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Supply chains and their management: Application of general systems theory

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Abstract

This theoretical paper discusses the application of general systems theory to supply chains and the management of supply chains. Applying general systems theory to supply chains and their management allows them to be abstracted from their real world complexity. The abstraction process uses the view of general systems theory developed by Yourdon E. [1989. Modern Structured Analysis, Yourdon Press, Prentice-Hall International, Englewood Cliffs, NJ] in his seminal work on the fundamental characteristics of information systems. In particular, Yourdon's (1989) four general systems theory based principles for information systems are applied to supply chains and their management. Through a theoretical discussion informed by relevant research literature it is considered that a more fundamental view of supply chains has been developed. That is, the application of the four general systems theory principles developed to supply chains is supported and this application provides deeper insights into how supply chains operate. This in turn should allow better supply chain management processes to be developed.

Keywords: Supply chains; Supply chain management; General systems theory; Retailing

1. Introduction

This paper is concerned with a theoretical (rather than a practical) discussion of supply chains; that is, its purpose is to discuss supply chains as abstractions rather than consider these inter-organizational artefacts as they operate within the real world. The abstraction is performed through the use of general systems theory, in particular that view of general systems theory developed and applied by Yourdon (1989) to the field of information systems. Abstraction should allow real world complexity to be removed and so reveal the more fundamental aspects of supply chains. A benefit of developing this more fundamental view of supply chains should be greater insight into how supply chains operate and how their management can be improved. For example, using Yourdon's (1989) third principle of structured decomposition the basic building blocks or components of supply chains can be revealed. The general systems theory concept of a system boundary can then be used to better understand how these supply chain components interact. Given greater understanding of the supply chain concept it is hoped that greater agreement emerges about what constitutes a supply chain, and that with this a more consistent approach to supply chain management also develops.

The paper reviews the history of general systems theory noting the significant contributions made by von Bertalanffy (1969) and Weinberg (1975). The work of Miller (1978) and his application of general systems theory in the field of biology was a source of inspiration for Yourdon (1989) in his application of general systems theory to the field of information systems. The work of Yourdon (1989) is seen by the authors as truly innovative in the sense that he applied general systems theory to intangible objects and concepts as compared to earlier researchers such as von Bertalanffy (1969), Weinberg (1975) and Miller (1978) who applied general systems theory to tangible objects. Supply chains are considered to have similarities to information systems: for example, they are more intangible than tangible, they have defined and repeatable operating procedures, and they exist in order to

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assist the commercial objective of a business—the exchange goods or services. Given these similarities it was felt that the work of Yourdon (1989) would have applicability. Accordingly, the major aim of this paper is to apply Yourdon's (1989) four general systems principles of information systems to supply chains. These four principles are:

Principle 1: The more specialised or complex a system, the less adaptable it is to a changing environment.

Principle 2: The larger the system, the more resources are required to support it, with the increase being non-linear rather than linear.

Principle 3: Systems often contain other systems or are themselves components of larger systems.

Principle 4: Systems grow over time, both in terms of size as well as structural complexity.

Not only do these principles have applicability for information systems, but it is posited by the authors that they also have applicability to supply chains. It is considered that the analysis and discussion presented in this paper has benefits for both academics and practitioners. For academics, greater insight should lead to a more informed and consistent discussion of the supply chain concept. For practitioners greater insight should lead to better supply chain management practice, at the operational level—in the sense of more effective and efficient supply chains—as well as at the strategic level—in the sense of more flexible and adaptable supply chains.

2. Retailing, supply chains and their management

'Supply chains' and their management, typically referred to as 'supply chain management', are terms that emerged during the late 1980s (Harland, 1996) and have been popular terms used widely in textbooks, professional magazines, academic journals, courses of study and individual subject offerings (Chopra and Meindl, 2004; Christopher, 2005; Lysons and Farrington, 2006; Simchi-Levi et al., 2000). This practical and practitioner-based background has meant little conceptual work has been undertaken. For example, in many research studies there is a presumption that the terms 'supply chain' and 'supply chain management' are well defined and clearly understood by all (Hull, 2002; Moon, 2004). However, from a conceptual perspective this presumption should be tested. Handfield and Nichols (1999, p. 21) state that the supplier network consists of 'all organisations that provide inputs, either directly or indirectly, to the focal firm'. That is, the 'supply chain' may not be a chain, in which the links are considered to join peer companies, but rather a 'supply wheel' in which a number of subservient companies supply a dominant master (Avery, 1999). There are some obvious examples of supply wheels. A number of authors refer to the relationships between General Motors and its suppliers as an example of a supply wheel (Keen, 1991; Schwartz, 2000; La Londe, 2005). In addition, Keen (1991) made an interesting observation: does a supply wheel identify a single 'organization' made up of the master plus the participants, rather than a group of separate but collaborating organizations? This issue is further discussed later in terms of the general systems concept of a boundary and the types of interactions that occur across boundaries.

Other supply chain topologies exist. Christopher (2005) and Kemppainen and Vepsäläinen, (2003) argue for 'supply networks' in which there is still a dominant or focal firm, but the linkages between suppliers and customers with the dominant firm are not necessarily direct. Well-known examples of a network supply chain topology are StorebrandXchange.com (Beldona and Raisinghani, 2004) and Covisint (Kandampully, 2003; Johnson and Johnson, 2005). Covisint represents an evolution of supply chain topology: it has evolved from a supply wheel—originally a supply chain e-marketplace for the motor vehicle manufacturers General Motors, Ford and DaimlerChrysler—into a supply chain network that now services the healthcare industry as well as other motor vehicle manufacturers in addition to the three mentioned above (Covisint, 2006). Accordingly, the literature discussed above indicates that a number of different supply chain topologies exist, which means that the presumption of one generic topology is not correct.

Furthermore, not only does diversity exist in supply chain models, the literature review conducted indicates that several definitions exist for 'supply chain' and 'supply chain management', none of which could be considered dominant or generic. In most cases, these definitions are derived from a particular sub-group or category of supply chains rather than referencing or including all categories of supply chains. Alternatively the definition is asserted as an already accepted and generic definition of what is a 'supply chain' (Chan et al., 2003; Duclos et al., 2003; Kemppainen and Vepsäläinen, 2003; Lummus and Vokurka, 1999; Motwani et al., 2000; Stonebraker and Afifi, 2004; Svensson, 2000; Vickery et al., 1999). Flowing from these different definitions are argument, interpretations and conclusions that are divergent rather than convergent, and more importantly self-justifying by recursively indicating that support of the conclusion flows from the definitions asserted at the beginning of the discussion. The outcome of this is that comparisons of research findings are difficult and that any assertions about the general validity of the findings are difficult to support.

Finally, with respect to supply chain components the research literature again shows diversity rather than a common view on what are the most important or critical components of the supply chain. Assertions are made about the important or critical components but these assertions are rarely tested. For instance, Mouritus and Evers (1995) discuss the stages characterising flows of goods between a supplier and a customer. Each stage has different facilities which perform different activities, such as the need for intensive communication for their mutual co-ordination. The implication is that the most important component of a supply chain is the human interaction that occurs. On the other hand, Stevenson (1999) defines a 'supply chain' as a sequence of suppliers, warehouses, operations, and retail outlets. Stevenson (1999) goes on to differentiate between two classes of supply chains, one relating to goods (involving for example, manufacturing firms) and the other to services (involving for example, banks or other service providers), presumably because their core operational characteristics are different. The implication is that the most important component of the supply chain is the supply chain's structure or topology.

A common, agreed upon view about supply chain management is also lacking. For example, in discussing this activity, Gattorna and Walters (1996) observe that in a short period of time, 'physical distribution management' became 'logistics management', and then 'supply chain management'. For Gattorna and Walters (1996), this evolution reflected the increasing strategic importance of this activity. On the other hand, Handfield and Nichols (1999) claim that a 'logistics renaissance' era has arrived, in which new and emerging information technologies are used to meet the challenges of globalising markets with increasing domestic and international competitiveness. Handfield and Nichols (1999) also claim that supply chain management includes managing information systems involved in sourcing and procurement, production, scheduling, order processing, inventory management, warehousing, distribution, and customer service. This implies that an important characteristic of supply chain management is the technological infrastructure that facilitates the information flows (Childerhouse et al., 2003; Dawson, 2002; Ho et al., 2003; Zeng and Pathak, 2003; Kim et al., 2005).

As demonstrated through the discussion above, the concepts 'supply chain' and 'supply chain management' have a variety of different meanings. This differentiation is a reflection of the fact that these terms emerged from the world of commerce and that most research conducted to date has been applied rather than theoretical (Harland, 1995; Li et al., 2002; Stonebraker and Afifi, 2004). There has not been an attempt to find a common thread through the research findings and arguments. In most cases research findings and conclusions are important only within the context of their study and their ability to be generalized is limited. Although there have been attempts to define conceptual frameworks for supply chains most of these frameworks are specific rather than general in scope (Chan et al., 2003; Svensson, 2000; Prater, 2005). Therefore, can further research into supply chains and supply chain management benefit by an abstraction from the real world to identify more fundamental and presumably more generic, features of supply chains and activities of supply chain management? The answer to this question forms the central focus of the discussion outlined in the rest of this paper. The method of abstraction to be adopted is the application of general systems theory.

An argument could be put forward that variety and diversity reflect the fact that supply chains and supply chain management are emergent fields of knowledge. Given this fact it is premature to abstract to more fundamental concepts. The counter claim to this argument is that it has been done with respect to the information systems field of knowledge which is also an emergent field of knowledge. Yourdon (1989) adapted and applied the work of Miller (1978), who had earlier applied general systems theory to the field of biology to derive characteristics that could be used to distinguish between living and non-living systems. Yourdon's (1989) efforts did indeed show that there were benefits in undertaking this work. For example the process of abstraction allowed Yourdon (1989) to define abstract concepts such as the boundary of an information system; that is, the things the information system would do and more importantly what it would not do. Another insight was the development of the concept of structured decomposition—breaking a complex information system down into simpler components or sub-systems. That is, the process of abstracting information systems from their real world context led to new and deeper insights into how information systems operated and new techniques to use to build better information systems. In a similar vein it is proposed to take the work of Yourdon (1989) and apply it to another intangible system, namely supply chains to see if there are benefits from doing this in terms of a better understanding or insight into how supply chains work and how they can be better managed.

3. What is general systems theory?

General systems theory has a reasonably long history with major initial contributions by Boulding (1956), Forrester (1958, 1961, 1975), and von Bertalanffy (1969). Von Bertalanffy (1969) is recognized generally as the principal thinker in this area (Mulej et al., 2004). Other contributions to general systems theory have been made by Klir (1969, 1972), Weinberg (1975), Miller (1978), and Yourdon (1989). As indicated above it is Yourdon's (1989) work that forms the focus for this paper. In addition, contributions to the related areas of flexible system thinking, physical system theory, and the tools of systems thinking, have been made by Senge (1990), Senge (1992), Fowler (1999), Lin (1999), Skyttner (2001), Sushil (2002), and Liu (2003). Sushil (2002) considers that although there are differences between physical (or tangible) systems, and 'conceptual physical' (or intangible) systems, these two categories also have things in common. For example both categories can be disaggregated into smaller yet discrete components. This statement can be directly related to the general systems concept of decomposition: systems are constructed of sub-systems which are themselves constructed of sub-systems. As these discrete components are themselves sub-systems there is also the issue of the interactions between these discrete components. This interaction between system components is related to the general systems concept of a system's boundary. A boundary is necessary in order for systems to be able to interact with one another. Sushil (2002) also raises the question of whether supply chains are primarily tangible systems, mere dealing with the physical flow of goods; or are supply chains primarily intangible in nature, dealing with the flow of information or services (Johnson et al., 1995), or constructed out of a set of relationships between two or more organizations (Cousins and Robey, 2005; Daniel et al., 2004; Murtaza et al., 2004). Rather than attempting to classify supply chains as either tangible or intangible a better approach may be to use the concept of decomposition and so consider supply chains as a collection of sub-systems, most of which are intangible, e.g. systems that allow the transfer of information from one organization to the other, while others are tangible, e.g. delivery systems that allow the transfer of goods from one organization to the other.

4. Are supply chains systems?

To define the nature of supply chains, Skyttner (1996) outlines the work of a number of leading general systems theorists and their views on what would constitute a system. Furthermore, Skyttner (1996) makes interesting comments on what a system is: it is not normally something that is 'presented to the observer' (Skyttner, 1996, p. 16), but rather something that is recognized by that observer. Thus systems do not 'exist in the real world independent of the human mind' (Skyttner, 1996, p. 16). Skyttner (1996) also discusses various other definitions of a system as being anything unitary enough to deserve a name (Weiss, 1971), anything that is not chaos (Boulding, 1985), and a structure with organized components (Churchman, 1979). The common themes emerging from these definitions is that a system is composed of finite elements or components; the components combine to form an integrated whole; and the integrated whole exists in order to achieve some purpose.

Accordingly, in order for supply chains to be considered systems the above-mentioned themes should be present. Supply chains are composed of components: people, organisations, technological infrastructure, information flows, flows of physical goods, and flows of intangible services. From the perspective of purpose, supply chains are created for the benefit of the participants in terms of improving the flow of goods, services and information from one organisation to another. This argument indicates that supply chains are systems.

Ackoff (1981) states an important element of a system is its dynamic nature, with interactions of sub-systems across their boundaries: see also Klir (1991) and Backlund (2000). Ackoff's (1981) analysis of system dynamics led to three important conclusions: (a) systems interact and are influenced by their environment and by other systems; (b) the operation of each system component has an effect on the way the system operates as a whole; and (c) the operation of each system component is interdependent (also see Carbone (1999); Forrester (1961); and Lin and Cheng (1998)). Are Ackoff's (1981) conclusions applicable to a conceptual view of supply chains?

As part of an overall review of the supply chain literature, Caddy and Helou (1999) concluded that there was no generally accepted model of a supply chain. However, their findings outlined three common themes or constructs within existing supply chain models: (a) a focus on organization structure and/or organization strategy; (b) people and people-related issues such as interpersonal relationships and the roles of these relationships within supply chains (see also Talaq and Ahmed (2004)); and (c) use of information and communication technology within supply chains. Using these three basic themes, Caddy and Helou (1999) developed the Generic Supply Chain Model (GSCM) (see Fig. 1).

Ackoff's (1981) conclusions about what is a system are reflected in this model. For instance with respect to the third conclusion, the three supply chain components shown in Fig. 1 above are important in their own right, but each by itself does not provide a complete and comprehensive view of what a supply chain is and how best to manage it. Each component provides a separate as well as a related conjoint contribution which is Ackoff's (1981) second conclusion. Again these are arguments supporting the contention that supply chains are systems.

The model shown above, through the interactions of the components indicated by the arrows in the model, also supports the conclusion made by Ackoff (1981) and others that systems are dynamic. Burkhardt and Brass (1990), like Germain and Droge (1998) claim that organisational structure is influenced by technological change. Specifically, these researchers assert that a change in technology is, or should be, followed by a change in structure. That is, a change of the level or type of technology used in the supply chain will have an impact on the way both organisations and their employees interact with the supply chain. Caddy and Helou (1999) considered that the type

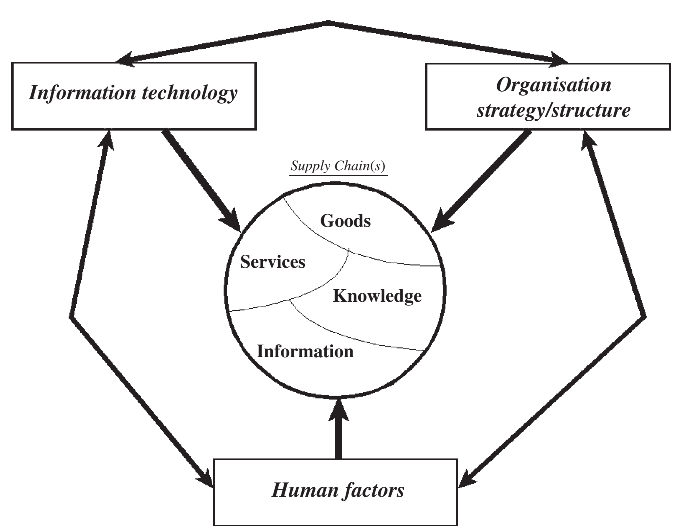

Fig. 1. Generic Supply Chain Model. *Source*: Caddy and Helou, 1999. Supply chain and supply chain management: towards a theoretical foundation. Presentation at the second international conference on managing enterprises, 18 November.

and level of interaction would be contingent upon factors such as organisational culture, the environment in which the organisation operates, the types of personnel that interface with the supply chain, and the frequency and types of exchanges that occur among the organisations using the supply chain.

The above discussion indicates that supply chains can indeed be considered as systems. Furthermore, this model also indicates the power of abstraction. For example, as an abstracted or conceptual model, there can be different real world implementations of it in which the importance of each of these components, with respect to the others, can differ. Therefore a single abstracted model can lead to different real world expressions with at least three different categories, namely as information and communication technology dominant supply chains, or human factor (relationships) dominant supply chains or structure/strategy dominant supply chains.

5. Application of general systems theory principles to supply chains

As was mentioned above, Yourdon (1989) utilised Miller's (1978) findings in applying general systems theory to the field of information systems. As a result of his analysis, he developed the following four basic general systems theory principles that could be applied to information systems:

Principle 1: The more specialised or complex a system is the less adaptable it is to changing environments.

Principle 2: The larger the system, the more resources are required to support that system—with the increase being non-linear.

Principle 3: Systems often contain other systems, and may in themselves be components of larger systems.

Principle 4: Systems grow both in size and complexity, with obvious implications for 'Principle 1' and 'Principle 2'.

These principles are considered to have application to the field of supply chains and supply chain management as indicated in the discussion below.

5.1. General systems theory—Principle 1

With respect to this principle, there are two crucial issues that organisations need to consider in terms of their supply chains. First, the longer the supply chain, in terms of the number of levels, or indirect suppliers as compared to direct or immediate suppliers to the firm (Copacino, 1997; Foster, 1999; Parker, 1999), the less adaptable or less 'agile' the supply chain will be to change (Rigby et al., 2000). Second, even within short supply chains, the more specialised each supplier is with respect to the product or service supplied, the less adaptable or less 'agile' the supply chain will be to change. From a first principles point of view, the larger the number of participants, the more difficult it will be to gain agreement on change. Furthermore, increasing the number of participants would also increase, by higher orders of magnitude, the number of interactions between these participants. This would also lead to higher degrees of difficulty in successfully implementing a change in the supply chain. Montuori (2000) suggests that less agile supply chains also have less chance of being long lived supply chains. From a practitioner perspective this general systems principle indicates that organisations should endeavour to build the shortest supply chains possible as these are likely to be more adaptable and more robust.

As supply chains have evolved from simple dyad relationships into quite complex networks (Stonebraker and Afifi, 2004), the greater the number of material flow, service-flow and information feedback loops. Long supply chains qualify as complex dynamic systems which are subject to potential problems of time delays, discontinuities, non-linearities (Fowler, 1999), and therefore would have difficulties in adapting to rapidly changing environments. Further support for this principle comes from Lai et al. (2001) in their discussion of the increasing complexity of Chinese service organizations and the increasing level of chaos as regards the operations of such service organisations.

Funk (1995) found that greater complexity in the logistics process requires more coordinating processes. Germain and Droge (1998) conducted a study that compared practices between buying organizations using just-in-time (JIT) procedures with those that did not. They found that JIT organizations had to impose far greater formality on their process than did non-JIT organisations. They also found that the JIT procedures required a higher level of integration with other business processes in the organisations. If there is a greater degree of integration and a higher level of formality, then this is considered will lead to a situation in which change, such as meeting new customer demands, compiling with new government regulation, or reacting to new industry entrants, is more difficult to achieve due to Principle 1.

As supply chains move more to the provision of services and knowledge, rather than more physical goods, it is considered that they become more complex. For instance, it is a more difficult task to ensure that the right information or knowledge is passed 'up' or 'down' the supply chain than it is to ensure that the right goods have been exchanged. Funk (1995), Mughal and Osborne (1995), and Simatupang and Sridharan (2002) all report that increased logistics complexity is associated with poor performance. Further, both lead-time compression (Mason-Jones and Towill, 1999) and the requirement for flexibility create a mismatch between supply and demand (Simatupang and Sridharan, 2002). Thus, the literature suggests that, as supply chains evolve, greater differentiation, and, accordingly, higher specialisation of these supply chains may occur in technology, products, processes, and markets. As such, the more complex and specialised the supply chain becomes, the less adaptable it will be to changing environmental forces.

Finally, a supply chain is only as strong as its weakest link. Neuman and Samuels (1996), as reported in Stonebraker and Afifi (2004), claimed that there were mismatches between expectations of improvement by executives due to supply chain integration, and actual supply chain performance. Malperformance issues included overstocking or hoarding, blockages in material or service flow due to relationship issues with staff involved in supply chain processes, an unwillingness to change existing practices, and the knowing provision of misinformation.

5.2. General systems theory—Principle 2

Principle 2 leads to an important issue with respect to managing an organisation's supply chains. That is, organisations should determine the level of activity of each of their supply chains, and ensure that this activity is appropriately resourced. The level of activity can be determined through key performance indicators such as the number of transactions processed per day, or the number of personal contacts made or the number of e-mails exchanged, etc. Obviously the higher the level of activity, the greater the amount of resources that should be devoted to that supply chain(s). As already indicated above for Principle 2, the increase in resources may not follow a linear scale, given that interaction between events or exchanges may give rise to additional work or things to do.

Principle 2 is also reflected in the way organisations respond to growth of activity in their supply chain(s). For example, supply chains offer the opportunity to outsource functions to other organisations (Chase, 1998; Holmstrom, 1998; Lawrence, 1999; Stundza, 1999). Nevertheless, organisations need to realise that outsourcing does not completely remove the need for the associated management and administrative activities. In fact, as the use of outsourcing grows by the organisation, more resources, often at a higher level compared to that when the function was provided in-house, are needed by the organisation to ensure appropriate management of the outsourced activities. What was initially seen as a benefit may become a burden: there are numerous references within the information systems literature that indicate outsourcing of information systems of information technology may not in the end save costs (Lacity and Willcocks, 1998). The implication here is that a supply chain's size and its consequent demand on resources is not necessarily reduced through the outsourcing of some supply chain activities.

Forrester (1961), Senge (1990) and Fowler (1999) assert that the 'physics' of a system limits its achievements and the possible emergence of stability and control problems may lead to the system's under- or even non-performance. Activities such as benchmarking or adopting other means of performance measurement for longer supply chains may be more difficult than it is for shorter supply chains. Furthermore, once a downstream disturbance initiates, it ripples back through the system with increasing amplitude (Forrester, 1961; Fowler, 1999; Towill, 1996; Wikner et al., 1991). For longer supply chains the amplification will repeat more times leading to a greater degree of disturbance. For example, take the case of a decision made by a third tier supplier to reduce costs by outsourcing the manufacture of a major component to a cheaper and lower quality firm. This may result in the component's failure after the release of the final end product by the focal manufacturing and so generate a huge and expensive recall of all products and possibly the retrofit of a higher quality and more expensive component. Witness the events in 2006 which saw Sony embroiled in an expensive and damaging recall of its batteries fitted to Dell, Hewlett–Packard and many other well-known laptop computers. It is considered that with longer supply chains the chances of the above or some similar scenario occurring increases which would lead to the consumption of more and more resources by the central firm related to issues such as customer recalls.

5.3. General systems theory—Principle 3

Principle 3 indicates that supply chains as systems are not monolithic but rather can be broken down into smaller and simpler sub-systems. Miller (1978) found that living systems can be broken down into a number of smaller sub-systems. Yourdon (1989) applied this principle in the development of structured systems methodology in which the often difficult task of successfully developing an information system (Chae and Lanzara, 2006; Guolielmos, 2003), is broken down into developing and implementing smaller, and more easily understood, components of the information system. Successful completion of each component brings the overall information systems development one step closer to its successful completion.

The same process can be applied to supply chains. For example, the GSCM (Caddy and Helou, 1999) can be broken down into three distinct sub-systems, namely organisational and inter-organisational processes, information technology dependent processes, and human-based processes. Principle 3 also informs that the process of decomposition would not stop here, i.e., each of these sub-systems could be further decomposed into its component sub-systems, and so on. For example, organisational and inter-organisational processes could be decomposed by product group or by location (domestic purchases as against overseas purchases); information technology dependent processes could be decomposed into the different types of information systems that say support the purchasing function or the inventory management function; human-based processes could be decomposed into front-office activities as compared to back-office activities.

More importantly applying Principle 3 forces attention on defining the boundary of the sub-system; that is, determining what the sub-system is supposed to do and what it does not do. Given that a boundary is defined then necessarily, as these sub-systems need to collaborate to achieve the overall objectives of the supply chain, there are interactions between these sub-systems across their boundaries (Lloret-Climent, 2003). Interactions across sub-system boundaries occur through normal operations. Take the case of using a new supplier: once negotiations with the supplier are completed (essentially human-based processes), information about the supplier is recorded in the purchasing database (information technology dependent processes). However, the more critical interactions are those due to changes within a sub-system. For instance, what are the implications to the information technology dependent sub-systems of a supply change due to changes either in the personnel interacting with these information systems, or to changes in organisation structure (such as a merger or a divestiture)? Alternatively, given that new information technology is introduced into supply chain systems, what are the implications, because of this change, to the personnel required or to the way current organisational processes operate? Obviously other combinations of change for these sub-systems could also be considered. Furthermore this analysis is also applicable at lower levels of decomposition when considering sub-sub-systems within these major supply chain components.

Organisations can also use Principle 3 whenever they are attempting to design and implement a new supply chain or when they are introducing modifications (either small or large) to an existing supply chain. In terms of building a new supply chain, Principle 3 provides the basis for a strategy to ensure project success; that is, decompose the supply chain development into smaller and more easily understood sub-systems and then progressively implement these sub-systems. This strategy should ensure more successful developments and hopefully build more flexible and robust supply chains. For modifications of existing supply chains, Principle 3 would indicate that organisations should identify what sub-systems need to be changed and then focus the development effort on these. The changes to these sub-systems would necessarily need to consider the changed interactions with other sub-systems across their boundaries. Finally applying Principle 3 to supply chain modifications should improve the efficiency of the re-development by identifying those sub-systems that do not require any changes to be made.

5.4. *General systems theory—Principle 4*

Yourdon (1989) stated that, even though information systems are artificial constructs, they do in fact grow. Growth of an information system can occur in a number of ways: the number of users interacting with the information system may grow, the amount of data processed by the information system may grow, and the amount of programming or the level of system functionality associated with the information system may also grow. Applying Principle 4 to supply chains, over time it would be expected that as the firm prospers, the amount of goods, services, products, information and knowledge exchanged through the supply chain may grow. It would also be expected that the number of organisations participating in the supply chain may grow, and that the number of personnel and information systems of these organisations interacting with the supply chain may grow. That is, organisations need to be aware that although supply chains, like information systems, are artificial constructs, they are dynamic and can grow. They can evolve over time as they develop through their interaction with the external environment as well as their internal sub-systems. It is worthwhile noting that Principle 4 has implications for both Principle 1 and Principle 2. Organisations should realise that as supply chains grow, there is a greater likelihood that these systems will become more complex, and, therefore, more difficult to change. Furthermore, organisations need to be aware that as supply chains grow over time, they will need to devote more resources to their support rather than less in order to preserve their value to the organization and ensure their on-going contribution to organization success and growth.

6. Summary and conclusions

This research study addresses the question of whether the field of general systems theory could make a contribution towards a greater understanding of supply chains. The work of Yourdon (1989) as influenced by both Miller (1978) and von Bertalanffy (1969) has been seen to provide a basis for applying general systems theory to supply chains and to the management of supply chains. In particular, the application of the principles developed by Yourdon (1989) that were based on general systems theory to supply chains, does lead to a deeper and more informed understanding of supply chains and their management.

For example, the first principle indicates that if organisations are to have 'agile' or 'quick response' supply chains (Erenguc et al., 1999; Perry et al., 1999; Mason-Jones and Towill, 1999), simpler supply chains, in terms of their topology, or type and nature of the product being exchanged, should be preferred to more complex ones. The second principle indicates that organisations need to manage their supply chains on the basis of their activity, devoting more management resources to highly active ones as compared to less active ones. The third principle allows organisations to better understand their supply chains by decomposing these systems into smaller and more easily understood sub-systems. The fourth principle indicates that organisations need to accept the fact that supply chains are dynamic rather than static, and so need to focus the attention of managers at all levels on the types of changes required, and the resource implications that these changes will have on the operation of the supply chain. Regular review and change of management practice will also be necessary in order to maintain supply chain effectiveness.

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