

The Supply Chain as a Complex Adaptive System

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The overriding aim of this paper is “to illustrate the supply chain as a complex adaptive system”, through a critically reflection of the dominant discourse of management theories and in the context of supply chains. The paper challenges the view that hegemonic universalisation of interests in the role of ‘professional supply chain management’ attempts to achieve control, certainty, and complete information to manage and inevitably this constrains human active systems, such as supply chains.

The notion of supply chain as a human active system is presented and this challenges the belief that traditional supply chain management cannot always achieve complete control and certainty. The quest for completeness and control may become counter-intuitive to support these types of human networks, hindering adaption, co-evolution and consequently the emergence of optimal levels of value, democratic leadership, trust, innovation and creativity within the continual sustainable development of such systems.

This discussion reveals the theoretical position of Complex Adaptive Systems (CAS) within a human active system / supply chain, therefore, “illustrating how the supply chain operates effectively as a complex adaptive system”. Consequently, two apparently contrasting viewpoints for supply chain management are presented, which in reality, appear to be struggling to operate simultaneously. The conclusions drawn are that traditional managerialism can be counter-intuitive for supply chains, whilst CAS supply chains are emasculating and emancipatory in nature.

Introduction

The originality and value of this conceptual paper represent an initial attempt to apply the taxonomy of supply chains as a complex adaptive system (CAS).

In a first paper which progresses a PhD proposal into the first stages of a doctoral study, the paper highlights the interaction between CAS and supply chain management and offers a theoretical position for CAS in that process. In doing so, the paper intentionally recognises and includes the use of older sources and references at this stage of the study. These aim to illustrate the origins and emergence of CAS, but also provide an aid to compare the notion of CAS supply chains besides a traditional position in management.

Early research within the UK and European Defence and Aerospace sector appears to indicate that there may be some lack of current thinking in exploring the supply chain as a behavioural and psychological system through CAS and perhaps, this further amplifies the potential originality and contribution to knowledge for such a study at the start of a PhD thesis? The structure of the

paper will cover the following four areas: -

Firstly, a context will be provided, to offer a strategic perspective of the supply chain as a human active system otherwise known as 'complexity theory' (CAS). This context will include the presentation of a theoretical framework containing the "Ten Generic Principles of Complexity [1].

Secondly, CAS will be defined and this will distinguish between CAS and the more traditional use of the term 'complexity' already being used within the supply chain vocabulary to indicate that complexity applied as CAS is different

The third section will outline a 'theoretical position for CAS' and as an alternative discourse for supply chain management. This section will include a focus upon the key theories and principles that underpin CAS within a supply chain context, offering a rationale for why CAS as an emancipatory approach, can provide a potentially new contribution to the field of supply chain management.

Finally, in the fourth section, suitable conclusions will be drawn to summarise the originality, value and contribution of CAS within the context of supply chain management as a PhD study for the UK and European Defence and Aerospace sector.

A context for the study

Challenging the view that hegemonic universalisation of interests in the role of 'professional management' always attempts to gain control, certainty, and complete information to manage and inevitably constrain human active systems, such as supply chains. This paper offers a perspective of the supply chain as a human active system, suggesting that traditional supply chain management could prevent human active supply chains from adapting and co-evolving. Therefore constraining the emergence of optimal levels of democratic leadership, shared value, trust, innovation and creativity for the continual sustainable development of such systems. The approach used here attempts to explore the theoretical position of Complex Adaptive Systems (CAS) only as an alternative approach and figure 1 below outlines the "Ten Generic Principles and Characteristics of Complexity" [1].

The attributes contained on the right hand-side of figure 1 are the ten principles of CAS [1]. These principles will form part the theoretical framework that could help explore how they might manifest within supply chains? The attributes on the left of the figure illustrate the 'origins of CAS', which position CAS ontological within a phenomenological methodology for this study. Epistemologically, knowledge would be socially constructed. The origins of CAS therefore emerge from parts of the natural sciences through for example "autopoiesis or self generation", [2, 3, 4] and also, within the social sciences, such as anthropology, most especially social anthropology, i.e. the study of humanity, sociology as well as economics.

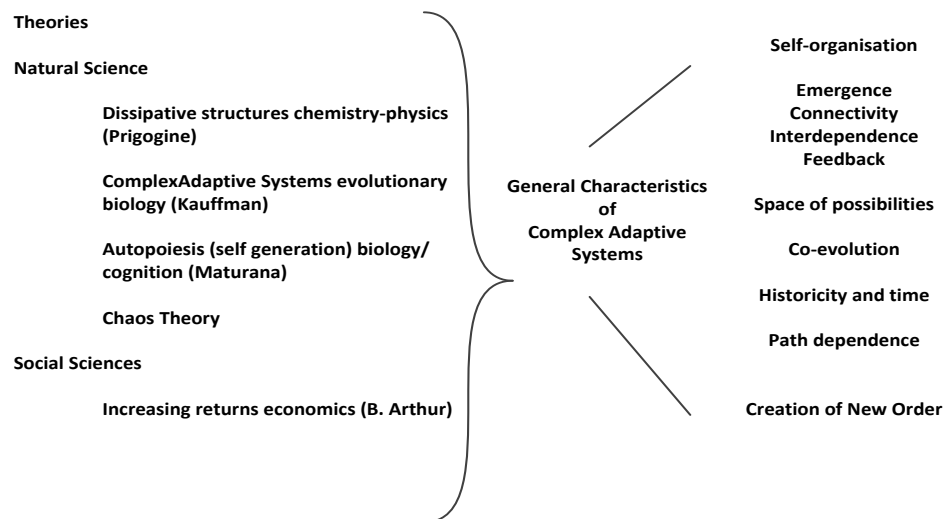


Figure 1 – The Ten Generic Principles of Complexity [1]

Defining CAS is important as it will emphasise how the terms “chaos” “complex” or “complexity” appears to be traditionally referred to within a supply chain context and how this meaning will be different within a CAS perspective.

Defining CAS

Referring to some key supply chain commentators, for example, Forrester [5], Wilding [6], Harland and Lamming [7], Macbeth [8], Sahay [9], Childerhouse and Towill [10], Christopher and Lee [11], and Peck [12] who all at times use terms associated with chaos and complexity in their work around the supply chain.

Sometimes CAS issues can be submerged within these dynamics, such as within demand magnification, risk, trust, supply networks, robustness, resilience and vulnerability, etc. However, interpretation could infer that usually “chaos and complexity” in this context can mean ‘difficult or complicated supply chain networks to manage’. Although there is some overlap, e.g. in Wilding [6] and Childerhouse and Towill [10], in that perspective, CAS might exist only in part. Overall these definitions seem to contrast with the principles of CAS, where the latter intends the use of chaos as an entropic state, from which complexity or new order emerges through adaption from an individual’s behaviour or agency within that system. This perspective therefore views a system such as a supply chain, predominately as “a human activity system” [13, 1, 14, 15, 16].

Initial ethnographic observations in the Defence and Aerospace sector, have indicated that within the traditional supply chain terminologies used by most professional managers, bodies governments and other key supply chain stakeholders, they all typically attempt to rationalise these dynamics, ‘dampening

them' through the use of control systems such as, governance structures (e.g. rules and regulations); EU procurement law and other legislation, e.g. Competition law, professional codes of conduct and ethical frameworks which just tend to develop into performance and control measures.

CAS acknowledges these regulatory frameworks as "bounded systems and structures", i.e. as boundaries but not as objectives [4, 1], to facilitate empowerment for the adaption and new order far from the original equilibrium state. The natural and social sciences refer to this as "autopoiesis or self-generated systems" [3]. In the current supply lexicon, Gattorna [17] for example might infer this notion as "living supply chains" and also, "dynamic supply chain alignment".

The more traditional and dominant discourse of supply chain management as a system is usually depicted within works such as Lysons and Farrington [18], Bailey et al. [19], Harrison and Van Hoek [20] more as a rational economic and linear system which is typically classically and scientifically managed.

It is contended by CAS thinkers, most notably Stacey, Griffin and Shaw [21], Stacey, [14]; Forsenca [22], Mitleton-Kelly [1]; Pascale et al. [15] and Cilliers [16], that the view of 'hegemonic universalisation of interests', is where the role of the professional supply chain manager, attempts to gain control, certainty, and complete information within that system. It is thought that this could constrain human activity and become counter-intuitive, preventing supply chains from adapting, co-evolving and emerging new order. Consequently this can potentially inhibit the emergence of optimal levels of democratic leadership, shared value, trust, innovation and creativity for the continual sustainable development within such systems.

However, some such as Forrester [5] and Childerhouse and Towill [10] contend that uncertainty derived from chaos is inherent in all supply chains and cannot be eliminated, only reduced and minimised from understanding the dynamic itself.

McGuffog [23] and then later Foster [24] further argued this point and suggested that there is some frustration where managers attempt to gain control of some supply chain dynamics, such as magnification and uncertainty through the use of Information Communication Technology (ICT). Motwani et al. [25] appeared to link this point back to Checkland [26] and propose that in reality, all organisations and supply chains are human systems anyway. Consequently because of this, it would be difficult to control everything through technology, as there will always be some elements within the supply chain that can never be controlled.

The implications of managerialism involving the notion of power and control over humans and its systems, is a quest for a continual equilibrium within that system and this might indicate some adversity towards change? This view would be opposite to how complex adaptive supply chain environments would behave in such situations.

CAS supply chains would thrive on a dynamic, chaotic and transitory state. Indeed, the 'search for equilibrium' smacks with the essence of CAS which strives for a new order 'far from the original equilibrium state' [1, 15]. CAS therefore views the search for original equilibrium as the potential 'death of the system' [15] and in that context, this could possibly mean the 'death of a particular (unfit) supply chain', if power and control are exerted excessively over the need to adapt and emerge new order within that chain?

These points are illustrated diagrammatically in figure 2 below, which suggest that through the 'hegemonic universalisation of interests' operating in traditional supply chains, will eventually reach a point of 'diminishing returns' [27] where a value threshold is achieved. It is this approach that appears to dominate the search for equilibrium and control currently in supply chains.

This paper will suggest that the gap created by the application of traditional supply chain management, can only be filled through a CAS supply chain approach, in which the chain acts more effectively and efficiently if enabled as a human active system. Such systems need to be empowered to search for and emerge optimal levels of democratic leadership, shared value, trust, innovation and creativity for the continual sustainable development of such systems, thus creating continuous new order and moving those systems 'far from the original equilibrium' state.

CAS therefore can potentially develop much 'fitter and sustainable supply chain landscapes' [4].

Figure 2 attempts to outline this idea as part of the potential originality, value and contribution of this study as it develops: -

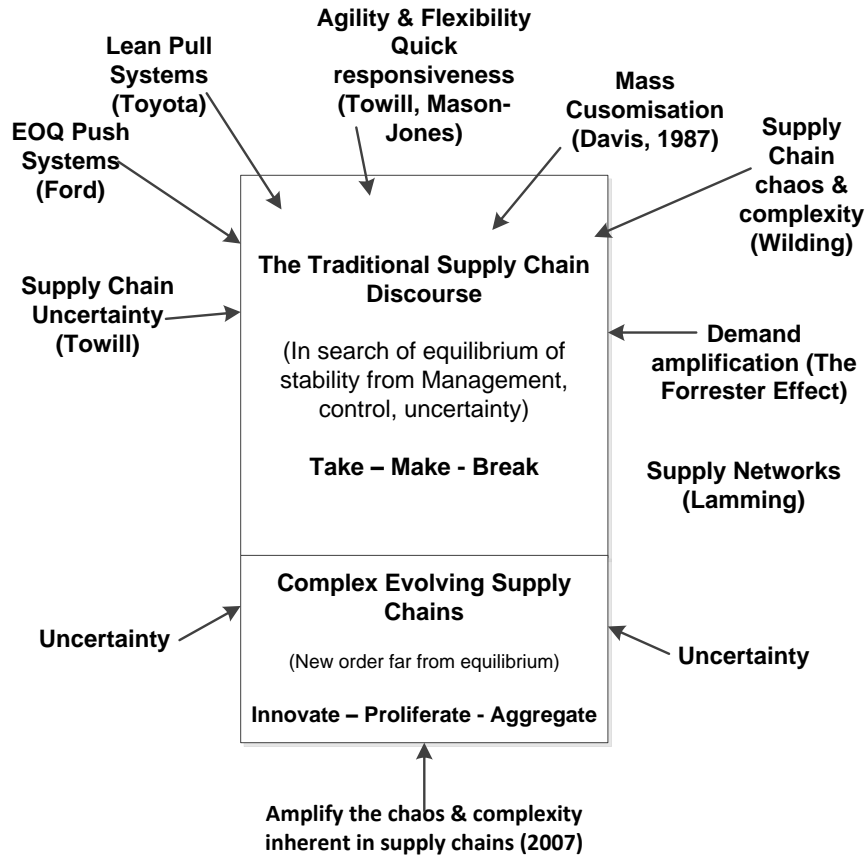


Figure 2 – How a traditional supply chain approach attempts to dominate the search for equilibrium and control

A theoretical position for CAS

The need to reflect critically upon the customarily innate economic principles of supply chain management where supply and demand is attempted to be controlled through the traditional dominant discourses of classical management [28] i.e. to plan and organise, command, co-ordinate and control the system and in addition, the verification element of Fayol's [28] work evolved within the thinking of Taylor [29], through the emergence of measurement within the scientific management era. In the latter the assumptions are that systems and process must be measured and controlled through 'science' and that managers can scientifically select each worker for a job or role in that process and, then match the science' of the job with the 'scientifically selected worker'. Moreover, according to that, management and workers must or will co-operate?

Consequently the exponent's of classical and scientific management [29, 28] and even within bureaucratic supply chain systems through the ideas of sociologist's such as Weber [30] have since always been principally concerned with linear and mechanistic systems and structures for organisations. Hence, supply chain management has constantly been presented in the academic arena by the likes of Lysons and Farrington [18], Harrison and Van Hoek [20] and Bailey et al. [19] as a rational-economic and linear system.

It is these deep-seated principles that arguably still prevail in the paradigms and practices of many supply chain managers in the 21 Century and also still within the majority of academic principles and concepts of supply chain management too.

These will be key assumptions that will have to be challenged through CAS insights within Defence and Aerospace supply chains as this study progresses [31, 15, 1, 14, 16]. Most especially to gain a real understanding of how deep and strong these mind sets are 'culturally rooted' within the 'DNA' of a UK and European Defence and Aerospace organisation and also within the supply chain profession there? This indeed will be the 'reality test' for the CAS assumptions offered in this paper and for the rest of this PhD study.

Within these key assumptions, people need to be motivated as agents in human active supply chains through a diversity of perceptions towards delivering, democratic leadership, shared value, trust, innovation and creativity for the continual sustainable development of such systems, adopting a far more sociological and psychological style for supply chain managers to consider. The belief that the well-established assumptions could co-exist alongside CAS in supply chain management, perhaps helps to underpin the contention that this study could be socially and inductively constructed as an interpretive study.

Within the 'older and traditional currency' of management thinking, CAS is probably nearer to human relations and psychological approaches of management, originated through Elton Mayo's work (i.e. in his Hawthorne Studies, 1927–1932), which places people as the focus of any system or organisation. These principles could also be used to underpin a similar approach to the system that we know as a supply chain. By adopting such a premise here, the origins for perceiving the supply chain as always operating as a 'human active system' and therefore, always in a state of "autopoiesis or self-generation", must be considered.

In any supply chain ecosystem, exogenous co-evolution can become endogenous co-evolution, if the supply chain is being viewed as a holistic process, for example such as in the works of Forrester [5], Wilding [6], Harland et al. [7], Macbeth [8], Childerhouse and Towill [10]. Within such a CAS holistic notion according to Lewin [32] there is no real external entity and this is where perhaps 'fuzzy boundaries', where uncertainty and other inherent supply chain dynamics exist [5, 6, 10].

If these dynamics are predominant, supply chains could be viewed as one quasi-entity behavioural system thriving upon co-operation, collaboration and integrative relationships? However, within the boundaries between these organisations there

is still the potential to compete and operate as separate organisations or entities, but the boundaries can become 'fuzzy' because of this [32]. Through co-evolutionary interaction in partnering type relationships, which may support inter-connectivity or interdependence, these traits might help indicate that CAS is 'naturally alive' in these supply chains [33]. Although CAS may arguably be omnipresent, perhaps this type of phenomena is not always realised by the key supply chain practitioners and their agents through an application of a traditional supply chain lens?

CAS views connectivity and interdependence through biological ecosystems and similarly within a supply chain system, with an "extended web structure" [34]. Mitleton-Kelly [1] proposed that "*.....in human ecosystems the same is true.....[and that] there are networks of relationships with different degrees of connectedness*" [and that the] "*greater interdependence between related systems or entities as the wider ripples of perturbation*", as arguably we might find in any supply chain?

So, in order to view supply chains methodologically through the lens of CAS, the notion of a socially constructed supply chain network would need to exist. In this context the focus will be upon how social groupings connect to perceive and create the 'right environment' in which their CAS supply chains could operate [35]. For example, forms of social capital, language and symbolic power. In addition and because of the social influences in human active systems, there will be a need to revisit qualitatively the "system dynamics" inherent in supply chains, beginning with Forrester [5] and how human behaviour through poor levels of transparency, adapt their behaviour and strategies when faced with this type of uncertainty.

The origins of such dynamics are arguably all 'man-made', through the diversity in human behaviour applied throughout the supply chain, e.g. supply chain magnification. This behaviour would become the basis to illustrate how other supply-side dynamics and their instigators, such as uncertainty [10], deterministic chaos [6], etc, would be better served through the application of CAS supply chain management.

So, if one supply chain dynamic is inherent, then arguably so are all the others too in various combinations? Figure 3 below attempts to illustrate this phenomenon: -

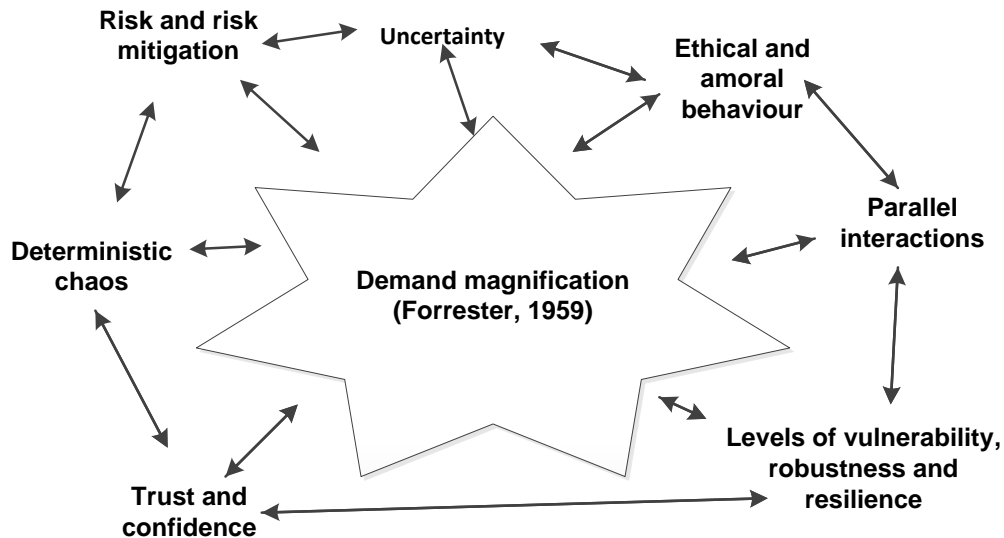


Figure 3 – Illustrating the diversity of the supply chain dynamics and the links between them

The causality suggested above could emerge adaption and new order far from equilibrium. These effects will be investigated further through the application of the CAS characteristics in Defence and Aerospace supply chains to understand the key underpinning attributes that create the optimum levels of emergence, adaption and new order in those supply chains.

CAS appears to indicate [4] that for the most effective systems or supply chains, they need to be 'enabling and self-generating chains, adapting fitness landscapes'. A supply chain 'fitness landscape', again Kauffman [4] would possess values that are inherently shared, because the supply chain is allowed to act as a natural human system. In such landscapes, leadership (and not management) is natural, as is the cultivation and fostering of creativity and innovation through an ability to take risks through continuous problem solving, to aid sustainability. However this is only possible if the culture or DNA of that organisation / chain is aligned to CAS principles in this way.

CAS appears to be more suited to the 'softer aspects' of systems methodology [26] i.e. through human relations, social and psychological perspectives. This also links to human perceptions and motivation, group relationships and leadership / management styles, contingency theory, all of which are embedded in the key seminal works of e.g. Likert [36] McGregor [37], Maslow [38], Handy [39], Mannion [40], Lam and Lambermont-Ford [41], Arnold and Loughlin [42], Russ [43]. To conclude this section, figure 4 below attempts to illustrate in overview how

one could present the theoretical position of CAS as a human active approach as shown on the right hand side of figure 4 below: -

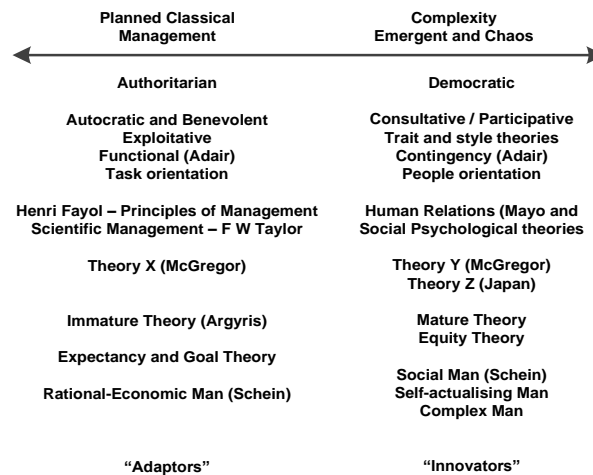


Figure 4 – A theoretical position for CAS supply chains

In this form, supply chains could be regarded as “*living systems*” and most crucial is the need for “*supply chain alignment*” [33, 17]. The notion of CAS in supply chains, potentially provides contributions to organisations and professional managers who are responsible for managing systems that are consistently chaotic and complex in nature and there must be a need to explore degrees of human active behaviour, such as, vulnerability, robustness and resilience [12, 44, 45] within the of their supply landscapes.

In addition, the “exploration of the space of possibilities” [1] within the supply chain enables potential adaption to influence and amplify new supply chain flows through innovation and to generate a variety of new order or as Kauffman [46] put it, “the exaptation and emergence”, where exaptation is “*the emergence of a novel function of a new part in a new context*” – i.e. not only a new order for the supply system far from equilibrium but also, far from the traditional thinking.

As stated earlier, supply chains typically tend to be perceived and depicted as linear structures or networks, [20, 18, 19]. However, perhaps in reality and if we are prepared to accept the notion of CAS supply chains [1], which are socially constructed [35], then these types of systems really have no real shape or structure at all? They would really be just entities which continually dissipate [47], once an agent(s) behaviour changes.

Therefore this paper and study will continue to contend that in reality, supply chains are abstract behavioural systems and by viewing the supply chain as a human active system, traditional supply chain management perspectives could be seen as inhibiting this notion. This could be counter-intuitive in the long term, as it

would prevent supply chains continually improving from adaptation, co-evolution and the emergence of new order, through optimal levels of democratic leadership, shared value, trust, innovation and creativity for the continual sustainable development of such systems

Conclusions and the potential originality, value and contribution of the paper

The overriding aim of this paper was *“to illustrate the supply chain as a complex adaptive system”*. The paper also challenged the notion that CAS principles and characteristics applied to supply chain management are an alternative view and approach from the traditional view of supply chain management. It is in the latter role of ‘professional supply chain management’ where control, certainty, and complete information required for management is the dominant or hegemonic approach which inevitably constrains human active systems, such as supply chains.

Through a CAS approach we explored the idea of supply chain leadership and not management. This was first conceived in figure 2 earlier, which outlined that there is a clear nexus between traditional and CAS based supply systems. The future aim of this study is to apply this thinking within a UK AND European Defence and Aerospace organisation heavily entrenched in traditional or classical supply chain practices of control, certainty, and complete information. Then to explore the potential there to move this organisation towards a new transitory state or new order, through the adoption of CAS supply chain methods.

This future study will account for two apparently contrasting viewpoints for supply chain management, which in reality, currently appears to be struggling to operate within the same human system at the organisation. One where the perception of control and clear information is the traditional approach, whilst the other, seemingly thrives when supply chains are in chaotic state’, i.e. when empowered to be complex adaptive.

If we revisit figure 2 again below, which attempts to illustrate a reality that the ‘hegemonic universalisation of interests operating in traditional supply chains, presents a point of ‘diminishing returns’ [27]. At that point, a ‘value’ threshold is achieved and this paper posits that it is that ‘gap’ created by traditional supply chain management, which can only be filled through a CAS supply chain approach.

The Supply Chain as a Complex Evolving System
 Christopher Lee, V Stephens, J Barrett

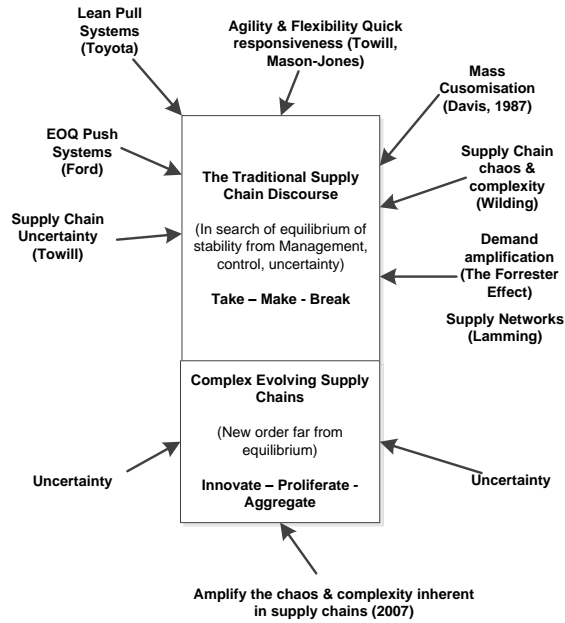


Figure 2 (revisited) – How a traditional supply chain approach achieves a point of ‘diminishing returns’ for supply chain management

Figure 5 below, offers the idea that in many cases, that elements of the supply chain perhaps already operates as a complex adaptive systems”, where certain behaviours and actions by people as agents in that system cannot be controlled and that certain information will never be complete.

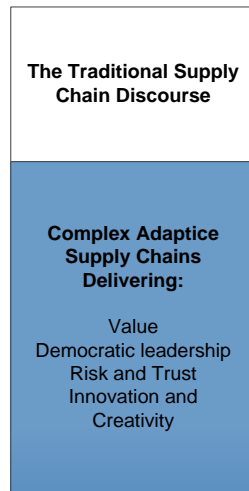


Figure 5 – The potential originality / value of CAS Supply Chain Management

If we compare figure 5 and figure 2, figure 2 now inverts and promotes the position of CAS over traditional supply chain management, where the key potential outputs of a CAS supply chain are predominant and prevail as the key values when applied to supply chains. In this case, the key changes are that it is leadership and not management that prevail. This in turn fosters an empowering culture and environment of shared value, which is the foundation for innovation and creativity from agents acting in that human supply chain. This becomes the basis for continuous sustainable development through agency problem solving.

Consequently, figure 5 and its CAS attributes applied to supply chain management attempts to 'bridge the gap' (i.e. the contribution of the paper), at the 'point of diminishing returns' / 'value threshold', as outlined around figure 2 earlier, which is the point where traditional supply chain management cannot perhaps entirely fill?

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