Laws of System Completeness

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Introduction

This article is about the TRIZ Law of Technical Completeness and how it compares to the findings of researchers from other disciplines. Specifically, the article compares TRIZ work with that of Stafford Beer with his 'Viable System Model', and the work on the application of Game Theory to business strategy described in Nalebuff and Brandenburger's seminal book, 'Co-opetition'.

The article seeks to draw together the experiences from the three pieces of research in order to derive hopefully useful new perspectives on the way we might interpret and use the TRIZ Law in both technical and non-technical scenarios.

The TRIZ Perspective

The TRIZ Law of System Completeness (Reference 1) describes four essential elements of a system as shown in Figure 1. The Law requires that all components are present and that 'if any component is missing, the technical system does not exist, if any component fails, the system does not 'survive'' (Reference 2).

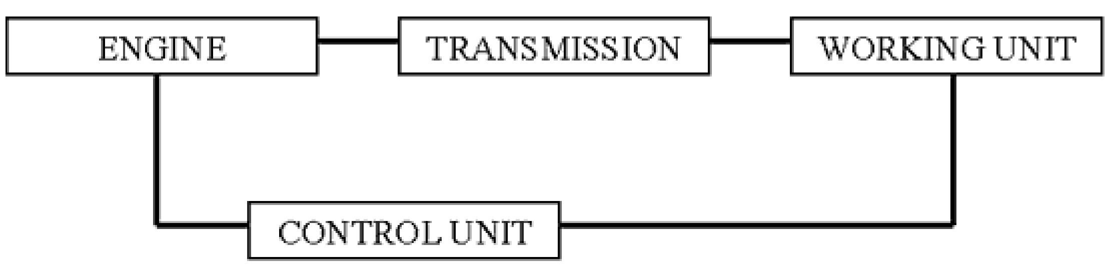

Figure 1: The 4 Essential Elements of a Technical System
(as defined in classical TRIZ)

By way of example, a technical system to achieve the function 'clean teeth' requires a working unit (or 'tool' in several texts) - the tooth-brush; an engine - our muscles; a transmission - our arm/hand/etc; and a control unit - in this case a combination of our brain, our nervous system and our view in the mirror. Take any one of the four away, and we are no longer able to deliver the required function.

More recent work reported by Savransky (Reference 3) has implied that actually the system is not complete with just the four elements, and that a fifth essential element is required. Savransky calls this fifth element ‘casing’. We might interpret this description more evocatively as a connection between the defined system and its surroundings. Perhaps ‘external interface’ or maybe just ‘interface’ would be suitably descriptive names. By way of example of what we mean by this fifth essential system element, in the case of the above ‘clean teeth’ example, we see that we are only able to successfully achieve the function because of the presence of teeth and thus there has to be an interface between the tool and those teeth.

Stafford Beer ‘Viable System Model’ Perspective

Much of Stafford Beer’s research into viable systems (Reference 4) was conducted with company organisation structures in mind. The bulk of the work was conducted during the 1960s and 70s, Despite the continued activities of a small band of devotees, much of the work has been largely ignored in more recent times. A possible reason lies in a significant cloud of complexity in the way ‘viable systems’ are described. This is a shame as the work has much to offer.

A connection between Beer’s work and the TRIZ Law of System Completeness was first described in Reference 5, an overview of TRIZ tools applied to non-technical, business processes. Beer’s work describes the necessary conditions for system viability, and concludes that there are five; policy, intelligence, implementation, control and co-ordination. We examine each of them briefly here in order to identify possible connections with the TRIZ Law.

Implementation - defined as the parts of the system responsible for the conducting of primary activities. Those responsible for producing the products or services implied by the organisation’s identity are at the core of a system model that is shown within the VSM model to be recursive. A company offers products and services through the combined actions of different levels of ‘viable systems’. Generally speaking, although the level of recursion in any given organisation can be taken to the level of an individual, it is more likely to stop unfolding a structure at the complete work task level (e.g. a manufacturing cell). We would expect to see most viable systems, at whatever structural level they occur, containing further sub-systems as a way to help them handle the complexity of their environments. These sub-systems are responsible for carrying out the value-adding tasks of the system-in-focus.

The ‘implementation’ element of the viable system corresponds directly to the concept of ‘tool’ used in the TRIZ Law of System Completeness.

Co-ordination - a viable system also requires systems in place to co-ordinate the interfaces of its value-adding functions and the operations of its primary sub-units. In other words, co-ordination is necessary between the value-adding functions as well as between the embedded primary activities.

‘Co-ordination’ in the VSM context suggests that the more teams “share common standards, approaches and values, the greater the chances that spontaneous lateral communication will occur, resulting in less ‘re-invention of the wheel’ and more chance of synergy. The stronger these lateral links, which are of both a technological and human nature, the less the requirement for management to attempt to impose control from above and the greater the sense of autonomy and empowerment experienced by the subsumed primary activities” (Reference 6).

The VSM ‘co-ordination’ definition is most closely related to the concept of the TRIZ Transmission term used to denote the relationships between the Engine and Tool parts of the system. In the VSM context, again, the ‘co-ordination’ definition is much more suggestive of the need for an effective two-way (communication) link.

Intelligence - is defined as ‘the two-way link between the primary activity and its external environment’. Intelligence is described as fundamental to adaptivity; firstly, it provides the primary activity with continuous feedback on marketplace conditions, technology changes and all external factors that are likely to be relevant to it in the future; secondly, it projects the identity and message of the organisation into its environment.

The intelligence function is, in Beer’s definition, strongly future focused. It is concerned with planning the way ahead in the light of external environmental changes and internal organisational capabilities so that the organisation can invent its own future.

Control - is defined in the VSM as the (two-way) communication between sub-unit and meta-level unit. Of the different elements of the Model, Control is the one most directly connected to its equivalent in the TRIZ Law. Perhaps the most interesting difference, however, is the stressed importance of ‘two-way’ communication in the VSM. From a technical system perspective, we interpret this as the need not just for the tool to provide feedback to the engine, but that the engine should in turn be providing control information to the tool.

Policy - is the last function in VSM, and as such the policy making function gives closure to the system as a whole. The main roles of Policy are to provide clarity about the overall direction, values and purpose of the organisational unit; and to design, at the highest level, the conditions for organisational effectiveness.

The Policy element of the VSM most closely maps to the Engine element of the TRIZ Law. The mapping is not so direct as for other parameters, but the concept of ‘policy’ being the driving force that powers the implementation is felt to be a strong enough analogy to justify inclusion here.

The Viable System Model is not a tool that is used widely. Part of the reason for this may lay with its apparent complexity to the newcomer. Certainly the commonly used pictorial representation of the Model - Figure 2 - does not help in this regard.

The Model is further complicated by attempts to use the model mechanistically; “it is above all a thinking framework which helps people to share a common language and model of their organisation to manage more effectively its complexity and aid debate and adjustment. Its effective use requires a common understanding of the philosophy and relational management approach behind the model” (Reference 6).

Whether more people will adopt more of the ideas contained in Beer’s work remain to be seen. In the meantime, beyond the comparisons with TRIZ made here, the readers attention is drawn to the important idea of recursion in the Model. The principle is illustrated in Figure 4 via the presence of viable sub-systems within the Implementation system. There is much in common here with the 9-Windows, sub-system/system/super-system model.

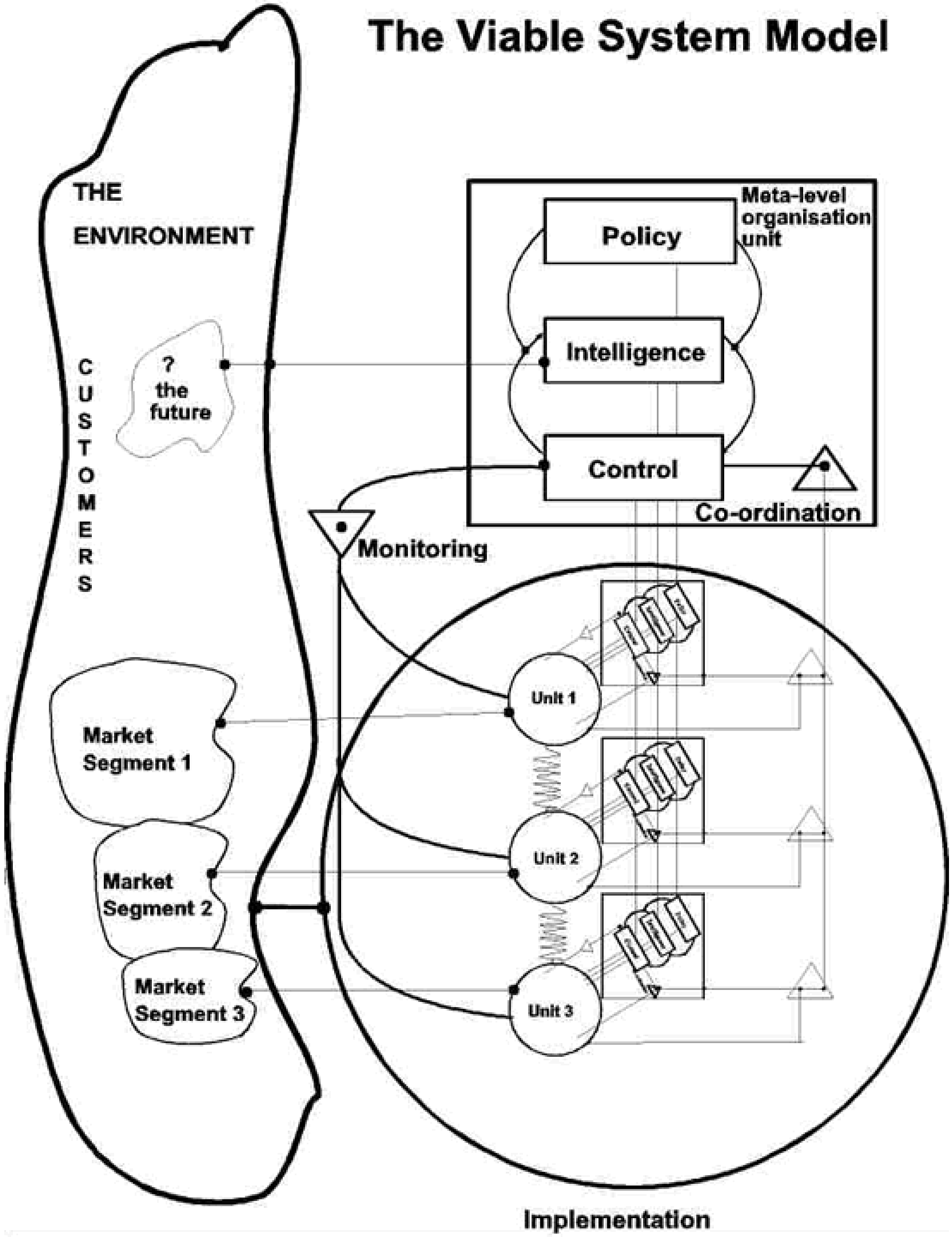

Figure 2: The Viable System Model (from Reference 6)

'Co-opetition' Game Theory Perspective

Co-opetition by Barry Nalebuff and Adam Brandenburger (Reference 7) offers a seminal account of the application of game theory in the world of business strategy. Game theory applied to business dates back to the mid 1940s and the publication of the book 'Theory of Games and Economic Behaviour'. The underlying principles have already begun to have significant impact across the fields of law, computer science, politics, evolutionary biology and military strategy. The Co-opetition book describes ways of changing the way business gets done. The book starts from the basis that we all already use elements of game theory in what we do, but that how we use those elements is usually unstructured and incomplete. Co-opetition offers a systematic methodology aimed at covering the full range of possibilities available when trying to 'change the game'. In this regard, it offers very definite parallels with the Law of System Completeness; in effect the book describes the elements that make up a complete viable game. The number of elements is five.

The book collects the five essential elements of a game under the acronym PARTS. The five elements are Players, Added values, Rules, Tactics and Scope. Collectively they describe the 'game' (system); if we want to change the game, we need to take due account of each and every element. In a little more detail, then, the five PARTS are defined as follows:

Players the book offers an interesting perspective on the players involved in a game, describing the concept of a 'value net'. Starting with a company at its centre, the value net contains the players illustrated in Figure 3.

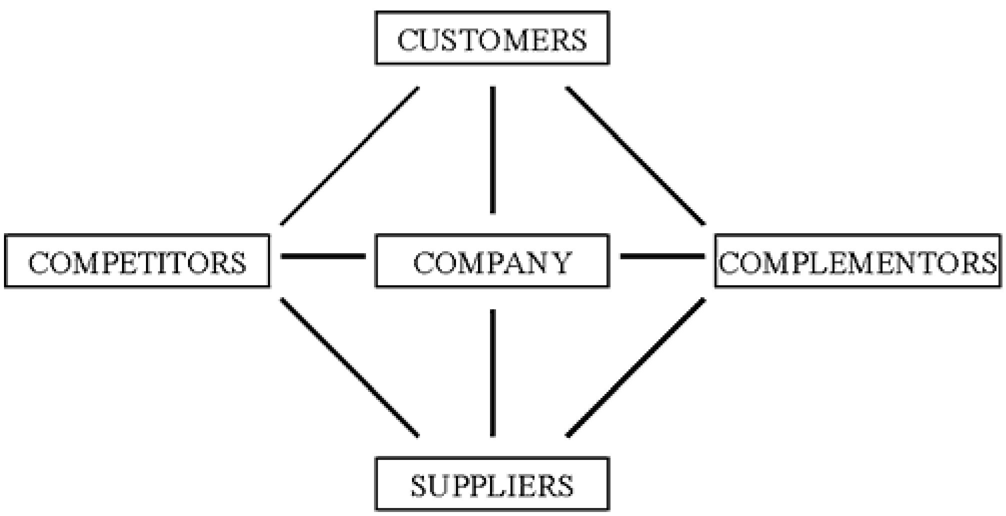

Figure 3: Players in the 'Value Net'

Perhaps the most interesting part of the value net - and certainly the part that Co-opetition devotes the most attention is the 'complementor'. Complementors are independent outside agencies who offer the potential to enhance the value of a companies offering. Frequent flyer programmes in which customers are given 'miles' when they buy fuel or groceries are good examples of complementary relationships in action. Complementors offer the prospect of 'win-win' situations in which everyone comes away with a better deal than they would if the complementary relationship did not exist - the shopper gets miles, the grocery store gets more customers, the airline gets advertising and more customers. The idea of 'win-win' or 'trade-on' - another Co-opetition theme - are obviously very closely linked to the TRIZ concept of contradiction elimination.

The Players in a game represent the equivalent of the 'working unit' or 'tool' in the TRIZ Law of System Completeness; the players are the ones who make the game happen, they deliver the useful function.

Added Value - is the measure used in game theory that determines what a player brings to the game. For a formal definition, Co-opetition suggests added value as *the size of the pie when the player in question is in the game minus the size of the pie when you are out of the game*. By way of example of the two extremes of added value, we might see that an individual car company has limited added value; take that player out of the game and customers still have many other options available to them when buying the car. The size of the pie called 'car market' is pretty much the same whether an individual (mass-production) car maker is there or not, and so the added value of that car manufacturer is low. A film actor like Julia Roberts or Sean Connery on the other hand, has very high added value. People often go to a particular movie specifically because it features a particular actor; the movie would not be the same if that actor wasn't there. The actor plays a big part in defining the size of the pie.

With this stark definition, 'added value' represents one of the five essential elements of a game, and as such, has very definite parallels with the TRIZ concept of the 'engine' as the driver of the system.

Rules - are probably the first thing we will think of when someone talks to us about 'changing the game'. One of the main points of Co-opetition is to record the other four PARTS that can be changed. The rules are the things that govern the way business gets done. They might be legal or contractual or they may be the unwritten ethical and moral codes we live and work by. Rules are an important source of power in games. They are the things that determine the mechanism by which the Players deliver the Added Values, and as such are highly analogous to the Transmission element of the TRIZ Law of System Completeness.

Tactics - are the fourth of the essential elements of a game. Tactics are all about the perceptions of the players, and the way one player interprets the actions (or non-action) of others, and the way he/she thinks the other players will perceive their actions. Co-opetition defines tactics as *the actions that players take to shape the perceptions of other players*.

Tactics represent the equivalent of the Control Unit in the TRIZ Law of System Completeness; they are the things that govern the way the Engine (Added Values) powers the Tool (Players).

Scope - the fifth and final essential element of a viable game is scope. We are able to change a game by changing its scope - either making it smaller when we focus in on sub-systems, or by making it larger when we zoom-out and look at the super-system.

Scope has no equivalent in the classical TRIZ Law of System Completeness, but it has very distinct parallels with the 'Casing' idea discussed in Reference 3, and, in terms of parallels with the Viable System Model, is directly analogous to the Co-ordination element of a viable system.

All in all, the Co-opetition perspective on game theory and its five essential elements offers both close parallels and interesting new angles on the way we see and use the TRIZ Law of System Completeness.

Discussion

The overall correlation between three methods of looking at system 'viability' and/or 'completeness' which have essentially been developed completely independently of one another is quite remarkable. Figure 4 illustrates how each of the three methods - TRIZ, VSM and Game Theory - describe the 5 essential elements that define a complete system.

TRIZ Law Of System Completeness	Stafford Beer Viable System Model	'Co-opetition' Game Theory
Engine	Policy	Added Values
Transmission	Co-ordination	Rules
Control Unit	Control	Tactics
Working Unit	Implementation	Players
*'Casing'**	Intelligence	Scope

* as described in Reference 3 only – not a part of 'classical' TRIZ

Figure 4: Comparison Between Different System Completeness Tests

Several useful comparisons and synergies between the three different approaches may be hypothesised:

Some Useful Synergy Between Different Models

Players/9-Windows

The Co-opetition idea of a 'value net' is of significant interest when thinking about a holistic approach to business oriented problems. This becomes particularly so when taken together with the TRIZ '9-windows', 'multi-screen' or 'system operator' approach. Taken together, the two offer a much more complete definition of 'holistic' in fact - offering a much more broad reaching view of any business problem or opportunity. In effect the 'value net' appears in each of the windows of the system operator tool - Figure 5.

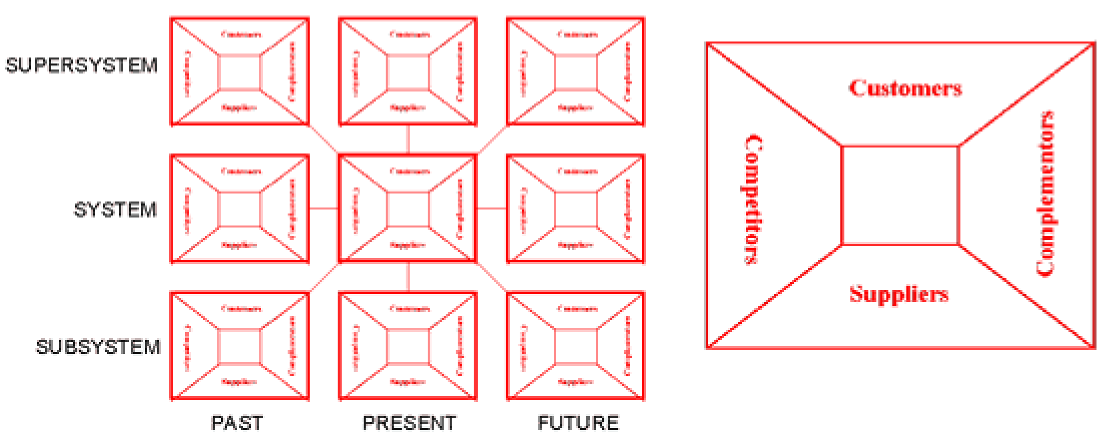

Figure 5: Combined 9-Windows and Value-Net Concepts

This is so because the value net may well change with respect to both SPACE and TIME. Thinking about SPACE, for example, with many problems the system operator approach might cause us to think about 'customers' and 'suppliers' only as a part of the super-system. Or we might place 'suppliers' as a part of 'sub-system. The point re-enforced by Figure 5 is that every element of the value net potentially needs consideration at each hierarchical level of a problem - at super-system, system and sub-system - because the relationships between the different elements of the value net may well be different at different levels. By way of a simple example, company A may be collaborating with company B on one particular (system level) project, while being competitors in a more global (super-system) business sense. This is particularly apparent in an increasing number of defence businesses.

The model has much in common then with the recursion ideas contained in the Viable System Model.

Implications for Technical Systems

Few engineers would claim that the TRIZ Law of System Completeness is a regularly used part of the method. The Law in fact is accepted without being explicitly articulated by the large majority of engineers, and is implicitly understood from most engineering education programmes. Probably the only time, then, that it does get used explicitly within TRIZ is during use of Trimming tools - in that none of the 4 (5) essential elements are likely to be candidates for trimming (in fact, according to the Law, the only way they can be trimmed is by replacing them). The 'system completeness law' concept has rather more value in non-technical areas, however, in that there seems to be much more inclination to try and trim things out of a system without realising the likely downstream consequences.

That being said, the new perspectives presented by the comparisons in Figure 4, do have one or two useful things to contribute to the application of the Law to technical problems, not least of which are the recognition of the need for the fifth 'external interface' element, and the importance of two-way communication between different elements.

Implications for Non-Technical Systems

The implications for non-technical application of either the TRIZ Law, VSM or Game Theory are perhaps more profound in that there is a much lower level of scientific understanding of the workings of organisations filled with humans.

Perhaps the most immediate benefit comes from the very simple recognition that different researchers have all concurred that the 5 essential system elements are exactly that, And from that, it is therefore neither prudent nor logical to 'trim' organisation structures during down-sizing or BPR activities without recognising that you may be trying to trim out something which turns the system from viable to non-viable.

Complementors

The Complementor concept discussed in Co-opetition does not appear specifically in TRIZ, but has several parallels with concepts and solution triggers emerging from use of the different tools. Most notably these are:-

- Inventive Principles 5 (Merging), 7 (Nesting - complementor example - ‘store-in-store’s), and 24 (Intermediary)
- Standard Inventive Solutions - any of the standard solutions involving addition of new substances, moving to the super-system, or merging systems.
- Trends of Evolution - perhaps most notably of all of the connections with TRIZ is the connection to the Mono-Bi-Poly trend. Taken at the organisational level, ‘complementors’ represent the outside organisations that are relevant in turning one (mono-system) organisation into an ideality-increasing bi- or poly-system.

Co-opetition amply demonstrates the importance of complementors; the benefits of which ought not to be lost by the TRIZ community when thinking about spreading the TRIZ message more widely.

Conclusions

1. Three independently developed definitions of system completeness, all originated from widely differing backgrounds, have each made very similar conclusions on what the **5** essential elements of a viable system are.
2. Each offers interesting new perspectives on the interpretation of definitions made in the others for both technical and non-technical systems.
3. The Co-opetition derived ‘Value Net’ offers a potentially important new perspective - particularly with respect to the concept of the ‘complementor’ - on the management of complexity within problem situations. There is significant scope for integration of ideas beween ‘value net’ and the TRIZ ‘9-Windows’/’system operator’ tool.

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