

Abstract code: 008-0483

**A CONTRIBUTION FOR A BETTER UNDERSTANDING OF SUPPLY CHAINS
VULNERABILITY¹**

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POMS 19th Annual Conference

La Jolla, California, U.S.A.

May 9 to May 12, 2008

¹ Work supported by the Fundação para a Ciência e Tecnologia - project PTDC/EME-GIN/68400/2006.

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Abstract

Increased globalization of supply and consumer markets, along with the trend toward outsourcing have contributed to more complex and uncertain supply chains. Other factors have also contributed to increased supply chain complexity and uncertainty, namely customers demand, shorter product life cycles, global economic and competitive forces, and management practices. So, organisations, integrated in a supply chain, are becoming quite vulnerable since they depend on their partners to survive and to be competitive on the market.

A literature review shows that have occurred changes on the environment of organisations: new business philosophies have emerged, and dependencies among organisations and risks involved in supply chain activities have increased.

The main objectives of this paper are to identify and to analyse the causes that have contributed to increase supply chains' vulnerability, and to propose a conceptual framework to understand the main causes of supply chains vulnerability.

Keywords: Supply Chain Vulnerability, Supply Chain Uncertainties, Environment Changes.

1. INTRODUCTION

Traditionally, and in the last two decades, supply chain designs focused on cost efficiency (Nahamias, 2005) rather than effectiveness. Also, supply chains and business practices are designed for a stable world (Monahan *et al*, 2003). However a set of changes have occurred in the environment of firms obliging them to adapt to new realities.

The main changes that firms are facing on its environment are: (i) an increase on customer expectations; (ii) a stronger global competition; (iii) a longer and complex supply chains; (iv) a decrease on products' life-cycle; (v) an increase on outsourcing (vi) a decrease on the number of suppliers. All this changes are creating additional uncertainty to firms and supply chains. Thus, the level of market turbulence has increased bringing with it a reduction in predictability of demand, i.e., increasing the demand volatility.

Most of the business philosophies that have been adopted, such as, Just-In-Time (JIT), Quick Response (QR), Supply Chain Management (SCM), and Lean Supply Chain (LSC), have as objective the cost minimization and appoint to the integration of supply chain entities which could lead to an increase on the dependencies among them.

Generally, the cost minimization is obtained through the reduction of system redundancies, such as, extra inventory (material and time), and low capacity utilization, which can decrease the responsiveness to a disturbance.

The dependencies between organisations integrated in a supply chain may contribute also to become them more vulnerable to a disturbance. Disruptions in supply chain can often be attributed to a failure in one link, by definition, the more complex the Supply Network the more links there are and hence the greater the risk of failure (Sheffi, 2005).

A supply chain with these kinds of constraints, mostly of the times contributes to the following: (i) an increase on demand volatility; (ii) a reduction on redundancies; (iii) an increase on dependencies among supply chain entities; and (iii) a lack of responsiveness to the negative effects of the disturbances that may occur. So, the supply chains are quite vulnerable to these disturbances.

In this context, the main objectives of this paper are to identify and to analyse the causes that have contributed to increase supply chains' vulnerability, and to propose a conceptual framework to understand the main causes of supply chains vulnerability.

The remainder of the paper is organized as follows. In Section 2 and 3, a brief presentation of the two main theories (the Dynamic Capabilities theory and the Network theory) that supports the supply chain studies is made. In Section 4, the more evident trends which characterize the organisations' environment are presented. After, in Section 5, the types of dependencies among organisations in supply chain context are pointed out. In Section 6, we discuss and introduce a definition of supply chain vulnerability, and a literature review about that subject. Then, in Section 7, we try to better understand the main direct and indirect causes of supply chains vulnerability and, for that, a conceptual framework is proposed. Finally in section 8 suggestions for future research are presented.

2. THE DYNAMIC CAPABILITIES THEORY AND THE SUPPLY CHAIN

Research into managing the inter-organisational relationships (where supply chain management is included) has been accompanied by research across a range of academic disciplines making use of its own theoretical lens, such as Dynamic Capabilities Theory and Network Theory.

Teece *et al.* (1997) define dynamic capabilities as ‘the ability to integrate, build, and reconfigure internal and external competencies to address rapidly-changing environments’. That is, the ability of an organisation to achieve new forms of competitive advantage by renewing competences-organisational resources to achieve congruence with the changing business environment (Teece *et al.*, 1997; Eisenhardt and Martin, 2000). This capability is dynamic because the organisation must continually build, adapt, and reconfigure internal and external competences to achieve congruence with the changing business environment.

Dynamic capabilities are not in themselves a source of long-term competitive advantage. They are a mean to achieve resource configurations that provide advantage through resource development and renewal. The development of dynamic capabilities reflects the following management's ability: (i) timely responsiveness and rapid innovation; and (ii) coordination and redeployment of internal and external resources or competencies based on managerial and organisational processes, market positions, and path dependencies (Leonard-Barton, 1992; Teece *et al.*, 1997). Dynamic capabilities create resource configurations that generate value-creating strategies. Their advantage lies in applying them sooner, more astutely, or more fortuitously than rivals (Eisenhardt and Martin, 2000).

In a supply chain vulnerability context the Dynamic Capabilities Theory helps to explain the necessity of organisations enhance their superior abilities in order to adapt quickly to environmental changes, achieve a high degree of resilience and gain/maintain their competitive advantage as an entity of a supply chain.

3. THE NETWORK THEORY IN A SUPPLY CHAIN CONTEXT

In the network approach, the network is seen as a set of interconnected relationships whereby one relationship is dependent upon exchange in another. It involves resources, actors and activities and their interaction (Cook and Emerson, 1978; Håkansson and Snehota, 1995). The network may be depicted on the basis of some interdependencies specifically technological, relational and time (Johanson and Mattsson, 1988).

In the supply chain management (SCM) literature, a supply chain is defined as a network of organisations involved in upstream and downstream flows from sub-supplier to ultimate customer (Christopher, 1998; Mentzer *et al.*, 2001). This means that the supply chain is a very specific type of network, which looks at the connections and dependencies between organisations from raw material to final customer.

Furthermore, integration is seen as an important change process in supply chain networks, which actually means a transformation from loose co-operation to a higher level of internal fit, involving a higher degree of synchronization between the partners. This process makes it possible to act collectively in the supply chain. The integration of a supply chain would involve information sharing, common standards, common culture, coordination of interdependent flows, joint planning, joint mission, joint product development and/or an increase in social contacts (Ludvigsen, 2000). These dependencies between organisations integrated in a supply chain may contribute to increase their degree of vulnerability. Organisations integrated in a supply chain are more exposed to environmental changes since each one depends on their partner ability to react to them.

4. SUPPLY CHAINS MEGA TRENDS

Actually organisations are competing on the business markets not individually but as part of a whole entity named supply chain. A supply chain comprises a network of linked and interdependent organisations, mutually and co-operatively working together to control, manage and improve the flow of material, information, relationships processes activities and integrated systems (Peck, 2006) from suppliers to end users. These linkages, relationships and flows that goes upstream and downstream by the organisations involved in the same supply chain must be coordinated and managed as a way of enhancing the competitiveness and profitability of each organisation (Lambert *et al.* 1998a). Being so, the SCM is receiving increasing attention in literature and practice.

Cooper and Ellram (1993) consider SCM as an integrative philosophy to manage the total flow of a distribution channel from the supplier to the ultimate user. Svensson (2002) considers a SCM as bi-directional dependencies of activities, actors, and resources between the points of consumption and origin in and between channels in the marketplace.

In the last years organisations are facing a lot of changes in their environment which reflect a paradigm shift. Among them we may point out the fact that organisations are more conscious about the necessity of enhance a good relationship with their partners as a way of become more competitive. That is, they must develop a long-term and intensive buyer-supplier relationship which may adopt the form of partnership arrangements (Lambert *et al.*, 1999; Hoyt and Huq, 2000).

Bowersox *et al.* (2000) call attention to other trends that have occurred on organisations' environment which may not only create new business opportunities but also new dependencies between them (Lambert *et al.*, 1998a). These trends reflect a set of changes,

namely: i) the shift from customer service to relationship management; ii) the shift from adversarial relationships to collaborative ones; iii) the shift from forecasting to endcasting; iv) the shift from functional to process integration; v) the shift from vertical to virtual integration, and vi) the need for more information sharing between the supply chain partners. This last trend reports us also to the increase on interdependence between organisations (Dupre and Gruen, 2004) which may result also on the use of some business philosophies such as: Efficient Customer Response, Just-In-Time; Just-In-Sequence, Quick Response (Fernie, 1994), and Supply Chain Management (Haywood and Peck, 2003b).

Many of these trends result not only from the transformation in the geographical scope but also on the mode of operations by organisations. The emphasis is moving from being locally responsive to balancing of multinational operations (Kempainen and Vepsalainen 2003).

4.1 Customer service to relationship management

As regards the change of the focus from customer service to relationships management, many organisations are coming to realize that their real assets lie on, not mainly in their plants and machinery, but in their relationships (Sawhney and Zabin, 2002). Organisations embraced the notion of strategic buyer-supplier relationships as a way of improving efficiency and effectiveness across the value chain and integrate their physical distribution function with supply partners to achieve greater benefits (Anderson *et al.*, 1994). The partners work together to leverage their assets and capabilities toward better integration of the delivery activities to satisfy the ultimate needs of their customers. Such close relationships mean that channel participants share risks and rewards and are oriented for long-term

relationship (Kaufman *et al.*, 2000; Kotabe *et al.* 2003) contributing for superior customer responsiveness (Stalk and Hout, 1990).

Moreover, through a long-term relationship, the supplier will become part of a well-managed chain and will contribute to the competitiveness of the entire chain (Choi and Hartley 1996; Chen *et al.*, 2004). A better relationships management makes possible an improvement on customer service. However to attain this organizations must invest on logistics in order to provide faster deliveries and to reach higher degree of responsiveness since these are key components of customer service for any type of organization (Fawcett *et al.*, 1997; Swafford *et al.*, 2006).

4.2 Adversarial relationships to collaborative relationships

Traditionally, buyer-supplier relationships were considered as adversarial, arm's-length transactions. However, this relationship is moving towards a more collaborative approach. This change is supported by the belief that suppliers are essential sources to gain competitive advantage in world markets in terms of their expertise, knowledge and their ability to share risks (Humphreys *et al.*, 2001).

In recent years, the relationship between buyers and suppliers has received considerable attention. With the globalization of markets combined with a restructuring of many organisations, with a focus towards costs, quality, flexibility and technology, a new importance was gave to collaborative relationships (Herbig and O'Hara, 1995; Goh and Lau, 1999). Briggs (1994) emphasizes the need for organisations to move toward closer cooperation in the buyer-supplier relationship. Market pressures for increased product complexity and variety based on a wide range of technologies and response at higher levels of quality and reliability but declining cost, have demonstrated that few, if any, organisations

can do it all by themselves. Consequently, they need to supplement their core competencies by allying with other providers of complementary competencies to satisfy their customers.

4.3 Forecasting to endcasting

Demand forecast is prepared by extrapolating the past data using a set of techniques and considering that the past pattern of the demand will continue into the future. Nevertheless there is always an error associated with any kind of forecast technique since there are always differences between the actual value and what is forecasted (Chase, 1995). However there are some cases where there are not past data and consequently the forecasting its impossible applying quantitative models. This situation occurs mainly in the presence of new products which have not sales history and also with relatively new products with a short history. Another phenomenon associated with the forecasting is the “bullwhip effect”. Instead of using past data organisations need to be access to the demand level at the last echo of the chain. When this real data don’t goes back upstream the supply chain or this is distorted then the bullwhip effect occurs (Towill *et al.*, 2002). The bullwhip effect is caused by long delays in information flow and product flows, missing or distorted information on current and future customer demand (Arndt, 2006).

To overcome this situation organisations are using the endcasting method. This consists on using the last data reached at the end of the supply chain as inputs to forecasting. Sharing customer demand information across the chain is an important contribution to decrease errors and consequently stock-outs, large and expensive capacity utilisation, lower quality products, and considerable production/transport on-costs as deliveries are ramped up and down at the whim of the supply chain (Ouyang, 2007).

4.4 Functional integration to Process integration

The vision of the SCM that links all the players and activities involved in converting raw-materials into products and delivering them to customer at the right time and at the right place in the most efficient manner reflects the process integration approach. The SCM involves many business processes that must be coordinated upstream and downstream crossing many functions inside and outside organisations' boundaries (Copacino, 1997).

The nature of global competition heightens the need for process integration across organisation boundaries since success often depends on the sum of the value created by an entire association of activities develop among a set of companies. Indeed, competition is no longer company versus company but supply chain versus supply chain (Fawcett and Cooper, 2001).

If we think about some business processes namely customer relationships management, (CRM), production development, order fulfilment or return management (Lambert *et al.*, 1998b) they cross many functions inside organisations and go on organisations boundaries. So, in a supply chain perspective the process integration must be highlighted.

4.5 Vertical integration to Virtual integration

Vertical integration occurs when an organisation produces its own inputs or owns its distribution channel. It is a critical component of corporate strategy, as it is often one of the first diversification strategies that an organisation considers (Harrigan, 1984). Integration is a mean to incite organisational growth, gain scale economies, attain a higher degree of control, stabilize quality or quantity, manage process flows of costly or risky technologies and increase efficiency (Stonebraker and Liao, 2006).

Vertical integration, the precursor of supply chain integration, is a long-held and central precept of management theory. Corporations in numerous environments, including the transportation, energy, and communications industries, have benefited from vertical integration for at least a century. Despite this, executives have questioned the value of vertical integration, largely due to the higher costs and inflexibility associated with it.

Virtual integration is a viable strategy in industries characterized by rapid product innovations and a high degree of competition (Abebe, 2007). Virtual integration enables information technology driven supply chain coordination.

In the network economy and due to the news Information Communication Technologies (ICT), vertical integration has being replaced by virtual integration. The virtual integration is supported by virtual channels which consist of a means of communication using telecommunications information and multimedia technologies (Sousa and Voss, 2006).

4.6 Share of information among supply chain participants

The sharing of information upstream and downstream the supply chain is more than ever crucial. According to Sohn and Lim (2008), the information sharing has a significant impact on supply chain performance, especially in organisations where the product life cycle is short and multiple generations of products coexist. The information sharing increases the performance of each organisation on a supply chain in terms of the order fulfilment process (Olvera, 2008), the inventory management/replenishment (Ouyang, 2007), the alignment of all activities, and a set of performance measures such as quality, delivery reliability, delivery lead times, flexibility, and costs (Schnetzler and Schönsleben, 2007). This contributes, not only to enhance the agility of organisations while improves the stability and performance of

the whole supply chain (Li and Wang, 2007), but also to increase the dependencies between them.

4.7 Other trends

Beyond the previously referred mega trends that are occurring in organisations environment, Dupre and Gruen (2004) call attention also to the impact that some business processes have on the relationships between organisations and supply chains.

Other trends referred by Byrne (2006) are the increasing on sourcing materials, parts, and finished products from low-cost countries and also the emerging of a large consumer class in many of those countries. This result in a confluence of opportunities to organisations because can develop capabilities that combine worldwide (sourcing, manufacturing, and logistics) with the ability to support growth in rapidly expanding markets. These trends reinforce the importance of supply chain strategies attend to new markets and access to new sources of supply.

These transformations are giving rise to a higher dependence between organisations exposing them to the negative effects of the disturbances that may occur. Chong *et al.* (2003) highlight the disturbance on production systems. These authors state that most of production systems fail to sustain productivity when process disturbances occurs, either external (e.g. frequent product changes and demand fluctuations) or internal (e.g. machine breakdown and process variation).

5. DEPENDENCIES BETWEEN ORGANISATIONS IN A SUPPLY CHAIN CONTEXT

There are dependencies between organisations' business activities in supply chains (Lambert *et al.*, 1998a; Håkansson and Snehota, 1995). The term dependence refers to the fact that there is a link, a tie, or a bond between organisations in relation to another (Lambert *et al.*, 1998a; Håkansson and Snehota, 1995).

There are different types of dependencies considered by several authors. Hammarkvist *et al.* (1982) consider the followings: technical, time, coordination, knowledge, social and economical as well as judicial. Svensson (2004) points out other type of dependencies, such as: knowledge, social, economic, juridical, technical, market and information technologies dependencies. In a simplified way, Svensson (2004) defends that the dependencies that exist between organisations may be categorized into three groups, namely i) time dependencies, ii) functional dependencies, and iii) relational dependencies. These categories proposed by Svensson (2004) enclose the ones considered by Hammarkvist *et al.* (1982).

5.1 Time Dependencies

Time dependencies arise from the fact that there is a chronological or sequential dependence between organisations' activities in supply chains. This occurs because organisations have a time-based need or a synchronization need of their mutual business activities (Hammarkvist *et al.*, 1982). This might rise from either the activities *per se*, or from the resources that are available to perform them (Mattsson, 1999). Svensson (2004) and also Lambert *et al.*, (1998a) consider that the time dependence is motivated by the fact that time issues have become increasingly important in recent supply chain network structures and in different industries that emphasize leanness. Time dependencies are observed mainly in the

automotive industry where Just-in-time and Just-in-sequence principles are applied (Sugimore *et al.*, 1977), in the retail industry where the business relationships are inspired by highly time-based and consumer driven logistics flows and also in textile industry in which the ideas of Quick Response (QR), time compression and agility have gained acknowledgement among practitioners (Ferne, 1994).

5.2 Functional Dependencies

Functional dependencies, refer to the fact that organisations' activities in supply chains are specialized and complement each other in channels or networks (Bucklin, 1966). They include technical adaptations and coordination (Svensson, 2004) and might be explained by the division of labour which usually develops and takes place in supply chains (Stern and El-Ansary, 1992; Stigler, 1951) and networks (Lambert *et al.*, 1998a). These functional dependencies lead to cooperation and coordination between organisations' business activities to facilitate the achievement of internal, and in some cases, mutual goals (Bowersox and Closs, 1996).

5.3 Relational Dependencies

Regarding the relational dependencies they are identified by several authors in a context where organisations develop relationships with other organisations in a supply chain context (Bucklin, 1966, Håkansson and Snehota, 1995). It comprises business activities which are dependent on the interaction process in supply chains (Svensson, 2004).

According to Haywood and Peck (2003b), and Svensson (2004) the perceived dependencies in business relationships towards suppliers and customers may be influenced by factors, such as: the degree of outsourcing, the inventory levels, the number of suppliers/customers, the standardization, and the globalization of commercial supply chains.

These business philosophies take on the overall channel and for that reason reinforce the time, functional and relational dependencies in supply chains.

Håkansson (1982) suggests the use of the Interaction Model to explain the time and functional dependencies. This model identifies four groups of variables which describe and influence the interaction, as well as the dependence between buying and selling organisations. These variables are the overall environment, the atmosphere of interaction, the actors of interaction and the interaction process.

The higher the dependence the higher is the level of perceived vulnerability by organisations. Organisations' activities are highly dependent upon each other and thus very vulnerable in today's highly integrated supply chains (Paulsson, 2005).

6. SUPPLY CHAIN VULNERABILITY

Supply chain vulnerability is a relatively new and under explored area of management research. In literature we can find some definitions of vulnerability in a context of supply chain. Christopher and Peck (2004) consider that supply chain vulnerability is related with the exposure to serious disturbance, arising from risks within the supply chain as well as risks external to it.

So, we observe in the literature some confusion about the two concepts: vulnerability and risk. Haywood and Peck (2003a) define the term vulnerability as “where the supply chain/network is at risk: vulnerable; likely to be lost or damaged”. So, according to these authors, risk is the same as vulnerability.

According to Deloach (2000) the risk is “the level of exposure to uncertainties that enterprise must understand and effectively manage as it executes its strategies to achieve its

business objectives and create value”. But the level of exposure to uncertainties doesn’t represent the vulnerability? It seems that this author share the same perspective of the last one.

Another perspective is the one which considers that the risk is a consequence of the vulnerability in a supply chain context. In these circumstances, Norrman and Joansson (2004) present a number of current business trends that increase the vulnerability to risks in supply chain, such as: i) increased use of outsourcing of manufacturing and R&D to suppliers; ii) globalization of supply chains; iii) reduction of supplier base; iv) more intertwined and integrated processes between companies; v) reduced buffers; vi) increased demand for on-time deliveries in shorter time windows, and shorter lead times; vii) shorter product life cycles and compressed time-to-market; viii) fast and heavy ramp-up of demand early in product life cycles; and iv) capacity limitation of key components chains.

This last point of view can be found also in the executive report of the SCV (2002:2) about supply chain vulnerability. In this report it is considered that the supply chain vulnerability is “an exposure to serious disturbances from risks within the supply chain as well as risks external to the supply chain”. This same definition of supply chain vulnerability can be found also in Chapman *et al* (2002).

As said by Svensson (2002, 2004) vulnerability is a condition that affects an organisation's goal accomplishment depending upon the occurrence of negative consequences of disturbance.

Svensson (2000, 2002, 2004) has contributed a lot to the study of supply chain vulnerability. He develops several conceptual models for the analysis of it. The conceptual framework and model that can be founded in Svensson (2000), consists of three principal

components, namely: source of disturbance, category of disturbance and also the type of logistics flows. To him the source of disturbance is itself divided into two dimensions, such as atomistic and holistic sources. The category of disturbance is divided into quantitative and qualitative disturbances; and as regards the type of logistics flows he considers different kinds of it in terms of their complexity, inventory buffers, materials and components.

Later Svensson (2002) considers that the construct vulnerability is constituted by two components: disturbance and negative consequence of disturbance. He considers the disturbance as a random quantitative or qualitative deviation from what is normal or expected and the negative consequence of disturbance as a deteriorated goal accomplishment in terms of economic costs. The negative consequence of disturbance could be also quantitative or qualitative. As example of quantitative deviations the author points out the increased cycle times and down times and as qualitative ones, the breakdowns or delays in transport caused by unexpected conditions, bad weather, and so on. In the same work the vulnerability is analysed in a context of organisations inbound and outbound logistics flows. It is proposed that the vulnerability in the inbound and outbound logistics flows may be measured and evaluated by the following four principal dimensions: service level, deviation, consequence, and trend. In the author perspective, the vulnerability in inbound and outbound logistics flow decreases when preventive activities are introduced. Being so, in this circumstances the vulnerability construct is positioned under the umbrella of the contingency planning concept.

Berman (1996) defines contingency planning as a series of events that are designed to take full advantage of a business opportunity or to reduce the impact of an event that generally would be ruinous to an organisation. In a different way Coyle *et al.* (1996) consider it as preparing to deal with calamities (e.g. floods) and non-calamitous situations (e.g. strikes)

before they occur. That is, it comprises unexpected and random situations that may occur in and between organisations' activities.

Svensson (2004) develops a different perspective about the supply chain vulnerability. He proposes the visibility model of vulnerability in upstream and downstream supply chains. According to this model a poor visibility upstream and downstream leads to enhance the supply chain risk since there is frequently only a limited exchange of information between adjacent entities in the network. Greater visibility and control improves quality and allows managers to make their supply chains more responsive and manageable, thus preventing inventory buffers or additional safety time built into logistics lead-times (Christopher and Lee, 2001).

This lack of visibility may be reflected on the fact that most organisations are forecast-driven rather than demand-driven taking decisions in isolation of each other which could represent a source of considerable additional cost to the supply chain and consequently a significant source of vulnerability. According to the visibility model of vulnerability two factors influence the perception of corporate vulnerability in the upstream and downstream supply chains, namely the degree of transparency and the degree of obscurity. The degree of transparency increases as the accuracy of the information shared in the supply chain improves.

Svensson (2004) defends that the gap between perceived dependence and perceived trust has an impact on companies' perceived vulnerability in business relationships. The importance of trust in supply chain vulnerability can be explained by the fact that it is seen as a phenomenon that contributes to the strength of interpersonal relationships, intra-organisational relationships and inter-organisational relationships (Grönroos, 1990;

Håkansson and Snehota, 1995). The level of perceived trust is influenced by the dependability/ reliability, the honesty, the competence, the buyer/seller orientation, and the friendliness in dyadic business relationships. Therefore, the gap between perceived dependence and perceived trust is assumed to have an impact on the perceived vulnerability in business relationships towards suppliers and customers.

To Svensson (2004) the degree of corporate vulnerability may be interpreted as proportional to the degree of time, functional and relational dependencies, and the negative consequence of these dependencies, in a supply chain.

Sheffi (2005) proposes the following for reducing vulnerability: i) focus on methods to detect and identify a disruption quickly and correctly; ii) learn and share for safety and security; iii) avoid not only the use of multiple suppliers, safety stock, extra capacity, added workers, and low utilization, but also that operations and the supply chain are too lean; iv) design a resilient supply chain; v) in case of demand break down organisations may adopt risk pooling, the theory of postponement, interchangeable engineering, and collaborating with supply chain partners and customers.

Besides the lack of consistency about the vulnerability concept, in this work we consider the supply chain vulnerability as the incapacity of the supply chain, at a moment, to react to the disturbances and consequently to attain its objectives.

7. CONCEPTUAL FRAMEWORK

The frameworks proposed until now on the field of Supply Chain vulnerability are quite narrow in their scope to realize the kind of relationships that exist among organisations and which are important to understand the supply chain vulnerability phenomenon. So with this study we try to better understand the main direct and indirect causes of supply chains vulnerability and for that a conceptual framework is proposed.

The changes that have occurred on the organisation' environment contribute to enhance the dependencies between organisations involved in the same supply chain and consequently the risk they face on in a day-to-day management. In addition, a variety of business philosophies which are grownup, such as Efficient Customer Relationship (ECR), JIT, JIS, QR and SCM are contributing to reinforce the dependencies between supply chains' partners, figure 1.

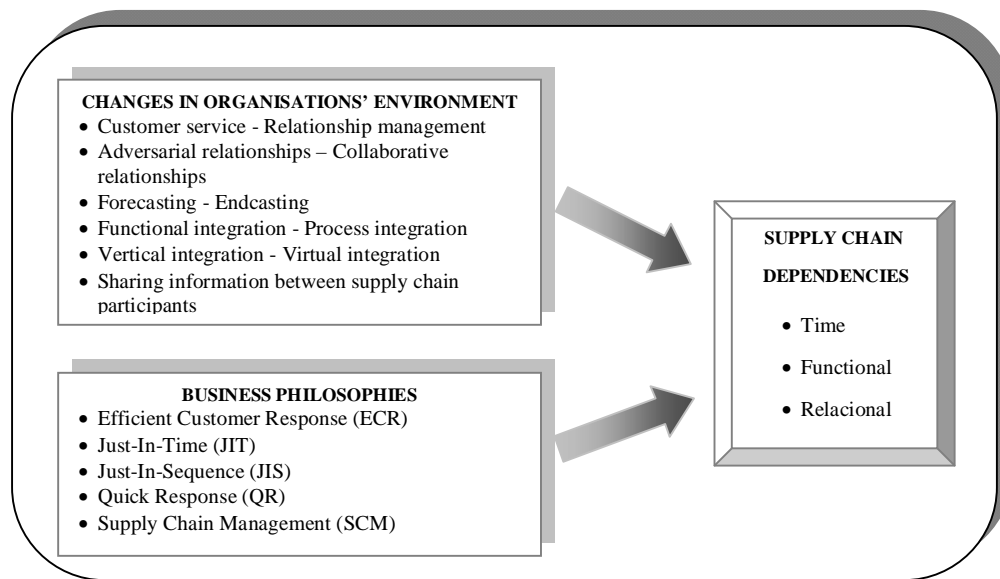


Figure 1. Factors that contribute to supply chain dependencies

Organisations need to be competitive, so they have to increase their efficiency applying to a set of business philosophies, such as JIT and Lean manufacturing, which have the objective

of cost minimization and appoint to the integration of supply chain entities. However, these actions lead to an increase not only on their vulnerability but also on the supply chain where they are inserted.

Let's look to the situation of a Portuguese organisation, referred by organisation B, producer of a set of products. Organisation B is the focal organisation, which sells the products in Portugal, namely, to organisation C, as well as on several foreign markets (Figure 2). Some of the raw materials used on the production by organisation B are single sourced (organisation A). The production of some products subsets is outsourced to organisation D, which facility is located outside Portugal.

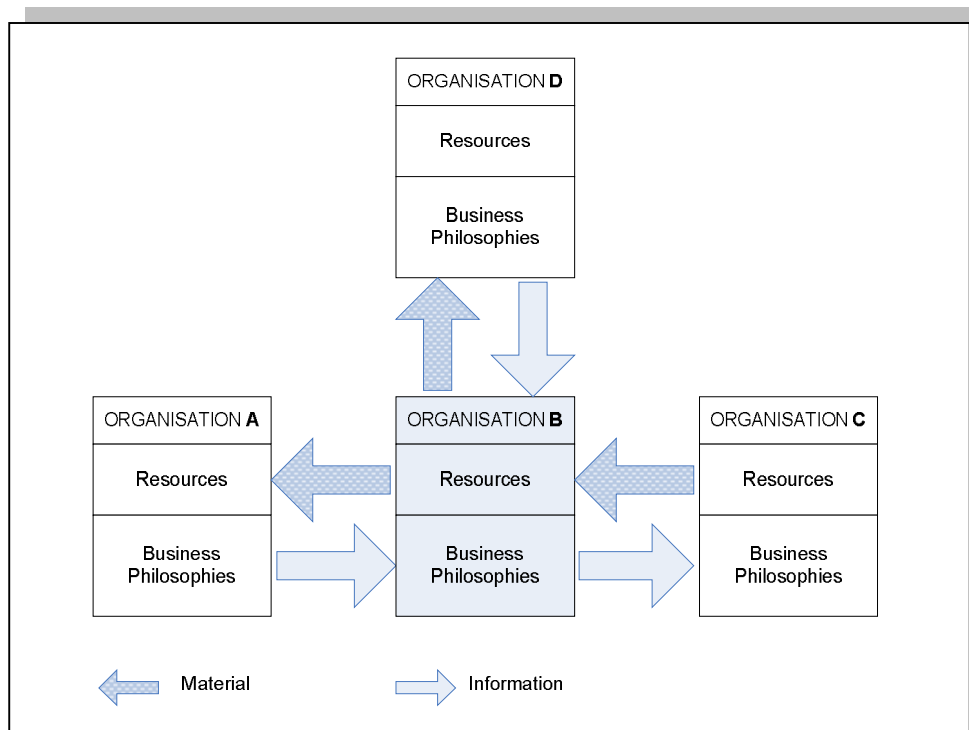


Figure 2. Some entities with direct connected with organisation B

Organisation B manages the production and supplies according to JIT philosophy adopting a set of efficient principles in order to minimize the redundancies, in material, time, and

capacity form. So, production is streamlined with low level of inventories, and short lead times. The machine resources capacity is used at close to the maximum levels. Organisation B doesn't keep buffer inventory of raw materials as well as finished products.

There is a high degree of interdependence between organisation B and their suppliers. As organisation A is the single supplier of some raw materials, there is a close relationship between both the entities. The information flow between organisation B and their suppliers is well established. There is a high visibility about inventories and product requirements across the entities.

Suppose that a strike of motorists hinder the delivery of the raw materials produced by organisation A to organisation B. This event can generate a supply chain disturbance if organisation B doesn't be able to react.

Some of the characteristics of the organisation and/or supply chain can cause the increase of organisation B vulnerability when disturbance take place, namely:

- (i) Organisation B only has raw materials inventory to satisfy production demand during the raw materials lead time, which increases the probability of bring to a halt the production activities at organisation B and, consequently, the increase of finished product stockout occurrence probability.
- (ii) Raw materials supplied by organisation A to organisation B are single sourced, so there is a high dependence of this supplier. This can reduce the flexibility to react to the disturbance, so its responsiveness. The raw materials procurement to a new supplier may have a longer supply lead time which may not mitigate the disturbance. Also, the product purchase price may be higher.

- (iii) The outsourcing of some activities, allow organisation B to focus on their core activities. However, organisation B reduces the control on product quality, and increases its dependence toward organisation A. The focus on core activities allows the development of new product technologies/methodologies/approaches to be more competitive, reducing, for instance, the product life cycle.
- (iv) The outsourcing of product subsets production to organisation D raise both the number of entities, and information and material flows in the supply chain, and therefore, increase supply chain complexity. A more complex supply chain is more prone to disruptions. Also, by outsourcing, organisations motivate decentralization. The production of organisation D is focused, which can reduce the flexibility to react to a disturbance.
- (v) Global demand is a recent characteristic of organisation environment. With shorter lead times and customized products, a disturbance occurrence at a supply chain entity can seriously affect the customer service quality. This can mean the customers loss and, therefore, the lost of market share.
- (vi) Usually, the relationship across supply chain entities, promote a greater information share and a greater visibility in the supply chain. In this case, the organisation/supply chain will be less vulnerable to the negative effects of the disturbance.

The negative effects of the strike occurrence reach the organisation B and the supply chain too.

From the example presented above it is possible to state that the organisation/supply chain vulnerability to the disturbance can depends on several factors, namely: complexity, decentralisation, globalisation, outsourcing, reduced lead times, and reduced supply base.

According to the literature review and the analysis of different organisations a conceptual framework to illustrate the supply chain vulnerability is proposed (figure 3).

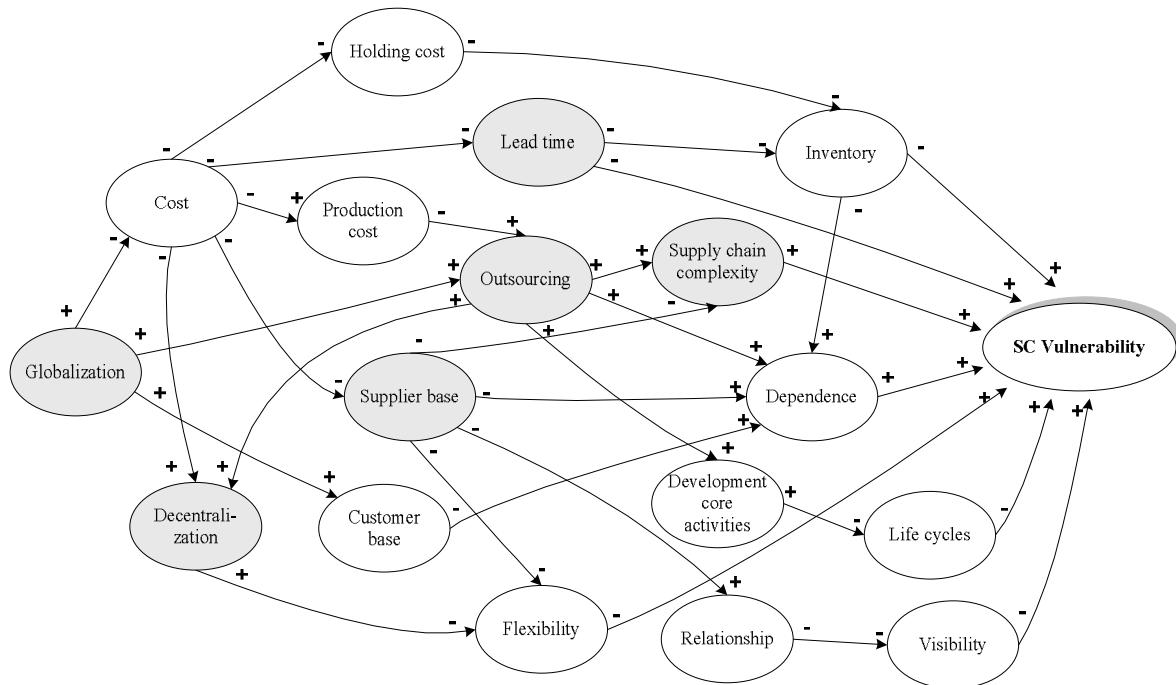


Figure 3 – Conceptual framework: Supply Chain Vulnerability

As can be seen in the figure 3 we propose a set of direct and indirect relationships that influence the supply chain vulnerability. Lack of visibility, products life cycles shortest, bigger supply chain complexity, reduced lead time, reduced inventory, low flexibility, and, not less important, more dependencies, are causes that can (negatively) influence the supply chain vulnerability to a disturbance. Some of these factors are resultants of trends and developments verified in the last years in the SC.

It is becoming increasingly clear that traditional SC management approaches must be enhanced to include means by which the new uncertainties arising from these trends and developments can be addressed, becoming the SC less vulnerable to a disturbance.

Being so, the vulnerability grows since the negative consequences of a disturbance on any supply chain' partner will also involve and affect all the others deeply because of the dependent relationships.

8. CONCLUSIONS

A number of recent trends and their influence on the supply chain flow have been discussed above. Many of those trends tend to lead to more serious negative consequences of disruptions for the supply chain in the whole as well as for an individual organisation of the supply chain. At the same time, the importance of many of the traditional risk handling methods (like buffer stocks and lead time slack) has been substantially reduced by these trends. So, some trends can create a changed risk situation for many organisations becoming them more vulnerable to a disturbance.

Competition is a constantly present driver for increased efficiency. The actions taken to increase the efficiency in the chain can be clustered into different trends. But, some of those trends not only increase supply chain competitiveness, they also affect supply chain vulnerability.

With all the changes that are occurring in organisations' environment the competitiveness of the organisations are changing in scope. Organisations are conscious that they could only stay in the scene if they are completely integrated in a supply chain. This is because the competitiveness is occurring between supply chains and not between organisations in an

isolated way. Being so, they are adopting a set of business philosophies, such as, Efficient Customer Response, Just-In-Time, Just-In-Sequence, Quick Response and Supply Chain Management, which are contributing to enhance the dependencies between them. These dependencies make supply chains more joined but also more vulnerable. A disturbance that may affect directly only one member of the supply chain, in a question of time, will have also an impact on all the others.

Being so, what will be the solution to it? The changes that are occurring in organisations' environment are exogenous factors, so organisations don't have any possibility to change it. As regards the new business philosophies, it is feasible to organisations avoid use it? We don't think so, because they represent the answer back of organisations to these new environment organisations' changes. So, the answer may be put on the resilience. Supply chains must develop some behaviours that make them more resilient to these kinds of disturbances. This could be the topic for future research.

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