Third parties in the context of Smart Grid: information processing theory based approach

Completed Research

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Abstract

Given the augmented consumption related to increasingly limited resources, power grids based information technology (IT) such as smart grids (SG) are more solicited. Modernization of the electricity sector through SG involves third parties (eg, IT organizations) in the electricity supply chain. Based on information processing theory (IPT), this research aims to contribute to the understanding of the relationship between information processing capabilities, third parties (inter-organizational relationships), information requirements and organizational performance. The results of this research improve scientific knowledge of Information System (IS) by proposing an extension of the IPT taking into account the inter-organizational arrangements brought by the introduction of third parties in the context of SG. Furthermore, these results provide the electricity sector with insights that will help responding to changes due to disruptive technologies such as SG, improving effectiveness of provided services and meeting energy and economic goals pursued by the SG.

Keywords

Smart grid, third parties, information requirements, information processing capabilities, alignment, organizational performance, inter-organizational information systems.

Introduction

Electricity consumption continues to increase in the world (IEA, 2016). Investing in renewable energy is one of the most viable options for reducing the carbon footprint (Bélaïd and Youssef 2017). Thus, concepts around the construction of electricity and sustainable energy distribution networks are attracting more and more attention (Kezunovic et al., 2017). Managers adopt environmental sustainability in their strategic vision (Malhotra, Melville et al., 2013) and the technologies supporting sustainable development are sought by the electricity sector (Erlinghagen and Markard 2012, Wunderlich et al., 2012). Similarly for the academic world, Watson et al. (2010) highlight the need to introduce a new field of research to the discipline of IS. This is the "energy informatics" allowing recognizing the role that IS plays in reducing energy consumption and emissions of greenhouse gases (Watson et al., 2010). The main concepts in this field of research include the SG, which have gained considerable popularity in both practitioners and academics (Skjølsvold and Ryghaug 2015). SG refer to the smart electricity grids that are broadly interested in the modernization of the electricity sector, including the introduction and generation of distributed and renewable energies, infrastructure for self-monitoring and advanced measurement infrastructures (Smart Meters, or SMs) (Corbett 2011, Goel 2015). SG are composed of a range of technologies with real-time bi-directional information flow capability between the consumer and the network manager (Wunderlich et al., 2012).

On the one hand, this information enables power generation organizations to improve their consumer services as well as their billing, planning, network management and other processes, etc. On the other hand, they provide timely feedback to consumers (Sodenkamp et al., 2017) to help them control their consumption, save money and reduce their CO_2 emissions (Hargreaves et al., 2010). However, the revolution of the environment of the sector of the electricity by the integration of SG poses major challenges for power distribution organizations in the processing of information generated by SG

technologies (IBM, 2012). Previously, IT could often be integrated without fundamentally changing organizations in the electricity sector, but SG technologies are seen as disruptive technologies that require organizations in this sector to revisit their information processing for better organizational performance (Schuelke-Leechetal et al., 2015). As a result, several organizations are using third parties to meet the energy and economic goals pursued by the SG and to cope with the large volumes of information generated by SG technologies. For example, in 2014, Hydro-Québec (one of Canada's largest electricity suppliers) decided to process consumption data from SM externally by the American company C3 Energy, an organization that offers IT solutions that help electricity providers in the management of SG.

In the context of SG, a third party is defined as a service supplier providing customers with energy efficiency products and services by accessing information generated by SG technologies as well as home devices such as display screen connected to SM (Ercot, 2014). The introduction of third parties into an organization's supply chain can have significant organizational impacts such as the creation of new business processes that cover partners with different objectives and stakeholders (Premkumar et al. 2005). Electricity generation organizations must then have the capacity to process the information needed for a better management of the exchanges (Schuelke-Leechetal et al., 2015). The information must be managed in a way that serves the different actors (Brandstätt et al., 2014). The use of IS is one of the strategies for improving information processing capacity (Galbraith, 1974). The literature emphasizes that the support of inter-organizational processes with IS is very complex (Kurnia and Johnston 2000). These inter-organizational information systems (IOS) must take into consideration that supply chains (multi-actors) are composed of multiple partners with a wide range of communication and exchange needs (Premkumar et al. 2005). With the emergence of SG, the traditional supply chain for electricity services has evolved significantly. Third parties are now part of the new supply chain (Buchmann, 2017). The fit between the technological capability of the organization and the requirements of business processes is a necessity (Premkumar et al., 2005), especially in the case of power generation organizations that are rapidly evolving from one system (single organization) to a multi-stakeholder system (Brunekreef et al., 2016). The integration of these third parties poses significant challenges for power generation organizations in managing information processing (Buchmann, 2017).

The presence of third parties can reduce the efficiency of information processing if electricity distribution organizations do not adopt new governance approaches to ensure better information management between different parties (Brandstätt et al 2014). In addition, the literature shows that the uncertainty in inter-organizational interactions is greater than that at the organizational level because these are interactions that involve multiple organizations with different objectives and stakeholders (Premkumar et al. 2005). This uncertainty comes from the complexity of the environment and dynamism, or from the frequency of changes in various environmental variables (Galbraith, 1974). The electricity sector is in full swing (Schuelke-Leechetal., 2015), the introduction of third parties may increase the level of uncertainty (Schuelke-Leechetal et al., 2015). The involvement of third parties increases the level of uncertainty surrounding the future design of this sector and the corresponding information management system (Buchmann, 2016b). In the field of IS, a niche of research has begun to develop around SG (eg, Erlinghagen and Markard 2012, Corbett, 2013, Wunderlich et al., 2012, Goel, 2015, Yesudas, 2015). This research niche focuses on the technical issues associated with chain modernization (eg, Ramchurn et al., 2012, Strueker and Dinther 2012, Goel, 2015) and the factors influencing the adoption of SM by consumers (Kranz and Picot, 2012, Wunderlich et al., 2012, Huang and Palvia 2016). However, little researches have focused on understanding the change that third parties bring to the treatment of information. Those researches includes Buchmann's (2017) research, which highlights the need to develop a new governance approach to ensure better information management between third parties. This paper focuses on understanding the changes that can be made by the involvement of third parties in the process of information processing at the level of power generation organizations. Specifically, my research objective is the understanding of the relationship between information processing capabilities, third-party inter-organizational relationships, information requirements, and organizational performance in the context of SG.

To achieve this, I will use the IPT developed by Galbraith (1974) as a theoretical foundation. This is a relevant theory for understanding the relationships between an organization's information processing capabilities, the new information requirements of a multi-stakeholder supply chain, and organizational performance (Busse et al. 2017). Moreover, the IPT provides a relevant theoretical perspective in the context of SG (Corbett, 2013). This study offers several theoretical and practical contributions. On the one

hand, it allows enriching the literature in SI by developing an extension of the TTI allowing the consideration of inter-organizational relations due to the involvement of third parties in the electricity sector. On the other hand, it enables electricity distribution organizations to improve their environmental performance by providing them with a set of best practices that will enable them to improve the processing of information and meet energy objectives pursued by SG implementation projects.

This paper begins by presenting the theoretical foundation, followed by the methodology and the presentation of the proposed research model. Main contributions to the literature as well as the practical implications are presented. Finally, limitations of the research and future research directions are proposed.

Literature review

1.1. SG and the revolution of the electricity sector

Electricity generation organizations are responsible for the generation, transmission and distribution of electricity. Traditionally, this process has been mainly electromechanical, with relatively few needs for sophisticated information processing (Schuelke-Leechetal, 2015). However, in recent years, the electricity industry has undergone significant changes related to deregulation, decentralized generation, cogeneration, legislative and public pressures to incorporate renewable energy sources and renewable energy and to improve efficiency and energy conservation (Cama, 2015, Weiss et al., 2012). These changes require a continuous update of IS to match the increasing requirements of demand, access and reliability (Schuelke-Leechetal, 2015). This has been accompanied by an impetus in the use of the data generated by these IS (Zhou et al., 2016). Power grids are extremely complex with an instant need to match millions of requirements from demand to supply (Schuelke-Leechetal, 2015). The main source of information is the advanced measurement infrastructure that deploys a large number of SMs and other measuring terminals on the end-user side (Zhou et al., 2016). The SM collects generally the information of consumption of electricity of the customers every 15 minutes; meter readings alone have created and accumulated a massive amount of data (Daki et al., 2017). Electricity generation organizations then face major challenges in processing the information generated by SG technologies (Daki et al., 2017). In fact, the management of the large volume and speed of data generated by short SM readings can outpace the power provider's computing resources (IBM, 2012). Ensuring the confidentiality of sensitive data collected from customers' meters is also a major problem facing power generation organizations (Huang and Palvia 2016). These organizations must also meet the regulatory requirements related to the retention of data collected for many years (IBM, 2012).

In addition, due to increased data volume and retention requirements, data storage costs can explode if organizations use traditional relational database technologies (IBM, 2012). Reporting and analysis can become very slow due to high volumes. This cumbersome analysis of the data set can affect the quality of decision-making and organizational performance (Huang et al., 2014). Having advanced analysis requires an integrated view of the organization's data (Wamba et al., 2015). In order to face the challenges of all these elements, some power generation organizations call upon the services of third parties. Some electricity generation organizations believe that the third parties allow a better treatment of the information generated by SG technologies (eg Hydro-Québec). However, the introduction of these third parties requires a new approach to manage exchanges and communication between the different actors (Buchmann, 2017). Multi-stakeholder supply chains connect different partners with different needs for communication and exchange (Premkumar et al., 2005). Organizations must have IS supporting this communication and ISO presents a solution to ensure better exchange for multi-stakeholder supply chains (Robey et al., 2008).

1.2. Inter-organizational information systems

IOS designate ISthat are shared by two or more organizations to coordinate activities, make transactions, or share knowledge to achieve individual and collective goals (Lyytinen and Damsgaard, 2011). IOS provide pooled information resources such as shared databases, communication networks, and common applications (Robey et al., 2008). They also support multi-stakeholder supply chain management (Robey et al., 2008) and support collaboration by exchanging different information (Kumar and van Dissel 1996). Most IOS are implemented to facilitate collaboration and manage potential conflicts through electronic

integration (Kumar and van Dissel 1996). With the emergence of IT integrated with SG, power generation organizations are moving towards a multi-stakeholder system (Brunekreef et al., 2016). This change requires new collaborative governance between the different parties (Buchmann, 2017). To that end, it would be necessary to have IOS for the expansion of activities and the reorganization of inter-organizational processes (Kambil and Short 1994). These IOS allow organizations to improve their information processing capabilities to cope with uncertainty and increase their performance (Premkumar et al., 2005). However, ISare not purely technical, they are rather designed and optimized jointly in the organizational contexts in which they will be used (IIvari, 1991). Challenges in developing organizational structures and technical artifacts are more important when creating IOS across multiple organizational boundaries (Corbett and Montgomery 2017). Indeed, the creation of an IOS requires individual and collective efforts to identify and align interests (Rodon et al., 2008) that will define the inter-organizational structure (Finnegan et al., 2003), especially in the new multi-actor context in power generation organizations (Brunekreef et al., 2016).

1.3. Information processing theory

The IPT evolved during the 1970s with intra-organizational interest in response to the organizational design problems of large organizations (Galbraith, 1974). Then, it has been extended to a dyadic and inter-organizational level to evaluate purchaser-provider relationships (Bensaou and Venkatraman 1995). The IPT postulates that organizations need quality information to cope with uncertainty and improve their decision-making (Galbraith, 1974). The greater the uncertainty, the higher the volume of information to be processed in order to reach the desired level of performance (Huang et al., 2014). This theory identifies three key concepts: information requirements, information processing capabilities, and the alignment of these two concepts to achieve optimal organizational performance. The first concept refers to the amount of information needed to cope with uncertainty (Tushman and Nadler 1978). The second one refers to the ability to gather, synthesize and disseminate information appropriately to cope with uncertainty (Tushman and Nadler 1978). Information processing refers to the accumulation, analysis and synthesis of information in the context of organizational decision-making (Edstrom and Galbraith 1977, Tushman and Nadler 1978). Galbraith (1974) explains the subtleties of adopting integrated mechanisms to increase information processing capabilities. However, the success of these mechanisms depends on the ability of the organization to manage them. Since information requirements evolve according to a task or situation, different organizational structures must emerge to meet these requirements (Spang, 2012). Information processing is effective when the appropriate information is collected, the flow of information is rapid and the information is transmitted without distortion (Tushman and Nadler 1978).

In the face of uncertainty, organizations have two main options: to reduce the amount of information processed or to increase their information processing capabilities (Galbraith, 1974). Indeed, information requirements and information processing capabilities need to be balanced (Spang, 2012). According to Tushman and Nadler (1978), information processing requirements depend on three components: the degree of stability and uncertainty of the environment, the level of interdependence of tasks, and the complexity of tasks. To meet these requirements, the organization implements information processing capabilities by committing a variety of resources (Huang et al., 2014). Galbraith (1974) suggests that IS can be used to increase the organization's information processing capabilities. ISincrease the information processing capacity by facilitating the flow of information and developing the decision-maker's cognitive capacity (Galbraith, 1974, Ginzberg, 1980). Information processing mechanisms that provide real-time, accurate, and relevant information allow companies to be flexible in adapting activities during an uncertain event (Mithas et al., 2011). An example of this strategy is the introduction of integrated information systems that improve the flow of information and reduce uncertainty (Premkumar et al., 2005). The IPT has been used in the field of IS to understand how IS are used at the intra-organizational level (eg Cooper and Wolfe, 2005) and inter-organizational (eg Premkumar et al., 2005).

The IPT has also been used as the theoretical basis for analyzing the influence of information systems on organizational agility (eg Huang et al 2014 Park et al 2017), the decision-making process (eg Kowalczyk and Buxmann 2014), the supply chain (eg Zhu et al., 2017) and the organizational performance in general (eg Fairbank et al., 2006, Hult et al., 2000, Tams, 2016, Kock and Chatelain-Jardón 2011). For example, it has been shown that information processing mechanisms influence organizational decisions in the context of big data (Kowalczyk and Buxmann 2014). The IPT is applied in various contexts related to the

IS domain. However, few studies have applied the IPT in the context of SG. For example, Corbett (2013) focused on understanding the impacts of SG on the performance of demand side management. According to Corbett (2013), demand side management can be viewed as an information processing task where the technologies embedded within the smart grid provides utilities with new information processing capacities.

In addition, the dramatic growth of information processing capabilities to support inter-organizational interactions provides an excellent opportunity to empirically test IPT in the new environment (Premkumar et al., 2005) such as SG's. With the emergence of SG technologies, the traditional electricity supply chain is undergoing significant changes. Third parties are now part of the new supply chain (Buchmann, 2017). The use of IOS presents a promising strategy for increasing organizations' ability to process information (Premkumar et al., 2005). However, the choice and design of IOS require efforts to define and align different needs (Rodon et al., 2008). This is especially true in the new multi-stakeholder context of power generation organizations (Brunekreef et al., 2016).

The emergence of the electricity sector towards a multi-stakeholder supply chain increases the level of uncertainty (Buchmann, 2016). In the context of inter-organizational interactions, uncertainty is magnified since each of these organizations has different objectives and different stakeholders (Premkumar et al., 2005). The concept of alignment between information requirements and information processing capabilities can help reduce uncertainty in power generation organizations. This will increase organizational performance (Galbraith, 1974). So, the involvement of third parties poses significant challenges for power generation organizations in managing the exchange of information between different actors (Buchmann, 2017). Hence my interest in understanding the relationship between information processing capabilities, the inter-organizational relations provided by the third parties, information requirements, and organizational performance in the SG context.

To do this, I will rely on the IPT. A theory that provides a relevant theoretical perspective in the context of SG (Corbett, 2013), including understanding the requirements, information processing capabilities of a multi-party supply chain, and organizational performance (Busse et al., 2017). My research question then is: what is the influence of information processing capabilities, inter-organizational relationships and information requirements on organizational performance in the SG context?

Methodology

In order to develop the theoretical framework a set of articles have been identified and analyzed. Four databases are queried: Web of science, ABI / Global Inform, EBSCHost and AIS eLibrary. AIS eLibrary is an essential electronic library for Literature Reviews in Information Systems (SI) (Schryen, 2015). It allows to consult the eight best scientific journals in organizational information systems appearing in the Senior Scholars' Basket, namely: European Journal of Information Systems, Information Systems Journal, Information Systems Research, Journal of AIS, Journal of Information Technology, Journal of MIS, Journal of Strategic Information Systems, MIS Quarterly. Furthermore, the search was expanded by including articles from conference proceedings such as IEEE / ACM, CIHI, PACIS, AMCIS, ACIS, ECIS and CONF-IRM conferences (Muller & Ulrich, 2013). All of these resources are available on the AIS eLibrary. We conducted title and abstract searches, using key words such as ((("Smart grid") OR ("electricity")) AND (("information processing") OR ("information capabilities") OR ("information requirements") OR ("third parties") OR ("inter organizational relationship") OR ("Supply chain"))) without published date limitation. In total, 632 papers were identified based on initial search criteria. After removing duplicated papers, we selected the studies that will be included in our literature review using a three-steps strategy: (1) We verified the inclusion and the exclusion criteria from reading the title, the summary, the keywords and the introduction of each study. The first sorting led to retain only 158 studies. (2) We made a detailed reading of the papers to only retain relevant papers. Overall, 43 papers were identified and included in the final analysis on relationship between information processing capabilities, third parties (inter-organizational relationships), information requirements and organizational performance. Three main topics are identified: Data management and governance (eg. Brandstatt et al., 2014; Brandstatt et al., 2017; Corbett, 2013; Buchmann, 2016a; Buchmann, 2016b; Buchmann, 2017), policy of and regulation (eg. Erlinghagen and Markard, 2012; Brunekreeft, 2015; Friedrichsen, 2014), design and implementation of SG technologies (eg. Pathak et al., 2016).

Results (proposed theoretical framework)

The literature review suggests that a variety of relationships may exist between information processing capabilities, third parties and information requirements and organizational performance in the context of SG (Figure 1). Based on the literature, a framework explaining the extension of IPT is developed.

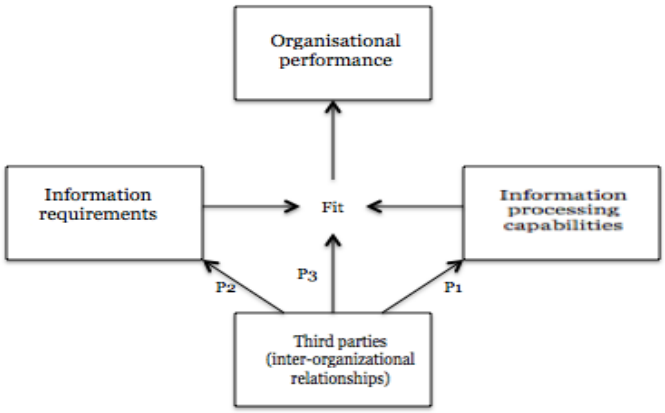

Figure 1 : the influence of information processing capabilities, inter-organizational relationships and information requirements on organizational performance in the SG context.

2.1. Theoretical propositions

2.1.1. Third parties involvement and information processing capabilities

Electricity generation organizations are moving towards multi-stakeholder systems (Brunekreef et al., 2016). It is necessary to have a management approach and exchange of information between the different parties (Buchmann, 2017). IOS presents one of the strategies that increase information processing capabilities by supporting new inter-organizational processes (Premkumar et al., 2005). These capabilities are defined as the level of technological support for various inter-organizational interactions (Bensaou and Venkatraman 1995). The IOS offers a range of categories of information processing capabilities such as communication technologies (Premkumar et al., 2005). The exchange of information between different organizations can be divided into three broad categories: one-for-one (1: 1), one-for-many (1: m) and several-for-many (m: m) (Premkumar et al., 2005). Organizations have to choose the adequate IOS that will support their interaction patterns (Bensaou and Venkatraman 1995). For example, electronic data interchange (EDI) offers an effective technological support for these dyadic interactions (1: 1) (remkumar et al., 2005). By transposing this inter-organizational logic to the SG context, the exchanges between the power generation organizations and the third parties can take different configurations. For example, in the case of Hydro-Québec, information collected from SMs is hosted on a cloud service in Toronto and then transmitted to C3 Energy (a US service provider). The latter has set up a website that allows Hydro-Québec customers to see their electricity consumption in real time. Thus, we propose that:

P1: The involvement of third parties contributes to the increase of information processing capabilities.

2.1.2. Third parties involvement and information processing requirement

Information requirements refer to the amount of information needed to cope with uncertainty (Galbraith, 1974). The introduction of third parties increases the level of uncertainty because it involves interaction between different partners with different objectives and stakeholders (Premkumar et al., 2005). According to Galbraith (1974), uncertainty arises from the complexity of the environment or the frequency of changes in various environmental variables. The electricity sector is revolutionizing (Schuelke-Leechetal , 2015) and the introduction of third parties may increase the level of uncertainty

regarding the future design of this sector, as well as the corresponding information management system (Buchmann , 2016b). We can then propose that:

P2: The involvement of third parties contributes to the increase of information requirements

2.1.3 Third parties involvement and the alignment between information requirements and information processing capabilities

The alignment of information requirements with information processing capabilities determines the performance of the organization (Tushman and Nadler 1978). This alignment is a complex concept that captures the interaction between requirements and information processing capabilities (Bensaou and Venkatraman 1995). The high level of uncertainty in the inter-organizational context means that information requirements are important (Premkumar et al., 2005). Information processing capabilities must align with these informational requirements. Information processing and the means of communication must correspond to the level of uncertainty (Daft and Lengel 1986). Used IOS must then adapt to inter-organizational processes (Premkumar et al., 2005). This alignment poses significant challenges for organizations as it concerns supporting interactions that involve multiple actors with different objectives and different stakeholders (Premkumar et al., 2005). SG technologies have significant impacts on information processing processes (Schuelke-Leechetal et al., 2015). As explained in P2, the introduction of third parties in the new supply chain of the electricity sector can contribute to the increase of information requirements. Power generation organizations must respond to this situation by aligning these information processing capabilities with the new information requirements brought by evolution towards a multi-stakeholder model of the SG context. Hence the following proposition:

P3: The involvement of third parties can influence the alignment between information requirements and information processing capabilities.

2.1.4. Alignment between information requirements and information processing capabilities and the increase of the organizational performance in the SG Context

Alignment between informational requirements and information processing capabilities influences organizational performance (Galbraith, 1974). The literature emphasizes that at the inter-organizational level, the interactive effect of information processing requirements and capabilities has a significant effect on performance (Bensaou and Venkatraman , 1995, Premkumar et al., 2005). The uncertainty in inter-organizational interactions is greater, since they concern several organizations with different objectives (Premkumar et al., 2005). The greater the uncertainty, the higher the amount of information that needs to be processed to achieve the desired level of performance (Huang et al., 2014). SG are revolutionizing the electricity sector (Schuelke-Leechetal, 2015). Several uncertainties surround the future design of this sector and the information management approaches associated with it (Buchmann, 2017). Given complex inter-organizational relationships, organizations need to use a variety of strategies to optimize their organizational performance (Premkumar et al. 2005). For example, in the SG context, power generation organizations need to develop new strategies to manage and process information to address the challenges of introducing third parties (Buchmann, 2017). Achieving the level of environmental performance pursued by the SG depends on effective management and processing of information (Sodenkamp et al., 2017). Thus, we propose that:

P4: Alignment of information requirements with information processing capabilities increases environmental performance pursued by SG

Conclusion and contributions

This research helps to understand the transformation of power organisations du to the rapid development of disruptive technologies such as SG. Services provided by electricity sector have to respond to changes. This study offers theoretical and practical contributions. On the one hand, it enriches the literature in organizational information systems by answering the call of the use of the IPT in the context of SG. The IPT is perceived as a promising theory for the development of theoretical frameworks relevant to understanding of SG technologies (Corbett, 2013). This research proposes an extension of IPT that takes

into account the inter-organizational arrangements brought about by the introduction of third parties in the SG context. The developed theoretical framework allows for an understanding of the relationships that may exist between information requirements, inter-organizational relations (related to third parties), information processing capabilities and the environmental performance pursued by SG. It may be used as a basis for empirical research seeking to understand the influence of the integration of parts of an organization's supply chain on information processing capabilities, information requirements and the alignment between these two elements. On the other hand, the results of this research are not limited to enriching the understanding of a field of research that requires more investigation (SG). It also allows smart city domain a research perspective to explore in order to address energy considerations and improve the performance of the energy sector (Buch, 2014). With regard to the benefits for the practice, it contributes to the achievement of the energy objectives pursued by the SG implementation projects by providing electricity distribution organizations with a set of best practices that will enable them to improve their organizational performance (including environmental performance).

Limitations and future research

Despite his contributions, the paper suggests a preliminary framework based on a small number of articles. Future empirical research can test the proposed model. The choice of the electricity sector is based on its specificity regarding the evolution and transformation of the information processing caused by SG's disruptive technologies. However, the proposed model can be applied in other contexts.

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