The Theory of Constraints and Systems Dynamics: A Suitable Case for Multi-methodology

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Abstract

Prior work using the classificatory frameworks of Mingers, Mingers and Brocklesby has proven useful in understanding the complementary nature and characteristics of traditional Operational Research/Management Science (OR/MS), Theory of Constraints (TOC) and systems methodologies, by examining the philosophical assumptions that underpin them. This paper uses a case illustration to demonstrate how the specific methods and methodologies known as TOC can be used to complement the use of traditional systems approaches involving the associated tools of Systems Dynamics (SD) such as Causal Loop Diagramming (CLD) and to develop a better understanding of operational and strategic decision-making. In doing so, the paper surfaces the systemic qualities of TOC methodologies, methods and tools, and identifies the communality and complementarity of TOC and SD approaches to problem solving.

Keywords

Theory of Constraints, OR/MS; Systems Dynamics; Systems, Multi-methodology.

Introduction & overview

The development of multi-methodology has received considerable attention over the last three decades as practitioners and academics seek to develop approaches that guide multi-methodological intervention, and thus to understand and create benefit from the use of different yet complementary tools, techniques, methods and methodologies. In this paper, we seek to demonstrate how the specific methods and methodologies known as TOC can be used to complement the use of traditional systems approaches involving Causal Loop Diagramming (CLD) and Systems Dynamics (SD). First, we seek to clarify how these methodologies and their associated methods and tools etc are underpinned by different philosophies, value systems or paradigms, and how such understanding can provide a theoretical basis for mixing methodologies and for their complementary use.

In doing so, we draw on the work of Mingers (2003a, 2000, 1997 a&b), Mingers and Brocklesby (M-B) (1997, 1996), Jackson (1990), Jackson and Keys (1984), and others who have sought to develop classificatory frameworks that would be useful in understanding the nature and characteristics of OR/MS and systems methodologies[1]

[1] A methodology is a structured set of guidelines or activities to assist an individual in undertaking research. A methodology will embody the assumptions and principles of the paradigm. They may develop subconsciously or emerge as prescriptions for good practice for using particular techniques within a paradigm. A framework is a conceptualisation window to see, hear, and to

and the philosophical assumptions underpinning them. Whilst Jackson (1990) sought to classify and reveal the utility, strengths and weaknesses of different systems methodologies and how such features relate to fundamental assumptions underpinning such methodologies and the problem contexts in which they were likely to be used, Mingers and Brocklesby (1997) had a modified vision in mind. They sought to examine and classify the relative strengths of different methodologies as a basis for constructing multi-methodological approaches and mixing methodologies, a purpose in keeping with Burrell and Morgan's (1979) acceptance of multi-paradigm and therefore multi-methodology development (Brocklesby 1993; Gioia & Pitre 1990). Indeed, much of the work in the field of multi-methodology has arisen out of need to better understand the complementary use of different approaches, techniques, methods and methodologies. This need is especially marked when these approaches etc are underpinned by different value systems or paradigms, and especially when different world-views lead to alternative perspectives of problem situations (Davies & Mabin 2001). Reflecting this position, and building on his previous work, Mingers (2003a) has developed a framework facilitating the examination and classification of the fundamental philosophical assumptions underpinning OR/MS and systems methodologies, with a similar purpose being to better inform and support the design of multi-methodological approaches to problem-solving.

At the practitioner level, the need for clarity about the distinctiveness, substitutability or complementarity of different methodologies has been addressed by the development of classification systems and frameworks (Jackson & Keys 1984; Flood and Jackson 1991). Additionally, several frameworks regarding method choice (Mingers 1997b; Flood 1995; Flood & Romm 1996) have also emerged. However, one consequence has been that some descriptive frameworks such as Jackson and Keys' System of Systems Methodologies (SOSM) have come to be viewed (and used) uncritically, perhaps unwittingly, as frameworks providing meta-methodological guidelines for method choice (Brocklesby 1995) - a criticism that, ironically, has also been levelled at the M-B framework for mapping methodologies (Mingers & Brocklesby 1997). Nevertheless, in support of that concern, we concur with Zhu (1999) of the need to make our frameworks, tacit or otherwise, the basis for dialogue and learning, of the need to promote critical discourse and critical appreciation of the different methods and methodologies. We suggest that whilst existing recognition of such needs is evident in the broad domain of OR/MS and systems, such needs must also be addressed in the emergent domain of TOC if its potential contribution to multi-methodological intervention is contemplated.

Whilst many people will be familiar with Goldratt's early works such as *The Goal* (Goldratt & Cox 1984, 1992; Goldratt & Fox 1987, 1986; Goldratt 1990b), the body of knowledge now called the Theory of Constraints (TOC) which has emerged from this base has been considerable in volume and impact, and extends far beyond the original domain of production scheduling both in terms of application area and methodological development. Indeed, over a period of two decades, TOC methods and tools have grown in acceptance beyond practitioners within the field of production and operations management (POM) to others within the POM academic

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make sense of the outside world; any framework is mutually conditioned and shaped by other frameworks (5. Mingers, J. and J. Brocklesby, *Multi-methodology: Towards a framework for critical pluralism.* Systemist, 1996. **18**(3): p. 101-132.).

Kuhn's notion of paradigm as 'models for thinking' – 'a constellation of concepts, values, perceptions and practices shared by a community which forms a particular vision of reality that is the way a community organises itself'; - 'A systematic set of ideas and values, methods and problem fields, as well as standard solutions, that explain the world and inform action.' 'It's the way we see the world – not in terms of our visual sense of sight, but in terms of perceiving, understanding, interpreting.' (Kuhn, 1974, quoted in 8. Clarke, T. and S. Clegg, *Changing Paradigms: the transformation of management knowledge for the 21st century*. 1998, HarperCollins: London. p. 9 - 15.)

community. TOC has already found a place alongside JIT, TQM, MRP etc in standard POM texts (Chase et al. 2001; Finch & Luebbe 1995) and in leading POM academic journals; and has reached a stage of developmental maturity signalled by a recent TOC-based POM text (Cox et al. 2003). TOC's relevance is also appreciated in the related project management field. Indeed, we make an observation that the broader practical problem domain in which TOC methods have been used is essentially the same domain in which OR/MS and systems methods have been traditionally employed. However, the development of TOC has been predominantly practice and practitioner-led, and it has been subject to little in the manner of methodological critique – a gap that the authors have sought to remedy here and elsewhere (Mabin, Davies & Balderstone. 2003).

A contribution that this paper seeks to make is to understand issues of a meta-methodological nature that relate to the use of TOC methods in multi-methodology. We have used the classificatory frameworks of Mingers (2003a) and Mingers and Brocklesby (M-B) (1997) to better appreciate the nature of selected TOC methods. The classificatory analysis, which is provided in Appendices 3 and 4, helps position such methods in relation to the tools and methods of other methodologies. We also briefly summarise and clarify the philosophical assumptions, ontological and epistemological that underpin the various methods and activities that make up TOC and SD. Building on these analyses, we argue that much may be gained from further exploring how TOC and the associated methods of SD may be used in combination. As such, the paper seeks to provide a basis useful for comparing TOC methods and representational tools such as the Negative Branch Reservation (NBR) Process and the Evaporating Cloud (EC) with an alternative methodology and its associated tools, for example, the Causal Loop Diagrams (CLD) of Systems Dynamics (SD). We do so through examination of a case study (Appendix 5) developed for use in the classroom. The paper now continues with a resumé of the frameworks of Mingers (2003a) and Mingers & Brocklesby (M-B) (1997, 1996) before examining the Power case study using the chosen methodologies.

The Mingers and Mingers-Brocklesby Frameworks for Mapping and Classifying Methodologies

The work of Mingers and Brocklesby (M-B) and Mingers has sought to clarify the role, function and purpose of different OR/MS and systems methodologies and their philosophical underpinnings. Such fundamental assumptions relate to the nature of organisational and real world phenomena - what we regard as ontology; the nature of knowledge about those phenomena – epistemology; and the nature of ways of studying and examining those phenomena – methodology (Gioia & Pitre 1990; Mingers 2003a). The original M-B framework provides a basis for relating methodology and method to problem content and problem-solving activity using a 2-dimensional mapping grid (See Figure 1) with the purpose of alerting analysts to the appropriateness of different methodologies in different contexts. However, Mingers (2003a) has since suggested that as the M-B framework links methodology and method to problem content and problem-solving activity more in a general rather than specific way, a consequence has been that the placement of methods within the grid has been seen as somewhat ad hoc. Such criticism can be traced, in part, to the mapping grid capturing just two primary dimensions. The first relates to the problem domain, specifically the nature of the world being investigated – be it social, personal or material – and the second relates to the methodology, particularly, the conceptually distinct but highly related phases of 'intervention'. These phases of intervention are described within the M-B framework, for example, as building an *appreciation* of the

material world that provides a necessary base for *analysis* of that world and relationships between key entities, before developing and *assessing* alternative futures and options to bring that future about; and then finally being able to choose and *implement* alternative courses of action that bring about that future. The classification of an activity associated with a method or methodology then requires a determination of whether that activity is one that is deliberately designed for that phase of intervention.

Figure 1: Mingers-Brocklesby Framework for Mapping Methodologies

		Phases of Intervention			
		Appreciation of …	**Analysis of …**	**Assessment of …**	**Action to …**
Problem Domain	**Social**	Social practices, power relations	Distortions, conflicts of interests	Ways of challenging & altering power structures	Generate empowerment and enlightenment
	Personal	Individuals' beliefs, meanings, emotions	Different perceptions and Weltanschauung	Alternative conceptualizations and constructions	Generate accommodations and consensus
	Material	Physical circumstances	Underlying causal structure	Alternative physical and structural arrangements	Select and implement best alternatives

Following his erstwhile self-critique of the limitations of the M-B framework, Mingers (2003a) has sought to develop an alternative classificatory framework that would more readily highlight salient features of traditional OR/MS and systems methods. He does so by invoking additional dimensions that facilitate discrimination and comparison of methodology and method, and by the explicit surfacing of the philosophical assumptions underpinning the methodology and the purpose of intervention. Mingers suggests that any attempt to classify methodologies should reflect what would be their most common and general characteristics – those being, for example, the purposive action orientation of OR/MS methodologies; an acceptance of the notion and value of problem representation and analysis using models; the nature of modelling itself, with different modelling and representational approaches being founded on different philosophical assumptions; and, in some cases, the relationship of methodologies to specific theoretical frameworks or to practical experience, an issue which is not covered in this paper. He insightfully synthesises these characteristics and conceptual notions into a SSM root definition for a generalised methodology. The definition, which embeds a cognitive structure espoused by Checkland and Scholes (1990) makes explicit and emphasises the ontological, epistemological and axiological nature of modelling assumptions (See Figure 2). It forms the basis for the extended classificatory framework shown in use as Appendices 2 and 3.

Figure 2: SSM Root Definition of a Generalised Methodology

"**To do** X **by** Y **in order to** achieve Z" Checkland & Scholes 1990

A system **to do** the process specified,

by developing models of that assumed to exist,

in the specified form of representation based on necessary information gained from particular sources

in order to assist users achieve specific purposes.

From Mingers (2003a:562)

Action orientation	what it does	model, simulate, represent, question, diagnose, assist, surface, challenge
Ontology	that assumed to exist	real world measurable objects, associations, conceptual systems, logical/causal relationships, choices, uncertainties, premises
Epistemology	**form of representation**	equations, diagrams, trees, schema, spreadsheets, rich pictures, maps, iconic models, statements
	necessary information	quantities, beliefs, meanings, views, attitudes, purposes, structure, interests, options, likelihood
	sources of information	objective measures, observations, plans, theories, participants, discussions, workshops, groups
Axiology	users	analysts, researchers, facilitators, participants, stakeholders, planners, managers
	purpose and values	optimising, learning, experimenting, challenging, explore, understand, synthesise, surface, clarify

Mapping of Methods and Associated Tools of Systems Dynamics

For the purpose of this paper, it will be assumed that the reader's knowledge of SD as an umbrella methodology and its associated or constituent tools or techniques will be sufficient to make sense of the Mingers and M-B frameworks, and how the mappings and classifications shown in Appendices 1 and 2 have been derived. Further detailed discussion can be found in Mingers and Brocklesby (1997, 1996), Mingers (2003a & b, 2000, 1997a), Mingers & Gill (1997). Whilst Mingers' classificatory judgements about the nature of SD, its associated CLDs and of SSM, summarised in Appendices 1 and 2, were informed by advice from many of the methodology innovators or developers, the judgements made here about the classification of TOC tools are those of the authors (The equivalent classifications of individual TOC methods and methodology are shown in Appendices 3 and 4).

In illustration of how that mapping takes place, we may suggest that within SSM, for example, we regard the development of rich pictures as an activity that supports building an appreciation of individual beliefs, meanings and emotions, whilst the development of CATWOEs[2] contributes to further analysis of the different perceptions and worldviews or Weltanschauung held by individuals. Following these phases of activity, SSM then requires the building of alternative models and conceptualisations that can be assessed for appropriateness in recognising and describing the problem, and that help provide an assessment of alternative actions that address the problem (Appendix 1.1).

By contrast, the 'strength' of cognitive mapping lies with its purpose of capturing and making explicit individual beliefs, meanings, assumptions and emotions, the relationships between them, and thus the surfacing of the existence of different perceptions and worldviews (See Appendix 1.2). At that point, cognitive mapping has 'done its job,' whereas SSM has been designed as a methodology to work towards purposeful improvement of situations.

[2] CATWOE = Customers, Actors, Transformation, World View, Owners, Environment

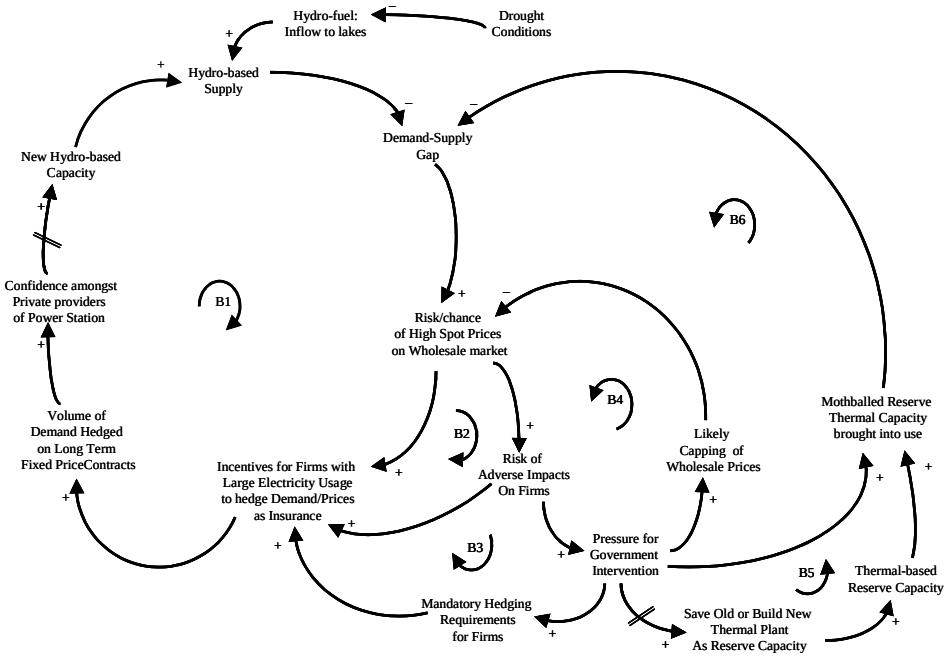
Of course, in making these comments, we are also surfacing often implicit assumptions about users and purpose, that is, we are entering discussion that can be effectively characterised by Minger's classification of the underpinning philosophical assumptions that are axiological in nature. Similarly, our awareness of ontological issues is heightened by making explicit the beliefs, meanings and relationships which we assume to exist and which we regard as meaningful and important in understanding our problematic situation. Finally, that which we take for granted about our modes of representing aspects of problems - the connotative links in rich pictures and the cause-effect links in CLDs and in TOC diagrams - require us to reflect upon our epistemology.

The Power Case

The Power Case (See Appendix 5) reflects a topical and recurring chronic problem for the NZ government and for many other nations' government. In 2003, NZ was confronted with a second electricity power crisis in three years, and the government was faced with a perceived need to provide security of electricity supply to cover the risk of a dry year in the hydro system - in particular, the need for about 800MW of "firming capacity"*. The case provides sufficient information for students to identify what may be important variables in the power generation system, the inter-connectedness of those variables, and the predictable and otherwise emergent properties of the overall system.

At this stage, we provide an illustration of how the case narrative may be framed using a CLD (See Figure 3), but defer consideration and discussion of insights that may emerge from the building of that representation, including the identification of possible core issues and choice dilemmas, until we have outlined the possible contribution of TOC.

Figure 3. – An Illustrative Causal Loop Diagram (CLD) for the Power Case



We will show how TOC tools, in particular, the EC of TOC can help structure a dilemma in the process of attempting to resolve the inherent conflict between alternative plausible and seemingly mutually exclusive actions or options.

The Theory of Constraints – TOC – and The Mapping of TOC Tools and Methods

Given the nature of this paper, it may be sufficient to state that TOC as an espoused methodology seeks to assist with the 'management of beneficial change' in organisations by using logic-based modelling and analytical tools in the belief that organisations as systems can be subject to on-going improvement aiding long-term survival - if those barriers, obstacles and other factors constraining or limiting improvement can be identified, and removed or managed more effectively. In brief, TOC seeks to identify what needs to change; what to change to; and how to bring about that change. As such, it addresses the identification of root causes to constrained performance – what to change; it addresses organisational purpose and strategy development – what to change to; and it seeks to identify causal actions and action plans that will improve performance through the modelling of causal relations believed to exist and have meaning in the organisational context. We may therefore regard the emergence of the field of TOC as reflecting a functionalist paradigm and as a systemic methodology reflecting an ontological assumption that organisations and organizational contexts can be viewed or conceptualised as systems that exhibit emergent properties manifest of interrelationships and interdependencies between people/processes/internal/external environments.

Goldratt (1994Luck) has evolved a suite of logic tools in his quest to devise TOC as a systemic and systematic approach to help managers develop solutions (based on both intuition and logic) to their problems. These tools comprise four tree diagram tools and the Evaporating Cloud (EC), which are known collectively as the TOC Thinking Processes or TP tools (see books by Kendall 1998; Dettmer 1998; Scheinkopf 1999; and Cox et al. 2003).

The TP's exist for the purpose of managing change, starting with identifying what is preventing an organisation from achieving its goal. They embrace what we refer to as the Current Reality Tree (CRT), the Future Reality Tree (FRT), the Prerequsite Tree (PRT), the Transition Tree (TrT) as well as the Evaporating Cloud (EC). The TPs are constructed from three basic building blocks: cause-effect sufficiency thinking, necessary condition thinking, and a set of rules governing the logic-in-use (Scheinkopf 1999). The CRT, FRT and TrT are sufficiency-based *if-then* logic diagrams, whereas the PRT and the EC are necessity-based *"in order to…, we must …"* logic structures (Rizzo 2001). Goldratt has provided logic rules (see the Categories of Legitimate Reservation (CLRs) in Noreen et al. (1995), Dettmer (1998), Scheinkopf (1999) that are used to add rigour to the modelling process and to check the validity of the constructed logic relations.

In Appendices 3 and 4, we characterise each of the TOC Thinking Processes - TP tools - and the 5 Focusing Steps of On-going Improvement (5FS) method used within TOC. We provide brief descriptions of selected tools and methods as a basis for such characterisation and classification. It is worth noting that whilst the tools and methods may be used on their own for day-to-day problems, they would be used in combination for more infrequent and complex situations (Mabin & Davies 2003).

The TOC Logic Trees – the CRT

Goldratt (1994L) developed the first of the logic trees, the CRT, as a map of the cause and effect relationships perceived to underlie an existing or current undesirable situation. His notion was that the other tree structures within the TOC can then be used to determine the desired future (FRT) and to map out how it may be achieved (PRT). Use of these logic trees signals an acknowledgement of broader systemic influences that bear upon our decision making, and that need to be understood.

Readers may find it beneficial to refer to other TOC texts such as Scheinkopf, Dettmer (1998) or Schragenheim (1999), Smith (2000) or Cox et al (2003) for elaboration on these tools.

An initial step promoted by use of the CRT frame might be to list symptoms that currently indicate all is not well within the organisation. Such symptoms may include, for example, ongoing friction between departments, frequent late orders, the sales force feeling powerless and frustrated dealing with customer complaints, lots of unplanned overtime, and the company not doing as well financially as it would like to do. The approach then requires that for each symptom we explore a chain of possible cause-effect relationships responsible for their manifestation. Using cause-effect analysis with the logic rules, we attempt to trace these symptoms back to the root of the problem, representing symptoms, intermediate cause and effects as a causal map of entity boxes linked by directional arrows, and seeking to identify whether a single core problem exists that needs addressing[3]. We note that Goldratt's CRT may bear some similarity to cause-effect diagrams from other disciplines, but that similarity disappears on more detailed examination, when considering the tools as applied in context (Zotov 2004).

At this point, we may note how seductive the previous statements about CRTs appear in terms of their intent and purpose. As a consequence, we may overlook or take for granted the epistemological assumptions embedded in the method or methodology about, for example, the nature and observable existence of problems, symptoms, causes, effects and logical relations, and how they may be modeled or represented. Similarly, it is possible to overlook the axiological assumptions about who will make use of the model of cause-effect relations, and who may effect or be affected by the enactment of the method or methodology.

In continuing the discussion, we may restate a belief that CRT analysis should identify and/or validate the core problem(s) underlying all (or most of) the symptoms, that is the issues we normally complain about. Then given our acceptance of the modeled logical relationships, we act assuming that if the core problem were to be dealt with appropriately, these symptoms would disappear. Frequently, the core problems are (at least in hindsight) well known to the organisation, but may have been avoided or ignored for some time because they are deemed to be 'too hard' to deal with. Kendall (1998), for example, in describing measurements, policies and training as 'three pillars' of an organization, asserts that weaknesses in any of these areas are often identified as core problems in a CRT analysis, but that they are often subject to what Bird and Waters (1989) describe as 'moral muteness', and are not always subject to open discussion.

Modeling the problem situation as a CRT emphasises the acceptance of a systems perspective, and the likely systemic nature of relationships and links between key variables and entities. It also emphasises the view that there is no point in fire-fighting the symptoms - it embraces a view that there may be a single or small set of causes and that it would be useful to recognise, address and eradicate cause(s). So whilst we suggest that the CRT highlights the web of interrelationships between symptoms, policies, measures and behaviors etc, in a different manner to the CLD, rather than debate the merits or otherwise of the CLD and TOC's CRT, we choose here to draw attention to how TOC methods may complement those of SD not only in

[3] There are two alternative approaches to building the CRT: one works down from the symptoms; the other works upwards from a cloud depicting the core conflict thought to lead to the symptoms. Either way, the symptoms are traced back to the underlying cause, the core problem, which is viewed as a conflict.

building an understanding of the problem situation, but also in finding ways of dealing with problems and their symptoms.

TOC - the Evaporating Cloud (EC) or Conflict Reservation Diagram (CRD)

Underlying many such problems would be a dilemma. In the illustration captured as Figure 4a, we note a dilemma about whether or not the Government should intervene to increase the security of electric power supply, which is the subject of the case described in Appendix 5. The perspective developed by using Goldratt's EC framework (1992, 1990b, 1994L) is one that draws attention towards the assumptions that underpin or give life to the dilemma. The purpose for which the EC is often used is reflected in the alternative title used by Dettmer (1998), namely the Conflict Resolution Diagram (CRD), though the EC title applies equally well to dilemma and trade-off situations. The EC frames the problem starting with two diametrically opposed actions or views (represented in boxes D & D'), and implicitly assumes these can be resolved by a win-win solution. The frame or model is constructed as a schematic depiction of the dilemma, and the reason for conflict can be explored by examining the assumptions that underlie the necessity-based logic relationships, depicted here by arrows connecting the boxes in the diagram. In order to find a solution, we elicit those assumptions, perceptions or reasons why the relationships are thought to hold. Some of these assumptions are often shown as annotations in thought bubbles on the diagram.

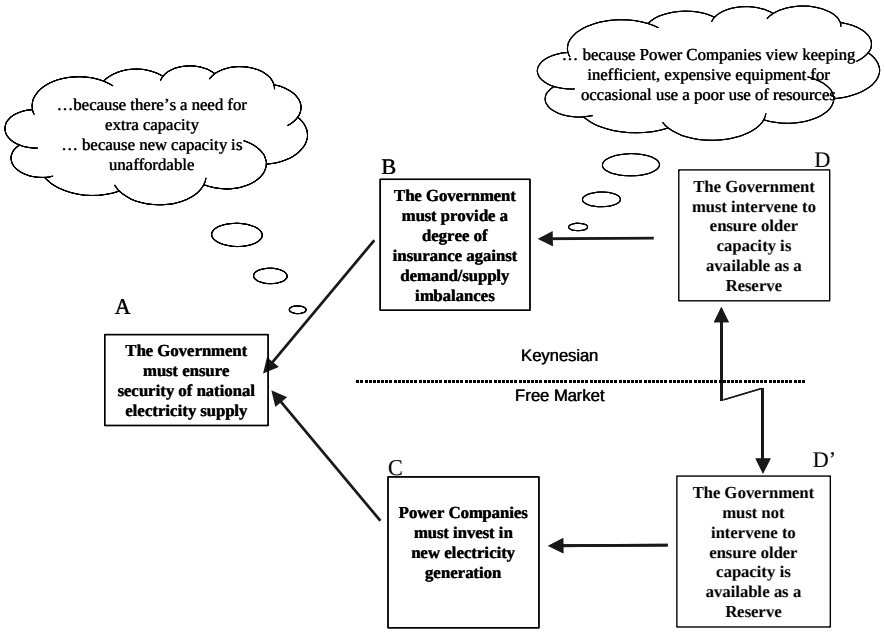


Figure 4a. TOC Evaporating Cloud

The Keynesian view represented in Figure 4 is that **in order** to ensure security of national electricity supply, **the Government must** provide a degree of insurance against demand/supply imbalances, … and **in order to** provide a degree of insurance against demand/supply imbalances, **the Government must** intervene to ensure older thermal capacity is available as a reserve. On the other hand, the Free Market view is that **in order** to have security of electricity supply, **the Power Companies must** invest in new electricity generation, … and, **in order** to ensure **Power Companies** invest in new electricity generation, **the Government must not** intervene to ensure older capacity is available as a reserve. Hence the conflict!

As soon as we verbalise the dilemma or conflict in this way, we may quickly come up with ways of resolving the dilemma. Whether or not we develop immediate insights, we may still need to elicit the assumptions that underpin each of the logical relationships, represented as arrows in the diagram, in a more methodical way before

we can confirm action solutions or surface other possible actions. Some of these assumptions are often shown as annotations in thought bubbles on the diagram.
Figure 4b provides, in illustration only, a summary of those assumptions considered to underpin the overall objective, and to provide a rationale for the beliefs implicit in the cause-effect necessity relationships of B and C being requirements to achieve the cloud objective. It also presents a list of challenges to those assumptions and beliefs, some of which could act as 'injections' breaking those assumptions and providing a basis for resolving the core dilemma.

Figure 4b: The TOC Evaporating Cloud - Assumptions and Injections

Assumptions		*Ideas for Solutions*	
A	Growing economy requires more electricity. Healthy economy needs adequate power supplies. Secure supply minimises loss of industrial production. Secure supply keeps prices in check.	A	Encourage eco-friendly industry growth. Diversify power supply to maintain production. Stabilise production.
AB	Existing capacity is not enough. Extra capacity required. All new capacity is unaffordable. All new capacity is uneconomic.	AB	Encourage greater energy efficiency amongst industrial and retail users. Develop/find new low-cost source of new supply.
BD	Power Companies are reluctant to maintain investment in inefficient, expensive equipment used occasionally. Power Companies view keeping inefficient, expensive equipment for occasional use a poor use of resources so … Power Companies view risky gains a poor trade-off against costly mothballing and maintenance costs.	BD	Market-driven high spot prices for power will make older thermal capacity economic. Encourage utility companies to take a national perspective. Encourage through incentive rather mandate.
AC	Current capacity is insufficient and inefficient. New capacity is necessary sometimes. New capacity is more efficient. New capacity provides good returns.	AC	Make better use of existing capacity. Encourage greater energy efficiency amongst industrial and retail users. Examine alternative sources of energy Encourage home generation.
CD’	Intervention to ensure old capacity is kept will distort the market. Intervention lowers the returns/profitability of new capacity, and discourages investment. Market forces will be sufficient to drive investment. Lack of intervention is necessary to allow free market movement of spot prices providing opportunities for profit taking, thus generating incentives for investment in new capacity. All intervention is unwanted.	CD’	Interventions can be designed that do not distort the market. . Intervention can include tax breaks and other ways of maintaining the returns/profitability of new capacity. Interventions such as mandatory hedging could be used to ensure sufficient profit instead of relying on high spot prices. Some interventions are desirable: eg..Promote and encourage desirable behaviour, not control or curtail.; Encourage energy-efficient rather than cost-related behaviour.
DD’	Can’t 'intervene' and 'not intervene' simultaneously.	DD’	There are degrees of intervention. Intervention could be reframed as 'positive' … as promoting and encouraging desirable behaviour through incentives, not mandating, controlling or curtailing – as rationalisation, 'sponsorship'.

Often when assumptions and 'reasons' are surfaced and articulated, they may be seen as false, and the conflict seems to evaporate as the thought bubble bursts! However, even in circumstances where assumptions are initially recognized as valid, they may then be addressed in a manner that invalidates them, that reduces their importance or impact, and that allows for a resolution of the conflict. [4]

[4] By mapping these aspects of EC 'activity' to the M-B framework (See Appendix 4.2), and by recognizing the underpinning philosophical assumptions set out in summary tabular form (Appendix 3), we further demonstrate how the EC method can provide an effective bridge from the problematic current situation to the desired future by contributing to all phases of intervention.

TOC's other Logic Trees – the NBR, FRT, PRT, TrT

We have stated that whilst modeling the problem situation as a CRT reflects a systems perspective and the likely systemic nature of relationships between key variables and entities, such modelling is also founded on a belief that it is possible to identify major causes of symptoms and to find ways of dealing with them. This can be achieved through use of the various TOC TP tools that aim to provide guidance leading to the successful implementation of the solution. For example, whilst the CRT links undesirable effects to root causes, the FRT approach begins with identification of actions, conditions or solutions of choice, what Goldratt collectively names as 'injections', and then through the mapping of sufficiency-based logic relations, checking whether the causal links will lead to what we have decided are preferred desirable outcomes. As Rizzo (2001) states, construction of the FRT can be viewed as a "what-if exercise", helping to identify what actions and conditions will be necessary and sufficient to bring about desirable effects or change, and whether or not additional undesirable effects will also emerge from our actions (1998).

Sub-trees (also known as Branches) may be constructed in this FRT process whenever someone raises a “Yes, but …” type of reservation. Such situations indicate that the ‘objector’ has thought of a possible negative side-effect of the proposed solution. Rather than brush the comments aside or abandon the proposal, we are encouraged, by TOC, to explore ways of adapting the proposal to avoid such negative side-effects while still keeping the positive effects of the proposal, using a another process known as the Negative Branch Reservations (NBR) (Cox et al. 2003; Boyd & Cox 1997).

The NBR process is used formally to create each branch of the FRT, but can be used as a standalone tool to improve critical feedback and develop 'half-baked' ideas such as, for example, changes to organisational performance measures. Such tree-based approaches thus capture different perceptions or alternative conceptualisations and attempt to generate accommodation and consensus, enlightenment and empowerment. Appendices 4.3-4.4 then represent how the M-B framework captures and reflects such assessments of the role of the FRT and NBR.

Using the NBR Process

We will now show how the NBR process can augment the previous views. Each of the injections raised in the EC process may be good idea to some extent, but are likely to be at most short term unless thought through. Most will lead to problematic side effects unless carried out very carefully. For the next step in the process, the building of a fundamental solution, we will use TOC’s cause and effect thinking tools and their concomitant protocols, the Categories of Legitimate Reservation.

For the purposes of illustration, we will show how the NBR method can clarify (as featured in Goldratt (1994L; 1996) or Boyd & Cox 1997) how and why a proposed solution may be good but flawed, and how to remove those flaws to create a full, workable solution, formally described as a Future Reality Tree (FRT). The NBR process has recently been developed considerably into a method that guides the analyst to draw up the CRT and Future Reality Branch (FRB), resulting in a well-thought-through solution (Cox et al. 2003). However for the present illustration, we will use the simpler NBR process here, and indicate later how the CRB, FRB process would be developed.

The NBR process starts with a proposal and extrapolates the effects of undertaking that proposal, using cause-effect logic. The usual approach is to list three positive effects that would come out of the proposal and three negative effects, and then to develop the logic to explain why taking the action stated in the proposal will lead to the feared (as well as desired) effects. The final step in the NBR process is to work

out the minimal set of supporting actions to take to ensure the positive effects arise, but prevent the negative effects for occurring. In this example, we may start with the proposal that the Government intervenes. Based on the case material, we propose that two likely forms of intervention are for the Government to insist or legislate that old plant is kept in reserve and to cap spot prices. Hence we "start" the NBR tree (Figure 5) at the "bottom" with the notion that the Government intervenes, and we lay out the two chosen interventions.

Three positive effects we expect from intervention might include ideas listed in the cloud, such as security of supply (our Box A in Figure 4): in terms of both the avoidance of power shortages, and power prices that are reasonable. Negative effects might include concerns that saving plant will lead to fewer new stations being built, and subsequently power cuts in the future; again, these sentiments echo those in the cloud.

The tree itself is read from the bottom up using Sufficiency Logic, read as *"If …(and …) then…."* For example: *If* D The Government intervenes *and* 10 One chosen intervention is to insist on saving old plant capacity as reserve, *then* 20 Old plant is saved. *If* 20 Old plant is saved, *then* 30 Spare capacity is in reserve if needed. *If* 30 Spare capacity is in reserve if needed, *and* 32 Some years demand exceeds supply, *then* 40 Old plant is used some years when needed. We continue up the tree, reading "and" whenever two or more arrows leading to an effect are linked by a line across them.

After we have laid out the logic, we then identify where in the tree the effects start becoming negative or undesirable in and of themselves. We suggest that action would best be targeted just "below" these negative effects, and we can devise actions or "trims" that, if implemented, would stop the negative effects from occurring, without causing new negatives of their own! Because this stops the negative effect from occurring, it's like trimming the tree at that point, which is why it is referred to as a "trim." Because the trims are applied judiciously, there is less chance that unnecessary or counterproductive actions are taken. And we are able to gain the benefit of the idea, without the negative side effects.

The method was originally devised as part of the Future Reality Tree, to be used when a listener says, "Yes, but I think that could lead to (something bad)" when the presenter is reading a part of the FRT. At that point, an NBR can be constructed, leading to the insertion of one or more new injections in the FRT to prevent the negative effects from getting in the way of achieving the desired effects.

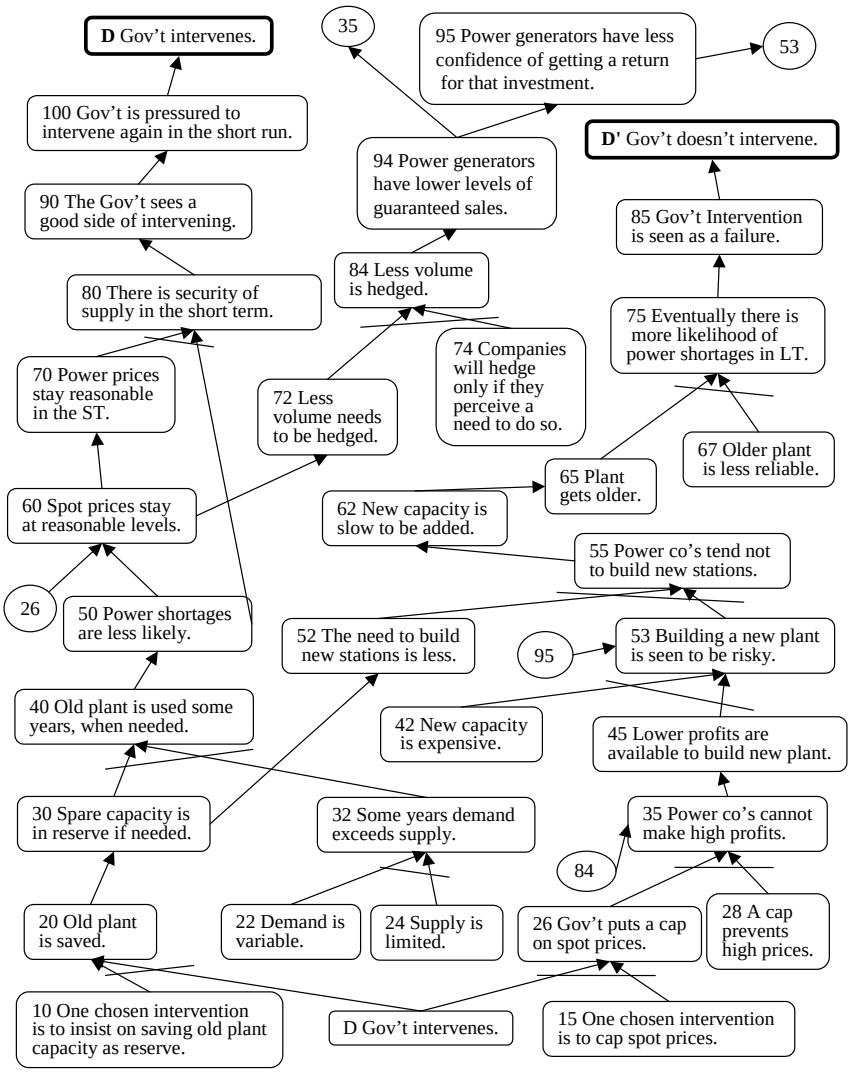
The more recent CRB method (Cox et al. 2003) is more directly linked with the cloud, and starts with side D from the cloud and works through methodically the positive and negative effects of undertaking D to achieve the B requirement and then repeats the process for undertaking action D' to achieve the C requirement. In the CRB method, a series of Current Reality Branches are developed to show in turn:

1. why taking action D leads to B and hence A from the cloud,
2. why taking action D makes it hard to achieve C, hence preventing objective A from being achieved (since A requires both B and C)
3. why taking D' leads to achieving C and hence A
4. why taking D' leads to not achieving B and hence preventing A

5. we may also show how D (and/or D') may lead to other unanticipated side effects that further prevent A from being achieved.

Once all these logical links are laid out, we have a more comprehensive understanding of the logical relationships and assumptions underpinning the problematic situation. It is much clearer to see what needs to be done. Injections from the EC are selected and adapted till a workable solution is derived, that meets both requirements B and C and ensures objective A will be achieved. Again, as with the NBR method, we try to choose a minimal yet sufficient set of actions (injections) that will yield the desired outcomes of achieving both requirements B and C and ultimately the objective A. The resulting branches with the injections inserted will then provide a map for the desired future, and these are termed Future Reality Branches (FRB), which together form (part of) the FRT.

Figure 5: An illustrative tree diagram from the Negative Branch Reservation process



Development of the PRT, complementing and building on the FRT, seeks to identify local obstacles, conditions and omissions that might block the path to the desired outcomes, and then to set new 'intermediate' goals and objectives that would equate to overcoming those obstacles, barriers and other forms of resistance to change - many of which have received attention in the management of change literature (Mabin et al 2001). Development of the PRT is often conducted by a team needing to address

obstacles that may confront it, and hence social practices and power relations will be considered implicitly, if not explicitly. If the team structure or working relationships are perceived to be an obstacle, then such issues will usually be raised. However, the PRT is no more designed to account for social practices and power relations than other tools or practices, and this is thus reflected in the presentation of Appendix 4.5.
The development of the final logic structure, the TrT, seeks to identify the tasks and actions both necessary and sufficient to meet the intermediate objectives of the PRT, to overcome what might go wrong, to provide a rationale and schedule for each action, and, as such, to provide what we may regard as a coherent step-by-step implementation plan, which also accounts for prevailing beliefs, feelings and norms.
As we move through the tools, CRT through to TrT, there is generally more involvement from the wider group affected by the problem, or by actions designed to address it. We also move from a strategic to a tactical and ultimately to an operational view of the problems, the solutions and the implementation plan. The PRT and TrT in particular are designed to help in the implementation phase. The end goal and normal outcome of the NBR, FRT, PRT and TrT processes is to help people gain a better understanding of the problematic situation and the results of their actions, and to feel empowered through having an agreed course of action. The CRT alone enlightens but does not necessarily empower. The CRT may often paint a gloomy picture of the current situation and of the impact of inaction, and while it does motivate into action, it would not be seen as empowerment in the critical sense of the concept.
We note therefore that the tools, techniques and methods of TOC contribute to all phases of problem-solving activity that lead to implementation as well as implementation itself. The finding becomes equally evident when Figure 6 is presented as a summation of the analyses relected in Appendices 4.0-4.6. The methods and tools are seen to directly target or deliver on all but one of the cells in the M-B grid – apart from an *assessment of ways of challenging and altering power structures* within the social dimension of the problem domain.

Figure 6: Mapping TOC as Meta-Methodology

	Appreciation of …	**Analysis of …**	**Assessment of …**	**Action to …**
Social	Social practices, power relations	Distortions, conflicts of interests	Ways of challenging & altering power structures	Generate empowerment and enlightenment
Personal	Individuals' beliefs, meanings, emotions	Different perceptions and Weltanschauung	Alternative conceptualizations and constructions	Generate accommodations and consensus
Material	Physical circumstances	Underlying causal structure	Alternative physical and structural arrangements	Select and implement best alternatives

We may recognise that this is because TOC does not directly set out to challenge or assess power structures, and may not address such issues unless the diagnosis (using say the CRT) points to the power structure as being a core problem, or if it is seen to be an obstacle in the PRT. In these cases, the power structure will be tackled, but TOC methods have not been necessarily designed for this purpose, and so, since TOC does not aim to do this from the outset, nor is it a natural common outcome, and although it can be argued that the 'empowerment cloud' does this, we have left this box unshaded.

The Power Case – Comparative Views

We will now draw together the various elements that have been laid out, detailing how the various tools/approaches might be applied to the Power case. We note that

the CLD, shown in Figure 3, captures the interconnectedness implicit in the Power case narrative. In doing so, it helps build an understanding of the systemic nature of the relationships, not only highlighting the dynamic time-based nature of feedback, the existence of both balancing and reinforcing feedback loops, delays and side-effects; but also distinguishing between individual and systems behavior, between seemingly predictable individual behavior and local outcomes, and the systems behavior that may be expressed as the unpredictable or unanticipated 'emergent' properties of the system. As such, construction of the CLD can draw attention to patterns of behavior that arise from the systemic structure of relationships. We may note that positive reinforcing loops can lead to virtuous or vicious cycles of escalating participant behavior and/or to outcomes that either get better and better or persistently deteriorate over time. Additionally, we may gain recognition of how such participant or system behaviour can lead to unintended, unanticipated, yet often patterned and predictable outcomes or consequences. For example, we may note how Government intervention that leads to capping of wholesale electricity prices may reduce the chance of high spot prices on the wholesale market in the short term, as shown in the balancing or negative-feedback loop B4. However, the sequence of behaviours and effects captured in B4 when linked to the entities shown in the negative-feedback loop B1 that plays out in the longer term, creates an extended feedback loop that demonstrates how investment in the provision of hydro-capacity may be jeopardized in the longer term. Similarly, we note how other forms of Government intervention that may include mandatory hedging or fixed term supply contracts for large electricity users (B3) or mandatory requirements for electricity generators to provide reserve thermal plant capacity (B5) may interact with feedback loop B1 to create a system-wide reinforcing loop that will continually undermine the favorable conditions necessary for long-term investment in expensive hydro-capacity.

Such a CLD is developed by a process of surfacing variables as contributory causes or consequential effects of existing entities, and then by building on and extending links in iterative fashion until a sense of systemic wholeness and understanding is achieved. In minor contrast, the CRT of TOC is developed by first focusing on undesirable events and entities (UDEs), and then attempting to link them in an Effect-Cause-Effect (ECE) chain of logic that may not only reveal a subset of the most undesirable events to be overcome or changed, but which may also facilitate the tracking of a causal hierarchy of links through the same ECE logic to a few root causes or core problems. As such, the CRT also captures the interconnectedness and the systemic nature of the relationships, but does so using a different protocol and different intent, thus surfacing some complementary and some different insights.

For example, the very focus that is placed on consideration of UDEs helps draw out otherwise implicit values and what may be valued as outcomes or behavior in the system. The consideration of UDEs can also help distinguish mere symptoms from 'genuine' undesirable effects on the one hand, and help to identify causes and root causes on the other hand. Indeed, we note that the TOC CRT thus helps identify what to change, that is what is perceived to be the root cause or core problem, just as the EC injection and the FRT identify what it needs to change to - which may be to turn undesirable effects into desirable effects. In this case, we may recognize the lack of sufficient 'firming' thermal capacity to supplement dwindling hydro-supply in times of drought as our root cause or problem. Where the core problem presents as a choice dilemma - as in this case, whether the Government should intervene or not - we may then use the EC or to structure the dilemma, explore why that problem or dilemma exists, and to begin to resolve that dilemma.

The CLD representation of entities and relationships (Figure 3) is meant to be reflective of the perceived systemic reality of the Power case. We may therefore find it to be instructive to explore the subtle differences, communalities, complementarities and synergies offered by the CLD, the CRT and the EC. Whereas it may be claimed that identification of the core choice dilemma, that is the basis for the EC, may be drawn from the CLD, we suggest that iterative and mutually informed construction of both diagrams is possible and desirable. For example, we note that whereas the CLD does not necessarily or explicitly present the choice dilemma as mutually exclusive options, it can and does present action options for different modes and degrees of intervention, mapping the systemic consequences and interactions that emerge. In particular, we note that injections designed to challenge assumptions and relationships embedded within the EC may surface as action options within the CLD. As such, we can signal the complementary nature of the EC and the CLD, the EC and the CRT, as well as their distinctive features. For example, whereas the EC highlights distinct options, and seeks to establish those options as prerequisites for desired objectives, the CLD would seek to capture the immediate and subsequent effects of these options through a sequence of cause-effect and feedback relationships that play out over time. It is the very existence of these feedback relationships and how they are mapped that most clearly differentiates the CLD from the CRT.

From the EC, we may start to build the FRT as a means of identifying and establishing the Effect-Cause-Effect chain that will link the action options to outcomes that are desired or that may ensue. We may also 'build' the NBR branch (Figure 5 illustrates one such branch) using *if-then* logic to identify and describe the positive and negative effects and otherwise unforeseen side-effects that emerge from the injection or alternative actions suggested by the EC. In the final step of the NBR process, the solution is honed. Finally, we would show the PRT and TrT that together provide the basis of an implementation plan that addresses potential side-effects (NBR), overcomes intermediate obstacles in working towards to the desired objectives identifying and sequencing actions to achieve them (PRT), and providing the logic to cause the actions to lead to the desired effects (TrT).

We thus conclude that each of the related approaches not only helps build a complementary understanding of complexity through specific representational processes, either as a CLD or as a TOC CRT or EC, but can then help purposefully develop a program of action that seek to bring about desired outcomes whilst avoiding pitfalls and unwanted side-effects (NBR) and overcoming other anticipated obstacles (PRT and TrT). Indeed, we offer a view that the CLD can offer a 'helicopter' perspective of the system and also directs attention to how to structure the NBR and other TOC diagrams for alternative actions.

Summary and Conclusions

Elsewhere, we have shown how problems can be tackled using a variety of Goldratt's TOC tools, principles and methods, spanning the simplistic product mix algorithm to the powerful thinking processes including the evaporating cloud (EC) (Cox et al 2003; Mabin & Davies 2003; Mabin & Balderstone 2000; Cox & Spencer 1998). In the appendices, we provide a summary indication of how these different approaches purposefully attend to different issues and surface different insights, using different kinds of information sourced in different ways. These matters are reflections not only of what a tool or method is intended to do, but what it assumes to exist – its ontological base; and the nature of what is represented or modeled, with what kind of information – that is, its epistemology.

The mapping of the various TOC frames, models and methods to the Mingers and Mingers-Brocklesby (M-B) frameworks shows that they not only overlap or substitute for each other to some degree, in terms of intent, purpose and underlying philosophical assumptions, but that they may also be complementary in nature to the associated systems tools and methods of SD. Whilst we may expect similar insights to arise from different frames or methods, we find that TOC and SD frames can also surface new insights about the problem, and how it should be tackled. At a surface level, we may comment on how each methodology seeks to depict and understand cause-effect relationships through similar but different forms of diagrammatic representations.

We have shown how our Power dilemma can be reframed using two of TOC's tools, the Evaporating Cloud (EC) and the Negative Branch Reservation process (NBR). The first of these tools frames the problem as a dilemma or conflict, and by identifying the assumptions that underpin the dilemma, allow us to identify a possible solution. This potential solution is then checked, using the NBR process, for its likely effects, both positive and negative, before modifying the solution to enhance the positive effects of the solution without causing any unwanted side effects.

We may comment, for example, on how the CLD draws attention to the potential longer-term dynamics of cause-effect relationships and the inherent feedback driving those relationships. In particular, we note how the CLD draws attention to the nature of negative feedback loops that characterize self-correcting or self-regulating behaviour as well as the positive feedback loops that can characterize virtuous or vicious cycles of behaviour or outcomes. By contrast, TOC methods, by virtue of what they seek to explore, may offer different insights about how specific goals may be reached and about the obstacles that arise as implementation of action and policy choices takes place.

Furthermore, TOC diagrams seek to capture and explicitly signal the precise nature of cause-effect necessity and sufficiency logic embedded in relationships, but do so using a different protocol to the CLD of SD. As such, we see benefits from complementary use of the methodologies, especially the power of the tools as complementary graphical depictions to enhance conceptualisation and understanding, and the use of logic rules for critiquing presumed cause-effect relationships. In our example, the EC and NBR can be seen to complement the CLD allowing the problem owner to develop fundamental solutions to fix the real problem underlying the problematic symptoms. We restate a view that the insights that we gain from complementary use of such methodologies, methods and tools relate to how the respective methodologies frame relationships, especially how and what each frame highlights or shadows. Additionally, we restate a view that the insights that we gain from complementary use of such methodologies relate to how the respective methodologies frame relationships, especially how and what each frame highlights or shadows.

In discussing this complementarity, we note how system-wide framing of entities and relationships induced through the building of a CLD representation can provide or add to the contextual framework by identifying emergent systemic behaviours and outcomes that are founded on complex feedback loops. Both TOC and CLD representations use logic rules that allow us to surface and critique often implicit assumptions, adding to the scope for generating beneficial solutions. Whilst both methodologies identify leverage points, the evolution of TOC tools has followed a need to provide focused corrective action at those leverage points, as here, for example, to rectify/prevent fixes that fail, and to develop fundamental solutions.

We have stated that seldom are any of the TOC methods and tools used in isolation. Indeed, further tools provided within the TOC Thinking Processes to assist with implementation are available, but these have not been covered here. Nevertheless, we have demonstrated that TOC, as a methodology, offers methods that embrace the whole range of activities or phases from symptom and environment analysis, problem identification and representation, the setting of appropriate objectives, generation and evaluation of alternatives, through to implementation. Using the constructs of the original M-B framework, we recognise the additional value of TOC and the associated tools and methods of SD as further complements to broaden or heighten, for example, the appreciation phase of intervention, or to complement assessment and evaluation with a stronger action/implementation phase. When the fuller sets of TOC and SD tools and methods discussed in this paper are mapped to the M-B framework (Appendices 1 & 4), we note how they may comprise a multi-method approach. Nevertheless, it has been necessary and instructive to surface and clarify the philosophical assumptions, ontological and epistemological, that underpin the various methods that make up TOC and SD (Appendices 2 & 3). Consequently, we not only see TOC and SD as offering a complementarity which mirrors what others have sought through the development of multi-method and multi-methodological approaches, but also as having a theoretical basis and justification for such complementary use. Our use of a seemingly recurring problematic situation has provided opportunity to demonstrate that that multi-methodological approaches embracing TOC and other systems methodologies could be beneficial in complex problems and applications.

The promotion and/or pragmatic adoption of a multi-method or multi-methodological approach, that our experience, here and elsewhere, suggests would be worthwhile, accords with the views of Burrell and Morgan (1979) and Brocklesby (1993) in their discussion and acceptance of the efficacy of multi-paradigm and multi-methodology development. We have sought to demonstrate how TOC may be aligned with SD and its associated methodologies and methods on practical and philosophical grounds. We have done so through use of an illustrative case and by application of the classificatory frameworks of Mingers and Brocklesby (1997) and Mingers (2003a) to facilitate identification of communalities in purpose, and the nature of the assumptions underpinning their seemingly different tools, techniques and methods. Additionally, we state that much may be gained from further exploring how TOC methods and methodologies may be combined with SD and its associated systems methods and methodologies.

In summary, we have demonstrated that that the tools, techniques and methods of TOC and SD can be viewed as a methodological set of complementary hard and soft tools and methods that contribute to all phases of activity and across all three social, personal and material dimensions of the Mingers and Brocklesby (M-B) framework. Using Mingers' framework, we have also demonstrated that TOC methods, as a methodological set, share unifying ontological, epistemological and axiological characteristics and assumptions with each other, with other extant OR/MS methodologies (Mabin et al. 2003) and here, with the methods and methodology of SD.

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Appendix 1

Appendix 1.1: Mapping Methodologies – SSM Mingers' (2000) decomposition of SSM*

*

	Appreciation of …	**Analysis of …**	**Assessment of …**	**Action to …**
Social	Social practices, power relations	Distortions, conflicts of interests	Ways of challenging & altering power structures	Generate empowerment and enlightenment
Personal	Individuals' beliefs, meanings, emotions	Different perceptions and Weltanschauung	Alternative conceptualizations and constructions	Generate accommodations and consensus
Material	Physical circumstances	Underlying causal structure	Alternative physical and structural arrangements	Select and implement best alternatives

Appendix 1.2: Mapping Methodologies – Cognitive Mapping

	Appreciation of …	**Analysis of …**	**Assessment of …**	**Action to …**
Social	Social practices, power relations	Distortions, conflicts of interests	Ways of challenging & altering power structures	Generate empowerment and enlightenment
Personal	Individuals' beliefs, meanings, emotions	Different perceptions and Weltanschauung	Alternative conceptualizations and constructions	Generate accommodations and consensus
Material	Physical circumstances	Underlying causal structure	Alternative physical and structural arrangements	Select and implement best alternatives

Appendix 1.3: Mapping Methodologies – Systems Dynamics

	Appreciation of …	**Analysis of …**	**Assessment of …**	**Action to …**
Social	Social practices, power relations	Distortions, conflicts of interests	Ways of challenging & altering power structures	Generate empowerment and enlightenment
Personal	Individuals' beliefs, meanings, emotions	Different perceptions and Weltanschauung	Alternative conceptualizations and constructions	Generate accommodations and consensus
Material	Physical circumstances	Underlying causal structure	Alternative physical and structural arrangements	Select and implement best alternatives

* A convention of shading is used to show whether, and to what extent, a methodology, method or activity supports a phase of intervention represented by a particular grid cell. The stronger the shading, the more support a methodology may offer through appropriate method or activities in that area.

Appendix 2.: Mingers' Framework for Characterising the Philosophical Assumptions underlying Systems Methodologies

Methodology/ Technique	What it does **A System to …**	*Ontology* What it assumes to exist	*Epistemology* Representation **by modelling …**	*Epistemology* Necessary Information	*Epistemology* Source of Information	*Axiology* Users	*Axiology* Purpose **in order to …**
Soft Systems Methodology – SSM / Rich Pictures	**… explore different worldviews** relevant to a real-world situation and to contrast them in a process of debate	Real-world problem; conceptual human activity systems; worldviews	Systems concepts; rich pictures; analyses 1, 2 & 3; logical relations	Hard and soft information concerning structure, process, climate and relevant worldviews	Concepts, language, logic and participation by concerned actors	Analyst, researcher, facilitator, participant	**… learn about and improve** a problematic situation by gaining agreement on feasible and desirable changes
SODA & Cognitive Mapping	**… represent** explicitly an **individual's views** about a particular issue or event in their own language	Individual beliefs about particular issues expressible in terms of inter-related constructs	Psychological constructs and their mutual influences in the form of a map; and using software for representing, analysing and merging maps	Personal constructs and their inter-relationships	Interviews, workshops with groups of participants	Researcher, facilitator, participant	**… surface and understand** individual beliefs, and generate consensus about possible strategic actions
Systems Dynamics / Causal Loop Diagrams and Influence Diagrams	**… simulate the behaviour** of physical and social stocks, flows and processes, and their causal relationships	Material and immaterial stocks and flows, and their causal feedback relations, information and decision that link them	Influence diagrams, SD diagrams, software-generated icon diagrams	Structure of causal relations between flows, with quantifies data and mathematical relationships	Observation and measurement of the real world, together with judgement and opinion	Analyst	**… explore** the operation of a complex real-world system to aid understanding and "control'
Strategic Assumption Surfacing & Testing - SAST	**… surface** a variety of contrasting **strategic options** and achieve consensus through debate	Groups with competing views, and the assumptions that underly these views from different stakeholder viewpoints	Seemingly diametically opposed viewpoints, underlying assumptions and relevant stakeholders.	Options, individual characteristics and viewpoints, stakeholders and their interests	Formations of different groups to present and debate different viewpoints	Facilitator, participants, stakeholders	**… synthesise** competing viewpoints about complex interactive messes

Appendix 3: Framework for Characterising the Philosophical Assumptions underlying TOC Methods

Methodology/ Technique	What it does **A System to …**	*Ontology* What it assumes to exist	*Epistemology* Representation **by modelling …**	*Epistemology* Necessary Information	*Epistemology* Source of Information	*Axiology* Users	*Axiology* Purpose **in order to …**
TOC / Current Reality Trees	**… search** for root causes, and **explain** how these lead to problem symptoms	Problems, symptoms, cause-effect relations	Cause-effect / logic relationships	Objective facts, subjective opinions, logic relations, perceptions, judgements, patterns of behaviour	Observation and measurement of real world, logic relations, judgement and opinion	Decision-maker, analyst, consultant, facilitator, participant	**… discover** root causes to problems
TOC / Evaporating Clouds	**… represent** explicitly one or more persons' or function's **conflicting views**	Individual beliefs about competing views and the assumptions underlying these views of different stakeholders	Seemingly diametrically opposed viewpoints, underlying assumptions of relevant stakeholders	Options, stakeholder viewpoints, their interests and common objective	Interviews, discussion, argument, debate with participants, analyst's reasoning, storylines	Analyst, participant	**… surface and understand** individual beliefs, **synthesise** competing viewpoints, explain how these lead to conflict, generate actions to resolve conflict
TOC / Future Reality Trees	**… determine effects** and outcomes following from proposed actions and solutions	Problems, actions, desired outcomes, outcomes, cause-effect relations	Cause-effect/ logic relationships	Objective facts, subjective opinions, logic relations, judgements	Observation and measurement of real world, judgement	Decision-makers, analyst, consultant, facilitator, participant	**… show** how actions lead to desired outcomes
TOC / NBRs	**…identify** possible side-effects and actions to prevent them	Existence of undesirable side-effects of proposed action	Cause-effect / logic relations and side-effects from actions, in the form of a map	Objective facts, subjective opinions, logic relations, judgements, side-effects and actions to overcome them	Observation and measurement of real world, judgement and opinion	Participants, decision makers and implementers, stakeholders	**… identify** causal actions required to prevent undesirable side-effects
TOC / Prerequisite Trees	**… surface and list** obstacles and necessary corrective actions to achieving desired outcomes	Existence of implicit obstacles to achieving desired outcomes	Necessity relations between necessary actions to overcome obstacles in the form of a map	Obstacles, and actions to overcome them, logic relations	Viewpoints, intuition, judgement	Participants, decision makers and implementers, stakeholders	**… map** the necessary sequence of actions required to achieve desired outcomes or target
TOC / TrTrees	**…identify** required actions to generate desired outcomes and results	Problems, actions, desired outcomes, outcomes, cause-effect relations	Cause-effect / logic relations in the form of a map, actions, desired outcomes	Objective facts, subjective opinions, logic relations, judgements, desired outcomes, actions to achieve them	Observation and measurement of real world, judgement and opinion	Participants, decision implementers, stakeholders	**… to create** an action plan to achieve desired outcomes
TOC / 5FS	**… identify** and manage constraints on on-going improvement	Constrained performance, barriers to improved performance	Process of identifying and examining constraints on performance	Objective facts, opinions, logic relations, judgements, desired outcomes, actions to achieve them	Observation and measurement of real world, judgement and opinion	Participants, decision makers and implementers, stakeholders	**… to improve** global performance long-term

Appendix 4.1: Mapping Methodologies – TOC CRTs

	Appreciation of …	**Analysis of …**	**Assessment of …**	**Action to …**
Social	Social practices, power relations	Distortions, conflicts of interests	Ways of challenging & altering power structures	Generate empowerment and enlightenment
Personal	Individuals' beliefs, meanings, emotions	Different perceptions and Weltanschauung	Alternative conceptualizations and constructions	Generate accommodations and consensus
Material	Physical circumstances	Underlying causal structure	Alternative physical and structural arrangements	Select and implement best alternatives

Appendix 4.2: Mapping Methodologies – Evaporating Clouds

	Appreciation of …	**Analysis of …**	**Assessment of …**	**Action to …**
Social	Social practices, power relations	Distortions, conflicts of interests	Ways of challenging & altering power structures	Generate empowerment and enlightenment
Personal	Individuals' beliefs, meanings, emotions	Different perceptions and Weltanschauung	Alternative conceptualizations and constructions	Generate accommodations and consensus
Material	Physical circumstances	Underlying causal structure	Alternative physical and structural arrangements	Select and implement best alternatives

Appendix 4.3: Mapping Methodologies – TOC FRTs

	Appreciation of …	**Analysis of …**	**Assessment of …**	**Action to …**
Social	Social practices, power relations	Distortions, conflicts of interests	Ways of challenging & altering power structures	Generate empowerment and enlightenment
Personal	Individuals' beliefs, meanings, emotions	Different perceptions and Weltanschauung	Alternative conceptualizations and constructions	Generate accommodations and consensus
Material	Physical circumstances	Underlying causal structure	Alternative physical and structural arrangements	Select and implement best alternatives

Appendix 4.4: Mapping Methodologies – TOC NBRs

	Appreciation of …	**Analysis of …**	**Assessment of …**	**Action to …**
Social	Social practices, power relations	Distortions, conflicts of interests	Ways of challenging & altering power structures	Generate empowerment and enlightenment
Personal	Individuals' beliefs, meanings, emotions	Different perceptions and Weltanschauung	Alternative conceptualizations and constructions	Generate accommodations and consensus
Material	Physical circumstances	Underlying causal structure	Alternative physical and structural arrangements	Select and implement best alternatives

Appendix 4.5: Mapping Methodologies – TOC Prerequisite Trees

	Appreciation of …	**Analysis of …**	**Assessment of …**	**Action to …**
Social	Social practices, power relations	Distortions, conflicts of interests	Ways of challenging & altering power structures	Generate empowerment and enlightenment
Personal	Individuals' beliefs, meanings, emotions	Different perceptions and Weltanschauung	Alternative conceptualizations and constructions	Generate accommodations and consensus
Material	Physical circumstances	Underlying causal structure	Alternative physical and structural arrangements	Select and implement best alternatives

Appendix 4.6: Mapping Methodologies – TOC Transition Trees

	Appreciation of …	**Analysis of …**	**Assessment of …**	**Action to …**
Social	Social practices, power relations	Distortions, conflicts of interests	Ways of challenging & altering power structures	Generate empowerment and enlightenment
Personal	Individuals' beliefs, meanings, emotions	Different perceptions and Weltanschauung	Alternative conceptualizations and constructions	Generate accommodations and consensus
Material	Physical circumstances	Underlying causal structure	Alternative physical and structural arrangements	Select and implement best alternatives

Appendix 4.7: Mapping Methodologies – TOC 5FS

	Appreciation of …	**Analysis of …**	**Assessment of …**	**Action to …**
Social	Social practices, power relations	Distortions, conflicts of interests	Ways of challenging & altering power structures	Generate empowerment and enlightenment
Personal	Individuals' beliefs, meanings, emotions	Different perceptions and Weltanschauung	Alternative conceptualizations and constructions	Generate accommodations and consensus
Material	Physical circumstances	Underlying causal structure	Alternative physical and structural arrangements	Select and implement best alternatives

Appendix 5

The Power Generation Dilemma: Using CLDs & TOC Frames

Power Options Need Balance

Government faces dilemma of whether to intervene or not, and if so, how

"Confronted with the second power crisis in three years, the Government has been grappling with the problem of how to ensure security of electricity supply.

New Zealand is estimated to need about 800MW of "firming capacity"* to cover the risk of a dry year in the hydro system.

This is thermal generation capacity which would normally be surplus to requirements but which could be called on when inflows to the hydro lakes dwindle to a tiny trickle.

There are two ends to this problem.

At one end, the aim is to ensure that efficient modern generation plant is built.

But it is also desirable to ensure that doing that does not entirely dislodge older, more expensive capacity from the system so that it cannot be called upon in emergencies.

The risk the Government faces is that intervening to ensure that older capacity is available as reserve capacity could distort the market in a way that has a chilling effect on new investment in generation, especially by the private sector.

The aim is to provide a degree of insurance against the sort of supply/demand imbalances that send spot prices on the wholesale electricity market through the roof, and trigger a loss of production by firms exposed to the spot price.

The less risk there is of high spot prices, the less incentive there is for firms to hedge against them by signing fixed-price contracts.

But the more demand is hedged, the more comfort that anyone building a new power station would have.

The danger is that providing too much insurance against dry years would leave too little incentive, for the private sector at least, to build new generation.

The price signals from the spot market may sometimes be shrill and piercing, but policy makers muffle them at their peril.

So the Government intervention - to ensure that older capacity is available - which could encourage more people on to spot prices, might have to be complemented by some mandatory hedging arrangement of the kind contemplated in the mid-1990s – a requirement that electricity retailers and major users cover at least a large percentage of their expected demand in hedge contracts."

"Firming capacity should not be thought of in terms of whole power stations … It is capacity that comes on progressively depending on how dry it is … Some plants, however, might be exclusively held in reserve … and never be used."

Fallow, B., Weekend Herald, May 17-18 2003, p.C5

A non-exhaustive list of variables that you may wish to take into account include:

The (demand - supply) gap; use of thermal supply; use of hydro supply; hydro-generation capacity; hydro fuel – inflow to lakes; drought conditions; private thermal generation capacity; confidence amongst builders of power stations; mothballed thermal reserve capacity brought into use; tendency to to add new generation capacity; save old plant; security of supply in short term; security of supply in long term; likely capping of wholesale electricity prices; Government intervention; incentives for firms to hedge demand/prices as insurance; volume of demand hedged by firms as long-term fixed price contracts.

Back to the Top