The theory of constraints: a methodology apart?--a comparison with selected OR/MS methodologies.(Operational Research/Management Science)

_Omega; 12/1/2005; Balderstone, S.J.

Mingers (J. Oper. Res. Soc. 54 (2003) 559; Int. Trans. Oper. Res. 7 (2000) 673; J. Mingers, A. Gill (Eds.), Multimethodology: Towards the Theory and Practice of Combining Management Science Methodologies, Wiley, Chichester, 1997), Mingers and Brocklesby (Omega--Int. J. Manage. Sci. 25(5) (1997) 489; Systemist 18(3) (1996) 101) and others have sought to develop classificatory frameworks that would be useful in understanding the nature and characteristics of Operational Research/Management Science (OR/MS) methodologies and the philosophical assumptions underpinning them. This paper extends their work to the domain of methods and methodologies known as the Theory of Constraints (TOC). In particular, the paper helps position TOC methods and tools in relation to traditional OR/MS methodologies, methods and tools, and provides a basis for continuing multi-methodological development across the two domains.

The paper concludes that the tools, techniques and methods of TOC 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-Brocklesby framework, and share the ontological and epistemological characteristics and assumptions of extant OR/MS methodologies.

Keywords: Theory of constraints; OR/MS; Soft OR/Systems; Methodology; Multimethodology; Classification frameworks

1. Introduction & overview

Mingers [1-3], Mingers and Brocklesby [4,5], Jackson [6], Jackson and Keys [7] and others have sought to develop classificatory frameworks that would be useful in understanding the nature and characteristics of Operational Research/Management Science (OR/MS) methodologies (1) and the philosophical assumptions underpinning them. Whilst Jackson [6, p. 664] 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 [4, p. 489] 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 seemingly at variance with but also in keeping with Burrell and Morgan's [9] acceptance of multi-paradigm and therefore multi-methodology development [10, p. 151, 11, p. 584]. Indeed, much of the work in the field of multimethodology 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 are underpinned by different value systems or paradigms, and especially when different worldviews lead to alternative perspectives of problem situations [12, p. 65]. Reflecting this position, and building on his previous work, Mingers [1] has developed a framework facilitating the examination and classification of the fundamental philosophical assumptions underpinning OR/MS methodologies, with a similar purpose being to better inform the design of multi-methodological approaches to problem-solving.

The development of multi-methodology and multimethod approaches has received considerable attention over the last two decades and such attention has been justified on several grounds. Mingers and Brocklesby [5] have argued for the considered use of multi-methodology both on theoretical/philosophical grounds and on the practical grounds that practitioners are increasingly doing so already. They argue that the complexity and multi-dimensionality of real-world problem situations require a multi-methodological approach to be able to focus and refocus attention on the many different aspects of any problematic situation and to provide associated multiple perspectives. Indeed, they contend that it is necessary "to go beyond using a single methodology to always combining methodologies, in whole or part, and possibly from different (even incommensurate) paradigms to make the most of dealing with the richness of the real world". This contention accords with the view of Gioia [13] who writes about achieving an increased level of complementarity amongst perspectives, and the need for more comprehensiveness in portraying the complexities facing decision makers concerned with satisfying different stakeholders [14].

As such, the use of multi-methodology or multi-method approaches has been described as an opportunity for researchers/analysts/managers to develop competence in managing complexity [15]. However, whilst the emergence of such approaches presents an opportunity 'to see, think and act' in a more systemic way in handling complexity, it has also generated an accompanying debate about the challenges and feasibility of doing so. Indeed, there has been an ongoing debate about the philosophical, theoretical, cultural and psychological feasibility and challenges associated with the use of multi-methodology and multi-method approaches [10,16,17].

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. Jackson and Keys' System of Systems Methodologies (SOSM) [7], together with Flood and Jackson's development of Total Systems Intervention (TSI) [18], linked hard, soft and critical methodologies to particular theoretical rationalities embodying the distinctive concerns of stakeholders, and necessarily focusing on, and making assumptions about different aspects of the reality in which problem situations are embedded. Zhu [15], quoting Midgely [19] has suggested that the problematique confronting practitioners has always been the need to identify an appropriate method choice or methodological intervention. Several frameworks regarding method choice [3,20,21] have subsequently emerged. One consequence has been that descriptive frameworks such as SOSM have come to be viewed (and used) uncritically, perhaps unwittingly, as frameworks providing meta-methodological guidelines for method choice [22]--a criticism that, ironically, may also be levelled at the Mingers-Brocklesby (M-B) framework for mapping methodologies [4]. Nevertheless, we concur with Zhu of the need to make our frameworks, tacit or otherwise, the basis for dialogue and learning.

However, the development of such frameworks--the so-called 'framework' approach--is viewed by some [23] as leading to an uncritical or unwitting limiting of method choice tied to the theorised links between an a priori categorisation of problem situations and the appropriateness of pre-specified methods. Both Gregory [23] and Midgely [19] disavow attempts to, or suggestions that one can, bring about a 'once-and-for-all' theoretical unity to the growing multiplicity of problem-solving methods and methodologies through the development of a singular meta-theoretical framework--such as Jackson and Keys' SOSM [7]. They welcome the tension between perspectives that distinct and complementary methodological approaches can give rise to, and they see value in celebrating differences and accepting 'similarities' in perspective and method, as exemplified in the work of Ackermann and Belton [24] and others [25]. We also suggest that such frameworks have utility in surfacing and addressing issues that arise amongst those who use different methodologies but who may share interest or value perspectives [13] or who may wish to better understand the practical implications of operating within a particular methodology or paradigm [5].

Indeed, we agree with Zhu [15] of the need to promote critical discourse and critical appreciation of the different frameworks, and of different methods and methodologies, and perhaps, in doing so, to meet the requirements of 'discordant pluralism' favoured by Midgely [19] and Gregory [23]. However, accepting that this need reflects a far from recent recognition of the value of addressing these issues in OR/MS does not detract from the view that such need may have greater immediacy in the emergent domain of Theory of Constraints (TOC).

We note that many people will be familiar with **Goldratt's** early writing disseminated in works such as The Goal [26-29]. However, the body of knowledge now called 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. Over a period of two decades, TOC methods and practices have grown in acceptance not only amongst its initial 'target market' of practitioners within the field of production and operations management (POM) but also within the POM academic community. TOC now finds a place alongside JIT, TQM, MRP etc. in standard POM texts [30,31] and in leading POM academic journals; and has reached a stage of developmental maturity signalled by a recent TOC-based POM text [32]. TOC's relevance is also appreciated in the related project management field. Recent surveys of TOC published work [33-37] suggest that whilst TOC would have much relevance to the OR/MS community, it has yet to be widely embraced by this community, though important contributions and inroads have been made for example by Guide [38], Perez [39], Mabin and Gibson [40], Rand [41], Ahituv and Elovici [42], Troutt et al. [43], Shaw and Burgess [44], and others. Indeed, we note that the practical problem domain in which TOC methods have been used in the above papers is essentially the same domain in which OR/MS methods have been traditionally employed.

The contribution that this paper makes is to extend the classificatory work of Mingers [1] and Mingers and Brocklesby [4] to the domain of methods and methodologies known as TOC, with the intent of using their classificatory frameworks to better

understand the nature of TOC methods, first by deconstructing and categorising them, and as such to help position them in relation to traditional OR/MS methods and methodologies. In particular, the paper seeks to provide a basis useful for comparing TOC methods and representational tools such as Current and Future Reality Trees, Negative Branch and Transition Trees, Evaporating Clouds and Prerequisite Trees, with other OR/MS methodologies and specific associated tools, for example, Soft Systems Methodology (SSM) and SSM's rich pictures, Strategic Options Development and Analysis (SODA) and cognitive maps, and the influence and causal loop diagrams of Systems Dynamics. However, limitations on paper-size preclude such comparisons here.

The paper continues with an outline and discussion of the frameworks of Mingers [1], Mingers and Brocklesby [4,5]. It follows with an illustration of the frameworks-in-use for selected OR/MS methodologies, especially how they can clarify the role of such methodologies. A brief outline of TOC is then provided prior to using the frameworks in similar fashion to better understand the nature of TOC methodology and selected constituent methods, tools and techniques in terms of their role, purpose and the philosophical assumptions that affect how they are used. 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 [11, p. 58, 1, p. 562].

At this point, 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 continuous 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 can be viewed or conceptualised as systems that exhibit emergent properties that are manifest of the often unforeseen and unpredictable nature of embedded systemic relationships.

2. Frameworks for mapping and classifying methodologies

In this section, we seek to outline the work of Mingers and Brocklesby [4,5] and Mingers [1] in clarifying the role, function and purpose of different OR/MS methodologies and their philosophical underpinnings.

2.1. The Mingers-Brocklesby (M-B) framework for mapping methodologies

The M-B framework [4] provides a basis for relating methodology and method to problem content and problem-solving activity using a two-dimensional mapping grid (See Table 1), with the purpose of alerting analysts to the appropriateness of different methodologies in different contexts. However, Mingers [1] 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 [1, p. 560]. Such criticism, expounded fully by Mingers in his 2003 paper [1], can be traced, in part, to the mapping grid capturing just two dimensions. The first relates to the problem domain, specifically the nature of the world being investigated--be it along social, personal or material dimensions--and the second relates to the methodology, particularly, the conceptually distinct but highly related phases of 'intervention'. These phases 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 it about; and then finally being able to choose and implement alternative courses of action that bring about that future.

We suggest that a methodology that provides a method or activity for this final phase of selecting and implementing real-world alternatives may well need individuals to 'buyin' to the actions and directions being taken. This, in turn, may need to be facilitated through a process of acculturation that may create a sense of collective ownership, responsibility and authority to act. As such, we note that the M-B framework does provide a basis for capturing many of those generalised activities that contribute to effective action.

In a further attempt to surface understanding of these phases of intervention, we draw parallels between the M-B phases and those of Ackoff's rational model of decision-making [45] and Simon et al.'s, conceptualisation of problem-solving and decision-making [46]. We also note that although Ackoff's model of process is depicted below as linear (See Fig. 1), it is important to recognise its fundamental nature as one based on iteration and feedback.

[FIGURE 1 OMITTED]

For example, the implementation of decisions may create outcomes that cause the decision maker to revisit his/her prior understanding of the nature of the problem; the objectives that were set for attempts to solve/resolve or dissolve the problem; the criteria used for evaluation of outcomes; and/or the completeness of the set of choices or actions under consideration. We suggest that the phases of intervention within the M-B framework may be similarly interpreted. However, within the M-B framework, classification of an activity associated with a method or methodology requires a determination of whether that activity is one that is deliberately designed for that phase of intervention. Mingers' classificatory judgements (summarised later in Table 2 and in Appendix A, Tables A.1a-d) were informed by advice from many of the methodology innovators or developers and/or from those most closely involved in the development of traditional OR/MS methodologies. We may recognise, for example, that whilst some may see no reason why Systems Dynamics (SD) models cannot be applied to elicit and capture different perceptions and alternative constructions of "reality" in particular contexts, such activity is not considered to be the main purpose of SD modelling, and Mingers does not classify it as such (Appendix A, Table A.1d). Of course, such classification would not preclude any attempt to use the SD for such purpose. Our attempt at using the classification processes mirrors that of Mingers. However, in as much as we were able to benefit from advice from some who have played leading roles in the development of TOC tools, the classifications represent the authors' assessment of how the classificatory criteria are met.

Following his erstwhile self-critique of the limitations of the M-B framework, Mingers has sought to develop an alternative classificatory framework that would more readily highlight salient features of OR/MS methods as a precursor to multi-methodological use. 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. As a necessary beneficial by-product, Mingers saw the classification as offering a more rigorous base for mapping methodologies to the initial M-B framework. Others, including an unnamed referee, would suggest that if we need to be able to compare, discriminate, and seek complementarities between methodologies and methods as a precursor to multi-methodological use, then some form of classificatory framework is inevitable.

2.2. The Mingers framework for classifying the philosophical assumptions of OR/MS methodologies

Mingers [1] suggests that any attempt to classify OR/MS methodologies should reflect what would be their most common and general characteristics--those being 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.

Mingers [1] insightfully synthesises these characteristics and conceptual notions into a SSM root definition for a generalised OR/MS methodology. The definition, which embeds a structure espoused by Checkland and Scholes [47] makes explicit and emphasises the ontological, epistemological and axiological nature of modelling assumptions (See Fig. 2). It forms the basis for the extended classificatory framework shown in Appendix A, Table A.2.

3. Application of the frameworks-in-use

For the purpose of this paper, it will be assumed that the reader's knowledge of hard and soft methods and methodologies used within OR/MS will be sufficient to make sense of the M-B and Mingers frameworks, and how the mappings and classifications shown in Appendix A, Tables A.1a-d and A.2, have been derived. Further detailed discussion and critique of these frameworks can be found in Mingers and Brocklesby [2,4,5,48], Mingers [1,2,48-50].

Balderstone [34] provided a preliminary categorisation of TOC as a whole against the earlier M-B grid, which was possibly the first attempt at analysing TOC's strengths as a systems methodology. Here we have taken a different approach to Balderstone,

and attempt the classification of individual TOC methods--which then provide a basis for aggregation and for examination of TOC methodology and methods as a whole. In doing so, we have used the Mingers protocol for mapping methodology or method to the M-B grid. We have also attempted the characterisation of TOC methods and methodology using the Mingers classificatory framework (later evident in Table 2, and also in Appendix A, Table A.2), to examine the philosophical underpinnings of the various methods. The protocol used for mapping methodology, method or activity to the revised M-B grid requires the method, say, to be explicitly linked to the phase of intervention by purposeful activity, and to be so linked, either by design--deliberately incorporating under lying assumptions--and/or by common purposeful usage in practice. As such, it is more appropriate to perform this categorisation treating each of the individual TOC methods separately--as we have done in this paper--rather than collectively. 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. First, the paper will provide a sufficient minimal overview of TOC tools and methods for the reader to be able to form a basis for understanding the development of the mappings and classifications to be provided later in Tables 2 and 3a-h.

4. Mapping hard & soft OR/MS methods

This section provides some examples, extracted from Mingers and Brocklesby [4], and Mingers [1], which illustrate distinctive features of traditional hard and soft OR/MS methodologies that relate not only to the umbrella methodology, but also to constituent method, tool or technique, and also to particular spheres of problem-solving activity within different domains at different levels of 'intervention'. These examples are later complemented by similar attempts to map TOC methods, tools and techniques to the grid.

As an illustrative example, we may suggest that within SSM, 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 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 provides an assessment of alternative actions that may address the problem (See Appendix A, Table A.1a).

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 A, Table A.1b). At that point, cognitive mapping has 'done its job,' whereas SSM has been designed as a methodology to work towards purposeful improvement of situations.

5. The theory of constraints--TOC--and the mapping of TOC tools and methods

Goldratt [51] has developed a suite of logic tools in his on-going quest to devise a systematic approach to help managers develop solutions (based on both intuition and logic) to their problems. These logic tools comprise four tree diagram tools and the Evaporating Cloud (EC), which are known collectively as the TOC Thinking Processes or TP tools (see Kendall [52], Dettmer [53], Scheinkopf [54]). The TOC approach was first used in a manufacturing environment and reported at an APICS conference in 1980, and developed into an effective methodology for production applications [55]. Hrisak [56] reports that TOC is used worldwide by companies of all sizes, stating that many managers who routinely use TOC believe they understand their businesses for the first time. From this understanding they gain a sense of control and of being able to act proactively. Hrisak argues this is because TOC empowers managers by providing a consistent framework for diagnosing problems.

The TP's exist for the purpose of managing change, starting with identifying what was preventing an organisation from achieving its goal [57]. They embrace what we refer to as the Current Reality Tree (CRT), the Future Reality Tree (FRT), the Prerequisite Tree (PRT), the Transition Tree (TRY) as well as the Evaporating Cloud (EC) or Conflict Resolution Diagram (CRD). The TPs are constructed from 3 basic building blocks: cause-effect thinking, necessary condition thinking, and a set of rules governing the logic-in-use [54]. The CRT, FRT and TrT are sufficiency-based logic diagrams, whereas the PRT and the EC/CRD are necessity-based logic structures [58]. An example of these logic structures is the CRT, which is essentially a map of the cause and effect relationships perceived to underlie the current undesirable situation, with cause and effect entities depicted as boxes linked by directional arrows to reflect the logical relationships. Use of the logic tree structure signals an

acknowledgement of other systemic influences that bear upon our decision making, and which need to be understood. **Goldratt** has provided logic rules (see the Categories of Legitimate Reservation in Noreen et al. [59], Dettmer [53], Scheinkopf [54]) that are used to add rigour to the modelling process and to check the validity of the constructed logic relations as logic trees.

In Tables 2 and 3a-h, we characterise each of the TP tools and the 5 Focusing Steps of On-going Improvement (5FS) method used within TOC. We provide brief descriptions of each of the tools and methods as a basis for such characterisation and classification. It is worth noting that even though the tools and methods may be used on their own for day-today problems, they would be used in combination for more infrequent and complex situations [60].

6. TOC--the five focusing steps in the process of on-going improvement (5FS)

The 5FS is a TOC method whose name connotes activity and practical purpose for some, and an underpinning philosophy of purpose for others. As a method or approach developed to foster on-going improvement, the 5FS provide a perspective on those forces or barriers constraining or limiting improvement--but does so without limiting that view only to tangible constraining resources or activities. A full description of the 5FS is given elsewhere [61,62]. However, a brief summary and an example are provided below. Note that preceding any discussion of use of the 5FS process, we would assume that the overall goal of the organisation had already been determined. Indeed, this would be part of the first question addressed by a TOC approach, namely 'What to change?' as discussed elsewhere [51,53,54].

For example, if machine X had been IDENTIFIED as the bottleneck or constraint in a manufacturing process, and is constraining flow through the whole system, then we should EXPLOIT the constraint, and make sure the machine is working productively every minute. It should be serviced out of hours, never be kept waiting for work, never be kept waiting for repairs, maintenance or set-up, never be left running unattended, nor working on products that are not in demand. It then becomes clear that everyone else and all other processes should organise themselves or SUBORDINATE themselves to make sure that machine X never has to wait, that it is working only on real throughput, that other processes ensure that work is ready and waiting for machine X, and that machine X only does what it has to do, meaning that other jobs are off loaded to non-bottleneck machines. If such efforts have not released enough hidden capacity in machine X (and usually it does), only then should we consider adding more capacity, that is ELEVATING the constraint on machine X, through overtime, extra shiftwork, extra staff, an additional machine or through outsourcing. If the constraint is lifted, and then another constraint on performance appears, we GO BACK and start over. Of course, our illustration can apply equally well to any physical process, including people in service systems, stock-keeping systems, and also to less tangible market processes.

Oftentimes we can proceed through these 5 Focusing Steps without difficulty acting at an operational level, but other times the constraint may be an organisational policy--sometimes explicit, sometimes implicit, unstated and intangible, and as such all that is perceived is a seemingly unrelated tangle of symptoms or problems.

In such cases, the use of TOC's logic trees is appropriate and can facilitate diagnosis of the nature of the illness (core problems), lead to prescription of appropriate remedies and to the institution of a treatment program, as will be discussed below.

Five Focusing Steps in the Process of On-Going Improvement

Step 1: IDENTIFY the system constraint(s)

Step 2: Decide how to EXPLOIT the constraint

Step 3: SUBORDINATE other activities to decisions made in Step 2

Step 4: ELEVATE the constraint(s)

Step 5: If anything has changed ... GO BACK to Step 1.

7. The TOC logic trees

Goldratt [51] 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. The other tree structures within the TOC can then be used to determine the desired future and to map out how it may be achieved. 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 [54], Dettmer [53], or Schragenheim [63], or Smith [64] for elaboration on these tools. An example of a CRT is given in 2.

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. Appendix B provides an illustration of a CRT that emerges from this process. We note that the CRT and other trees that evolve out of using **Goldratt's** TP's may bear some similarity to cause-effect trees from other disciplines, but that similarity disappears on more detailed examination, when considering the tools as applied in context [65].

At this point, we may note how seductive the previous statements 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 [52], for example, describes measurements, policies and training as 'three pillars' of an organisation and asserts that weaknesses in one or more of these areas are often identified as core problems in a CRT analysis, but not always subject to prior open discussion.

The core problem(s) in our CRT is/are depicted as boxes (with no arrows leading into them) which lead to the majority of the undesirable symptoms. In some cases, we identify performance measurements that are misaligned with the organisation's goal or with other parts of the system. For example, each department in an organisation might be assessed/measured according to its own goals, with say Production trying to maximise output and Sales trying to maximise sales revenue. This may be related to outdated or erroneous policies such as commission schemes which unwittingly set departments at loggerheads, or even the use of traditional cost accounting, or inappropriate priorities used in the scheduling of jobs. Alternatively, core problems may be the lack of appropriate training, with, for example, staff being unaware of the importance of a particular piece of equipment, or not trained to achieve the best production flow.

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 fire-fighting 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). It highlights the web of interrelationships between symptoms, policies, measures and behaviours but posits that despite the tangle, 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, starting with the CRT discussed here, and other tools that aim to provide guidance leading to the successful implementation of the solution.

8. TOC--the evaporating cloud or conflict resolution diagram

Underlying many such problems would be a dilemma. For example, the dilemma might simply be 'Which product should be given priority in our company when Production and Sales think differently?' The perspective developed by using **Goldratt's** Evaporating Cloud (EC) framework [29,51,62] 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 given by Dettmer, namely the Conflict Resolution Diagram (CRD), though the EC applies equally well to dilemma and trade-off situations. The frame or model is constructed as a schematic depiction of the dilemma, and the reason for conflict can be explored by examining assumptions that underlie the relationships, depicted here by arrows connecting the boxes in the diagram.

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. In order to find such a solution, we elicit those assumptions or reasons why the relationships are thought to hold. Some of these assumptions are shown as annotations in the thought bubbles on the diagram. Often when the assumptions are surfaced and articulated, they may be seen as false, and the conflict evaporates. Where assumptions are recognized as valid, they may then be addressed in a manner that invalidates them, reduces their importance or impact, and that allows for a resolution of the conflict. Fig. 3b provides an illustrative, indicative list of such assumptions and the accompanying "injections" that may be used to "attack" or address those assumptions to resolve the conflict. Indeed, Fig. 3b may provide a basis for under standing how insights may develop about the nature of root causes, and about the core problem identified in our illustrative CRT.

In summary, we see then that the mapping of EC 'activity' to the M-B framework demonstrates 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.

9. TOC's other logic trees

We have stated that whilst modeling the problem situation as a CRT reflects a systems perspective and the likely systemic nature of relationships and links between key variables and entities, it 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, the CRT links undesirable effects to root causes, (2) and by contrast, the FRT approach begins with the 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 [58, p. 14] states, the 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 the desirable effects or change, and whether or not additional undesirable effects will also emerge from our actions [52, p. 39].

Sub-trees may be constructed in this 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 method known as the Negative Branch Reservations (NBR). The NBR is formally a sub-tree 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 [66]. Illustrations of the NBR method can be found, for example, in Boyd and Cox [60], Mabin and Davies [66].

These trees thus capture different perceptions and alternative conceptualisations and generate accommodations and consensus. Both of the different sides are heard and the situation is better understood, leading to greater enlightenment and empowerment.

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 [67]. The PRT is generally developed by a team, in addressing obstacles that may confront them, 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 practices, although, indeed, it may contribute in that arena.

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. 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 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 usually paints 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 tools directly target or deliver on all but one of the cells in the M-B grid (See Table 3h)--leaving Assessment of ways of challenging and altering power structures alone unshaded.

We may observe that this is because TOC does not directly set out to challenge or assess power structures for it is not necessarily designed for this purpose--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 during the development of the PRT. In these cases, the power structure will be tackled; but as in other cases, even though such challenge to power structures may be an emergent property of the systems approach, since TOC does not aim to do this from the outset, and neither is it a natural common outcome, we have left this box unshaded to maintain consistency with Mingers' approach.

10. Summary & 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) or conflict resolution diagram (CRD) [35,60]. Here, too, we have indicated how these different approaches purposefully attend to different issues and surface different insights, using different kinds of information sourced in different ways. We have shown how the choice and use of a TOC TP tool reflects, in essence, a deliberate 'framing' or modeling of the problem in different ways, each frame or model being used with specific intent, and thereby representing or highlighting certain aspects while downplaying or ignoring other aspects. These matters are reflections not only of what the 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. For example, whereas we may expect similar insights to arise from more than one frame or method, in general there will be new insights about the problem, and how it should be tackled, arising from each frame. As a result, we suggest there is, in most cases, no one best frame, model, method or methodology; and as such the often implicit search for a 'best-fit' model or method should be surfaced explicitly and abandoned. As such, the pragmatic adoption of a multi-method or multi-methodological approach accords with the views suggested by Burrell and Morgan [9,68] and Brocklesby [10] in their discussion and acceptance of the efficacy of multi-paradigm and multi-methodology development.

We have stated that seldom are any of the TOC methods and tools used in isolation. Certainly, for complex problems, several tools may be used as problem-solving intervention moves through the stages from diagnosis to implementation. Using the conceptualisations of the original M-B framework, we recognise that TOC methods are used as 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 full set of TOC tools and methods discussed in this paper are mapped to the M-B framework (See Table 3h), we note how TOC methods comprise a multi-method approach, and can be regarded as a

methodological set. We also note the potential for further discussion of whether the broad umbrella of TOC can be regarded as a meta-methodology, a meta-framework or a multi-methodological approach.

Indeed, we see TOC as offering a complementarity which others have sought through the development of multi-method and multi-methodological approaches combining different, traditional hard and soft OR/MS methodologies and methods. We suggest that TOC, as a methodology, offers methods that embrace the whole range of activities or phases from problem identification and representation, the setting of appropriate objectives, generation and evaluation of alternatives, through to implementation. In this respect, it has been instructive to surface and clarify the philosophical assumptions, ontological and epistemological, that underpin the various methods that make up TOC, and also the various activities embraced by TOC (See Table 3h). Additionally, we suggest that much may be gained from further exploring how TOC methods and methodologies may be effectively combined with traditional OR/MS methods and methodologies.

We have sought to provide a brief analysis that will help position TOC in relation to traditional OR/MS methodologies and methods, and that does so by identifying the often common purpose of TOC and OR/MS methods, and the nature of the assumptions underpinning seemingly different TOC tools, techniques and methods. This has been facilitated using the classificatory frameworks of Mingers and Brocklesby [4] and Mingers [1]. We acknowledge that a likely outcome of using such frameworks in classifying the elements of any systems approach is that an emergent property of that approach--enlightenment, insight etc--may be missed as beyond classification. As such, we may expect that no one grouping of classificatory criteria will necessarily constitute a full comprehensive set. Given this rider, we seek to use the frameworks of M-B and Mingers to provide insights about those features of method that can be clearly identified--that is, where the basis of classification is meant to reflect the nature and philosophical underpinnings of purposeful and targeted intervention made possible by the method.

The paper concludes that the tools, techniques and methods of TOC 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 also see that TOC methods, as a methodological set, share unifying ontological, epistemological and axiological characteristics and assumptions with each other, and with other extant OR/MS methodologies. As such we may suggest that TOC offers OR/MS practitioners a set of methods worthy of consideration for use alongside traditional OR/MS methods and tools.

So, finally, we return to the question posed in the paper's title. In one sense, TOC methods have yet to be fully endorsed by the OR/MS community, implying that TOC has been set apart from OR/MS. In another sense, TOC can be considered a complete methodological set that makes it stand apart from other methodologies which are not a complete methodological set. However, in this paper, we have shown, in seeming contrast, the complementary nature of TOC methods with respect to OR/MS methods, and as such, demonstrate that TOC embraces and can be embraced by OR/MS. The next step is to continue to build awareness of such complementarity, and how and when a multi-method approach can be best used.