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CO-PRODUCTION AND SERVICE DISRUPTION IN THE BUSINESS TELECOMMUNICATION SERVICES: A NUMERICAL TAXONOMY OF B2B BUYER NETWORK STRUCTURE COMPLEXITY

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1. INTRODUCTION

Two of the most important tenets in the literature on supply chain risk are the search for the key drivers that lead to supply chain disruptions and their potential negative consequences for firms along the chain. In this search, authors have analyzed and associated disruptions with a variety of events and characteristics like operational choices and problems (e.g. outsourcing, supply delays, and machine breakdown) (Chopra and Sodhi, 2004; Hendricks and Singhal, 2003, 2005a; Kleindorfer and Saad, 2005; Tomlin, 2006), natural and planned catastrophes (Knemeyer, Zinn and Eroglu, 2009), practices and culture (Braunscheidel and Suresh, 2009), preventive maintenance (Jonsson, 2000), supply chain and supplier characteristics (Choi and Krause, 2006; Craighead, Blckhurst, Rungtusanatham and Handfeld, 2007; Zsidisin and Ellram, 2003; Zsidisin and Smith, 2005), demand uncertainty (Spekman and Davis, 2004; Wagner and Bode, 2006), decision-making perceptions and behavior (Ellis, Henry and Schokley, 2010; Zsidisin, 2003b), labor turnover (Jiang, Baker and Frazierb, 2009), and even with threats to customer life and safety (Zsidisin, 2003a). Because of its great emphasis on manufacturing supply chain, though, the supply chain risk literature has paid little attention to events associated with characteristics emanating from service supply chains.

Despite such little attention paid by the supply risk literature, differences between manufacturing and service supply chains have been discussed and recognized in the overall extant literature (Armistead and Clark, 1993; Baltacioglu, Ada, Kaplan, Yurt and Kaplan, 2007; Ellram, Tate and Billington, 2004; Frohlich and Westbrook, 2001; Sengupta, Heiser and Cook, 2006; Zelbst, Green, Sower and Reyes, 2009). For example, in their study about supply chain integration, Frohlich and Westbrook (2001) conclude that manufacturers should follow a demand chain management practice, while service providers should be more concerned about demand integration. Sentupta and Heiser (2006) found that operational performance of manufacturers tends to be more influenced by heading the risk of supply chain disruptions but that of service providers tends to be influenced by their ability to share information with customers. In the context of supply chain disruptions, however, the most important characteristic distinguishing manufacturing and service supply chains might be the participation of business-to- business (B2B) buyers during the service delivery and co-production processes (Chase and Tansik, 1983; Kellog and Chase, 1995; Kellog and Nie, 1995; Roth and Menor, 2003; Sampson, 2000). Because they vary in characteristics, motivation, ability, and level of resources necessary to co-produce the service (Andreassen and Lindstead, 1998; Bettencourt and Gwinner, 1996; Bitner, Faranda, Hubbert and Zeithaml, 1997; Cook, Goh and Chung, 1999; Larrson and Bowen, 1989; Xue, Hitt and Harker, 2007), B2B buyers can influence the quality and performance of services, becoming an additional source for disruptions during the supply process.

After this brief introduction, we can now shed light and make some intriguing questions about one important piece making up a service supply chain: the B2B buyer network structure. Drawing on organizational management literature (Auster, 1990; Ghoshal and Bartlett, 1990), we can define B2B buyer network structure as the set of geographically spread out organizational units linked together by the common ownership of a unique B2B buyer. B2B buyer network structures, therefore, vary depending on the number and location of their organizational units, which brings some implications for service delivery process. First, the larger quantities of services (Cook et al., 1999), which may be unevenly delivered among the organizational units, may increase the service complexity to which B2B buyers have to handle in order to distribute their resources and the coordinate actions with the service provider to co-produce the service within their boundaries (van der Valk, Wynstra and Axelsson, 2009; Wynstra, Axelsson and

Valk, 2006). For example, a given B2B buyer may have 58 services delivered to their organizational units while other B2B buyer may have only 7. Without any additional information we can speculate that the service complexity present in the network structure of the first B2B buyer seems higher than that of the second, which leads us to question: how can we develop a service complexity taxonomy of B2B buyers based on service characteristics? Second, we can extend this line of reasoning to speculate also on how the geographic characteristics of a B2B buyer network structure may influence the ability of B2B buyer and service provider to encounter and execute the delivery process regardless of the location. For example, a B2B buyer may have services delivered in 3 organizational units relatively close to each other, while other B2B buyers may have services delivered among 25 organizational units spread out over a large area. Thus, because B2B buyers can vary in the amount and location of their organizational units, how can we develop a geographic complexity taxonomy of B2B buyers based on their characteristics?

Moving beyond these insightful questions, we can now turn back our attention to the problem of disruptions. As a synthesis of all discussion made so far, we can argue that the inherent distinguishing characteristics of service supply chains involving the network structure of B2B buyers may have some influence on the required integration and coordination between B2B buyers and service provider to successfully execute the service delivery process. Higher levels of service and geographic complexity existent in a B2B buyer network structure may hinder B2B buyer and service provider ability to coordinate efforts and encounter to perform a fast recovery process after a disruption, which in turn may affect the magnitude of such disruptive event. Our questions, hence, turns back to following questions: how can high levels of service complexity be associated with the magnitude of service disruptions? Similarly, how can high levels of geographic complexity be associated with magnitude of service disruptions?

In an effort to answer those questions, the objective of this paper is threefold. First, we seek to come up with a taxonomy for service complexity that helps to distinguish B2B buyer according to the quantity and variability of novel services delivered to them as well as the amount of nodal services, a term introduced by us bellow, existent in their network structure. Second, we also seek to develop a taxonomy for geographic complexity to classify B2B buyers according to the amount, distance, and position of organizational units as well as the density of the B2B buyer network structure. Finally, we search to evaluate the differences in magnitude of service disruption for B2B buyers combining different levels of service and geographic complexity. To achieve these goals, we conducted two cluster analyses and one two-factor ANOVA with data from 192 B2B buyers of telecommunication services of the largest telecommunication service provider of Brazil. Very briefly, our results show that high levels of service and geographic complexity are associated with higher magnitude of service disruptions, but the effects are not evenly distributed. That is, service complexity has a greater effect on such differences than geographic complexity.

Our study attempts to make some modest contributions to the service and supply chain risk literature. First, by briefly highlighting the differences between manufacturing and service supply chains, we brought B2B buyers into the discussion of supply chain risk and point to new directions of research. Second, by bringing B2B buyers into the context of service supply chain and risk, we also call attention to a so far neglected characteristic of this type of buyers: the B2B buyer network structure where services are delivered. Third, by discussing and analyzing the B2B buyer network structure, we provide an operational definition for service and geographic complexity that can be used by other researchers in future studies that investigate the effects of these complexities in a variety of service and operation management phenomena. Fourth, by applying these developed concepts of service and geographic complexity to evaluate magnitude of service disruptions, we demonstrate how these new, and so far not considered, factors should come into play by future studies investigating the nature and consequences of supply chain disruption. Finally, from a methodological perspective, we introduce the use of a tool employed by researchers in geology field that can be used by researchers in service and operations management to obtain measures of geographic area and, then, precisely measure density of network structures.

The rest of the paper is organized as follow. In the literature review, we present a brief review of complexity and of the independent variables composing service and geographic complexity. Then, we turn our attention to the methods employed by us to conduct our study. After the methodology, we present and discuss the results in an attempt to provide insights about our findings. Finally, we discuss the contributions, limitations, and opportunities for future research.

2. LITERATURE REVIEW

2.1. Complexity

Organizational theorists are among the first in the management literature to study complexity in organizations (Blau and Schoenherr, 1971; Galbraith, 1973; Perrow, 1986). They conceptualize complexity as a function of organizational structure, which in turn is influenced by variables like specialization, verticalization, and standardization (Daft, 1995; Price and Mueller, 1986; Pugh and Hickson, 1968). Authors in related fields have adopted a similar perspective when defining complexity resulting from the number and degree of connection among parts making up a system (Banker, Davis and Slaughter, 1998; Novak and Eppinger, 2001; Pathak, Day, Nair, Sawaya and Kristal, 2007; Shostack, 1977; Surana, Kumara, Greaves and Raghavan, 2005; Wilding, 1998). In the field of supply chain management, complexity has been also defined in a variety of ways (Bozarth, Warsing, Flynn and Flynn, 2009; Choi and Hong, 2002; Craighead et al., 2007; Vachon and Klassen, 2002). For example, Craighead et al (2007) define complexity as the number of nodes forward and backward from a given firm in the supply chain, while Bozarth et al. (2009) conceptualize supply chain complexity as a function of many drivers: manufacturing, downstream and upstream complexity, variability, and number of parts. A comprehensive review and analysis of the different definitions and elements of complexity is beyond the scope of this study, but, based on the common elements present in all these studies, we can roughly summarize complexity as a result of the number, variability, and degree of interdependence among parts existent in a system.

2.2. Service Complexity

Similar to what has happen in other fields, complexity has also been conceptualized in many different ways in the field of service operations. For instance, most authors adopt a traditional perspective of service complexity by defining it as a function of the number and interdependency among the processes necessary to choose and deliver the service (Argote, 1982; Shostack, 1977; Skaggs and Huffman, 2003; Vroomen, Donkers, Verhoef and Franses, 2005). Dahaner and Mattson (1998) share a similar perspective but they are more specific about the processes involving service provider and customer during the co-production process. Thus, a brief review of the literature suggests that service complexity has been conceptualized similarly to the way complexity has been in other fields, even though some variation is present.

Not commonly mentioned in the service literature as a source of complexity, though, the degree of service novelty can be viewed as an additional element that may influence service complexity. In applying this concept to their study about product complexity, Novak and Eppinger (2001) argue that new product technologies or architectures may create instability and confusion on the interactions known and necessary to produce the product, increasing complexity. We extend this line of reasoning for the case of services in which a novel service may require a technology or design that is not entirely disseminated among all parties involved during the delivery process. More important is the impact of such novelty on customers' ability to co-produce the service because, in most cases, it is not part of their core competence to fully dominate these novel processes or they rely entirely on service provider's ability to deliver services for them.

Finally, most of service complexity definitions do not bring into context the characteristics of B2B buyers. This type of buyer has different characteristics than that of individual buyers, which may impact service complexity. For example, the type and usage of services influence the interaction between B2B buyer and service provider (Wynstra et al., 2006). In some cases, the long-term nature of services require certain specific capabilities from B2B buyers like project management skills (van der Valk et al., 2009). Also, B2B buyers are more likely to purchase services in larger quantities than those purchased by individual customers (Cook et al., 1999), which may affect the complexity of the service delivery process given the large number of processes that, not only the service provider, but also the B2B buyer has to handle. In addition, because B2B buyers have organizational network structures composed of multiple units (Ghoshal and Bartlett, 1990; Rudberg and Olhager, 2003), in most cases these services have to be delivered in multiple locations simultaneously (Lovelock, 1983), increasing the challenge for coordination and interaction between B2B buyer and service provider during the service delivery process. Even more important becomes the number of organizational units that can be viewed as critical in terms of number of services delivered and necessary for a B2B buyer operation, which can be viewed as dense nodal services, a term introduced by us and discussed in more details later. In sum, by relying of previous definitions of complexity and by bringing all these elements in the context of B2B buyer, we define B2B service complexity by analyzing the quantity and variability of novel services and amount of critical B2B buyer organizational units where services are delivered.

2.2.1. Quantity of services

The amount of products, parts, or elements existent in a system has been extensively cited and used in the related management literature to define and measure complexity in that system (Amaral and Uzzi, 2007; Banker et al., 1998; Bozarth et al., 2009; Craighead et al., 2007; Daft, 1995; Damanpour, 1996; Novak and Eppinger, 2001; Pich, Loch and De Meyer, 2002; Price and Mueller, 1986; Pugh and Hickson, 1968). Such increase in elements of a system is related to the size of the system *per se*, which in turn affect its complexity (Blau and Schoenherr, 1971). We borrow from these studies to argue that amount of services purchased by a given B2B buyer tends to increase service complexity in its network structure due to an increase in the number of processes involved for co-production and delivery of that service. Rather than planning for one service encounter, now service provider and B2B buyer have to plan for many service encounters, which pose additional challenges for coordination of efforts and increases the likelihood of failures during the delivery process. Also, more services imply a bigger structure and delivery system necessary to co-produce the service (Roth and Menor, 2003).

2.2.2. Variability in services

The amount of variation is another variable conceptualized as affecting complexity of systems (Bozarth et al., 2009; Choi and Krause, 2006). The classic example in the operations and management literature is the bullwhip effect, in which variations in demand can cause problems for coordination and fluctuation in production along the entire supply chain (Chen, Drezner, Ryan and Simchi-Levi, 2000; Forrester, 1958; Lee, Padmanabhan and Whang, 1997). Another example comes from the strategic management literature in which Kotha and Orne (1989) conceptualize product line complexity as a function of, among other variables, the variety in the number of different products produced by a firm. We draw on these studies to argue that variability in the amount of services existent in different organizational units of a B2B buyer network structure can also increase service complexity by requiring additional coordination and integration from the B2B buyer to co-produce the service internally.

2.2.3. Dense nodal services

Dense nodal services can be viewed as B2B organizational units that have a large number of services delivered to them relative to the number of services delivered to other organizational units. Similar to the concept of node criticality (Craighead et al., 2007), this variable attempts to conceptualize the importance of a given organizational unit in terms of the services delivered to it. In other words, as the number of services delivered to a given organizational unit increases, so does its importance for B2B buyer daily operations. Consequently, a higher number of dense nodal services in a B2B buyer network structure tend to increase the service complexity.

2.2.4. Degree of novelty

As mentioned previously, the degree of novelty is another component influencing the complexity of a system, as demonstrated by Novak and Eppinger (Novak and Eppinger, 2001).

We rely on their work to conceptualize that the degree of service novelty also influences the service complexity because the processes needed to deliver the service may not be well understood by all parties involved in the co-production process. A good example of degree of novelty and complexity comes from technological services. Many studies suggest that the ability of customers and B2B buyers to co-produce technological services is one of the major barriers for their successful implementation, delivery, and usage (Bendoly, Rosenzweig and Stratman, 2009; Devaraj and Kohli, 2003; Harland, Caldwell, Powell and Zheng, 2007). Even in the field of operations and service management, researchers are still searching for ways to better understand the impact of technology in traditional operations (Beckman and Sinha, 2005; Karmarkar and Apte, 2007; Roth and Menor, 2003), which shows that novelty is a potential source of complexity. We extend this rationale based on studies on technological services to conceptualize that the degree of novelty contributes to increase service complexity.

Hypothesis 1a: Group of B2B buyers with high levels of service complexity will be distinguished from other groups by exhibiting higher number of novel services in their network structure.

Hypothesis 2a: Group of B2B buyers with high levels of service complexity will be distinguished from other groups by exhibiting higher variability in novel services in their network structure.

Hypothesis 3a: Group of B2B buyers with high levels of service complexity will be distinguished from other groups by exhibiting higher number of dense nodal services in their network structure.

2.3. Geographic Complexity

The same rationale presented to conceptualize service complexity can be used here to conceptualize geographic complexity. That is, because B2B buyers may have services delivered in multiple organizational units located in different places (Ghoshal and Bartlett, 1990; Lovelock, 1983; Rudberg and Olhager, 2003), geographic complexity becomes a function of the amount and distribution of those B2B buyer organizational units over a geographical space. Different than the service complexity, though, and to the best of our knowledge, geographic complexity has not been explored in service operations management yet.

2.3.1. Number of locations

The rationale discussed previously on how the number of services influences service complexity can also be used now to conceptualize how the number of locations where services are delivered within a B2B buyer network structure may influence geographic complexity. An increase in the number of points where organizational units are located tends to increase geographic scope (Kotha and Orne, 1989) and complexity in the network (Kadushin, 2004), posing additional challenges for B2B buyer intra-firm coordination of resources and activities (Rudberg and Olhager, 2003), which in turn may affect the co-production of services. In the supply chain management literature, the number of nodes, customers, and suppliers have been conceptualized and used as important elements of supply chain complexity studies (Bozarth et al., 2009; Choi, Dooley and Rungtusanatham, 2001; Choi and Hong, 2002; Craighead et al., 2007).

Hypothesis 1b: Group of B2B buyers with high levels of geographic complexity will be distinguished from other groups by exhibiting higher number locations where services are delivered.

2.3.2. Density of network structure

We draw on the definition proposed by Creaghead et al. (2007) to define network structure density as the geographical spacing encompassing all organizational units within a B2B buyer network structure, with network structure density being inversely related to geographical spacing. That is, holding constant the number of locations, the larger the geographical area where all organizational units of a B2B buyer are located, the smaller its density. B2B buyer network structures characterized by a small density may be more complex to manage given the larger geographical area that is necessary to overcome in order to reach and manage resources in all organizational units. Stock et al. (2000) employed a similar variable called geographic dispersion that sought to assess the number of supply chain agents (e.g. suppliers and customers) located in different continents. Their results show that firms geographically dispersed firms needed more sophisticated logistic resources to achieve a high business performance.

Hypothesis 2b: Group of B2B buyers with high levels of geographic complexity will be distinguished from other groups by exhibiting smaller density of network structure.

2.3.3. Distance

The distance that a B2B buyer needs to travel to reach all its nodes in the network structure may also influence geographic complexity because higher distances may require more resources and coordination to manage all nodes. Distance has been conceptualized and employed in the supply chain management studies as a variable affecting complexity (Choi and Hong, 2002) and product variety and performance (Randall and Ulrich, 2001). Organizational management studies have also shown the negative effects of distance on transmission of knowledge (Bell and Zaheer, 2007) and on firm innovation (Schilling and Phelps, 2007). Thus, we conceptualize similar effects of distance on geographic complexity.

Hypothesis 2c: Group of B2B buyers with high levels of geographic complexity will be distinguished from other groups by exhibiting higher distances to reach all their B2B organizational units.

2.3.4. Position of organizational units in the network structure

Finally, we borrow from social network theory (Freeman, 1979; Kadushin, 2004) to define position of a B2B buyer organizational unit as how close it is to a given point in the network structure, which in turn leads to another social theory concept: centrality. A central node is one that reaches all other nodes through the fewest number of links and distance (Freeman, 1979). Other criteria can also be used to define the central node and, therefore, the center of a network structure. A classic example is the work of Abernathy and Hershey (1972) in which the center of health-care organizations vary depending on three criteria analyzed: maximum utilization, minimum distance per capita, and minimum distance per encounter. Among the innumerous criteria available, we choose the maximum availability of resources existent in a B2B organizational unit as the criteria to define the central node because integration with service provider and co-production processes may require considerable amount of B2B buyer's resources depending on the type of service purchased (Roth and Menor, 2003; van der Valk et al., 2009; Wynstra et al., 2006). Thus, the central node in our study is defined as the B2B buyer organizational unit with the greatest amount of resources relative to all other nodes in the B2B buyer network structure. Conversely, peripheral position is that in which a B2B buyer organizational unit is far away from the central node.

These concepts have been applied in the related management literature to investigate the effects of position and location of organizations on hospital performance (Goldstein, Ward, Leon and Butler, 2002), human cognition (Perry-Smith and Shalley, 2003; Walker, 1985), collaboration (Stuart, 1998), firm capabilities (Zaheer and Bell, 2005), and it can be also applied in this study to hypothesize the effects of B2B buyer organizational unit's position on geographic complexity. Our argument is based on the rationale that B2B buyer organizational units close to the center are likely to have access to more resources as well as manage them better than those organizational units occupying peripheral positions. Therefore, a B2B buyer network structure composed of a large number of peripheral organizational units is likely to be more complex to manage than one composed of the same number of organizational units occupying a central position.

Hypothesis 2d: Group of B2B buyers with high levels of geographic complexity will be distinguished from other groups by exhibiting higher number of organizational units occupying peripheral positions.

2.3.5. Proximity to surplus of resources

Because any co-production process requires resources from both B2B buyer and service provider, then proximity to points of surplus of resources may attenuate the negative effects of geographic complexity. Nachum et al. (2008) introduce the idea of a country proximity to other countries to evaluate how a country's access to knowledge, markets, and resources impact multinational enterprise location choices. We rely on their ideas to develop our own about how the proximity of a B2B buyer organizational unit to a point of abundant resources can corroborate to alleviate the geographic complexity by reducing the need to travel longer distances carrying resources to perform tasks.

Hypothesis 2e: Group of B2B buyers with high levels of geographic complexity will be distinguished from other groups by exhibiting higher number of organizational units that locate proximate to surplus of resources.

2.4. Service and geographic complexity and magnitude of service disruption

Based on the extant literature on supply chain risk (Craighead et al., 2007; Ellis et al., 2010; Hendricks and Singhal, 2003, 2005a, b; Kleindorfer and Saad, 2005; Zsidisin, 2003a, b; Zsidisin and Ellram, 2003; Zsidisin and Smith, 2005), we define magnitude of service disruption as the consequential detrimental effects caused by an unplanned and unanticipated disruption in the flow of services from the service provider to the buyer. Such disruptions may be caused by multiple antecedents, like delays of suppliers, machine breakdown, inability of suppliers to process information, drop on plant capacity, natural disaster, shortfalls, and shortage, among others (Chopra and Sodhi, 2004; Hendricks and Singhal, 2003; Kleindorfer and Saad, 2005). More important for the purpose of this study, though, is the fact that, as product and service complexity increases (Harland, Brenchley and Walker, 2003) and as firms become more dependent on each other during co-operation activities (Hallikas, Karvonenb, Pulkkinenb, Virolainenc and Tuominen, 2004), the likelihood of disruptions also increases. Because of the inherent co-production characteristics of services (Fitzsimmons and Fitzsimmons, 2008; Roth and Menor, 2003), we follow this line of reasoning by arguing that service and geographic complexity may affect the magnitude of service disruption in the sense that they may hinder the ability of service provider and B2B buyer to quickly coordinate actions and recover from potential unplanned disruptive events, increasing the magnitude of service disruptions.

Hypothesis 3: Group of B2B buyer with higher levels of service and geographic complexity will experience higher magnitude of disruption in their services than those groups with lower levels of service and geographic complexity.

3. METHODOLOGY

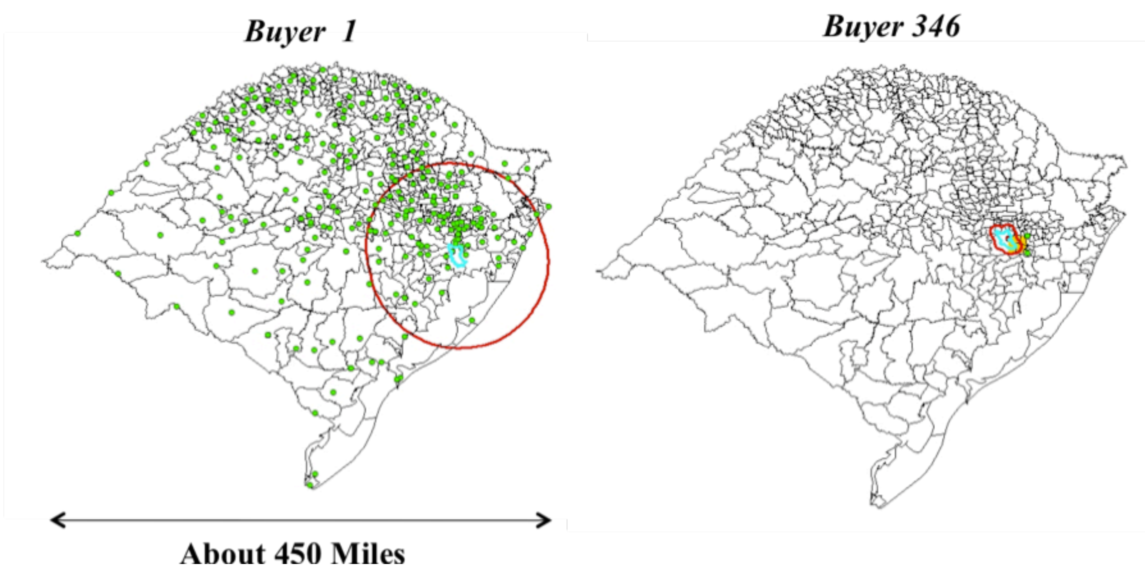
3.1. Research Context, Network Structure, and Novel Services

The scope of this study concerns the B2B buyer network structure of telecommunication services in the context of the Brazilian largest telecommunication service provider and its B2B buyers located in Rio Grande do Sul, the southernmost state of Brazil. In 2008, the state of Rio Grande do Sul had a total population of 10,5 million habitants (5th highest) and annual GDP of 110 billion dollars (4th highest), which corresponds, respectively, to 5,2% and 6,8% of Brazilian entire population and total GDP. Composed of many former government telecommunication companies privatized in 1998, the telecommunication service provider has more than 10,000 employees and operations in all 26 Brazilian states, 40 million customers, and market share of land, mobile services of, respectively, 85% and 25%.

The B2B buyers network structure is basically composed of organizational units, hereafter called nodes, located in different geographic positions. It means that each B2B buyer performs operations nodes located in different places, characterizing its unique network structure where services have to be delivered. To illustrate, Figure 1 shows the network structure of Buyer 1 and Buyer 346 of our database. Each dot in the map is a location where the B2B buyer has operations and, consequently, where services have to be delivered in the state of Rio Grande do Sul, Brazil. Although the operationalization of position of nodes (central and peripheral) is only discussed later, the figure also shows the circle that make up the central area, delimiting and qualifying nodes according to their positions.

One important point to mention is the existent of two basic types of services: voice and data services. Voice services are based on a simple and disseminated technology (Fransman, 2001). Thus, most B2B buyers already possess the knowledge required to co-produce and operate voice services. However, data services are customized services based on more sophisticated, innovative, and constantly up-to-dated technology (Fransman, 2001). Hence, these two types of services have different degrees of novelty, in which data services can be used as a proxy for novel services, while voice services can be used as a proxy for non-novel services.

Fig. 1 – Network Structure for Buyer 1 and Buyer 346



3.2. Sample and Data Collection

Based on information gather during the exploratory phase of this research, we define the population as the segment of B2B buyers having at least one data telecommunication service delivered in their facilities. Given the nature of this study and recommendations in the literature (Hair, Anderson, Tatham and Black, 1998; Milligan and Cooper, 1987), the main guidelines driving the selection of sample units were: (i) maximization of the amount of B2B buyers with a network structure for service delivery composed of more than 3 locations (nodes) and (ii) population representativeness, maintaining almost the same representation of each major strata existent in the population. Based on these guidelines, the sampling process consisted of identifying characteristics of major population strata, so that these strata could be used as reference to guide the selection of sample units. Then, a randomized process was conducted to select B2B buyers in each one of these strata. Our sampling frame consists of 408 B2B buyers randomly selected from the telecommunication service provider database of operations located in the state of Rio Grande do Sul, Brazil. As shown in Table 1, some strata are overrepresented in our sample because we tried to maximize the number of multiple node B2B buyers. According to the formula for sampling size provided by Dillman (2007), this sample yields a sampling error of 4,65%, assuming a 95% confidence level and the highest proportion of variation in the population characteristics (p=0.5). The characteristics of population and sample of B2B buyers are shown in Table 1.

Table 1 – Population and Sample Characteristics

	Population[1] (N)		Sample (n)		Sample Representation of Population (n/N)
B2B Buyers with data services	4,887		408		8.3%
Number of data services	29,756		7,888		26.5%
Number of voice services	496,346		110,390		22.2%
Monthly expenses with data services[2]	USD 17,641,182.86		USD 3,201,838.62		18.1%
B2B Network Structure	**Frequency**	**% of Population**	**Frequency**	**% of Sample**	
Single nodes	3,108	63.6%	216	52.9%	6.9%
Multiple nodes	1,749	35.8%	192	47.1%	11.0%
Missing[3]	30	0.6%	0	0.0%	
B2B Industry					
Manufacturer	848	17.4%	112	27.5%	13.2%
Retailer	609	12.5%	62	15.2%	10.2%
Services	1,356	27.7%	171	41.9%	12.6%
Government	472	9.7%	44	10.8%	9.3%
Energy	9	0.2%	5	1.2%	55.6%
Entretainment	67	1.4%	14	3.4%	20.9%
Other[4]	1,526	31.2%	0	0.0%	0.0%

Notes:
1 Population of B2B buyers located in the state of Rio Grande do Su, Brazil (Base = January 2009).
2 Monthly expenses on January 2009.
3 Missing data here is caused by error in thetelecommunication service provider database impeding identification of the B2B network structure.
4 Composed of B2B buyer of small businesses in many industries not identified in the telecommunication service database.

3.3. Operationalization of Variables

This study is based on variables involving distances, area, and density of nodes. For this reason, it is important to clarify the procedures adopted to operationalize some variables. To do so, we employed the ArcGis 9.2 software and performed the following steps:

1) Identification of the geographic position where each node is located. Each node is a dot in our map (see Figure 1). Because each node has a specific position in the two-dimension geographical space, we identified the latitude and longitude of each node to plot it in the ArcGis software. This procedure was performed for all nodes of all B2B buyers with more than one node. Identifying the geographical information of each node allowed us to use ArcGis software tools to measure distances and establish areas of network structure.

2) Definition of central node. As discussed in the literature review section, we define the central node as the one with the greatest amount of resources. According to qualitative interviews with information technology managers from seven B2B buyers and five sales account managers from the telecommunication service provider, the node with such characteristic is the headquarters of a B2B buyer. Thus, we follow the findings from our qualitative interviews to determine the headquarters of the B2B buyer as the central node.

3) Definition of central area of a B2B buyer network. To define the central area of a B2B buyer network, we first measured the distance between the farthest node and the central node of a given B2B buyer network structure. Second, we defined the radius of the central area as one-fourth of the highest distance. Finally, we established the central area by drawing a circumference with the radius starting at the central node. Therefore, B2B buyers with larger distances have larger central areas, while B2B buyers with smaller distances have small central areas. Figure 1 shows the circumference delimiting the central area for two B2B buyer network structures from our database.

4) Identification of central and peripheral nodes. After determining the central area, we used some tools available in ArcGis software to identify those nodes within the central area as central nodes and the others as peripheral nodes.

3.4. Selection of Variables

The selection of variables comprehended an iterative process in which, first, a set of variables was defined (service and geographic variables). Second, correlation and multicollinearity existent among variables were assessed to avoid their impact on further analysis (Hair et al., 1998). Finally, some variables were eliminated and we started over the process until have variables prone to cluster analysis. Table 2 presents descriptive and correlation measures for all variables in this study.

Table 2 – Correlations

		Mean	Std Dev	2	3	4	5	6	7	8
1	Total number of nodes	20.69	49.33	-0.10						
2	Density of network structure	12.49	46.87	-						
3	Average distance from the center (Km)	103.69	84.66	-0.3	-					
4	Percentage of central nodes	55%	24%	0.23	-0.5	-				
5	Number of nodes in big cities	2.28	2.26	-0.22	0.39	-0.21	-			
6	Percentage of nodes in big cities	32%	32%	-0.14	-0.2	0.12	0.16	-		
7	Quantity of data services per node in the central node	1.73	5.04	0.02	0.03	0.11	-0.04	0.26	-	
8	Quantity of voice services per node in the central node	3.98	25.76	0.02	-0.10	0.16	-0.06	0.06	0.35	-
9	Ratio data to voice services in the central node	0.28	0.59	0.03	-0.11	0.14	-0.2	0.17	0.25	-0.04
10	Average number of data services per node excluding the central node	0.81	1.16	-0.11	0.08	-0.03	0.38	-0.10	0.05	-0.07
11	Average number of voice services per node excluding the central node	2.37	5.22	-0.03	0.01	-0.01	0.12	-0.01	-0.01	0.05
12	Ratio data to voice excluding the central node	0.13	0.34	-0.07	-0.11	0.15	-0.07	0.08	0.07	-0.04
13	Coefficient of variation in data services	0.81	1.35	-0.1	0.30	-0.2	0.41	-0.2	-0.10	-0.07
14	Coefficient of variation in voice services	0.73	1.22	-0.1	0.14	-0.2	0.32	-0.15	-0.06	-0.06
15	Number of dense nodes	4.85	11.18	-0.11	0.36	-0.2	0.51	-0.3	-0.09	-0.06
16	Percentage of dense nodes	0.20	0.26	-0.2	-0.02	-0.14	0.19	0.02	-0.07	-0.07
17	Mean magnitude of service disruption (min)	319.01	634.18	-0.04	0.02	0.09	0.14	-0.01	-0.05	-0.01

Correlations > |0.13| are significant at 0.05 level

(Table 2 - continued)

		9	10	11	12	13	14	15	16	17
1	Total number of nodes									
2	Density of network structure									
3	Average distance from the center (Km)									
4	Percentage of central nodes									
5	Number of nodes in big cities									
6	Percentage of nodes in big cities									
7	Quantity of data services per node in the central node									
8	Quantity of voice services per node in the central node									
9	Ratio data to voice services in the central node	-								
10	Average number of data services per node excluding the central node	0.00	-							
11	Average number of voice services per node excluding the central node	-0.04	0.24	-						
12	Ratio data to voice excluding the central node	0.28	0.24	-0.12	-					
13	Coefficient of variation in data services	-0.14	0.02	0.07	-0.06	-				
14	Coefficient of variation in voice services	-0.05	0.37	0.12	0.27	0.22	-			
15	Number of dense nodes	-0.13	0.35	0.06	0.03	0.15	0.29	-		
16	Percentage of dense nodes	-0.05	0.30	0.08	0.13	0.05	0.22	0.31	-	
17	Mean magnitude of service disruption (min)	-0.10	0.10	0.07	-0.02	0.06	0.08	0.11	0.04	-

Correlations > |0.13| are significant at 0.05 level

3.4.1. Service variables

This set of variables deal with the service complexity existent in B2B buyer network structures. Based on results found during the exploratory phase, we created different variables to get information about the central node and about all other nodes in a B2B buyer network structure. Because the central node is the B2B buyer headquarters, it, typically, has a disproportional number of data and voice services than the number of data and voice services delivered to all other nodes in the network structure. The rationale is that as the number of nodes increase, so does the number of potential data services emanating from the central node to all these nodes to exchange data. Thus, to obtain more precise information about overall service complexity, we decided to have variables specifically designed to capture these nuances.

Quantity of data services per node in the central node. It refers to the total number of data telecommunication services existent in the central node adjusted for the total number of nodes in a B2B buyer network structure. Operationally, it is simply the total number of nodes existent in the central node divided by the total number of nodes. We adjusted this variable by the total number of nodes because B2B buyers with higher number of nodes tend to have more services in the central node than B2B buyer with fewer nodes.

Quantity of voice services per node in the central node. This variable is similar to the previous one, the only difference is that this variable measures voice services in the central node. In other words, it measures the total number of voice telecommunication services existent in the central node adjusted for the total number of nodes in a B2B buyer network structure.

Ratio data to voice services in the central node. This variable provides information about the amount of technological services existent in the central area of a B2B buyer network structure relative to amount of non-technological services. Operationally, it is the total number of data services divided by the total number of voice services delivered in the central node.

Average number of data services per node excluding the central node. It refers to the total number of data telecommunication services delivered to all nodes but the central node divided by the total number of nodes minus one (excluding the central one).

Average number of voice services per node excluding the central node. This variable measures the total number of voice telecommunication services delivered to all nodes but the central one divided by total number of nodes minus one (excluding the central node).

Ratio data to voice services excluding the central node. This variable provides information about the amount of technological services existent relative to amount of non-technological services out of the central node.

Coefficient of variation in data services. It refers to the amount of variation in the number of data services among all nodes, excluding the central one, of a B2B buyer network structure. Operationally, this variable is the standard deviation divided by the mean number of data services delivered to a B2B buyer.

Coefficient of variation in voice services. Similar to the previous variable, this one refers to the amount of variation in the number of voice services among all nodes, excluding the central one. It is the standard deviation in the number of voice services divided by its mean.

Number of dense nodes. This variable is the sum of all nodes that has a number of data services above the average number of data services in a given B2B buyer network structure. It does not take into account the number of data services delivered in the central node because of reasons discussed previously.

Percentage of dense nodes. It refers to the amount of dense nodes relative to the total number of nodes in a B2B buyer network structure.

3.4.2. Geographic variables

Total number of nodes. It refers to the total number of nodes in a B2B buyer network structure where services have to be delivered. It provides information about the size of a network structure. Operationally, this variable is simply the sum of all locations in which B2B buyers have telecommunication services delivered.

Density of network structure. It is a measure to determine how close nodes are to one another within a network structure. Operationally, it is the total number of nodes divided by the geographical area of which these nodes encompass. It can be interpreted as the number of nodes per 1,000 $Km^{2.}$ The higher this measure, more concentrated a B2B network structure is.

Average distance from the center to a given node. It refers to the average distance, in Km, from the central node to any given node in a B2B network structure. We used ArcGIS software to calculate the distance from the central nodes to all nodes of each B2B buyer. Then, we sum all them and divided by the number of nodes minus the central node.

Percentage of central nodes. It refers to the percentage of total number of nodes that are located in the center of a B2B buyer network structure. This variable gives information about the proportion of nodes close to the center and, theoretically, closes to the point of resources scarcity.

Density of network structure in the central area. This variable is similar to the density network structure presented previously. The difference is that this variable measures the density only within the network structure central area.

Number of nodes in big cities. It is the sum of B2B buyer nodes located in one of the six biggest cities, whose populations vary from 300.000 to 1.5 million people.

Percentage of nodes in big cities. Different than the previous variable, this one assesses the B2B buyer amount of nodes located in big cities relative to its total number of nodes.

3.4.3. Magnitude of disruption variable

Mean time of disruption. This variable averages the time, in minutes, for all disruptions that occurred in data services of a given B2B buyer within a 13-month period. The time for a disruption is defined as the time elapsed between the registration of a disruption and its recovery. Each disruption corresponds to a specific data service, and information about the date and time of a disruption and its recovery allowed us to measure this variable.

3.5. Cluster Analysis

Cluster analysis was employed to identify the B2B buyer network structure types according to the service and geographic variable discussed above. However, we had to conduct cluster analysis only for B2B buyers with more than a single node. The main reason to exclude B2B buyer made of a single node is that this type of network structure does not have characteristics that could be measured by all variables discussed previously. For example, single nodes B2B buyers neither have distances to be measured nor have variation in the number of data services among nodes. In conducting our cluster analysis we followed similar procedures to those employed by other researchers in OM literature (Jonsson, 2000; Menor, Roth and Mason, 2001; Miller and Roth, 1994). We adopted a hybrid approach by using hierarchical and nonhierarchical techniques to establish the final cluster solution. Before performing cluster analysis, we first conducted univariate and multivariate analysis to identify outliers to be removed from our analysis (Hair et al., 1998). Thus, B2B buyers with standard scores above a threshold value of 3 and/or a Mahalanobis distance probability smaller than 0.001 were considered outliers. We employed Mahalanobis distance also to check for multivariate normality of the data. Then, we used the Ward's hierarchical method to generate a set of cluster solutions based on the standardized variables. To help determining the number of clusters, we relied on the following guidelines: (i) Lehmann's (1979) suggestion that the number of clusters should be between $n/30$ and $n/60$; (ii) pronounced increase in the tightness of clusters through evaluation of coefficient of agglomeration (Johnson, 1998); and (iii) managerial interpretability of cluster solutions based on ANOVA tests complemented with Tukey's pairwise comparison tests of cluster mean differences. After determining the best cluster solution, we profiled the cluster centers of each variable to get the seeds. We input these seeds in a nonhierarchical method to fine-tune the results and get the final solution with the appropriate B2B buyer's membership.

4. RESULTS

4.2. Service Complexity

The initial sample used to analyze service complexity is composed of 192 multiple nodes B2B buyers. We employed univariate and multivariate analysis to identify and remove 28 outliers, resulting in a sample size of 164 B2B buyers. For those multiple node B2B buyers, four clusters of service complexity emerged and are described in Table 3 in terms of cluster means (centroid) of each variable. The clusters differ from one another on all ten service variables at the 0.05 level of significance. The table also shows the probability that one or more cluster means differ from the means of other clusters in each given variable based on Tukey pairwise comparison test. The identification and interpretation of clusters are based on values assigned for clusters in each network structure characteristic and on significant differences among groups of clusters. Although the existence of two groups at the high complexity level (High Complexity and Medium-High Complexity), an overall analysis of these results provides evidence supporting hypotheses 1a, 1b, and 1c. That is, groups of B2B buyers exhibiting high number and variability of novel services as well as high number of nodal services can be distinguish them groups of B2B buyers exhibiting low levels of these variables. The interpretation for each cluster is given bellow.

Cluster 1: Medium-High Service Complexity. B2B buyers in this group correspond to 16% of the sample analyzed. This is a complex group of B2B buyers because they have the highest quantity of data services per node in the central node, which suggests that they exchange high amount of data information with other nodes in the network. This conclusion finds support on the high score on variable average number of data services per node excluding the central node. As a counterpart, this group has the lowest quantity of voice services per node in the central node and the lowest average of voice services per node excluding the central node. These differences between data and voice services are also shown on the high score on ratios data to voice in the central node and excluding the central node. Overall, these results suggest that B2B buyers in this group rely substantially on technological services in and out of the central node to perform their operations.

Table 3 – Service Complexity Groups

Variables	Service Complexity Groups: 1- Medium-High n = 26 - 16% Mean (Std Dev)		2 - Low n = 96 - 58% Mean (Std Dev)		3 - High n = 31 - 19% Mean (Std Dev)		4 - Medium-Low n = 11 - 7% Mean (Std Dev)		Statistics
Quantity of data services per node in the central node	**2.13** (1.91)	[2,3]	0.92 (0.9)	[1]	0.49 (0.65)	[1,4]	1.84 (1.64)	[3]	*F*=12.36, *p*<0.0001
Quantity of voice services per node in the central node	0.94 (1.37)	[4]	1.43 (1.38)	[4]	1.24 (1.53)	[4]	**12.99** (4.22)	[1,2,3]	*F*=157.85, *p*<0.0001
Ratio data to voice services in the central node	**3.12** (2.11)	[2,3,4]	0.47 (0.51)	[1]	0.7 (0.98)	[1]	0.17 (0.19)	[1]	*F*=49.82, *p*<0.0001
Average number of data services per node excluding the central node	**1.33** (1.04)	[2,4]	0.29 (0.45)	[1,3]	1.01 (0.78)	[2]	0.58 (0.81)	[1]	*F*=21.26, *p*<0.0001
Average number of voice services per node excluding the central node	1.11 (0.89)	[3]	1.6 (1.85)	[3]	**4.1** (3.84)	[1,2]	2.48 (2.59)		*F*=10.94, *p*<0.0001
Ratio data to voice excluding the central node	**1.3** (1.32)	[2,3,4]	0.16 (0.38)	[1]	0.28 (0.28)	[1]	0.23 (0.43)	[1]	*F*=23.41, *p*<0.0001
Coefficient of variation in data services	0.61 (0.64)	[3]	0.54 (1.06)	[3]	**1.52** (1.23)	[1,2,4]	0.13 (0.28)	[3]	*F*=8.95, *p*<0.0001
Coefficient of variation in voice services	0.83 (0.9)	[2]	0.33 (0.48)	[1,3]	**0.95** (0.68)	[2,4]	0.31 (0.48)	[3]	*F*=11.15, *p*<0.0002
Number of dense nodes	1.62 (1.24)	[3]	0.34 (0.71)	[3]	**13.16** (11.34)	[1,2,4]	0.82 (1.83)	[3]	*F*=53.40, *p*<0.0001
Percentage of dense nodes	0.33 (0.3)	[2]	0.09 (0.2)	[1,3]	**0.4** (0.26)	[2,4]	0.17 (0.3)	[3]	*F*=17.48, *p*<0.0001

Note: The number in bracktes indicate the group means from which this group is significantly different at the 0.05 as significance level as indicated by the Tukeys pairwise comparison test. Numbers in bold indicate the highest group centroid for that variable.

Cluster 2: Low Service Complexity. This is the largest group, responsible for 58% of B2B buyers in the sample analyzed. B2B buyers in this group can be characterized by the low quantities and variation of data and voice services out of the central node and by the lowest ratios of data to voice services in and out the central node. Consequently, they have the lowest number and percentage of dense nodes. Taken together, the results suggest that B2B buyers in this group have few services in and out of the central node, which in turn reveals the simplest service network structure among all groups.

Cluster 3: High Service Complexity. This group represents 19% of the sample analyzed. B2B buyers in this cluster can be characterized by the highest variation in data and voice services out of the central node, by the highest number and percentage of dense nodes among all groups, and by the highest average of voice services out of the central node. These results suggest that some nodes in the B2B buyers network structure are considerably important by concentrating high proportion of data services compared to other nodes. On the other hand, some nodes may not be so important and have fewer services, resulting in the high coefficient of variation scores. They also have the second highest average of data services out of the central node, which it is not significantly different than the highest score on this variable. Overall, these results suggest that B2B buyers in this group do not have a central node so complex as that of B2B buyers in the Medium-High Service Complexity group, but do have a highly complex network structure out of the center that is based on technological services that vary significantly among nodes, which makes the network even more complex given the potential distances that need to be overcome during service co-production. This high variety in technological services out of the central node is what distinguishes B2B buyers in this group from those in the Medium-High Service Complexity group.

Cluster 4: Medium-Low Service Complexity. This is the smallest group with 17% of B2B buyers analyzed. The major characteristics distinguishing these B2B buyers from all other is its abnormal quantity of voice services in the central node, making its ratio data to voice services the lowest among all groups. However, they have the second highest score in the quantity of data services in the central node, which is not significantly different than that of B2B buyers in the Medium-High Service Complexity group. Taken together, these results suggest that the central node has a substantial number of technological services but its operations rely heavily on non-technological services. It is important to node that B2B buyers in this group score high in the average number of voice services out of the central node as well. Finally, this group is characterized by the low scores in variation of services, in number of dense nodes, and in ratios data to voice services. In sum, this group has a significant amount of non-technological services in and out of the central node.

We validate this model by running a discriminant analysis with the service complexity groups as dependent variable and the ten service variables as independent variables. The significant value for Wilk's Lambda = 0.03 ($p < 0.0001$) shows evidence of overall multivariate relationship. Then, we analyzed the discriminant loadings, which represent the correlations between the service variables and the discriminant functions, a helpful measure in determining which variables most contribute to distinguishing complexity among clusters. That is, the canonical correlations indicate the relative impact of service variables on complexity membership of B2B buyers. According to Rao's (1973) approximate *F*-statistics, the two canonical correlations ($R_{C1} = 0.88$, $R_{C2} = 0.80$, and $R_{C3} = 0.77$) are statistically significant ($p < 0.0001$) (see Table 4). Analysis of Cramer and Nicewander's γ_6 (1979), a measure of multivariate association obtained by taking the average of squared canonical correlations, indicates that 67% of variance in the service complexity groups is explained by the ten service variables employed in our study.

Again, we analyzed canonical loadings > $|0.60|$ to interpret the underlying dimensions present in the service complexity. According to Table 4, the first discriminant function suggests a differentiation by the quantity of non-technological services in the central node. B2B buyers scoring high non-technological services are likely to present low scores on all other variables, which in turn suggest a low level of complexity given that they rely heavily on this type of services to perform their operations. The second discriminant function, on the other hand, suggests a differentiation of B2B buyers by technological services in the entire network structure. B2B buyers that score high on technological services present low scores on non-technological services, variation, and number of dense nodes. Finally, the third discriminant function implies differentiation of B2B buyers by the number of dense nodes existent in a network structure. Such relative high number of technological services characterizing dense nodes allows us to speculate that these nodes might be important nodes for a given network structure since they are likely to concentrate and exchange more data information than those nodes that do not present the same technological density. B2B buyers that score high on these important nodes present a moderate variation in technological services and in number of voice services out of the central node, but they have a small number of technological services in and out of the central node.

Table 4 - Canonical loadings for Service Complexity variables

	Canonical Correlation Function	Eingenvalue or Root	R_C	Squared Canonical Correlation	*p*-value
	1	3.52	0.88	0.77	$p < 0.0001$
	2	1.84	0.80	0.64	$p < 0.0001$
	3	1.53	0.77	0.60	$p < 0.0001$

	Canonical Loadings			Canonical Coefficients		
Service Complexity Variables	Function 1	Function 2	Function 3	Function 1	Function 2	Function 3
Quantity of data services per node in the central node	0.07	0.41	-0.36	-0.12	0.00	-0.14
Quantity of voice services per node in the central node	**0.94**	0.29	0.01	**1.97**	0.80	0.10
Ratio data to voice services in the central node	-0.39	**0.69**	-0.31	-0.33	**1.11**	-0.27
Average number of data services per node excl. the central node	-0.20	**0.60**	0.18	0.09	**0.29**	0.01
Average number of voice services per node excl. the central node	0.04	0.04	0.53	-0.30	-0.07	0.45
Ratio data to voice excluding the central node	-0.25	**0.59**	-0.23	-0.40	**0.43**	-0.27
Coefficient of variation in data services	-0.19	0.06	0.43	-0.06	0.19	0.26
Coefficient of variation in voice services	-0.22	0.35	0.30	-0.10	0.19	-0.16
Number of dense nodes	-0.18	0.22	**0.86**	-0.02	0.19	**1.11**
Percentage of dense nodes	-0.17	0.46	0.38	-0.11	0.28	0.33

Finally, we cross-validate our results by performing a jackknife discriminant analysis to compute the misclassification rate using $n - 1$, out of n cases (Lachenbruch and Mickey, 1968). In this analysis, a discriminant function containing the ten service variables is computed to classify the B2B buyer held out, and this process is repeated for all 164 B2B buyers in this sample. Table 5 shows the results for number of correct classification and misclassification rates for service complexity groups. The overall misclassification rate is 15%, an acceptable rate to classify B2B buyer into the four service complexity groups. More specifically, the Low and Medium-Low Service Complexity groups do the better jobs in classifying B2B buyers correctly.

Table 5 – Cross-validation of Service Complexity groups

Assigned to cluster:	1	2	3	4	
From cluster:	Medium-High	Low	High	Medium-Low	Total
1 Medium-High	21 (81%)	3 (11%)	2 (8%)	0 (0%)	26
2 Low	1 (1%)	93 (97%)	2 (2%)	0 (0%)	96
3 High	1 (3%)	8 (25%)	22 (71%)	0 (0%)	31
4 Medium-Low	0 (0%)	1 (9%)	0 (0%)	10 (91%)	11
Missclassification Rate	19%	3%	29%	9%	15%

4.1. Geographic complexity

This sample is composed of 192 B2B buyers with multiple nodes. Similarly to the procedures applied to analyze service complexity, we used univariate and multivariate analysis to identify and remove 15 outliers, resulting in a sample size of 177 B2B buyers. For those multiple node B2B buyers, the three clusters of geographic complexity are described in Table 6 in terms of cluster means (centroid) of each variable. The clusters differ from one another on five variables at the 0.05 level of significance. The table also shows the probability that one or more cluster means differ from the means of other clusters in each given variable based on Tukey pairwise comparison test. The identification and interpretation of clusters are based on values assigned for clusters in each network structure characteristic and on significant differences among groups of clusters. An overall analysis of these results provides evidence that support four of five hypotheses about the distinguishing characteristics of B2B buyers in terms of Geographic

Complexity. The number and percentage of nodes in big cities are the only variables that we cannot make any substantial conclusion that helps us to make a decision about the conceptualized hypothesis. The interpretation for each cluster is given bellow.

Cluster 1: High geographic complexity. Comprehending 37% of all B2B buyers of this sample, this cluster is labeled "high geographic complexity" because B2B buyers in this group have the (i) the highest number of nodes, (ii) the highest average distance from the center to any given node in the network, and (iii) the most dispersed network structure (given by the smallest coefficients of density of network structure). B2B buyers in this group have to be able to manage co-production in a large amount of different locations in which services are delivered and overcome large distances to reach this goal.

Table 6 – Geographic Complexity Groups

Variables	Geographic Complexity Groups						Statistics
	1 - High n=67 - 37% Mean (Std. Dev.)		2 - Medium n=69 - 39% Mean (Std. Dev.)		3 - Low n=41 - 24% Mean (Std. Dev.)		
Total number of nodes	**33.12** (44.07)	[2,3]	6.35 (6.12)	[3]	3.51 (2.1)	[1,2]	$F = 21.56$, $p < 0.0001$
Density of network structure	0.2 (0.17)	[3]	1.71 (3.06)	[3]	**9.95** (9.21)	[1,2]	$F = 56.64$, $p < 0.0001$
Average distance from the center	**198.36** (55.61)	[2,3]	70.32 (25.88)	[1,3]	18.55 (7.25)	[1,2]	$F = 336.19$, $p < 0.0001$
Percentage of central nodes	41% (0.15)	[2,3]	55% (0.21)	[1,3]	**72%** (0.27)	[1,2]	$F = 27.38$, $p < 0.0001$
Number of nodes in big cities	**3.45** (2.48)	[2,3]	1.74 (1.75)	[1]	1.22 (1.17)	[1]	$F = 20.56$, $p < 0.0001$
Percentage of nodes in big cities	26% (0.23)		**37%** (0.31)		**37%** (0.35)		$F = 3.03$, $p = 0.0510$

Note: The number in bracktes indicate the group means from which this group is significantly different at the 0.05 as significance level as indicated by the Tukeys pairwise comparison test. Numbers in bold indicate the highest group centroid for that variable.

Cluster 2: Medium geographic complexity. Responsible for 39% of all B2B buyers of this sample, this cluster is characterized by B2B buyers that have network structure characteristics that are the middle term between high and low geographic complexity. On overall, these B2B buyers have network structures composed of few nodes that are dispersed over a large geographic area, even though this area is almost one third of the area of B2B buyers in the high geographic complexity cluster. Also, they have the largest percentage of nodes in big cities, together with B2B buyer of low geographic complexity cluster.

Cluster 3: Low geographic complexity. B2B buyers in this group represent 24% of this sample and are characterized by having highly concentrated network structures where few nodes are located close to one another. The highest scores and significant differences in (i) density of network structure density as well as in (iii) the percentage of central nodes corroborate for this conclusion. This conclusion finds support on the small distances B2B buyers in this group have to travel to reach their nodes.

We validate our model by running a discriminant analysis with the geographic complexity groups as dependent variable and the seven geographic variables as independent variables. The significant value for Wilk's Lambda = 0.13 ($p < 0.0001$) is an evidence of overall multivariate relationship. The discriminant loadings were employed again to determine those variables that are more important to distinguishing geographic complexity among groups. According to Rao's (1973) approximate *F*-statistics, the two canonical correlations ($R_{C1} = 0.90$ and $R_{C2} = 0.46$) are statistically significant ($p < 0.0001$) (see Table 7). Analysis of Cramer and Nicewander's γ_6 (1979) shows that 52% of variance in the geographic complexity groups is explained by the set of six geographic variables employed in our study.

To interpret the underlying geographic complexity dimensions, we analyzed canonical loadings > $|0.60|$, as shown in Table 7. The first discriminant function suggests a differentiation by the distance each B2B buyer has to travel to reach any node in its network structure. Then, B2B buyers scoring high on distance tend to have nodes located far away from the central node. They also have a moderate number of nodes dispersed over a large geographic area and few nodes located in the central area. The second discriminant function, on the other hand, suggests a differentiation of B2B buyers by density of network structure. In other words, B2B buyers scoring high on network structure density are likely to have a relative small number of nodes very close to the center of their network structures. It is also reflected on the small distances between the central node and any other node in a given network structure.

Table 7 – Canonical loadings for Geographic Complexity variable

Canonical Correlation Function	Eigenvalue or Root	R_C	Squared Canonical Correlation	*p*-value
1	4.73	0.90	0.82	$p < 0.0001$
2	0.28	0.47	0.22	$p < 0.0001$

	Canonical Loadings		Canonical Coefficients	
Geographic Complexity Variables	Function 1	Function 2	Function 1	Function 2
Total number of nodes	0.48	0.22	0.06	0.05
Density of network structure	-0.55	**0.81**	-0.21	**1.28**
Average distance from the center	**0.98**	0.08	**2.02**	0.51
Percentage of central nodes	-0.52	0.30	-0.12	-0.03
Number of nodes in big cities	0.48	0.09	0.37	0.23
Percentage of nodes in big cities	-0.19	-0.11	-0.05	-0.30

Finally, we cross-validate our results by performing a jackknife discriminant analysis, as performed in the case of service complexity. Results for number of correct classification and misclassification rates are given in Table 8. The overall misclassification rate of 13% suggests that the six variables acceptably classify B2B buyer into the three geographic complexity groups. As the classification rates demonstrate, the Medium Geographic Complexity group does the better job in classifying B2B buyers correctly.

Table 8 – Cross-validation of Geographic Complexity Groups

Assigned to cluster:	1	2	3	
From cluster:	High	Medium	Low	Total
1 High	60 (90%)	7 (10%)	0 (0%)	67 (100%)
2 Medium	1 (1%)	65 (94%)	3 (5%)	69 (100%)
3 Low	0 (0%)	10 (24%)	31 (76%)	41 (100%)
Missclassification Rate	10%	6%	24%	14%

4.3. Service and Geographic Complexity and Magnitude of Disruptions

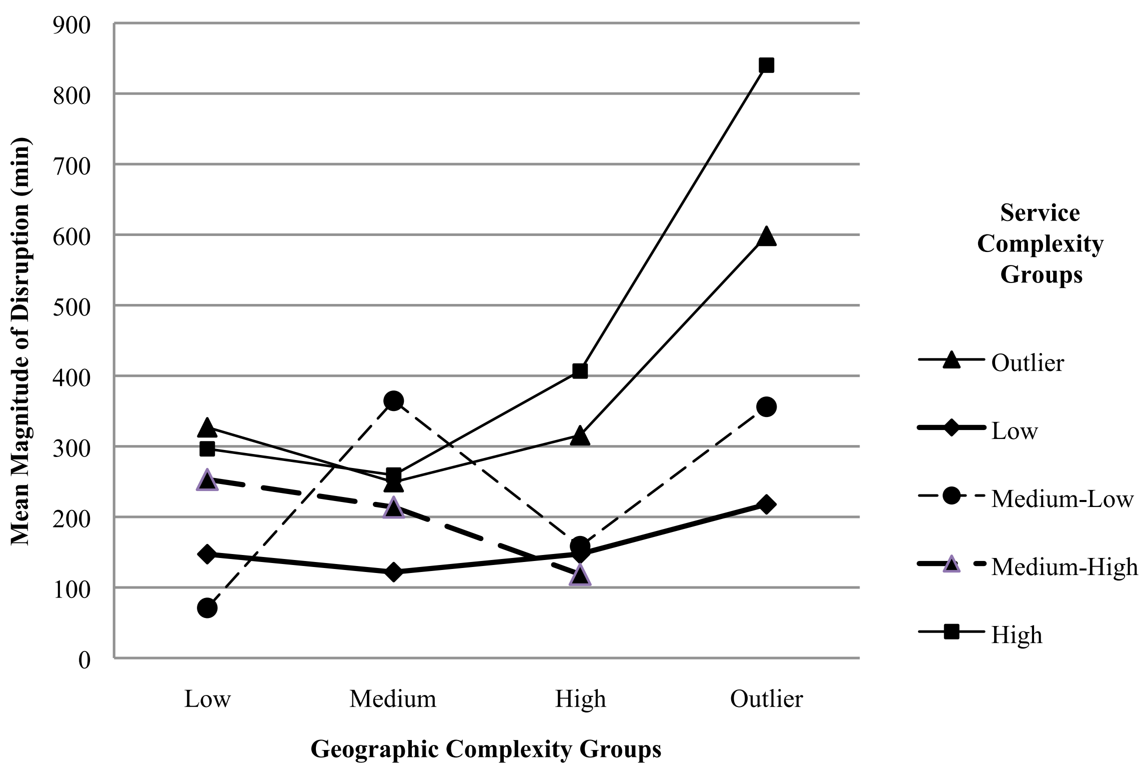
We now classify B2B buyers according to their group membership in each one of the Service and GeographicComplexity dimensions to conduct a two-factor ANOVA test to evaluate whether an interaction between these two dimensions are present. For this test, we also incorporated B2B outliers to evaluate their differences from other B2B buyers, yielding a 4x5 matrix. Because B2B buyers are not equally distributed among all cells in the matrix and because one cell is empty, we used Type III and Type IV sum of squares to make our decision. During the analytical process, we relied on residual analysis to identify and remove nineteen B2B buyers whose magnitude of disruptions was over-inflated. All other major assumptions for conducting ANOVA test were met.

Table 9 – Two-factor ANOVA results

Source	DF	Sum of Squares	Mean square	*F* Value	*P* Value
Model	18	2730815	151711.93	5.95	< 0.0001
Error	154	3928716	25511.143		
Corrected Total	172	6659531			
Source	**DF**	**Type IV SS**	**Mean Square**	***F* value**	***P* value**
Geographic	3	600936.5	200312.15	7.85	<.0001
Service	4	1290048	322511.89	12.64	<.0001
Geographic x Service	11	588461.6	53496.508	2.1	0.0235

The final results in Table 9 indicate that the interaction between Service and Geographic Complexity dimensions has an effect on the magnitude of service disruptions ($F = 2.09$, $p = 0.024$). To visualize the effects of such interaction, we plot the means of magnitude of disruptions for each combination of levels of Service and Geographic Complexity dimensions. Figure 2 suggests that High, Low, and Outlier groups of Service Complexity (solid lines in the figure) present similar patterns of magnitude of service disruption in relation to Geographic Complexity. That is, as Geographic Complexity increases, the magnitude of service disruption decreases and, then, increases at different rates for High, Low, and Outlier groups of Service Complexity, suggesting a U-shape relationship. On the other hand, Medium-Low and Medium-High groups of Service Complexity (denoted by dashed lines in Figure 2) show different patterns. As Geographic Complexity increases, the magnitude of service disruption in the former group presents high variability, increasing, decreasing, and increasing again substantially, while it only decreases in the latter group. Finally, it is important to note that our sample could not provide a single B2B buyer in the group combining Outliers in Geographic Complexity and Medium-High in Service Complexity, as Figure 2 demonstrate in the incomplete dashed line for this group.

Figure 2 – Interaction between Service and Geographic Complexity dimensions



To better evaluate the interaction between Service and Geographic Complexity, we conducted a Tukey pairwise comparison test for the means of magnitude of service disruption for all combinations of levels (all cells in our 4x5 matrix) of Service and Geographic Complexity (see Table 10)

Table 10 - Pairwise comparison test two-factor ANOVA means

Cell Number	Cell Complexity Group (Geographic x Service)	Mean Magnitude of Disruption (min)‡	Rank	Pairwise Differences†					
4	Low x Medium-Low	71.00	1	Cell 16***	Cell 19**				
13	High x Medium-High	118.63	2	Cell 16***	Cell 19**				
7	Medium x Low	121.79	3	Cell 16***	Cell 19***				
2	Low x Low	147.20	4	Cell 16***	Cell 19**				
12	High x Low	147.51	5	Cell 16***	Cell 19**				
14	High x Medium-Low	158.50	6	Cell 19**					
9	Medium x Medium-High	213.90	7	Cell 16***					
17	Outlier x Low	217.77	8						
10	Medium x Outlier	249.37	9	Cell 16**					
3	Low x Medium-High	253.11	10	Cell 16**					
6	Medium x High	259.31	11	Cell 16**					
1	Low x High	296.48	12	Cell 16*					
15	High x Outlier	315.78	13	Cell 7*	Cell 16**				
5	Low x Outlier	326.99	14	Cell 16**					
18	Outlier x Medium-Low	356.08	15						
8	Medium x Medium-Low	364.53	16						
11	High x High	406.73	17	Cell 2***	Cell 4**	Cell 7***	Cell 12***	Cell 14**	Cell 16**
19	Outlier x Outlier	598.40	18						
16	Outlier x High	840.27	19	Cell 17***					

‡ Least Square Mean
† Adjusted Tukey
*** Significant at 0.001
** Significant at 0.05
* Significant at 0.1

Base on these results, we can articulate some insights about the effect of Service and Geographic Complexity dimensions on the mean magnitude of service disruption. First, the set of cells with mean magnitude of service disruption bellow 200 minutes is characterized primarily by groups scoring low in Service Complexity, while scores vary more for Geographic Complexity. The mean in all cells of this group significantly differs from the mean in cells of the group with more than 400 minutes of service disruption. Second, the set of cells with mean magnitude of service disruption between 200 and 400 minutes is characterized primarily by groups scoring medium to high in the Service Complexity dimension and varying scores substantially in the Geographic Complexity one. The majority of significant differences found in this group are related to the means of cells with more than 400 minutes. Finally, the cells with a mean magnitude of service disruption above 400 minutes are characterized by groups scoring high on both Service and Geographic Complexity dimensions. Overall, these results suggest that the mean magnitude of service disruptions tends to be driven more by Service Complexity than by Geographic Complexity. Thus, to gain more insights about these dimensions, we tested the main effect of each dimension on each level of the other dimension (see Table 11).

Table 11 – Test for main effects of Service and Geographic Complexity

a)

Geograhic Complexity	DF	Sum of Squares	Mean square	*F* Value	*P* Value
High	4	870334	217583	8.53	<.0001
Low	4	237670	59417	2.33	0.0586
Medium	4	295029	73757	2.89	0.0242
Outlier	3	730769	243590	9.55	<.0001

b)

Service Complexity	DF	Sum of Squares	Mean square	*F* Value	*P* Value
High	3	508588	169529	6.65	0.0003
Low	3	61739	20580	0.81	0.4920
Medium-High	2	61544	30772	1.21	0.3021
Medium-Low	3	196055	65352	2.56	0.0570
Outlier	3	184680	61560	2.41	0.0689

The results corroborate with the previous speculations that the magnitude of service disruption is primarily influenced by Service Complexity dimension. Table (a) shows that Service Complexity has a significant effect for each level of Geographic Complexity. On the other, Geographic Complexity does not have significant effects for all levels of Service Complexity, only for High, Medium-Low and Outlier levels. Taken together these results provide some support for hypothesis 3, since higher levels of Service and Geographic Complexity are associated with higher magnitude of disruptions. However, the fact that Geographic Complexity does not have the same effect of Service Complexity place some concerns on the full support of hypothesis 3.

5. DISCUSSION

The taxonomy of Service Complexity presents two groups distinguishing themselves by high and low levels of complexity. One may say, then, that an alternative cluster solution could be two groups, rather than four. However, a detailed analysis shows that four groups distinguish B2B buyers better than a possible two group solutions. The pairwise comparison tests conducted indicate that the two groups on the high portion of Service Complexity (High and Medium-High) significantly differ in six out of ten variables employed to classify B2B buyers. Their scores vary substantially in these six variables, and forcing a two clusters solution, instead of four, could imply in loss of important information. Although the same rationale cannot be applied to the two groups in the low portion of Service Complexity because they are significantly different in only one variable, a careful analysis of such variable suggests that these two groups vary substantially in their score. The Medium-Low group scores almost ten times higher the score of the Low group in the quantity of voice services per node in the central node. Again, by forcing a two clusters solution could result in loss of information about characteristics of these B2B buyers.

What is clear from these results is that novel services play a key role in determining Service Complexity. For instance, groups with higher levels of Service Complexity exhibit higher scores on the amount and percentage of novel services in their network structure, which corroborates with the conceptualized hypotheses developed in the literature review section. On the other hand, groups with lower levels of Service Complexity present the smallest amount and percentages of novel services. The canonical loadings also corroborate with such findings.

Groups with high levels of Service Complexity also exhibit higher number of dense nodal services, which in turn is associated with higher variability. Such findings linking dense nodal services with variability indicate that a small number of organizational units tend to concentrate large amount of novel services, while a large number of those units concentrate small quantities. An important question that emerges is how these dense nodal services are distributed in the B2B buyer network structure, because the way they are distributed could serve as points of surplus of resources, given that may require more resources to operate.

Turning our attention to Geographic Complexity, the pairwise comparison results clearly indicate that the three clusters solution seems the best solution possible. The three groups significantly differ from one another in three out of six variables, while at least two groups significantly differ in other two. Only the percentage of nodes in big cities is not statistically significant between pairs of groups, even though it is in the limit of an overall significant different at 0.05 level. An overall analysis of scores clearly demonstrates that the three groups have centroids that justify their classifications as high, medium, and low in terms of Geographic Complexity.

With respect to treatment of outliers, the pairwise comparison of two-factor ANOVA and plot of results suggest that we made a good decision in considering them extreme cases. The presence of outliers in the interactions between Service and Geographic Complexity denotes a substantial increase in the magnitude of service disruptions in almost all combinations. The only exception is in the case of High Service Complexity group, since this group performs worst in terms of magnitude of service disruptions than the Outlier Service Complexity group.

In discussing about interaction, two results call attention. The first is the slightly U-shaped pattern in the magnitude of service disruptions for the High, Low, and Outlier groups of Service Complexity. More specifically, the magnitude of service disruptions has a small, and perhaps negligible, decrease when comparing low to medium Geographic Complexity groups, but it is still a counter-intuitive result, since an increase was expected. After reaching an optimal minimum point, however, the magnitude of service disruptions increases substantially when comparing medium and high Geographic Complexity groups. As a potential explanation for these results, we rely on some tenets of organizational contingency theory (Child, 1972; Galbraith, 1973; Pugh and Hickson, 1968) to speculate that an intermediate size of a B2B buyer organizational structure, denoted by an increase in the Geographic Complexity, allow B2B buyers to find the best fit between size and control, while a higher size in the B2B buyer network structure makes difficult to establish the appropriate control mechanisms. What is missing to make a better evaluation, however, is the age and of these organizations, because differences in size and control can be a function of the speed to which an organization grows. Thus, fast-pacing organizations may achieve higher sizes without the time required to establish the control mechanisms to handle an increase in complexity.

The second set of results that call for attention is that for groups presenting medium level of Service Complexity. These two groups are distinct in the use of novel services. The Medium-low group is characterized by the high amount of non-novel services, while the Medium-High group is characterized by the high amount of novel services. Not surprisingly, their results follow different patterns. Even if the differences in the magnitude of service disruptions are not significant among groups, the unexpected patterns presented in each case surprise. First is the erratic pattern of increase-decrease-increase in magnitude of service disruptions for the Medium-low Service Complexity group as one compares groups from lower to higher levels of Geographic Complexity. Second is the decreasing pattern in the magnitude of service disruptions for Medium-high Service Complexity group as one compares groups from lower to higher levels of Geographic Complexity. The only possible explanation with information at hands seems to rely on the size and resources of B2B buyers, the utilization of novel services and the lack of variability in the network structure. An important and realistic assumption that we have to make, though, in order to explain these results is based on the fact that co-production of novel services requires a disproportional amount of resources when compared to non-novel services. Thus, B2B buyers in the Medium-high group of Service Complexity (i.e. novel services) that are also in the Low group of Geographic Complexity may be small B2B buyers that find themselves in the process of establishing the required resources and activities to properly co-produce novel services, and the higher magnitude of service disruptions may reflect this characteristic. By having higher sizes, and more resources, B2B buyers in the Medium and High group of Geographic Complexity may have already established all necessary conditions to perform activities to co-produce the service. The lack of variability in their network structure may also contribute to facilitate managing these activities, and the small magnitude of disruptions may reflect this scenario.

On the other hand, B2B buyers in the Medium-low group of Service Complexity (i.e. non-novel services) do not need too many resources to co-produce such services. Hence, small firms and medium firms may not have the necessary conditions to perform activities of co-production, but a small geographic area (Low Geographic Complexity) may facilitate the managing of such services, while a larger geographic area (Medium Geographic Complexity) may pose difficulties to managing them. On the other hand, larger B2B buyers (High Geographic

Complexity) may have already reached the point in which they have enough resources to organize and manage the amount of non-novel services, and the erratic pattern in the magnitude of service disruptions reflect such variety of scenarios.

6. CONCLUSION, LIMITATIONS, AND FUTURE RESEARCH

The objective of was to classify B2B buyers according to Service and Geographic Complexity resulting from their network structure and evaluate the effects of the combination of these complexities on differences in the magnitude of service disruptions. We reached our goal and showed that a taxonomy of Service Complexity is based on the quantity and variability of novel services as well as on the number of organizational units with an abnormal amount of novel services. We also showed that a taxonomy of Geographic Complexity is based on the distances, positions, and number of organizational units as well as on the density of a B2B buyer network structure. Finally, we also provide some evidence showing that, in sum, as the Service and Geographic Complexity increases, the magnitude of service disruptions also tends to increase, however the effects of Service Complexity are more pronounced than those of Geographic Complexity.

We made some contributions for the service and supply chain risk literature. First, we brought B2B buyers to the discussion of supply chain risk and disruptions, discussing how they can become a source of potential disruptions. Second, we highlighted an important piece of service supply chain that has been neglected in the literature: the B2B buyer network structure where services are delivered. Third, we provided an operational definition and empirically classified B2B buyers into Service and Geographic Complexity. Fourth, we demonstrated how disruptions in service supply chains might be influenced by differences in B2B buyers Service and Geographic Complexity. And, finally, we introduced the usage of a new tool for service and operations management scholars so that they can make use of its as well to explore new variables so far unexplored because of limitations existent in measuring distances.

We recognize some limitations in our work, but we hope they serve as motivators to development of future research. First, Service and Geographic Complexity should be tested in other industries to validate their power to classify B2B buyers in the context of service supply chains. Some industries in which future studies could be developed are: software, public utilities, transportation, and other new technology industries. Also, other studies could add new variables to Service and Geographic Complexity in order to improve them. Second, we did not have information about the age of organizations in the sample, limiting our ability to make more definitive conclusions about the effects of Service and Geographic Complexity on the magnitude of service disruptions. Third, we did not have data to evaluate the real ability and resources of each B2B buyers to better assess the combination effects of the complexities analyzed in this study and disruptions. Future studies could develop empirically constructed measures to assess B2B buyers' ability to efficiently co-produce novel services. Finally, a longitudinal study to investigate the impact of change in the structure, resources, and knowledge of B2B buyers after the implementation of novel services could be developed to improve our knowledge about the relationship between these variables and risk of disruption.

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