SYSTEM DYNAMICS AS THE LINK BETWEEN CORPORATE VISION AND KEY PERFORMANCE INDICATORS

Keith Linard

Director, University of New South Wales - Centre for Business Dynamics & Knowledge Management

k-linard@adfa.edu.au

Cherylne Fleming

Assistant Director Strategic Planning Coordination, Science Policy Division, Defence Science & Technology Organisation, Department of Defence

Cherylne.Fleming@cbr.defence.gov.au

Lubomir Dvorsky

Consultant - CSC(Aust)

UNSW Postgraduate Student

ldvorsky@csc.com

ABSTRACT:

The BSC has gained corporate support because of its potential to link vision, strategy and deliverables via a coherent set of KPIs. Unfortunately, the BSC has largely failed to deliver this ideal because of the lack of a rigorous methodology for selecting the metrics and for establishing the relationship between the metrics and the corporate strategy. Rather, metrics are typically based on group consensus or individual intuition, influenced strongly by data availability and the effort of collection and maintenance.

This paper proposes an approach whereby possible metrics are plotted against the high level activities of the organisation. Cognitive mapping and hierarchical cluster analysis are used to derive a rational basis for identifying interrelationships between the metrics and their linkages to corporate strategy and vision, as a precursor to the development of a balanced scorecard framework.

Keywords: SYSTEM DYNAMICS; COGNITIVE MAPPING; CLUSTER ANALYSIS; BALANCED SCORECARD

ANY FOOL CAN DEVELOP PERFORMANCE INDICATORS

> *Performance information is a critical tool in the overall management of programs, organisations or work units. It is also crucial to public sector accountability. Put simply, it is the main means through which assurance is provided transparently to the Parliament and public that the Government's objectives are being met.*[1]

Despite strictures regarding the critical importance of performance indicators, a review of hundreds of evaluation and performance management documents on the Australian Federal Government web sites and in the Australian Defence Managers' and Government Managers' Toolboxes shows no evidence of the development of any rigorous methodology for the choice, specification or testing of performance indicators. Stripped of their platitudes, the only guidance is consensus and common sense. As indicated, however, in Linard's papers the 1995 and 1997 Australasian Evaluation Conferences[2], there is significant evidence that 'common sense' indicators can produce counterintuitive results. Linard (1995) also highlighted the limitations of the 'logic framework', as commonly applied, in the development of performance indicators.

This paper develops a rigorous framework for developing performance indicators and describes its application in the Defence Science and Technology Organisation. It highlights the significant improvement in understanding of performance indicators arising from this approach.

---

[1]   ANAO. Better Practice Guide Performance Information Principles. 01/11/1996

[2]   Linard, KT. Dancing Towards Disaster . . . The Danger of Using Intuitive Indicators of Performance. International Conference of the Australasian Evaluation Society 1995

Linard, KT & Paterson D. Building a Learning Organisation - Evaluating Performance Criteria through Simulation Games. International Conference of the Australasian Evaluation Society 1995

LOGIC ANALYSIS - FOUNDATION OF PERFORMANCE MEASUREMENT

Program logic analysis may be defined as the systematic study of the presumed relationships between political & regulatory environment, program resource inputs, ongoing program processes / activities, short term outputs, longer term results, and program objectives.[3]

The 1984, Financial Management Improvement Program (FMIP) Handbook, *Evaluating Government Programs*[4], proposed a structured logic analysis framework for planning and implementing program evaluations. The program logic framework was further developed by the various State Governments and private consultants over the subsequent decade.

A program logic framework remains significant in various federal departmental evaluation manuals[5] and in the reports and guidelines of the Australian National Audit Office[6] and the Federal Department of Finance and Administration[7].

Figure 1 depicts the most recent Department of Finance and Administration presentation of such a program logic framework.
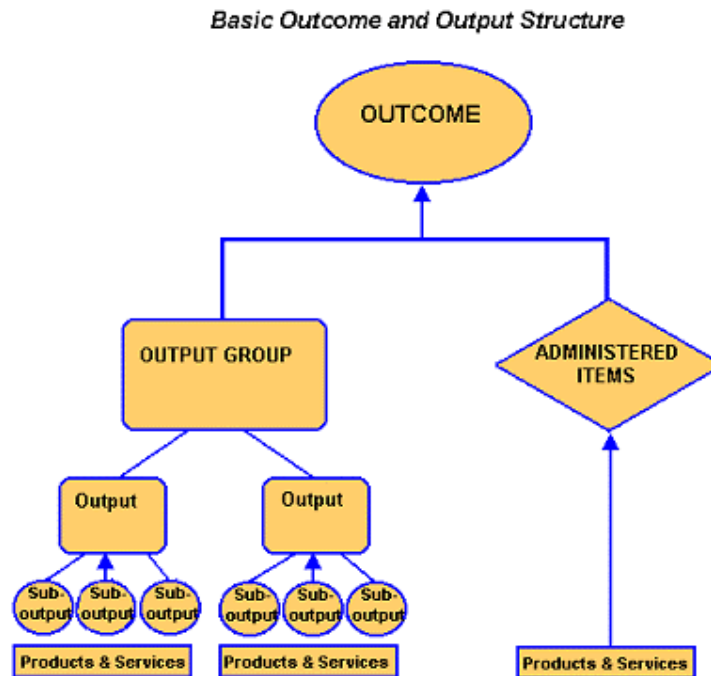

Figure 1: Causal Logic Model for Government Program (DOFA 2000)

The logic model "…provides for the use of output groups that can strengthen the strategic and causal connections between each level."[8] "The process of developing and analysing the underlying logic of programs … is a powerful mechanism for identifying the key areas and issues within a

---

3   Linard (1995).

4   Department of Finance. *Evaluating Government Programs - A Handbook*. AGPS, Canberra, 1987. pp.13-15.

5   E.g., Royal Australian Navy, Directorate of Corporate Management, ABR 2010, The Navy Quality Manager. Defence Centre, Canberra. Second Edition, 1996, Chapter 11. That document in turn draws heavily on Linard, KT, Evaluating Government Programs - A Handbook. AGPS, Canberra, 1987.

6   ANAO. Better Practice Guide Performance Information Principles. 01/11/1996

7   Department of Finance & Administration. The Outcomes & Outputs Framework Guidance Document. Nov 2000

8   ANAO (1996). Op. cit.

program, particularly in relation to outcomes, and hence enables the development of useful performance information".

Why Logic Analysis ?

Conceptually, the DOFA 2000 model is the same as the 1984 FMIP model, with minor terminology changes. The purpose in undertaking a logic analysis is to describe clearly the intended or assumed processes by which a program is expected to accomplish its objectives. This presumes that the program can be considered, and represented, as a causal system, as illustrated in its simplest form in Figure 2.
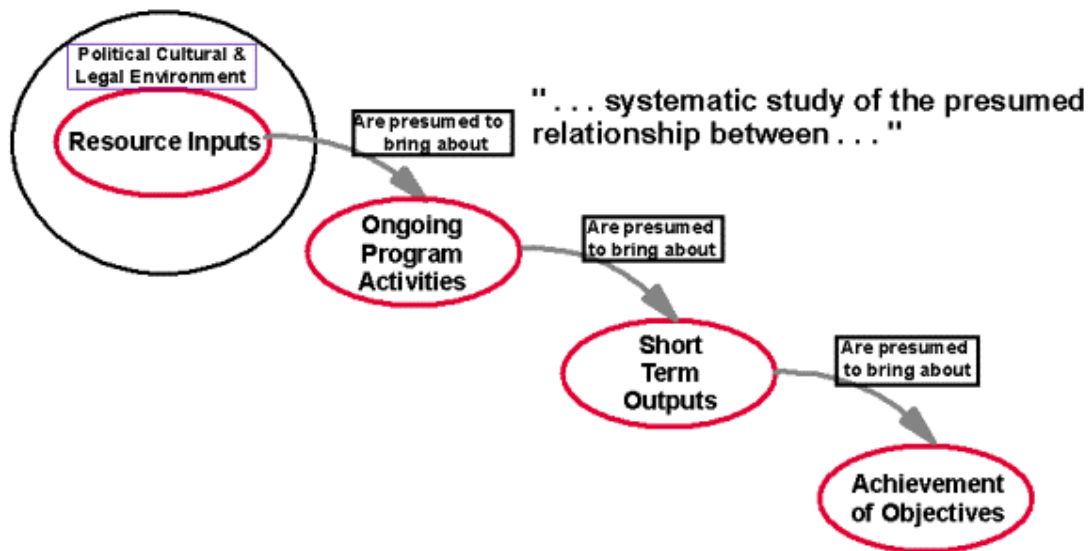
Figure 2: Essence of Program Logic - Causal Chain Leading from Inputs to Outcomes

Figure 1 and Figure 2 presume that the allocation of resources (including staff, managerial skills, staff skills, purchased services, equipment, accommodation, finance etc) will be adequate to implement the planned products and services. These products and services in turn are presumed to be adequate to achieve the planned sub-outputs, which in turn, result in achievement of the planned outputs. Finally, the aggregate achievement of these outputs, together with the administered items, are presumed to bring about the planned program outcomes. Such a model points to a host of assumptions, and raises many questions for the planner, in particular the relationship between the different program elements, and the effect on overall objectives achievement of inadequate performance in particular elements.

Most government program activities are, of course, very complex: there are often many interactions with other programs and with the external social and political environment; the 'causal chain' from program activities to expected results is often unclear; and the mapping from outputs to outcomes or objectives is often problematic. Logic analysis inevitably involves simplification of the real world. Nevertheless, it imparts a salutary rigour to program design, implementation and evaluation.

Analysis of the program logic aims to identify the risk of breaks or dispersion in the logic chain (Figure 3) by addressing:

- what are the key assumptions underlying the program and how will program success be affected if they are not valid;

- what tests or measures might be appropriate to check whether these assumptions are sound;

- what are the most sensitive or significant variables and what monitoring and control measures can we implement to rectify problems as they occur;

- what changes to program design, program management or program operations would improve the likelihood of achieving the desired objectives;

- how do various program element activities relate to each other, and how does performance in one affect the other activities;

- what aspects of the program are likely to be affected significantly by other programs or by factors outside of the program manager's control; and

- what are the significant unintended impacts of the program.
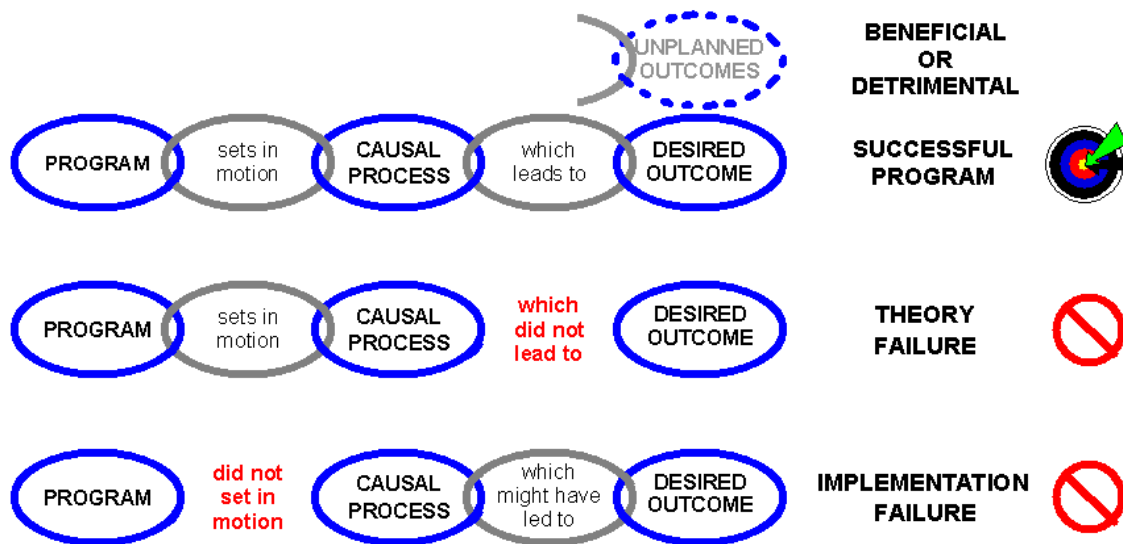
Figure 3: Logic Analysis Helps Identify Breaks & Dispersion in the Causal Assumptions

Steps in Doing the Program Logic Analysis

Assuming that the objectives or outcomes of the program have been defined at least in general terms, and that the broad strategy for achieving them has been decided in principle, the analysis of program logic involves the following steps:

(1) identify, and hierarchically order, the full range of outcomes expected or objectives to be achieved from this program;

    a. sub-dividing program operation into a small number of major outputs, activities or discrete phases (between 5 and 10 elements is desirable, at least initially);

(2) identify the inputs, processes, external influences, intended outputs and any significant side-effects (whether desirable or undesirable) of each of these phases;

(3) specify for each phase and the program as a whole the perceived logical relationships (that is, the hypothesised cause-effect relationship), between the inputs, operating processes, external influences, the outputs or outcomes and the objectives;

    a. confirming with the program managers / subject-area experts that the logic model is a fair representation of what is expected /supposed to happen;

(4) qualitatively or quantitatively model the assumed logic (e.g., using system dynamics modelling), to identify:

a. which are the key assumptions or most sensitive variables underlying the logic of the model and what are the implications if they are not valid;

b. identify the evaluation questions which are relevant to the testing of these assumptions; and

c. identify the performance indicators or measures which are warranted in each phase to monitor the program; and

d. identify appropriate policy levers and the associated business rules for responding to off-trend performance.

Step 1, hierarchical ordering of outputs and outcomes, has been extensively addressed at successive AES Conferences over the past decade, and will not be canvassed here.

Step 4, program modelling is addressed in a companion paper at this conference.

Our focus is on steps 2 and 3, identifying the components and the assumed cause-and-effect logic of the program. The UNSW Centre for Business Dynamics, through its consulting and its PhD program, have evolved a structured methodology for addressing this area.[9] Two invaluable tools applied in this are cognitive mapping and statistical cluster analysis.

TOOLS FOR INITIAL CAUSE-AND-EFFECT MODELLING

Cognitive Mapping

Cognitive mapping derives from the Psychology of Personal Constructs developed by cognitive psychologist, George Kelly[10]. An individual's or a group's perception and understanding of a problem is captured in a 'cognitive map' which consists of interconnected sets of elements (words/ideas) representing relationships that are perceived to exist among the attributes and/or concepts of a given environment.

Cognitive maps are used primarily to assist decision-makers gain a clearer understanding of the way different stakeholders view a problem. They provide a powerful and effective way to capture and analyse stakeholder concepts about strategic issues. Experience in many environments, including the Australian Defence Organisation (ADO), demonstrate that it can result in high levels of shared understanding among stakeholders, analysts and decision makers.

A 'cognitive map', 'concept map' or 'causal map' consists of nodes, known as concepts linked by arrows. The arrows may carry a sign, though the absence of a sign is usually taken to indicate a positive link and a negative sign indicates a negative link. Causality feedback and dominant mechanisms may be derived from these maps. McLucas, in his PhD program at the Centre for Business Dynamics, has developed a robust methodology, within an Australia context, for the application of this technique.[11]

Cluster Analysis

Cluster analysis is suggested as an initial step in structuring complex multifaceted problems. It is appropriate to any scale or any type of problem and is particularly suited to unstructured problems

---

9   A detailed methodological framework was developed in 1997 for the Department of Defence for the 'Defence Preparedness Resourcing Model - Scoping Study'. See also: Linard KT, Quality Assurance in System Dynamics Modelling. School of Civil Engineering, ADFA, 1998.

10   Kelly, G. A. (1955). "The Psychology of Personal Constructs: A Theory of Personality." Norton, New York

11   McLucas, A. Qualitative and quantitative techniques for addressing systemic complexity in the context of organisational strategic decision-making. PhD Thesis. UNSW. Aug 2001

and non-quantitative data. In essence, cluster analysis provides a rigorous basis for linking or grouping 'objects' (e.g., policies, objectives, KPI's) into groups or clusters, such that the objects in a given cluster tend to be similar to each other in some sense, while objects in different clusters tend to be dissimilar. Activities (or strategies or KPI's), which are similar to each other in so far as they serve similar objectives, are grouped into the same cluster, whilst different clusters separate activities that are dissimilar in so far as they are oriented to different objectives.

Cluster analysis has a theoretically sound basis and has been widely applied across many disciplines for decades. All major statistical software packages include this tool.

Cluster analysis helps achieve a better understanding of the problem being tackled, its basic structural components and their interrelationships, because it forces a simple yet systematic review of complex issues, and leaves the software to do the analysis. Careful attention at the problem definition stage can avoid ambiguities of meaning and intent; help eliminate unsuitable "package" solutions; and help ensure that the problem solution is based upon an understanding of the causal factors and not simply data related to the problem symptoms .

The first step in doing a cluster analyais is to identify those attributes or key characteristics of the program most relevant to the problem at hand, for example, the initial expression of KPI's and the organisation's strategies. The attributes are arrayed against each other in a matrix (*see table 1*), and compared pair wise (e.g., Activity_A.1 against Strategy_1.1).

The next step is to classify all attributes with respect to each other. Proceed by asking the question of each attribute pair: to what degree does an attribute impact on or support the other? Ideally, this step is done with key stakeholders so that they own the end result.

There are diverse ways that the multidimensional effects may be coded. The simplest approach is:

(a) If an attribute enhances or supports the other: this is termed a positive interaction, and is coded with a value of '+1'.

(b) If an attribute detracts or militates against the other: this is termed a negative interaction and is coded with a value of '-1'.

(c) If there is no interaction, either (+) or (-), or if the relationship is uncertain or could be either (+) or (-) depending on circumstances, it is coded with a zero value.

If there is good understanding of the interrelationships, a finer discrimination in the cluster analysis would be achieved by coding on a scale, for example, of (+10) to (-10).

Activity	Strategy Number					
	1.1	1.2	2.1	2.1	2.3	etc
	(Rank from -10 to +10)					
Activity A.1						
Activity A.2						
Activity B.1						
etc						

Table 1: Example of a Strategy / Activity matrix

Clearly there is subjectivity in such assessments, and the judgements in this step may be a source of disagreement. But since the process forces the judgements to be made explicit there is at least a

focus for discussion of differences of opinion. In the case of strong disagreement, separate analyses may be undertaken to see if the implications are significant in the end result.

Output of the Cluster Analysis

A variety of measures of similarity (indexes of cluster "goodness") are available with most cluster analysis programs. Probably the most useful output, however, is the dendogram, or "tree plot", Figure 4, which graphically represents the results of hierarchical clustering.
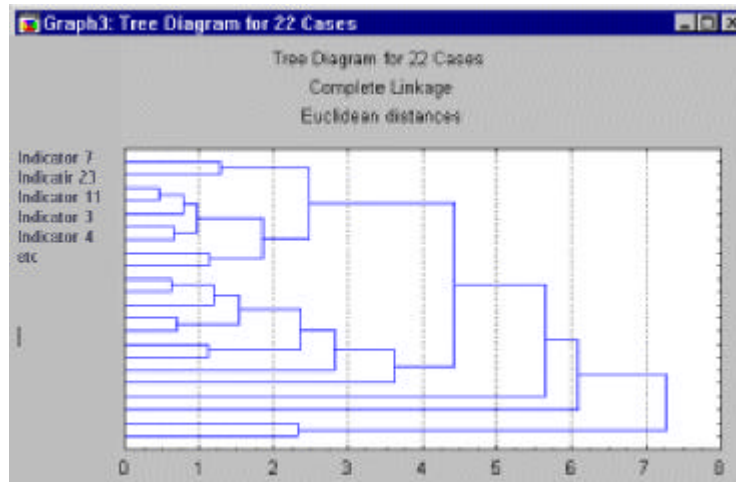

Figure 4: Dendogram Showing Relationship between KPIs & Strategy

This cluster tree plot allows one to gain rapid insights into the clustering. One may look for subsets which are clearly defined by the clustering. These are indicated by clusters which join together at a relatively low level (left hand side of Figure 4). In the example, indicators and strategies which join close to the origin are a more homogeneous (or tighter) cluster than are activities which form further from the origin.

CASE STUDY IN DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION (DSTO)

The DSTO is part of the Australian Department of Defence. DSTO's objective is *to give advice that is professional, impartial and informed on the application of science and technology that is best suited to Australia's defence and security needs*.

To achieve the necessary high level of confidence that the scientific advice given to Defence is right, DSTO conducts scientific investigations and undertakes research projects. Its understanding of developments in defence technology assists Defence in making informed decisions on the purchase of new equipment. DSTO also supports existing capabilities by enhancing operational performance and by reducing the costs of ownership of major defence equipment, including through life-extension.

DSTO Balanced Scorecard Project

The Balanced Scorecard (BSC) for DSTO was introduced to senior management against a background of changes as a model to assess the organisation's performance. The changes articulated by the DSTO senior management team involved the environment that DSTO needs to operate in externally, and within defence. In the external environment there is a worldwide trend to compete R&D in both private and public organisations, with the recent Government's Innovation Action Statement clearly articulating the necessity for all R&D funds to be competed. This places

pressure on DSTO from other government agencies to demonstrate our contribution to National wealth. With the current Defence environment there is an ongoing management reform agenda focused on making Defence more responsive to government, improving accountability and an emphasis on stronger leadership throughout the portfolio.

This changing environment leads the senior managers of DSTO to articulate where they currently see DSTO and where they would like to see DSTO in the future. Their key messages for the future success of DSTO include:

- Scientific excellence

- Close to our clients: the ADF is our Partner

- Source of defence science knowledge

- Independence of Advice

- Creative / innovative solutions

- Responsive / accountable

To demonstrate that DSTO is continuing to achieve against these areas, strategies were developed, with objectives and milestones. If DSTO's organisational performance is to continue to be successful then these strategies must relate to the BSC. This paper discusses the method used to ensure DSTO's change strategies and BSC are aligned.

For DSTO the BSC has a hierarchy of concepts. The highest level is the Critical Success Factor (CSF); these are core activities that DSTO must get right if it is to be successful as an organisation. Each CSF has between one and three Key Performance Indicators (KPI); these are activities or objectives for the organisation and often form the basis of an implementation strategy. The measures or metrics of the BSC relate to the KPI and more specifically the intent behind that KPI.

BSC - a Driver of Strategy

From Kaplan and Norton, and from the prolific marketing of BSC solutions by management consultants, we know that a "good" BSC is not simply a limited list of measures gathered into four categories. Rather, a "good" BSC *"... should tell the story of your strategy"*[12], communicating and promoting adherence to the strategy to all levels of the organisation.

A good BSC *"... tells everyone in your organization, in a single page, the story of your entire strategy: Every measure is part of a chain of cause-and-effect linkages. All measures eventually link to organizational outcomes. A balance exists between outcome measures (financial and customer) and performance drivers (value proposition, internal processes, learning & growth)"*.[13]

A good BSC will reflect the *vertical cause-and-effect* relationships for any given objective and summary measure, in the same way that the *causal relationships* are reflected *horizontally* across the business value chain by the four perspectives. In other words, having delineated the causal relationship between the Learning/Innovative Perspective, the Internal Business Process Perspective, the Customer Perspective and the Financial Perspective we take each summary objective/measure and disaggregate them to determine causation.[14]

---

[12]   Renaissance Worldwide Strategy Group. "The Balanced Scorecard -- An Overview"
        http://www.rens.com/viewpoint/papers/scorecard.html

[13]   Kaplan RS, "The Balanced Scorecard", July 13, 1999. http://www.mastersforum.com/kaplan/kaplan.txt

[14]   Jamesford Consulting, "The Balanced Scorecard - A Strategic Management System", http://www.jamesford.co.uk/the.htm

"Every measure selected for a Balanced Scorecard should be part of a chain of cause-and-effect relationships that represent the strategy".[15]

These perspectives have been adapted in the ADO and are known as People Matter (Learning / Innovation) Enabling Business Processes (Internal) Government as Customer (Customer) and Government as Owner (Financial). To align with the ADO, DSTO has adopted the same structure.

Understanding Cause-and-Effect Relationships

Virtually every reference to cause-and-effect in the BSC literature and the implementations in major corporate BSC software systems are flawed:

- cause-and-effect necessarily involves a time lag between cause and effect, however the BSC measures and presents both indicators at the same time with no analytical basis to present the implications of the time lag;

- the presentation of a cause-and-effect chain is a uni-directional causality which totally ignores feedback, and especially delayed feedback effects, whereas there are invariably inter-relationships both within and between the sectors of the BSC.

This paper discusses an approach to developing a BSC which includes these basic relationships to provide greater understanding on the impact strategies have on organisations.

Interrelationship amongst performance drivers - unidirectional causality

In most of their writings, Kaplan and Norton ambiguously describe the relationship between KPI on the BSC. Every example presented and every diagram describing cause-and-effect presents or implies a unidirectional impact, as illustrated in *Figure 5*.
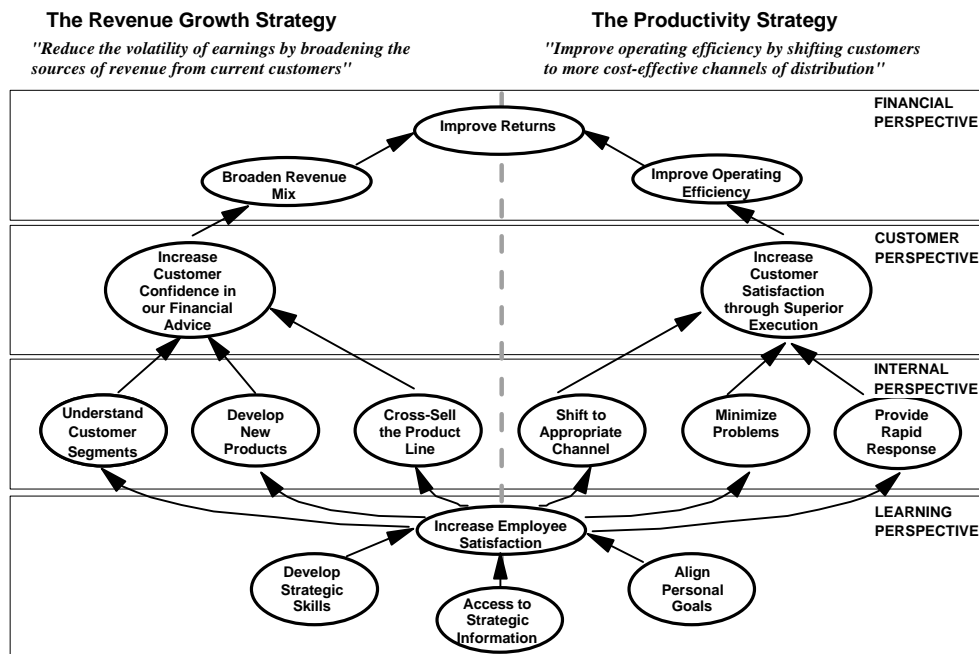
Figure 5: Unidirectional Cause & Effect Chain Supporting Strategy (Kaplan and Norton, 1996).

---

[15]   Ibid.

Figure 5 assumes that 'Employee Satisfaction' will not be affected by changes in work processes (internal perspective), changes that might involve staff reductions, reskilling, higher intensity work, etc. It assumes that there is no feedback from success in the customer sector to 'Employee Satisfaction'. Arguably, the feedbacks from the 'Internal' and 'Customer' perspectives would have greater impact on employee satisfaction than the 'causes' suggested in the Learning perspective. Also, *Figure 5* ignores the obvious feedback link from financial returns, which provides the capacity to invest in learning and growth or reengineering of internal processes.

In developing the draft Defence strategy map (*Figure 6*), the same unidirectional approach has been adopted. The detail of the strategic objectives (the concept bubbles) is not important. However the nature of the relationships and especially their uni-directional causality are.

The relationship between the strategic objectives and between the themes (strategies) reinforces in the unidirectional model introduces difficulties, with concepts only appearing once in the strategy map – and without reference to any of the other strategies. The concepts in the strategy map are often relevant for more than one theme For example, the concept of risk is only identified once, however the Defence White Paper (Oct 2000) discusses many types of risk, for example: technical risk, business risk and operational risk. This complexity could be included in the later drafts of the Defence BSC and strategy map by applying the method outlined in this paper. Indeed the current draft Defence strategy map would be one of the key inputs to that process.
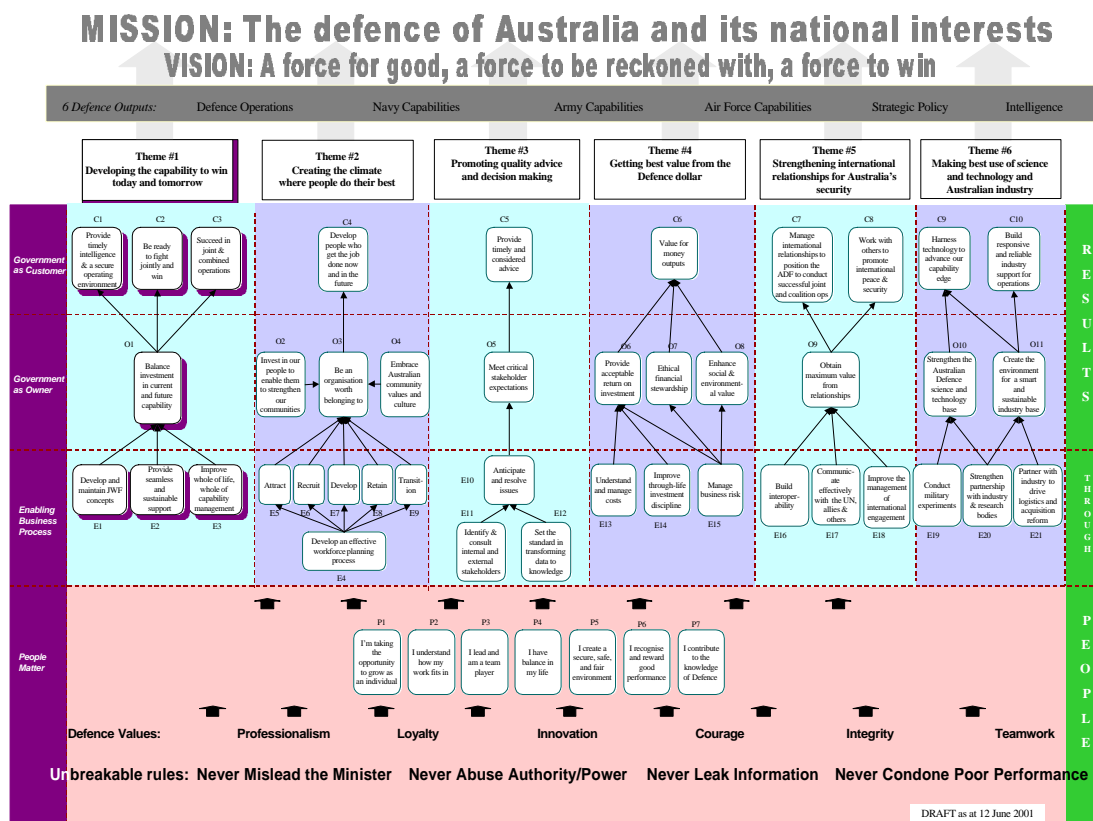
Figure 6: Draft Defence Strategy Map

BUILDING THE DSTO STRATEGY MAP

Cluster Analysis to Clarify the Complexity

The starting point for building the DSTO Strategy Maps was the use of Cluster Analysis. Figure 7 illustrates part of the matrix charting Change Strategies (CS) and sub-objectives as columns against the CSFs and KPI of the DSTO BSC as rows. A score of relevance of the KPI was placed at the intersecting cell of the KPI. This basic input for a cluster analysis can be used at various stages in developing a BSC. For example, in relating KPI to strategy, the management team (individually or collectively) assigns to each KPI a score (e.g., on a scale of -3 to +3) based on judgement of the degree to which a given KPI supports (1 to 3), is neutral (0) or detracts from (-1 to -3) a given strategy.

In a strategy-based organisation, the idea is that your strategies will transect the BSC perspectives (Kaplan and Norton 2001). When system dynamics theory was introduced into the DSTO BSC, this recognised that feedback loops will also transect the perspectives linking CSFs and KPI of each section of the business. As such, a successful strategy will have CSFs from each perspective from the BSC identified on the strategy map or cognitive map. Such a map will demonstrate the relationship between the various concepts on the BSC.

The simplicity of this matrix-based approach allows the senior managers to provide their perspective. The following analysis brings together the various perspectives with the cognitive mapping to provide a framework for discussion and debate.

Figure 7: Matrix of DSTO change strategies by DSTO BSC KPI

The results of such an exercise, e.g. on an Excel Spreadsheet, can then be fed directly to a cluster analysis program (standard with most statistical software packages). A variety of output formats is possible, including the dendogram tree in *Figure 4*. When analysed results drawn from these charts are used to determine how relevant specific KPI were to each CS and sub-objective. Questions can then be asked where no relationships between the CSF and CS were found for example is this measure adding value?

The BSC literature emphasises the importance of focusing on a small number of KPI, but again gives no suggestions on how this selection might be done. Statistical cluster analysis provides a

simple and robust technique. In essence, cluster analysis groups like factors with like, and separates unlike from unlike, allowing for informed decisions on which KPI add value.

The dendogram (refer F*igure 4)* identifies 'clusters' of (in this case) KPI, providing a rational basis for the development of the performance indicator hierarchy in the BSC and for the analysis of inter-relationships. The results showed relevance between the KPI and their associated DSTO CS. In addition, the visual representation showed whether the KPI was working to achieve the CS or working against it.

Cognitive Mapping to Comprehend Presumed Causality & Feedback

The process for developing DSTO's cognitive map was built on the cluster analysis previously described. After it was determined that all CS and sub-objectives were being measured, cognitive maps were designed for each CS. A cognitive map was completed for each CS (*Figure 8*) with a table describing the relationships (*Figure 9*).
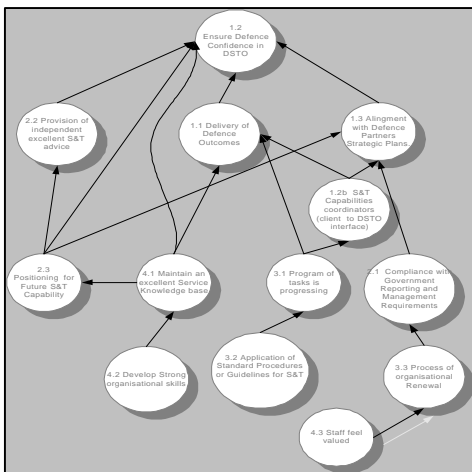
Figure 8: Change Strategy Cognitive Map

Figure 9: Description of relationships for each of the change strategies

An overall cognitive map (*Figure 10*) was then drawn using the intersections collected, and described in the associated tables from each of the CS maps. The overall map shows the strength of the connections between concepts

Figure 10 illustrates the end product of a cognitive mapping process focusing on elements of the draft DSTO BSC. The draft BSC exhibited the traditional uni-directional cause-and-effect chain. The cognitive mapping process, combined with a cluster analysis, not only revealed profound inter-relationships, but highlighted several negative relationships (dotted lines) which had not previously been appreciated. A negative relationship suggests that a particular strategy designed to promote achievement of one strategy has a side affect of countering another strategy … a possibility ignored in the BSC literature.

The group dynamics involved in developing the DSTO BSC has evolved significantly since the cognitive mapping concept, and the proposal to take a more analytical approach to developing the DSTO BSC, was first initiated. The start point was an audience who appreciated the benefits of a systems approach to various topics, but had no exposure to using system dynamic approaches in planning, evaluation or implementing management initiatives.

The first approach was presented to a deeply sceptical audience. Once they had participated in the cognitive mapping and viewed the impact of the cluster analysis a shared understanding was

developed, most importantly in the areas where the group disagreed. This process provided a framework to facilitate discussion, a common reference point and a way of improving the DSTO BSC to reflect the change strategies the senior leaders felt intuitively the organisation needed to progress.
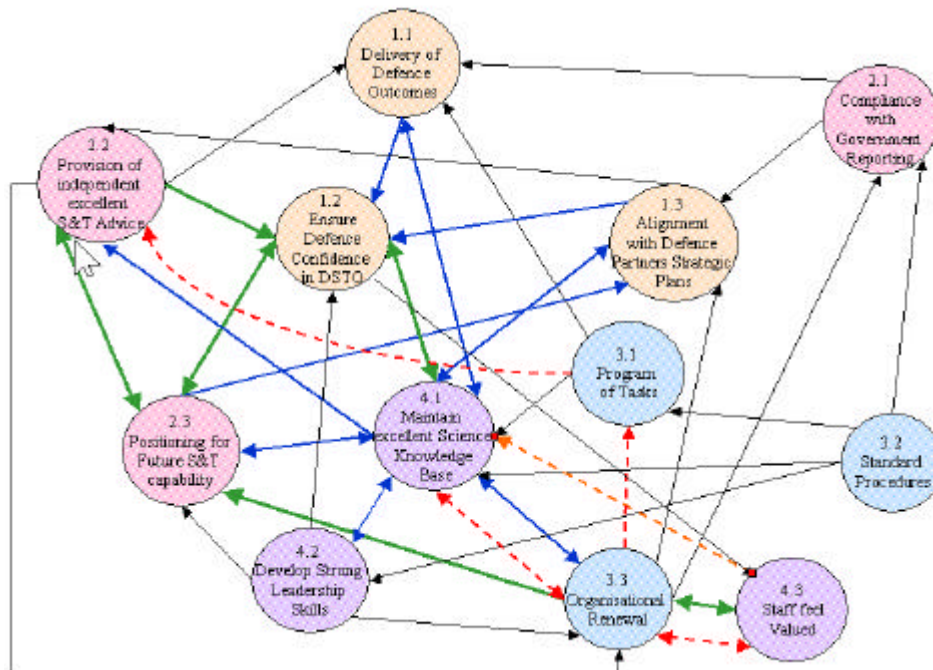

Figure 10: Overall Top Level Cognitive Map