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Social Network Theory and Management of the Sub-supply Network in Complex Sectors

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Abstract

Studies on complex product development have seen different improvement approaches to achieve shorter product development lead times and higher return on investment. Complex product development still lack on the 'better, faster and cheaper' paradigm for efficient communication and information exchange flow process. This paper aims at understanding how the critical interdependent techniques are managed in the sub-supply network of a complex sector such as Business Aviation Industry. Thus, the aim is to envisage the best practice approach for technical communication networks among these systems-design teams and also how the bottlenecks existing could be effectively and efficiently addressed to enhance collaborative industrial supply-chain management network competitive advantage.

This paper employing social network theory propose information flow process toward enhancing an industrial sustainable competitive advantage. From a methodological point of view, the research is based on a single case study, a questionnaire was used to collect data for the level of communication network from Business Aviation supply chain network.

The outcome of the research highlights how communication in the sub-supply network significantly influences the attention the teams pay to the organization of the critical interdependent techniques. Moreover this research identifies an effective and efficient communication is sees as the driver for effective organization management, which need enhancement for industrial competitive advantage. Finally, the research carried-out undoubtedly gives a considerable contribution in understanding critical and complex issues in the relationships in sub-supplying in Business Aviation Industry.

The outcome could be further developed by extending the interviews to the businesses involved in the sub-supply chain.

Keywords: sub-supply network, social network theory, business aviation, complex products, organization theory

1. Introduction

The airplane has such characteristics that businesses are stimulated to adopt a collaborative outlook (Izzo, 2009), including huge complex products such as jet engines, marine, automobile (Maier et al., 2008; Hsu and Wallace, 2007; Addo-Tenkorang and Eyob, 2012). From an organizational point of view, the manufacture of an airplane forces a business to assign each interdependent technical component to a team, also referred to as *design team*. The *team* is responsible for the planning, development, production of the sub-system, and the integration of the sub-system with other components to guarantee the proper operation of the overall product/system (Clark & Fujimoto, 1991). Moreover, this must be in an efficient and effective manner (Gligor and Holcomb, 2012, 2014; Gligor*et al*., 2013; Kampstra*et al*., 2005; Musa *et al*., 2014; Maier et al., 2008; Hsu and Wallace, 2007; Addo-Tenkorang and Eyob, 2012; Chandra and Grabis, 2007; Childerhouse and Towill, 2011).

The interface between the components defines the *interdependent techniques* among the design teams. Building an effective collaboration between independent teams is one of the main challenges in the production of a complex product (Thompson, 1967; Galbraith, 1973; Smith and Eppinger, 1997; Mihm*et al*., 2003; Sosa *et al*., 2004; Tenkorang and Helo, 2017). Though the attention (attention meaning the observation, the coding, the interpretation and the focus on time and effort the design teams dedicate to identifying and solving problems – Ocasio, 1997) on the interdependent techniques is crucial for the development of a complex product (Humphries *et al*., 2007; Puvanasvaran *et al*., 2009; Min *et al*., 2005; Tsanos *et al*., 2014), the design teams often ignore, or pay little attention to, a large number of interdependent techniques during the development of the product (Sosa *et al*., 2004, 2003).

It is inevitable that some interdependent techniques are overlooked, given the limited cognitive capacity of the economic agents (Simon, 1947; Ocasio, 1997). However, ignoring those critiques can have serious consequences on a business. In respect to this, numerous studies show the negative effects caused by a lack of attention placed on the critical interdependent techniques. For example, in the research on the industry of semi-conductors carried-out by Henderson and Clark (1990), they stress how new interfaces between existing components, which were often ignored by design teams, determined the loss of the businesses' dominant position. Furthermore, in the automobile industry, Ford and Firestone suffered great losses due to inadequate management of the interfaces between the design of the tires and the dynamics of the vehicles of the Ford Explorer (Pinendo *et al*., 2000). In the aerospace industry, Airbus suffered significant delays during the production of its A380 and, consequently, losses caused by the lack of attention placed on several critical interfaces between the electrical system and the fuselage (Gumbel, 2006; Hollinger and Wiesmann, 2006).

Industrial and institutional benchmarking for *best practice* competitive advantage in terms of effective and efficient enterprise communication network relationships can never be over-emphasized (Min *et al*., 2005; Humphiries *et al*., 2007; Puvanasvaran *et al.*, 2009; Tsanos *et al*., 2014). Moreover, it is imperative that organizations are capable of responding to any changing parameters concerning new/complex product development, and this must be done in an efficient and effective manner (Gligor and Holcomb, 2012, 2014; Gligor *et al*., 2013).

Despite the importance interdependent techniques can have in the development of a complex product, little is known of the factors that have an effect on the teams' attention. In other words, the question is, *Why are some teams better than others in managing critical interdependent techniques? Should the reason be attributed to the characteristics of the components of the product and/or methods of communication?*

According to Geunes *et al*.(2002) for sustaining enterprise supply chain competitive advantage in industrial organizations need them to implement new strategies based on collaboration with their supply chain network partners and make use of information technology systems and internet-based services. According to Puvanasvaran *et al.* (2009) communication is very important in organization management. Therefore, in generic terms, an effective and efficient communication network is a vehicle to function in a competitive economic network (Le Vassan, 1994; Wartner, 1985; Worley and Doolen, 2006). However, communication itself is influenced by many different interlinking factors. Thus, the methodology employed in this paper is a single-case study approach - Piaggio Aero Industries -, and the paper presents the communication factors in systems design teams.

Shown below is the theoretic framework of reference, followed by the methodology, the results and the conclusion.

1.1 Theoretical Background

Regarding the factors that have effects on the *attention* of the teams, recent research (Sosa *et al*., 2004), starting from the contributions of the *development of the product* (Ulrich, 2004) and of the *social network theory*, shows that both the *architecture of the product* (architecture meaning, 'The scheme by which the function of a product is allocated to physical components. Architectures are characterized by a higher or lower degree of modularity' - Ulrich, 2004:419), as well as the *network communication*, influence the *attention* the teams place on the management of the critical interdependent techniques.

Understanding how the *architecture* of the product and the *communication* between the teams in the network can influence the success of the development of a product (Le Vassan, 1994; Warten, 1985; Worley and Doolen, 2006; Simatupang and Sridharan, 2005; Tsanos *et al*., 2014; Vollman *et al*., 2005), allows the *system integrator* (the system integrator is the business which assembles the parts and produces the complex product) to make better decisions regarding which components require particular attention during the *design* process. Therefore, taking into consideration the implications for other decisions that are relevant, such as *outsourcing*, *off-shoring* and the management of the life-cycle of the single components.

Regardless of the focus, the studies on the *development of the product* coincide with the results of *research on R&D* (Allen, 1977; Brown and Eisenhardt, 1995), which point out the need of intense communication to handle the *attention* of the various *design teams* in the critical interdependent techniques.

Organizational studies inspired by the *social network theory* (Sosa *et al*., 2003, 2004), have dwelt on, in particular, the methods through which the communication of the networks can help or harm the capacity of the actors in collaborating with other interdependent entities.

Empirical facts show that this ability is strengthened by reciprocal *trust* and by the *collaborative nature* of the members of the network; trust seems to be essential in order to improve communication and the team's performance (Ahuja, 2000; Obstfeld, 2005; Coleman, 1990; Maier *et al*., 2008).

Based on the studies of the *sociological approach* (Coleman, 1990; Granovetter, 1985), several researchers have emphasized the role of the *communicative structure* in the network, in the ability of the actors to collaborate in complex tasks (Gargiulo and Benassi, 2000).

In summary, more studies (Allen, 1997, De Meyer and Mizushima, 1989; Jaffe *et al*., 1993; Keller and Holland, 1983; Van den Bulte and Moenaert, 1998) on the communication processes in R&D context describing how increasing distance between team members reduced the chances of two team members communicating about technical matters. However, little theoretical understanding of the correlation factors that influence communication in complex product development has been published.

Therefore, the importance of technical communication in collaborative complex engineering design and delivery process is indisputable. However there is no good or well-defined consensus on how to coordinate, or, at best, streamline their organizational 'best practice' operations to improve and enhance an industrial competitive advantage. In this research paper, a communication network is defined as the cognitive and social network process by which technical information or data are transmitted and exchange effectively and efficiently among complex engineering systems-design teams in an industrial enterprise manufacturing supply chain management.

Thus, the aim is to envisage the best practice approach for technical communication networks among these systems-design teams and also how the bottlenecks existing could be effectively and efficiently addressed to enhance collaborative industrial supply-chain management network competitive advantage.

The results offer insights for researching and managing communication networks across systems-design teams' interfaces. It so makes clear, how directly and/or indirectly linked factors influence technical communication networks among systems-design teams in complex engineering design and delivery. The factors which this research paper identifies, which directly or indirectly influence technical communication among complex engineering product system-design teams are based on person interview and questionnaire employed of data collection used in this research. The factors identified (Addo-Tenkorang and Helo, 2017; Addo-Tenkorang, 2014; Addo-Tenkorang*et al.*, 2014) in the research include:

1. frequency in communication among various design teams;
2. importance of design teams' technical communication for network complex product development;
3. level of collaboration among various design teams;
4. the level of mutual trust among various design teams.

These factors identified to have also been highlited in Maier *et al.* (2008), they observed 27 factors common across all industrial studies, forming the basis for exploring correlations between factors influencing communication in network complex product development.

The networks that are set as the know-how communication circuits, promote effective learning, collaboration among partners and *attention* to interdependence, only when there are relationships based on trust and, eventually, supported by formal limits (Doz, 1979; Pisano, 1990; Badaracco, 1991; Padula, 1998).

In light of the possible lack of balance in instruction, in the different contracting power of the parties involved and in the risks that can harm the relationship (e.g., violation of industrial secrets; speculative behavior) and generate costs, the only method used for coordination that is truly efficient in governing the transactional interdependence that is generated by the network is *trust*. Where trust is intended as – the expectation of predictable behavior, fair and cooperative – (Soda, 1998:82).

Trust strengthens in time and with experience and is based on interpersonal relationships that reinforce the information channels and develop multiple opportunities for interaction (sociological prospective). Time and experience represent decisive factors in order to establish the level of trust in a relationship and thus, the stability and intensity.

It is, therefore, obvious that trust does not exist in itself, but is built on daily and repeated behavior of the various actors and, as such, develops within an enduring and incremental evolutionary cycle (Lorenzoni, 1997; Larson, 1992; Gerlach, 1992; Ring and Van De Ven, 1992; Thompson, 1967).

Trust is also (in economics) the result of a cost-benefit analysis thus the actors choose whether to be collaborative or opportunistic based on a calculation of financial convenience. Consequently, trust also depends on the evaluation of the incentives underlying the cooperative relationship (Hill, 1990).

The mechanisms that are commonly appealed to in promoting trust in networks are linked to the *sharing of information* and to the promotion of *common norms* and *cultures*. The sharing of direct and indirect information breaks down barriers to the sharing of knowledge and simplifies collaboration in complex activities (Ahuja, 2000; Obstfeld, 2005).

The widespread interaction among members of the network could also facilitate the spreading of norms and common culture, reducing the impact of competitive and motivational obstacles to cooperation (Reagans and McEvily, 2003; Oh *et al*., 2004). Such a culture could promote the free flow of complex information and knowledge that is often essential in order to reach superior performance (Hansen, 1999).

In light of the previous considerations, the following propositions are advanced:

P1:The sub-supply network in the BA sector is characterized by an intense communication technique.

P2:The sub-supply network in the BA sector is characterized by a mutual vision of the project.

P3:The relationship between the knots in the sub-supply network in BA are enduring and stable.

P4:The great intensity in communication, the sharing of the project and the stability of the relationships in the sub-supply network in the BA sector significantly influences the attention the teams place on the handling of critical interdependent techniques.

This case study research paper presents a network of factors, which influence supply chain management technical communication networks. The following section below (Methodology) utilizes an industrial use case example in terms of the data collection and analysis approach adopted to simulate the technical communication of an industrial case study.

2. Method

This research analyzes the relationships that are established between the integrator and the airframe sub-suppliers since they are the most critical factors as they are more complex to manage because not very modular.

From the methodological point of view, the research is based on the analysis of a case-study, helping investigation of a specific complex phenomenon (Eisenhardt, 1989; Easton 1995; Dubois and Araujo, 2004; Yin, 1989, 2003, 2009, 2012). In particular, interviews were carried-out with the Research and Development Department of Piaggio Aero Industries.

In supporting the outcome of the interviews, reference was also made to the outcome of research carried-out on the same subject matter in the aerospace sector (Hira and De Oliveira, 2007; Achon and Klassen, 2007; Green *et al*., 2005; Bales *et al*., 2004; Esposito, 1996; Badaracco, 1991; Allen, 2000; Izzo, 2009).

In the opinion adopted, namely the *social network theory*, the teams represent the *knots* in the network and the communication technique between them represents the *bonds* of the network. This research analyzes the intensity of *technical communication* between teams, that is, between the integrator and its sub-suppliers.

The communication technique is seen as a *flow of technology* among the various knots in the network. Flow of technology means the assets incorporated in different components, as listed below (The Technology Atlas Team, 1987):

1. Machines – technology incorporated in the objects, components, instrumentation and systems;
2. Professionalism – technology incorporated in the people, i.e., the human know-how, ability and experience jointly;
3. Information – incorporated technology in the form of ideas and information reported in manuals, articles, memos and in any other form of written documentation;
4. Organizational Rules – incorporated technology in the form of organizational procedures and bonds.

A closed-ended questionnaire was used in order to provide a suitable list of responses (Robson, 2011; Mellenbergh and Adèr, 2008). The questionnaire used in this research paper was designed and structured in order to study the intensity of the *communication technique* between the integrator and the sub-suppliers of the airframe. In particular, interviewees were asked to express an opinion (high, average, low) on the following channels:

1. Flow of raw material;

2. Transfer of predefined components and parts;
3. Supply of equipment to the sub-supplier for specific problems;
4. Visits and suggestions made by the integrator;
5. Collaboration at the start of the commission;
6. Written documents;
7. Meetings at the client's;
8. Visits by the integrator to verify the status of the order;
9. Suggestions made by the client for the adoption of the quality control system;
10. Direct intervention by the integrator in order to improve the quality control system.

In addition to the close-ended questionnaires, there was open-ended questionnaire and interview to also capture relevant empirical data for the evaluation, validation and reliability analysis of the case study and questionnaire used. A face to face interview and open-ended questions were administrated to manager of the Research and Development Department of Piaggio Aero Industries.

3. Results

The Business Aviation (BA) industry, as the aeronautical one in general, is very complex. This can be attributed to the complex system of the product – the aircraft. The relationships that characterize this industry can be distinguished by two types: *inter-domain and infra-domain* (Esposito, 1996; Vicari, 1991; Izzo, 2009).

The first are stipulated among businesses in different industrial sectors. The second, instead, among businesses strictly in the aeronautical sector. The businesses that strictly belong to the aeronautical sector are producers of thrusters (engineers), producers of equipment and avionics and the integrators.

The integrator is the one that:

a) Manufactures the aircraft,
b) Designs the aircraft,
c) Decides what, how and how much to produce,
d) Chooses which businesses to involve in the project,
e) Organizes the flow of the parts, components and systems,
f) Assembles and markets the aircraft,
g) Saves all the information relating to the product for immediate access of each component's history at any time,
h) Designs and produces even part of the airframe,
i) Manages the relationship with the final client and is legally responsible for the aircraft.

During production of the airframe, the integrator uses a network of sub-suppliers. It is this type of relationship that is studied in this research, as it is more complex since it has little space for modularity.

In making management decisions in the production cycle, the integrator manages a serious *trade-off*. On one hand, resorting to external sources generates benefits tied to the access of specialized expertise. On the other hand, the need to dominate the interdependent techniques that characterize the development of the complex product (the aircraft) pushes towards developing inside expertise of the technology of the components.

Another problem regards the breakdown of the tasks in the planning, aimed at the management of the complex technical problems and the allocation of such tasks, directed at identifying the organizing units that are internal and external to the business (the teams).

In other words, the integrator divides the entire product (the aircraft) in systems and components, where the interface between the components defines the interdependent techniques among the teams. As emphasized in literature, to build an effective collaboration among independent teams is one of the main challenges in the development of a complex product.

The interview revealed that the interaction between the airframe sub-suppliers and the integrators can only be partially expressed by a general model, which has to be tested through the simulation, the construction of prototypes and by trial and error where implicit learning and expertise play an extremely important role.

The production of an aircraft involves a long sequence of processes, each one of which is chosen by a high standard set of possibilities. The relationship between the processes in their sequence can only be partially known. The interview revealed that the relationships in the sub-supply chain are intense not only at the start of the order. For example, through written documents and collaboration in the initial stage of the order, but also in the successive phases like through periodic visits.

The written documents through which the sub-supplying businesses receive the design and details of a commission from the integrator represent one of the main channels of circulation of technology. The great use of the channel "visits and suggestions" and "collaboration at the start of the commission" show that the sharing of technology is intense both in the initial production phase as during the entire period of the relationship.

Moreover, the system integrator shares information with suppliers on the vision project, and on common norms and cultures at the beginning of the relationships, in order to simplify collaboration in complex activities.

Due to the complexity of the relationships the system integrator limits the number of suppliers to have direct relationships with, using exclusively certified suppliers, capable of being independent, that is, able to produce complex components, to manage their own network of sub-suppliers and establish long-term relationships with them.

From the contractual point of view, the bond between the client and the sub-supplier generally does not provide for long-term written contracts and the short-term ones seem to be somewhat rare. Rather, the relationship is often ruled by a continual succession of orders which do not provide for a true and real contract, but a contractual structure based on reciprocal experience and trust.

The interview shows that the main factor in market competition in the sub-supply sector is quality, while the price remains a less relevant factor. Participation, trust and the reciprocal involvement positively influence the teams' *attention* in handling the critical interdependent techniques, thus improving the individual and overall performance.

4. Discussion

The outcome of the research shows that the integrator bases the productive organization on a planned network, or rather, participates from the conception of the project as the characteristics of the product require long-term cooperative relationships.

The network that is established is a *centralized* one since the reporting system responds to specific strategic objectives of the "central" business, i.e., the integrator.

The organization being assessed, establishing itself on the convergence of different businesses in a single aggregate, towards the fulfillment and use of synergies, requires a combined effort in bonding with planning and control processes by all the partners involved in the network. Finally, the clear strategic design that is generated through the performance of the common objectives, promotes coordination of the decisions that are made within each network unit.

The participation, involvement, the trust in the network of sub-suppliers in this sector, satisfy one of the main institutional tasks of businesses in aeronautics – produce a top quality and reliable product.

The outcome of the research emphasizes that communication in the sub-supply network significantly influences the *attention* the team has in handling critical interdependent techniques.

The research undoubtedly constitutes a significant contribution in understanding critical and complex situations in relationships in sub-supplying in this sector. The outcome could be further developed by extending the interviews to the businesses involved in the sub-supply chain. This paper employing social network theory propose information flow process toward enhancing an industrial sustainable competitive advantage. In particular, this research identifies an effective and efficient communication is sees as the vehicle for effective organization management, which need enhancement for industrial competitive advantage.

The main limitation is is attributable to the fact that this research doesn't give information on type and structure of a team's organization impact the communication network, it could be a suggestion for further research.

Finally, interesting aspects to be explored in future research are: *how communication can be systematically improved?* And *how technology and technological capabilities could improve communication?*

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