Information Systems: From Innovations to Innovation Generators

Philippe Marchildon and Pierre Hadaya
Department of Management and Technology
ESG UQAM
Montréal, Canada
e-mail: marchildon.philippe@uqam.ca
hadaya.pierre@uqam.ca

***Abstract*—The objective of this study is thus to investigate how IS can enable organizational capabilities that may lead to organizational innovativeness. (i.e., an organization's potency to generate innovations). To do so, we review the innovation and IS literatures and use structuration theory to propose a research model, its related hypotheses and methodological aspects tied to its validation. Finally, the proposed model's anticipated contributions are discussed.**

Keywords-innovation; organizational innovativeness; structuration theory; product lifecylce management systems; radio frequency identification devices.

I. INTRODUCTION

In today's complex technological era, organizational innovativeness – defined as an organization's potency to develop and introduce innovations in various forms (e.g., product, service, process, system, business structure, business model) [1][2] – is increasingly viewed as a multidisciplinary activity [3][4] based on a few key organizational capabilities: functional and integrative capabilities [5]. As such, and because evidence from the IS literature suggests that functional and integrative capabilities could potentially benefit from the support of IS [6][7][8] [9], it seems primordial that the IS literature acknowledges the double nature of IS by studying them not only as innovation per se but also as innovation generators.

Based on this premise, the present study aims to answer the following research question: "What is the role of IS in the creation of organizational innovations?" Accordingly, the objective of this study is to investigate the impact of IS on functional and integrative organizational capabilities and, indirectly, on organizational innovativeness.

The rest of the paper is organized as follows. First, in Section 2, the literature on innovations is reviewed to identify the potential antecedents of organizational innovativeness while structuration theory is examined to resolve the apparent conflict between the "push" and "pull" perspectives within the innovation literature. Third, in Section 3, anchored on this resolution and thus the now established duality of innovations, a set of hypotheses linking key organizational capabilities to organizational innovativeness is proposed. Fourth, in Section 4, we investigate the IS literature and more specifically studies that discuss Product Life-cycle Management (PLM) systems and Closed-loop PLM systems to propose a second set of hypotheses that establish the enabling role of IS in the creation of certain organizational capabilities which may lead to organizational innovativeness. Fifth, in Section 5, the key methodological aspects tied to the empirical validation of this study's hypotheses are discussed. Finally, this research's anticipated theoretical contributions and practical implications are discussed in Section 6.

II. THEORETICAL DEVELOPMENT

A. Novelty: the Key Characteristic of Innovations

Novelty – defined as the extent to which a product, service, process, system, organizational structure, or business model departs from what already exist – is the key criterion that an organizational component must have to meet to be considered an innovation. Aware of the importance of novelty in the making of innovations, researchers generally identify innovations as either radical or incremental [10]. Radical innovations are those that produce fundamental changes in the activities of an organization or an industry and represent clear departures from existing practices [11]. On the other hand, incremental innovations merely call for marginal departure from existing practices [11].

Another important aspect of innovations is that they are externally determined. That is, the concept of innovation can only make sense when an innovation is compared to a specific external referent. For example, cell phones can only be considered innovations when they are compared to regular house phones and not when they are compared to more evolved smart phones. Thus, to innovate an organization has to create a product, service, process, system, organizational structure, or business model that departs from what already exists in its specific frame of reference. As such, an organization in the manufacturing industry, relying on supply chain logistics and transportation systems might be considered innovative whereas a firm relying on these same systems in the transportation industry will only be considered attuned to what already exists. Therefore, organizational innovativeness not only depends on what an organization does but also on what is done by other external stakeholders within the same environment.

This dual nature of organizational innovativeness is epitomized in the innovation literature by the presence of two

 ISBN: 978-1-61208-614-9

overarching rival perspectives which see innovation generation as either a "push" or a "pull" phenomenon [12]. More precisely, there seems to be a polarization on innovation antecedents where the characteristics of the organization (i.e., "push" perspective) and the characteristics of its environment (i.e., "pull" perspective) are viewed as rival predictors of a firm innovativeness. Partisans of the "push" perspective have shown, for example, that a firm's structure, culture, management practices and strategies significantly influence organizational innovativeness while, on the other hand, adepts of the "pull" perspective have identified that an organization's industry, region, government policies, and technological environment significantly impact its innovativeness [12].

However, doubtful of the apparent conflict between "push" and "pull" adherents, some authors have argued, based on evidence from practice, that the process of innovation generation might be better conceptualized as an evolutionary, non-linear, iterative process between the firm and its environment [3][4]. In other words, this third and new perspective suggests reconciling previous research findings by defining organizational innovativeness as a duality where an organization is at the same time influencing and influenced by its environment rather than as a dualism where both types of innovation antecedents are considered orthogonal. Nevertheless, in spite of these authors' insightful observations, little theoretical let alone empirical work has been undertaken in the innovation research field to account for this duality. As such, the best rationale on the duality of innovations doesn't come from innovation studies but rather from the field of sociology and more precisely from Giddens' [13] answer to the debate between "functionalist/determinist" and "voluntarist" sociologists.

B. *Duality of Innovations: an Explanation Anchored on Giddens' Structuration Theory*

Giddens [13], analogous to authors of innovation research doubtful of the "push" and "pull" orthodoxy, acknowledged that the debate between Functionalist/determinist" – defined as sociologists entrenched in the orthodox consensus who saw agents' actions as a result of environmental forces and demands [14] – and "voluntarist" – defined as sociologists who argue that agents reflectively act without restraint and have the power to tailor their surrounding environment to their needs [15] – could in fact be resolved by acknowledging the duality of agents' behaviors. More precisely, noticing common grounds between these protagonists and the mutual influence between an agent and its environment (i.e., the duality of structure), Giddens [13] redefined the agency concept and then developed the structuration theory to provide a sound explanation to this duality. Indeed, recognizing that previous conceptualizations, which defined agency in terms of intention, failed to account for the duality of structure, Giddens [13] proposed to redefine agency in terms of transformative capacity. Thus, according to Giddens [13], agents are characterized by their ability to take action, to deploy a range of causal powers, including that of influencing those deployed by others [13]. Furthermore, similar to Bachrach and Baratz [16], Giddens [13] also recognized that agents' actions and thus their transformative capacity are to some extent limited, due to the rules and resources agents use when taking action. In other words, the rules and resources drawn upon by agents when taking action are simultaneously constraining and enabling agents' actions, creating the duality of structure. Thus, the concept of agency, which defines agents in terms of transformative capacity and entails the enabling and constraining role of rules and resources, is at the essence of the duality identified in the sociology and innovation literatures. As such, by instantiating the concept of agency to the particular context of society construction, Giddens [13] was able to demonstrate that social structures are not fixed but rather exhibit structural properties since social structures emerge from agents' constant reproduction of already existing rules and resources.

By instantiating the concept of agency in the context of innovation generation, one can realize that its basic assumptions still hold: agents, by taking action, still draw on rules and resources that simultaneously constrain and enable. However, instead of simply reproducing them, agents, because of the novelty criteria, also need to significantly depart from them (i.e., they enact a novel behavior). Therefore, similar to Schumpeter [17] who depicted innovation activities as a process of recombining and/or reconfiguring existing pieces of knowledge in some novel way [17][18], this view of innovations establishes that organizational innovativeness rests on the transformative capacity of organizations. In other words, an organization's innovativeness rests on its ability to draw from existing rules and resources while significantly departing from them by creating new knowledge.

III. CONCEPTUAL FRAMEWORK

Based on the theoretical background presented above, the premise of this article is that IS usage improves an organization's capacity to innovate. This section exposes the nine hypotheses tied to our research model shown in Figure 1. The first four hypotheses of our model explain how organizational capabilities (functional and integrative) lead to organizational innovativeness while the last five hypotheses explain how two types of IS (PLM and Closed-Loop PLM systems) may provide a platform to support and improve these key organizational capabilities.

A. *The Positive Impact of Functional and Integrative Capabilities on Organizational Innovativeness*

Having established, through structuration theory, that organizational innovativeness rests on an organization's ability to draw from existing rules and resources and to create knowledge, it is now essential to go back to the innovation literature and more precisely to the work of Verona [5] to define these key capabilities. Verona [5], who also anchored his research efforts on the premise that an organization's capacity for action resides in its capabilities [19], identified a set of capabilities that, similar to the ones suggested in structuration theory, are linked to the duality of organizational innovativeness. More precisely, the author identified two types of capabilities, functional and integrative [20], that enable the creation of knowledge. Functional capabilities refer

to capabilities that allow an organization to develop new knowledge while integrative capabilities are defined as capabilities that allow an organization to integrate knowledge from different sources [20]. Recognizing that sources of knowledge can be located within and outside organizational boundaries, Verona [5] sub-divided integrative capabilities into internal integrative capabilities and external integrative capabilities (i.e., those that integrate knowledge from sources within the organization's boundaries and those that integrate knowledge from sources outside the organization's boundaries). As such, Verona [5] and Giddens [13], although guided by different research objectives, both posited capabilities as a core property of agents and defined capabilities tied to organizational innovativeness as an ability to draw from existing sources of knowledge to create new knowledge. Accordingly, organizations aiming to maximize their innovativeness must develop functional capabilities as well as internal and external integrative capabilities. Based on this premise, the following three hypotheses are formulated:

Hypothesis #1: An organization's functional capabilities positively influence its innovativeness.

Hypothesis #2: An organization's internal integrative capabilities positively influence its innovativeness.

Hypothesis #3: An organization's external integrative capabilities positively influence its innovativeness.

Furthermore, because the duality of organizational innovativeness implies that sources of knowledge both enable and constrain the creation of innovations, an additive interaction between functional and integrative organizational capabilities is also expected. Based on this premise, the following hypothesis is formulated:

Hypothesis #4: The interaction between the three organizational capabilities will have a positive influence on organizational innovativeness.

B. The Positivie Impact of IS Usage on Functional and Integrative Capabilities

Recognizing the importance of organizational innovativeness to develop and maintain a competitive advantage, organizations have adopted various practices and IS to support their initiatives [9]. Amongst these, PLM practices and PLM systems seem the more promising since there is an increased awareness that they may represent the foundation upon which the key organizational capabilities that lead to organizational innovativeness may be developed [9]. For instance, Pratt & Whitney used the PLM system developed by Siemens (i.e., the Tecnomatix solution) to limit the development of its engines to within 3 years, which was considered competitive at the time [21]. Furthermore, by using this system, Pratt & Whitney was able to design innovative engines that minimize downtimes by making maintenance operations as simple as possible [21].

PLM can be defined as a strategic approach that aims to provide more product-related information to the organization during the whole product lifecycle. Building on and extending the ideas of product data management (PDM) [22], this approach emerged from the necessity to move beyond simple engineering concerns of products and to provide a shared platform for creation, organization, and dissemination of product related knowledge [23][24]. PLM systems consisting of information processing systems or a set of information technology (IT) systems were conceived in order to support these considerations by forming an organization's product information backbone [25]. These systems, rooted in computer-aided design (CAD) and PDM systems, establish a set of tools and technologies that provide a shared platform for collaboration among product stakeholders and streamline the flow of information along all the stages of the product lifecycle [22][26]. However, although these systems were originally intended to support every phase of a product lifecycle (i.e., beginning of life (BOL), middle of life (MOL) and end of life (EOL)), most PLM systems currently fail to support products once they are sold, that is during their MOL and EOL phases [27]. More precisely, PLM systems, because of business and technological constraints, cease to collect product information once the product leaves the control of the organizations or its boundaries [23][24][27]. As such, by (1) integrating people, processes, business systems and information throughout the whole product lifecycle, (2) fostering horizontal connection between an organization's silos, (3) enhancing information sharing, (3) facilitating change management, and (4) enticing use of past knowledge [23][24], current PLM systems only support functional and internal integrative organizational capabilities and leave external integrative capabilities unsupported. Based on this premise, the following two hypotheses are formulated:

Hypothesis #5: The use of PLM systems positively influences an organization's functional capabilities.

Hypothesis #6: The use of PLM systems positively influences an organization's internal integrative capabilities.

Even though traditional PLM systems fail to address external integrative capabilities, recent advances in product identification technologies (PIED), such as radio frequency identification (RFID) and Auto-ID now enable organizations to collect product information beyond their organizational boundaries [23][24][27]. These new systems that comprise previous functionality of PLM systems while also including the new functionalities provided by PEID are referred to as Closed-loop PLM systems [28]. These new systems, by automatically capturing data outside the boundary of the firm, alleviate both the business and technological constraints of traditional PLM systems and give organizations the potential to also support external integrative capabilities. Based on this premise, the following hypotheses are formulated:

 ISBN: 978-1-61208-614-9

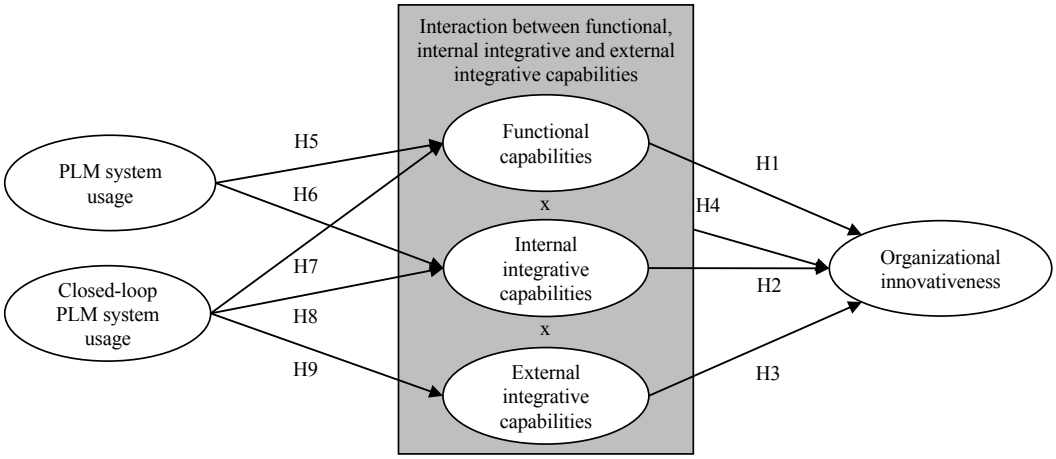

Figure 1. Research Model.

Hypothesis #7: The use of Closed-loop PLM systems positively influences an organization's functional capabilities.

Hypothesis #8: The use of Closed-loop PLM systems positively influences an organization's internal integrative capabilities.

Hypothesis #9: The use of Closed-loop PLM systems positively influences an organization's external integrative capabilities.

IV. METHODOLOGY

As our research is still in progress, this section explains the methodological framework we have devised, but not yet used, to test our research model. More precisely, we present our intended research setting, data collection procedures, survey instrument and data analyses procedures.

A. Research Setting

The up-to-date list of all Canadian manufacturing firms maintained by Statistics Canada (a Canadian government agency) will constitute this study's sample frame. More precisely, the sample frame will be limited to Canadian manufacturing firms active in the transportation equipment manufacturing industry (NAICS 336) (e.g., motor vehicle, aerospace, shipbuilding and other transportation equipment manufacturing). Three reasons justify the selection of this specific frame: First, manufacturing firms are often the middle men in the supply chain to which they pertain enabling them to influence and be influenced by both upstream and downstream partners and thus to the full range of the duality of innovativeness. Second, organizational innovativeness is already recognized as a key driver of success in this specific industry and thus is a salient topic to potential respondents. Third, manufacturing firms, especially in this particular industry, are amongst the very few organizations that have adopted to varying degrees PLM and Closed-Loop PLM systems, making this a rare setting where their influence on organizational capabilities is likely to be observed [29][30].

B. Data Collection

Data will be collected by the means of a field survey. More precisely, business managers will be asked via e-mail to fill the first-half of an online survey (available through a first hyperlink) and to ask their engineering counterparts to fill the second-half of the online survey (available through a second hyperlink). Business managers will answer questions regarding their organization's innovativeness (i.e., criterion variable). Considering the fact that innovation may be of various forms and taking into account this study's research setting, business managers will be asked to evaluate the innovativeness of their organization in regards to two forms of innovation: product and process innovations. On the other hand, engineering managers will answer questions regarding the organization's functional and integrative capabilities as well as the use of PLM and Closed-Loop PLM systems within their organizations (i.e., predictor variables). Seeking responses from respondents from two different organizational sub-units should alleviate some potential sources of common method bias. In addition, to maximize this study's response rate, a Tailored Design Method (TDM) will be used. Specifically, this procedure comprises four essential elements: (1) a respondent-friendly questionnaire; (2) a five-contact strategy (in the form of five different e-mails to be sent to business managers); (3) a personalized correspondence; and (4) incentives in the form of a privileged access to the research findings (e.g., a tailored benchmark report) and a chance to win an electronic gift card of a 500$ value on Amazon (i.e. one gift card for each type of respondent).

C. Survey Instrument

The electronic survey will comprise measures adapted from the literature. The measures tied to the organizational capabilities will be adapted from [5][31][32]. Measures tied to

 ISBN: 978-1-61208-614-9

PLM and Closed-PLM systems use will be adapted from [17][18][27][33][34][35]. Finally, measures of organizational innovativeness will be adapted from [1][2][36]. A pre-test of the questionnaire will also be conducted with several business and engineering managers in order to test the reliability and validity of the questionnaire as well as to identify potential upgrades prior to the full-scale inquiry.

D. Data Analyses

Structural equation modeling (SEM) based on LISREL covariance software package will be used to test this study's research model. LISREL is chosen over PLS and traditional regression methods as it better supports the study of interactions amongst research variables [37], a key particularity of this study. Furthermore, because most of this study's measures were previously used and tested, this research is more confirmatory rather than exploratory in regards to its measures. As such, it is more appropriate to use LISREL, which is more stringent then PLS [37]. Also, since using the SEM approach allows for the evaluation of both the quality of the measurement and the construct interrelationships, this approach will be used to first test the measurement model and then to test the structural model. To test the measurement model, a confirmatory factor model (i.e., the measurement model) will be used to measure the fit between the theorized model and observed variables. Then, to test the structural model, results of the measurement model will be used to create a path-analytic model to investigate the relationships hypothesized in this study [38].

V. CONCLUSION

Recognizing the potential of IS as innovation generators, the present study aimed to answer the following research question: "What is the role of IS in the creation of organizational innovations?" Based on the theoretical and conceptual background put forth in this study, we assess that IS play an enabling role in the creation of organizational innovations. Specifically, IS provide a platform to support and improve the key organizational capabilities (functional and integrative) that lead to organizational innovativeness. If validated, our understanding of the role of IS in the creation of organizational innovations is likely to yield important theoretical contributions and practical implications.

A. Theoretical Contibutions

From a theoretical perspective, by identifying novelty as a key criterion of innovations and by instantiating the concept of agency in the context of innovations, this research significantly improves our understanding of the creation of organizational innovations. Also, the sound conceptual framework developed in this study allows for the reconciliation of conflicting views on innovation generation and sets the groundwork for further research on this important topic. Furthermore, by highlighting the duality of organizational innovativeness, this study theoretically justifies the necessity of functional and integrative capabilities as well as the additive interaction stemming from their mutual influence. In doing so, this research also establishes the importance of IS in the innovation generation process, by revealing their positive impact on functional and integrative organizational capabilities. Accordingly, the present research also explains how IS can support the creation of organizational innovations.

B. Practical Implications

From a practical standpoint, the present research anticipated results should allow managers to improve the innovation capabilities of their organizations by identifying the key role of functional and integrative capabilities as well as their additive mutual influence. Furthermore, by being amongst the first study to highlight the role of IS in the generation of innovations, this study should enable organizations to not only improve their innovativeness but also to reap greater benefits from their current IS. Furthermore, by highlighting the key characteristics of PLM and Closed-Loop PLM systems, this research should also provide sound arguments for why firms that aim to innovate should use Closed-loop PLM systems that incorporate PEID and not limit their use to PLM systems.

C. Limits and Future Research Avenues

The theoretical and methodological contents presented above suggest a few limits and related future research avenues. First, our study sample only comprises Canadian organizations involved in specific industries. To address this limit, future research could aim to replicate our research efforts with a different sample frame. For example, it could be interesting to replicate our research efforts with organizations from service industries and/or from different countries. Second, although we use the concept of duality at the heart of structuration theory to show that organizational innovativeness rests on an organization's ability to draw from existing rules and resources and to create knowledge, our research model does incorporate all the tenets of structuration theory. In the future, we hope to extend our research model in order to take into account more tenets of the theory.

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 ISBN: 978-1-61208-614-9