baseline or benchmark for developmental work in this area to date. One of the key weaknesses associated with the development of the method articulated first by Vester (1976) and later by Vester and von Hesler (1982) has been the difficulty of discriminating between the functional roles of different factor types. In this research project the absolute numerical difference score (AND) has been used to address this problem. The AND score provides an additional key for classification of factors that has made it possible to distinguish between borderline cases that emerged when the multiplier and quotient scores tend towards intermediate values. The rationale underpinning the use of the AND score is simple – the larger the absolute numerical difference is between active sum and passive sum scores, the more likely a factor is to fall into the category of being passive or active. Small AND score likewise indicate critical and buffer functional character.

It is important to note that discrimination of factor functional types does not successfully rest on any one single key. For this reason, we gathered all the influence index calculations into one comparative Table (7), which made it much easier to classify the various factors according to their functional type based on these varied classification keys.

Another important methodological developed that has emerged from this project has been the use of active and passive sum scores to rank not only individual system factors, but groups of factors. This exercise was initially attempted as an experiment. The importance of this multiple scale approach became evident when the results for individual and group factors diverged. This indicates it is difficult to assess group influence from the influence of individual factors. System-wide influence would therefore appear to be an emergent property of system scale. Given this fact, it is important to explore-system wide influence at difference levels of organisational scale. In this project we have aggregated the factors into groups based on very simple ecological, economic and social groupings. However, this is not the only or necessarily the most valid type of organisational classification. Further research is needed in this area.

The colour map idea provides an alternative inductive way of evaluating an influence matrix quite separate from the deductive analytical tools developed by earlier researchers in this field. One point to consider in the adaptation of the colour map to the influence matrix is that this approach depends on the organisation of factors in the influence matrix. Our organisation of the influence matrix into economic, social and ecological quadrants seemed logical, but was not based on any deductive theory. As it turned out, this type of factor classification (Table 13) and organisation of the influence matrix happened to correspond very neatly with the model of ecosystem services developed by researchers at the CSIRO sustainable ecosystem in Canberra, Australia. However, this interrelationship between the influence matrix organisational metaphor (Table 11 & 12) and the ecosystem services metaphor (Figures, 5 & 6) suggests deductive logic may yet reveal further ways of evaluating the influence matrix in this manner. Further research is needed in this area.

The patterns revealed in the colour map evaluation of the influence matrix are themselves very interesting. An important point to consider is that it is not possible to bias the scoring of the influence matrix in a way that disguises what you are doing – the model system is too complex. Therefore, we can assume patterns that exist in the scoring of the influence matrix are a reflection of human perceptions. From a sustainability-values perspective, this type of evaluation makes it possible to see just how participants perceive value in a whole-of-system context. Insights of this kind play an important role in helping us understand better how and why we relate to the environment in the way that we do. This adaptation of the influence matrix method to the study of human perception links this participatory modelling tool with the theoretical domain of educational and developmental psychology. Ongoing research in this area will doubtless provide very valuable insights and is indeed needed as we broaden our current interdisciplinary research into the domain of transdisciplinary studies.

4. Conclusions

The aim of this report has been to document more fully the theoretical and methodological developments made with the use of the influence matrix as a participatory modelling tool in a Catchment research context. The main theoretical developments have been to (i) apply the influence matrix to the challenge of calculating whole-of-system sustainability values at Catchment scale, and (ii) to extend the conceptual power of the influence matrix into the realm of ecosystem services research.

This research has also added a number of important methodological refinements to the evaluation of an influence matrix, including: (a) the use of the absolute numerical index score as a key for functional factor classification; (b) the use of active and passive sum scores for the calculation of group factor influence; and (c) the use of the colour map as an inductive tool for the visual identification of pattern in the numerical structure of the influence matrix. As has been indicated in the discussion section of this report, these developments are not the end, but the beginning of future developmental work that is needed to refine this modelling tool further. The scope and nature of the theoretical and methodological developments outlined in this report suggest further research of this kind will yield valuable results.

5. Acknowledgements

This working paper represents an initial attempt to articulate for peer review in an international forum a methodological and theoretical synthesis of progress to date on the influence matrix research project. For a more mature development of this subject matter, the reader should refer to later published reports and journal papers.

This research project was funded with non-specific output funding from the Foundation for Research, Science and Technology (FRST), and was linked with an existing FRST research programme called Integrated Land and Water Resource Management in Complex Catchments[11]. The idea of using an influence matrix to study ecosystem services at a catchment scale was the result of collaboration between scientific staff at CSIRO sustainable ecosystems in Canberra, Australia and Landcare Research (New Zealand) Ltd. This research project represents one of a series of case studies associated with an ecosystem services research initiative at CSIRO sustainable ecosystems in Canberra funded by the Meyer Foundation.

This research project was made possible with the enthusiastic support and contributions of numerous people: ICM research programme leaders Breck Bowden and Andrew Fenemor, Motueka CRG members (Elizabeth Martin, Jan Langford, Iain Thorne, Gloria Higgins, Geoff Rowling, Judy Profitt, Lloyd Faulkner, Paul Gillespie and Roger Young) and colleagues at Landcare Research (Will Allen and Margaret Kilvington, Michael Krausse, Aroon Parshotam), Massey University (Murray Patterson, Gary McDonald), Greening Australia

[11] Contract Number: C09X0014

(Carl Binning), the ecosystem services national working group (David Wood and Linda Cameron (Treasury), Theo Stephens (Department of Conservation), Nick Potter (Office of the Parliamentary Commissioner for the Environment), Michael Jebson (Ministry of Agriculture and Fisheries) and Kirsty Johnson (Ministry for the Environment) and CSIRO sustainable ecosystems, Canberra (Steven Cork, Nick Abel, David Shelton).

6. References

Bingham G., Bishop R., Brody M., Bromley D., Clark E., Cooper W., Costanza R, Hale T., Hayden G., Kellert S., Norgaard R., Norton B., Payne J., Russell C., Suter G. 1995. Issues in ecosystem valuation: improving information for decision-making. *Ecological Economics 14:* 73-90.

Binning C., Cork S., Parry R., Shelton D. 2001. *Natural assets an inventory of ecosystem goods and services in the Goulburn Broken Catchment.* CSIRO Sustainable Ecosystems, Canberra.

Brenner J. 1999. Formen der entscheidungsfindung - einsatz von szenario-modellen? In Brenner J., Herrmann M., & Nehring M. (Eds.), *Moglichkeiten partizipativer elemente in entscheidungsfindungsprozessen am beispiel des verkehrs* (pp. 55-94). Stuttgart: Zwischenbericht im Projekt Verkehrsplanung im Diskurs.

Cole A.O., Allen W., Kilvington M., Fenemor A., Bowden B. 2006. Understanding whole-of-system sustainability in the Motueka Catchment: participatory modelling with an influence matrix (Rep. No. LCO506/087). Palmerston North, New Zealand: Landcare Research.

Cole A.O. 2002. Valuing ecosystem services: an emergent theory of individual and societal development. Presented at Ecological Society of Australia Conference, Symposium on *Theory and Practice in the Study of Ecosystem Services,* 2–6 December, 2002, Cairns Convention Centre, Cairns, Australia.

Cork S., Shelton D. 2001. The nature and value of Australia's ecosystem services: a framework for sustainable environmental solutions. *Environmental Engineering Society, Queensland Chapter, The Institute of Engineers, Australia, and Queensland Chamber of Commerce and Industry, Queensland, Australia.* Pages 151-159.

Cork S., Shelton D., Binning C., Parry R. 2001. A framework for applying the concept of ecosystem services to natural resource management in Australia. In: Rutherford I., Sheldon F., Brierley G., and Kenyon C. (Eds). *Third Australian Stream Management Conference August 27-29, 2001* (pp. 157-162). Cooperative Research Centre for Catchment Hydrology: Brisbane, Australia.

Coplak J., Raksanyi P. 2003. *Planning sustainable settlements* (Rep. No. EC Project Ecocity – EBVK4-CT-2001-00056 (WP4)). Bratislava: Slovak University of Technology.

Costanza R., Sklar F.H. 1985. Articulation, accuracy and effectiveness of mathematical models: a review of freshwater wetland applications. *Ecological Modelling 27:* 45-68.

Costanza R. 1987. Simulation modelling on the Macintosh using Stella. *Bioscience 37:* 129-132.

Costanza R. 1989. Model goodness of fit: a multiple resolution procedure. *Ecological Modelling 47:* 199-215.

Costanza R, Sklar F.H., White M.L. 1990. Modelling coastal landscape dynamics process-based dynamic spatial ecosystem simulation can examine long-term natural changes and human impacts. *BioScience 40:* 91-107.

Costanza R., Cornwell L. 1992. The 4P approach to dealing with scientific uncertainty. *Environment 34:* 12-42.

Costanza R, Wainger L., Folke C., Maler K. 1993. Modelling complex ecological economic systems. *BioScience 43*: 545-555.

Costanza R. 1996. Ecological economics: reintegrating the study of humans and nature. *Ecological Applications 6*: 978-990.

Costanza R., Folke C. 1997. Valuing ecosystem services with efficiency, fairness and sustainability as goals. In Daily G.C. (Ed.), *Nature's services societal dependence on natural ecosystems* (pp. 49-68). Washington DC: Island Press.

Costanza R., Hannon B. 1989. Dealing with the "mixed units" problem in ecosystem network analysis. In Wulft F., Feild J.G., and Mann K.H.(Eds.), *Network analysis in marine ecology: methods and applications* (pp. 90-115). Berlin: Springer-Verlag.

Costanza R. 2000. Social goals and the valuation of ecosystem services. *Ecosystems 3:* 4-10.

Daily G.C. 1997a. Introduction: What are ecosystem services? In Daily G.C. (Ed.), *Nature's services societal dependence on natural ecosystems* (pp. 1-10). Island Press: Washington DC.

Daily G.C. 1997b. *Nature's services societal dependence on natural ecosystems.* Island Press: Washington DC.

Fenemor A., Kearney M. 1997. Issues, options and practicality of transferable water permits in the Waimea Catchment: a discussion paper prepared with financial assistance from the Sustainable Management Fund. 1997. Richmond, NZ: Tasman District Council.

Environment Directorate (OECD) 2000. Project on environmentally sustainable transport: the economic and social implications of sustainable transportation. (pp. 1-153). Paris, France: OECD Working group on Transport.

Fried A., Volker L. 2005. *Towards an advanced impact analysis of intangible resources in organisations* (Rep. No. 2/2005). Germany: Department of Innovation, Research and Sustainable Resource Management (BWL IX), Chemnitz University of Technology.

Godet M. 1979. *The crisis in forecasting and the emergence of the "prospective" approach with case studies in energy and air transport*. New York: Pergamon Press.

Gordon T.J., Hayward H. 1968. Initial experiments with the cross impact matrix method of forecasting. *Futures 1[1]:* 100-116.

Iron Curtain Consortium 2004. *Integrated multilayer database for the reference areas and interpreted maps and time series* (Rep. No. QLK5-2001-01401). Germany: Institute for Geography – Geoinformatics, Friedrich-Schiller-Universitat Jena (UNIJENA).

Ko J.L.D., Chang T. 1997. The standardized influence matrix and its applications. *Journal of the American Statistical Association 92[440]:* 1572-1580.

Messerli P. 2000. Use of sensitivity analysis to evaluate key factors for improving slash and burn cultivation systems on the Eastern Escarpment of Madagascar. *Mountain Research and Development 20[1]:* 32-41.

Oxford University Press 1999. *The Concise Oxford Dictionary,* 10th Edition. Oxford: Oxford University Press.

Patterson M.G. 2002. Ecological production-based pricing of biosphere processes. *Ecological Economics 41:* 457-478.

Patterson M.G., Cole A.O. 1999. *Assessing the value of New Zealand's biodiversity.* Palmerston North, NZ: Massey University, School of Resource and Environmental Planning.

Schlange L.E. 1995. Linking future research methodologies, an application of systems thinking and metagame analysis to nuclear energy policy issues. *Futures 27[8]:* 823-838.

Shelton D., Cork S., Binning C., Parry R., Vertessy R., Stauffacher M. 2001. Application of an ecosystem services inventory approach to the Goulburn Broken Catchment. In: Rutherford I., Sheldon F., Brierley G., and Kenyon C. (Eds). *Third Australian Stream Management Conference August 27-29, 2001.* Cooperative Research Centre for Catchment Hydrology, Brisbane. Pp. 157-162.

Swiss Federal Office of Civil Defence 1995. *Catastrophes and disasters in Switzerland: a comparative overview* Bern: Swiss Federal Office of Civil Defence (FOCD).

Transformes 2002. *Human resources and mobility (HRM) activity: integration of transport and urban form in the European region of Strasbourg* (Rep. No. FP6-2002-Mobility-5). Strasbourg: Transformes.

Ulrich W. 2005. Can nature teach us good research practice? A critical look at Frederic Vester's bio-cybernetic systems approach. *Journal of Research Practice, 1:* 1-10.

Vester F. 1976. *Urban systems in crisis: understanding and planning human living spaces: the biocybernetic approach*. Germany: dva Offentliche Wissenschaft.

Vester F. 1988. The biocybernetic approach as a basis for planning our environment. *Systems Practice, 1:* 399-413.

Vestor F., Guntrum U. 1993. Systems thinking and the environment: novel insights from a biologist, business and systems thinker. *The McKinsey Quarterly 2:* 153-169.

Vester F. 2002. *Die kunst vernetzt zu denken, ideen und werkzeuge fur einen neuen umgang mit komplexitat*. (vols. Ein bericht an den Club of Rome) Germany: GmbH Munchen.

Vester F. 2002. *The ecopolicy game.* Germany: Studiengruppe für Biologie und Umwelt Frederic Vester GmbH.

Vester F. 2004. *Sensitivity model: the computerised system-tools for a new management of complex problems* Germany: GmbH Munchen.

Vester F., Hesler A.V. 1982. *Sensitivity model*. Frankfurt/Main: Umlandverband Frankfurt.

Walz A. 2006. *Landuse modelling for an integrated approach to regional development in the Swiss Alps.* Doctorate Mathematisch- naturwissenschaftlichen Fakultat, Universitat, Zurich.

Wenzel S., Igenbergs E. 2001. Agent systems architecture for complex and distributed product development systems: a methodology to measure the cost/benefit-ratio of different agent-system constellations. Melbourne, Australia: International Council on Systems Engineering INCOSE.

Wiek A., Binder C. 2005. Solution spaces for decision-making: a sustainability assessment tool for city regions. *Environmental Impact Assessment Review 25:* 589-608.

Wilson M.A., Howarth R.B. 2002. Discourse-based valuation of ecosystem services: establishing fair outcomes through group deliberation. *Ecological Economics 41:* 431-443.

Symposium: Theory and Practice in the Study of Ecosystem Services.

Convened by: *Dr Steven Cork*
CSIRO Sustainable Ecosystems,
Canberra, ACT.

The concept of ecosystem services is emerging worldwide as a way to acknowledge the dependence of humans on nature and to communicate the benefits of ecosystems in language and concepts that a wide range of people can understand. Interest in the concept has developed at a much greater rate than theory to underpin application. The two words "ecosystem services" potentially bring together theory from ecological, social and economic sciences, including equilibrium and resilience theory, economic theory of value, theory about fundamental human needs, and learning theory. In this symposium, scientists studying ecosystem services in New Zealand, Australia and South Africa will present and discuss the theoretical underpinnings of their work and consider what is needed in an overarching approach to theory for ecosystem services research.

Appendix 1

Table A1 *List of 171 factors, group names and aggregated factors names*

Group Names	*Disaggregated Factor Names (171)*	*Aggregated Factors Names (28)*
Ecological	Burning fields (producing smoke)	Climate and Atmosphere
	Climate	Climate and Atmosphere
	Pine pollen	Climate and Atmosphere
	1080 poison	Pest Management
	Ants (introduced pests)	Pest Management
	Bio-security	Pest Management
	Giardia	Pest Management
	Gypsy moths	Pest Management
	Pest control methods	Pest Management
	Pop. pressure (plant & animal pests)	Pest Management
	Tb Vectors (possum, ferrets, pigs, deer)	Pest Management
	Biodiversity	Maintain Biodiversity
	Changing crop seed mixes	Maintain Biodiversity
	Environmental integrity	Maintain Biodiversity
	Forestry	Maintain Biodiversity
	National parks	Maintain Biodiversity
	Ecological time	Maintain Ecological Processes
	Changing land use	Maintain Soil Health
	Does forestry cause erosion	Maintain Soil Health
	Erosion (coastal & river)	Maintain Soil Health
	Fertiliser & chemical use	Maintain Soil Health
	Landscape	Maintain Soil Health
	Nutrient levels	Maintain Soil Health
	Silt levels	Maintain Soil Health
	Soil productivity	Maintain Soil Health
	Soils	Maintain Soil Health
	Pasture	Maintain Soil Health
	Population pressure (stocking rate)	Maintain Soil Health
	Other pollution	Natural Assimilation & Purification
	Coastal erosion	Landscape Processes
	H20 for local economy (shortages?)	Water Quality & Supply
	Changing water quality	Water Quality & Supply
	Demand for water	Water Quality & Supply
	Irrigation	Water Quality & Supply
	Limits of aquifers	Water Quality & Supply
	Rainfall	Water Quality & Supply
	River flows	Water Quality & Supply
	Run-off	Water Quality & Supply
	Water pollution	Water Quality & Supply
Economic	Eeling	Customary Use
	Exchange rates	Economic Drivers
	Tourism pressure	Economic Drivers
	Urban development	Economic Drivers
	Inputs – chemicals	Economic Inputs
	Inputs – electricity	Economic Inputs

Group Names	*Disaggregated Factor Names (171)*	*Aggregated Factors Names (28)*
	Inputs – fuels	Economic Inputs
	Inputs – natural assets	Economic Inputs
	Inputs – road infrastructure	Economic Inputs
	Inputs – transport	Economic Inputs
	Roads (improving)	Economic Inputs
	Taxes	Income Tax & GST
	Employment	Labour Market
	Cropping	Primary Industries
	Dairying	Primary Industries
	Deer farming	Primary Industries
	Farming	Primary Industries
	Fisheries	Primary Industries
	Forestry	Primary Industries
	Forestry	Primary Industries
	Goats	Primary Industries
	Gravel extraction	Primary Industries
	Horticulture	Primary Industries
	Horticulture	Primary Industries
	Marijuana	Primary Industries
	Mining	Primary Industries
	Natural & farmed fisheries	Primary Industries
	Organics	Primary Industries
	Ostriches/emu	Primary Industries
	Sheep farming	Primary Industries
	Shell fisheries	Primary Industries
	Trout	Primary Industries
	Whitebait	Primary Industries
	Coastal corridor economic zone	Property Valuation
	Land prices	Property Valuation
	Land values	Property Valuation
	Sub-division	Property Valuation
	Arts and crafts	Secondary Industry
	Cottage industries	Secondary Industry
	Fish processing	Secondary Industry
	Horticultural packaging	Secondary Industry
	Industry	Secondary Industry
	Timber processing	Secondary Industry
	Wine processing	Secondary Industry
	Communication	Tertiary Sector
	Contracting	Tertiary Sector
	Education	Tertiary Sector
	Healthcare	Tertiary Sector
	Home stays & accommodation	Tertiary Sector
	Service sector	Tertiary Sector
	Social welfare & services	Tertiary Sector
	Tourism	Tertiary Sector
	Transport	Tertiary Sector
	Urban centres	Tertiary Sector

Group Names	*Disaggregated Factor Names (171)*	*Aggregated Factors Names (28)*
Social	Corporate farming divisive on local communities	Family & Community Wellbeing
	Decline in community social activities	Family & Community Wellbeing
	Emerging settlement patterns hard on rural schools	Family & Community Wellbeing
	Foreign ownership	Family & Community Wellbeing
	Growing socio-economic gap	Family & Community Wellbeing
	Housing issues – large community issues impacts on living & community support	Family & Community Wellbeing
	Lack of social activities	Family & Community Wellbeing
	Rural communities – less community cohesion	Family & Community Wellbeing
	School rolls	Family & Community Wellbeing
	Schools a major community focus	Family & Community Wellbeing
	Traditional family farms converted to corporate farms	Family & Community Wellbeing
	Health	Human Health
	Also people with good skills come into the community	Participation in Economic Life
	Hard for people to stay in community	Participation in Economic Life
	Influence of Māori owned land	Participation in Economic Life
	Large proportion of Māori leasehold land in Motueka leased for commercial purposes	Participation in Economic Life
	Low unemployment	Participation in Economic Life
	Poor socio-economic groups	Participation in Economic Life
	Young people can be trained locally	Participation in Economic Life
	Young people need to leave area for preferred careers	Participation in Economic Life
	Youth career opportunities	Participation in Economic Life
	Changing demographics	Population Dynamics
	Community very mobile (people always on the move)	Population Dynamics
	Farm workers hard to get	Population Dynamics
	Immigration	Population Dynamics
	Local economy based on seasonal workers	Population Dynamics
	Motueka is growing in terms of population	Population Dynamics
	NZ holiday destination	Population Dynamics
	Population is more transitory	Population Dynamics
	Population pressure (Human)	Population Dynamics
	Population pressures in summer	Population Dynamics
	Rural industries (main labour force)	Population Dynamics
	Seasonal workforce	Population Dynamics
	Housing issues – cheap housing in rural areas	Public Life - Governance
	Housing issues – dormitory effects	Public Life - Governance
	Housing issues – lifestyle blocks	Public Life - Governance
	Influence of iwi trusts	Public Life - Governance
	Iwi	Public Life - Governance

Group Names	*Disaggregated Factor Names (171)*	*Aggregated Factors Names (28)*
	Life-style blocks	Public Life - Governance
	Access to social facilities	Community Services
	Decline in community services	Community Services
	Decline in rural services	Community Services
	Increasingly good career training opportunities	Community Services
	Local polytechnics do a good job of career training	Community Services
	Mountain bikes	Community Services
	People send children to preferred schools	Community Services
	Policing varies across rural/urban community	Community Services
	Relative opportunities in rural versus urban education	Community Services
	Rural healthcare	Community Services
	Catchment topography (views, amenities)	Tourism, Leisure, Recreation, Sport
	Coastal and Mopeku areas growing	Tourism, Leisure, Recreation, Sport
	Coastal belt contains rich housing	Tourism, Leisure, Recreation, Sport
	DOC estate	Tourism, Leisure, Recreation, Sport
	Passive recreation verses active	Tourism, Leisure, Recreation, Sport
	Recreational use	Tourism, Leisure, Recreation, Sport
Institutions	Area health board	Governance of Social Institutions
	Community boards	Governance of Social Institutions
	Department of conservation	Governance of Social Institutions
	District health board	Governance of Social Institutions
	ENZA management	Governance of Social Institutions
	Fish and game	Governance of Social Institutions
	Tasman district counsel	Governance of Social Institutions
Regulatory	Sustainability	Policy, plans, rules, legislation
	Resource Management Act	Policy, plans, rules, legislation
	Government policy	Policy, plans, rules, legislation
	National park regulations	Policy, plans, rules, legislation
	Quota-management fishing	Policy, plans, rules, legislation
	Water conservation orders	Policy, plans, rules, legislation
Non-local	School curricula opportunities	Non-Local Influences
	Health care	Non-Local Influences
	Exchange rate	Non-Local Influences
	Interest rate	Non-Local Influences
	Absentee owners	Non-Local Influences
	Demand for produce	Non-Local Influences
	Foreign ownership	Non-Local Influences
	GM crop seed	Non-Local Influences
	Market demand	Non-Local Influences
	World trade regulations	Non-Local Influences

Appendix 2

Table A2 *A List of 28 key factors*

Ecological	Climate & atmosphere
	Pest management
	Maintain biodiversity
	Maintain integrity of ecological processes
	Maintain soil health
	Natural assimilation & purification
	Landscape change processes
	Water quality & supply
	Scientific research
Economic	Customary use
	Economic drivers
	Economic inputs
	Income tax & GST
	Labour market
	Primary industries
	Property valuation
	Secondary industry
	Tertiary sector
Social	Family & community wellbeing
	Human health
	Participation in economic life
	Population dynamics
	Public life – governance
	Community services
	Tourism, leisure, recreation, sport
Institutional	Governance of social institutions
Regulatory	Policy, plans, rules, legislation
Non-local	Non-local influences

Contact Information:

If you have questions or would like more information about this thesis please contact.

Dr Anthony O. Cole
Te Wānanga-o-Raukawa
PO Box 119
Ōtaki
New Zealand

Phone: 0064-6-364-7820
Facsimile: 0064-6-364-7822
Email: colea@twor.ac.nz