A GENERAL MANAGEMENT SYSTEM FOR DESIGN OUTSOURCING

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ABSTRACT

Industrial firms are recently turning to outsourcing design. Unlike in manufacturing the context in design is characterized by a lot of uncertainty. Technology and knowledge are critical when considering outsourcing in design. The firm's competitive advantage is subject to information leakage and loss of internal knowledge. The relationship between outsourcing and supplier firm is more complex due to human factors and innovation activities. Moreover outsourcing determinants in design must not be considered to be the same as in manufacturing. We focus in this paper on outsourcing in design phase and its interaction with other phases. We propose a general design outsourcing process in order to address the outsourcing question. The process approach will allow coordinating elements of the outsourcing problem (Make or Buy decision, supplier selection…) in a more complete manner thus covering all firm's activities that can impact outsourcing. We expand our process on two axes. The first covers all the impacts of outsourcing during the lifecycle of the product using horizontal processes. The second is internal to the design phase and allows alignment of strategic and operational issues.

Keywords: design outsourcing, systems engineering, development process

1 INTRODUCTION AND CONTEXT

After witnessing a large scale trend of outsourcing in support services and manufacturing inside industrial firms, outsourcing is now moving upwards in the product lifecycle and is starting to take place during the design phase of industrial product development. This has an impact on strategic activities inside the firm including strategic decision making. Industries in sectors such as pharmaceuticals or automobile that moved towards emerging countries such as India and are dealing with more complex supply chains (SCs) face design outsourcing.

The two most striking differences between classic outsourcing in manufacturing or services and design outsourcing can be stated as follows:

- A large degree of uncertainty exists when outsourcing in the design phase. The internal design teams do not themselves know the solution to the problems at hand. This makes it harder for them to know exactly what to ask the supplier for and how to control the supplier's deliverable.

- The nature of what is outsourced, essentially knowledge, has a deep impact on management, making crucial the questions on how to decide about outsourcing and how to manage it when teams do not master the knowledge. Outsourcing is no longer a matter of production, and has rather become a matter of know how.

Moreover, outsourcing in design exposes firms to a wide variety of risks vis-à-vis its competitors and suppliers due to the required flow of information.

Academic context

In this research project we study the case of an industrial firm that is searching for innovation beyond its boundaries, seeking specialized skills that allow it be more adaptive and reactive to the competitive environment of its industry. In addition, we assume that the firm faces an uncertainty in demand and will penalize overload of capacity. The firm looks for outsourcing in design in order to find new resources and a new set of competencies within the supplier's organization.

Until now, research about outsourcing has mainly focused on manufacturing outsourcing, with the main topics being: decision making processes [2], supplier selection [3] and strategic aspects such as cost [4] and specifications [5]

Industrial context

On the industrial side, the research work reported in this paper has been carried out within the framework of an industrial engineering PhD thesis sponsored by a leading firm of the oil & gas (O&G) services industry. For confidentiality reasons the name of the firm will not be disclosed. We will refer to it hereafter as the Client Firm (CF). The CF offers services for firms working in the O&G sector all along the well lifecycle from early phases of exploration until the well's end of life (i.e. downhole measurement, production monitoring…). One of the CF's competitive advantages comes from the internal development of measurement tools used on geographically varied O&G fields. These measurement tools are developed by the CF product centers all around the world. The CF has outsourced a great part of the manufacturing activity during the 90s and now is facing major challenges in design outsourcing.

The CF's product center where this project is implemented has two major departments: an engineering department and a manufacturing department. The engineering department may have limited manufacturing activity (prototypes) and its main role is to deliver product files to the manufacturing department in order for the later to proceed to series manufacturing.

The CF's main concerns about design outsourcing are on the one hand to gain access to new technological knowledge outside the firm boundaries, gain maneuverability in new product development (NPD) and handle cyclical work loads; on the other hand the CF wants to prevent exposure to risks of competitive advantage, knowledge leakage and dependency on suppliers.

In section 2 we will present the objectives of this research... We will then briefly describe our research methodology in section 3. Section 4 will report relevant literature. While trying to respect confidentiality, we will present in section 5 some learning from our study of the CF. In section 6 we will describe the outsourcing model we are proposing. While in section 7 we point out the answers to the research questions, in section 8 we describe the preliminary validation of the results. We finish the paper with a concluding section and presentation of remaining future work.

2 OBJECTIVES

The aim of this paper is to establish whether a systemic (as understood in Systems Theory) new model of design outsourcing that integrates both the design phase and the main interactions with manufacturing as part of the same system can lead to a better performing and more sustainable decision making and management process for design outsourcing.

Thus, the study tries to shed light on the following questions:

- What are the pertinent levels in design outsourcing decision making?
- How and under what conditions can the CF acquire access to new knowledge by outsourcing in design?
- How shall suppliers' management be positioned and organized to avoid pitfalls of design outsourcing such as information leakage?
- Can it be argued that outsourcing in design phase is subsumed under the term "open innovation"?

3 EPISTEMOLOGICAL POSITIONNING AND RESEARCH METHODOLOGY

We position our work in this article on the constructivist epistemology as described by Lemoigne J-L [19]. He opposes it to positivist epistemology that goes back to Descartes, Comte and Newton. Lemoigne describes a new approach, named as a systemic modeling, as adapted to study complex systems through modeling activity. The systemic approach as we understand it, takes its origin in the works of Heinz Von Foerster and Norbert Wiener (as the founders of cybernetics) [20] [21] as well as Ludwig Von Bertalanffy with the General Systems Theory [22]. The complexity of such systems is assumed to come from the interaction of the different elements or actors of the system. Moreover, the modeling activity is tightly dependant on the person realizing these models (or representations), and his/her interaction with the environment.

Based our epistemological position, and the context of our research we adopt the philosophical positioning of action-research (A-R) as it is described by of Harry Coenen [23] and Coyan Tromp [24]. . We are convinced by the mutual influence that exists between the researcher and the researched context and the bi-directional learning that can take place though we are not engaged in a formal A-R process with the CF. A more evolved version of A-R defended by Stig Ottosson [25] as participation action research goes a step further in the involvement of the researcher in the studied system.

We based our work on a literature review (see section 4), which covers works related to outsourcing, process representation, complex system modeling and Multi Criteria Decision Analysis (MCDA). The researcher had access to internal working documents related to the CF's previous exploration in matter of design outsourcing (see section 5). In addition, and taking the knowledge of previous reports as a basis to prepare interview sessions, the researcher carried out 45 semi oriented interviews with managers and engineers working in different departments of the CF including engineering, manufacturing, SC, human resources, technology services. These interviews were recorded for a better analysis. The first step in these interviews aimed at understanding in depth the CF's organization, culture and processes. The second step explored the outsourcing issue and the third and last step was directed at specific project examples in order to get indications and advice about CF's experiences in outsourcing. A brief analysis and information from these interviews will also be presented in section 5.

4 LITERATURE REVIEW

To the best of our knowledge no one has developed yet a model that discusses outsourcing of design as a complex process in the firm organization and that identifies the interactions with the product development process on different level of the process. There has nonetheless been papers that study specific issues such as the decision making process or the supplier selection process ([2]; [3]). Other researchers in the field concentrate on purely strategic aspects of outsourcing ([4]; [5]). Moreover, most of the literature on outsourcing concentrates on outsourcing in the manufacturing phase. The originality of our study is that it concentrates on outsourcing in design phase. This will help firms in benefiting from the results of outsourcing in design i.e. technological maneuverability and access to new knowledge while avoiding pitfalls such as information leakage, loss of knowledge and dependency on suppliers. Our contribution allows to take these issues into account and to analyze them in a holistic model. The classical approach to studying outsourcing is the Transaction Cost Approach, and it involves the first motivation of outsourcing which was cost reduction for the firm.

In the economics literature some work has been done using game theoretical approaches to identify the equilibrium in order to study the exchange prices and profits that can come out from an organization considering outsourcing [6], [7]..

The remainder of the review talks about methods and techniques that can be used at different steps of the general process proposed in section 6. This involves five main issues and process elements: Outsourcing decision, supplier selection, scan process, relation with supplier and strategy definition. But first we will start by presenting a relatively new concept termed by its inventor, Henry Chesbrough, Open Innovation and examine how it could relate to our work.

Open Innovation

The term Open Innovation has been promoted by Chesbrough H. [26] since 2003. He calls for a change of paradigm concerning industrial innovation. The shift is from a classical closed innovation paradigm to the new open innovation paradigm. In his book on open innovation in 2003 Chesbrough describes the erosion factors of the old paradigm which are four: increasing availability and mobility of skilled suppliers; venture capitals industry; external options for ideas sitting on the shelf; and increasing availability of capable suppliers. Even though he strongly calls for a shift in paradigm, Chesbrough also concedes that the need for this shift depends on industries [26]. The authors of this paper argue that systemic approaches are helpful in improving complexity representations as well as evaluating if firms can or cannot create more value than they do by accepting open innovation practices. If looked at from the perspective of open innovation, firms must carefully evaluate beforehand the degree to which they will open to their environment. Indeed open innovation attitude will depend on the industry the firm operates in and its conditions. We can consider that the proposal we develop in this paper is in itself a mechanism of openness that allows the CF to better "connect to the wealth of available external knowledge" developed by other firms and research organizations.

Outsourcing decision

Some researchers studied in more detail the Make or Buy decision process and the supplier selection process which are thought to be two of the most important elements of the general outsourcing process. Tayles and al. describes a "Sourcing decision model" to structure the outsourcing decision making for a manufacturing company [2]. Their model allows integrating two main cross-functional activities of the firm, the capitol allocation and the purchasing functions. This model is developed to be applied in manufacturing and does not take into consideration the product lifecycle phases. This

approach can be adjusted to fit the decision making process elements in design outsourcing, but cannot be considered as a general process by itself that allows management of outsourcing inside a firm.

Supplier selection

More analytical model based on outranking methods such as PROMETHEE and ELECTRE can be found when the supplier selection is handled. Araz and al. combine a Fuzzy Goal Programming method and a POMETHEE method and apply it for supplier selection in the textile industry [3]. These works also can support methods and techniques to apply at a process element level which is the supplier selection process. But as we suggest this cannot be separate from a holistic view of the complex outsourcing management process.

Strategic aspect

Some works propose to define certain criteria as determinants of outsourcing. Huang,Y.-A. et al. found that Technological Codification and Technological Competency are good determinants for outsourcing [8]. They propose what they call the R&D Sourcing strategy matrix model, using these two determinants and combining In-house R&D sourcing and R&D Outsourcing with Product Innovation Types (marginal and adaptive). Quinn and Hilmer already used such an approach to evaluate sourcing strategies, but with more classical strategic criteria to build the matrix: Strategic Vulnerability and the Potential competitive edge [10]. They identified three sourcing strategies leaving six empty cells in their matrix: "Produce internally", "Special Venture or contract arrangement" and "low control needed, buy off the shelf". These three typology sourcing strategies were probably plausible enough at the time Quin and Hilmer realized their study. Nellore and Söderquist completed Quinn and Hilmer matrix identifying thus additional half-way arrangements that are needed to deal with the increasing complexity ruling the interaction between the outsourcing firm and the supplier.

Barthelemy talks about the hidden costs of outsourcing, which is an issue often not well studied by managers while taking the outsourcing decision [4]. There is the classic risk of dependency on suppliers [11], which can come to be very constraining and leading to the loss of control on the value chain(i.e. Intel in the computer industry). Firms can try to prevent this by following multi-sourcing strategies or keeping a level of control on the activity being outsourced for an eventual internalization.

Upon outsourcing, a firm takes the major risk of loosing the knowledge and expertise of the outsourced activity [12] [10]. This loss of know-how may lead to the loss of the competitive edge, as the firm loses control over the strategic competencies. This is a subject that we pay special attention to while considering outsourcing in the design phase, as it plays a big role on both the strategic and the operational levels. While at the strategic level we look at finding the appropriate sourcing strategies for the firm, the operational level is more concerned with the outsourcing decisions and managing the relation with the supplier on a daily basis. Earl M. talks about the risks of selecting a non suitable supplier [13] lacking the competence to properly accomplish the task he/she is being given. The supplier might also not be using updated technology as the firm would have wished.

The work by Nellore and Söderquist and that by Harrigan K.R. talk about the negative impact of incompatibility in culture and management on the collaboration with the supplier [5] [14]. Richardson J. also evokes high transaction costs relative to time and effort in managing the supplier relation [15].

Some researchers study the outsourcing issue from a strategic managerial perspective. This is usually done in close collaboration with practitioners. Fine et al. present a strategic sourcing management model in combining both qualitative and quantitative models [17]. For their qualitative model they choose five criteria to be studied in order to realize a "Strategic Value Added". These five criteria are: Customer Importance, Technology Clock speed, Competitive Position, Capable Suppliers and Architecture (product architecture). The quantitative model generates a classic "Economic Value Added" and is based on four criteria: Cost, Asset, Revenues and Competitive Cost Structure.

Such approaches are adapted for a strategic perspective when dealing with outsourcing. They can be used to identify the critical technologies that need to be kept inside the firm as well as the peripheral technologies that can be outsourced to external suppliers. This paper considers that such methods can be applied when the strategic level of the general outsourcing process is of interest. The considered methods give guidelines to help us come up with rational and plausible criteria when dealing with technology and processes classification.

Scan process

Ulrich et al. use two concepts, integration and internalization to study the design and the production of product-specific components [16]. They came out with four organizational forms: "(1) internal design,

internal production; (2) internal design, external production; (3) external design, internal production; and (4) external design, external production. We propose to use the integration concept to study the process elements of the internal design process in order to identify which blocks of process elements can be outsourced. This type of analysis on internal process elements can have different levels of granularity, which can lead to the outsourcing of part or all the design.

Relation with supplier: Specifications as a communication medium

Nellore and Söderquist talk about the impact of specifications on the outsourcing strategy. They consider specifications as a determinant for outsourcing decisions depending on whether they have a quantitative or a qualitative aspect. In this paper specifications are not considered part of the outsourcing decision determinants. We instead look at them as prerequisites for a clean operational process. In this study we consider that specifications are a critical communication mean when relations between firms are considered and a collaboration intermediate especially in design phase. Other research work studied the risks and disadvantages associated with outsourcing. The related work was mostly carried out in the IT/IS industry. In the literature several generic disadvantages are discussed.

In his study based on the Dutch manufacturing section, Mol J.M. found a change in attitude towards R&D. While considered a negative predictor for outsourcing before the 90's, R&D became an attracting point for outsourcing from the 1990s on [9]. He also says that in R&D the relationship view is more adapted. This work is aligned with our sought encouragement for analysis of outsourcing in design, and explains why outsourcing is taking increasing importance in the design phase of products development.

Another aspect of the literature is the one related to the systemic approach. We will use this approach and mainly the representation described in [1] in order to represent the organization and the product development process of industrial products. We adopt a similar approach in order to come up with the general outsourcing process in order to couple the latter to the internal product development process.

This paper proposes a general outsourcing process that is developed in two axes. The first integrates different functions of the firm in the design phase starting from strategic issues all the way to operational issues and is elaborated as a vertical axis. The second direction allows the general outsourcing process to integrate the product lifecycle by considering issues related to the manufacturing phase by adopting a systemic approach. This is developed as a horizontal axis..

5 INDUTRIAL ANALYSIS RESULTS (WORKING DOCUMENT & INTERVIEWS)

As mentioned in section 3, we conducted a series of interviews, and were involved in the daily work of the CF. While our research is oriented towards the outsourcing issue, we detected malfunctioning inside the firm that impacts the outsourcing issue specifically in some cases and that has a broader impact in other cases. In this section we will briefly describe some of what we observed. We will mainly treat them as communication issues.

We start by presenting the more general observations:

- Lack of communication-1: we noticed that even though the company holds very qualified human resources, the lack of communication between project teams on the human level is blocking a synergy that the company can benefit from. We were the victim of this lack of communication. During our research work, an internal project was launched with the objective of conducting external development of a product, but unfortunately we were unable to interact with this project team, and had only access to a few pages of this project's report; this did not happen because of the confidentiality of the project or for any other intended reason.

- Lack of communication-2: In the following we describe a lack of communication between the design teams (or organizational structure) and the manufacturing teams. This is a common issue in industry, but the problem here is accentuated by the fact that these two departments are completely independent and each project/product team has to answer to a different hierarchy that can have very diverging goals. The gap was as if we were dealing with 2 different companies, since for example the engineering department is no longer involved in the project as soon as the manufacturing department validates the product files. We have to admit however that since our arrival several steps were taken to address the issue as a real lifecycle issue. But we think that there is a long way to go, and it is not a purely technical organizational issue but it must be addressed at the company culture level.

We now describe two issues more closely related to the sourcing problem:

- Lack of communication-3: Here we discuss formal communication, be it internal or external. We noticed that the CF rarely uses or uses weak specifications during the development process. Specifications are written after the solutions are developed, and it is considered like some kind of documentation, not as a design artifact. This is also an issue related to the CF culture, and is to be addressed with special care. We consider that being able to write proper and useful specification requires a certain type of competency (different than the technical one used to find the design solution, where the engineers working for the CF are top of the class), which is very important for internal development and is a condition sine qua non to outsourcing.

- The Supply Chain (SC) role: The role of the SC organization inside the CF is very limited, and it has very low influence on the teams working during the design phase. Their role is limited to operational tasks such as negotiating the price with suppliers, negotiating lead time and handling purchasing issues. In our vision we propose that the SC acquires a larger role in the organization, and be not only attached to the manufacturing organization. The SC teams should be able to cover the product lifecycle on the different phases. We recommend that the SC be more integrated in the design team, and work on the product in early phases of the lifecycle. This will require efforts from the SC teams in order to develop new competencies that are required to fulfill their new role. But it also requires a change in the habits and routines that characterize the engineering department.

In the following section will explain the general outsourcing process. This process will allow a better understanding of our vision of the sourcing in the design phase. Through this process will be able to answer the issues that we pointed out in this section.

6   PROPOSAL: THE GENERAL OUTSOURCING PROCESS MODEL

As mentioned in section 3, our epistemological foundation is constructivism. And we use the systemic modeling theory as described by Lemoigne [18] for the representation of the processes. We base our systemic representation of the product development system on the work of Bocquet [1]. We study outsourcing in the design phase of a product as well as its impact and interaction with the manufacturing phase of the product. This approach has many added values. First, we consider the outsourcing process in the design phase as part of the development system. It develops a Supply Chain Organization relative to a specific project that will be part of the manufacturing system of the studied project. Thus, it allows us to take into consideration various factors at different levels (strategic and operational) and from different types (technological, legal, innovation, resources…) of the organization, and integrate them in the outsourcing process model at different levels of this model, and relying them with the interaction (and rules) existing between process elements. Second, it allows taking into account some problematic issues that can occur in the manufacturing phase and deal with them in an early phase of the product design, where less variables are fixed in terms of specification of either the product design or the manufacturing system design. It also allows us to deal with outsourcing from a process perspective, and thus identifying clearly the role that needs to be realized by the firm's resources, the deliverables expected from an outsourcing organization and the interaction with the NPD teams. Practically this will facilitate the implementation of the outsourcing model on an operational level, and from the managers' perspective of organizing the firm and the resources. This last point was practically applied in the SC organization of the firm we are working with. It was relatively easy to identify what was expected from the SC team regarding NPD, what was their responsibility, as long as what was their authority in the sourcing decisions that needs to be taken.

6.1   Theoretical foundation

Our representation of the firm and the outsourcing process is inspired by the systemic representation presented in [1]. We limit the scope of our study on three systems: the Development, the Manufacturing System, and the End Product System (figure 1). This representation is highly adapted to the real organization of the firm we are studying. The Development System may be considered as the engineering teams working on the product design. The Manufacturing System is the manufacturing teams of the company. The latter already integrates a big number of suppliers. One of the goals of our study is to integrate suppliers in the first system, in what is called outsourcing in design. We introduce two additional systems that we deliberately isolate: the design outsourcing system and the manufacturing outsourcing system (figure 1). The main concern of this paper is the Design Outsourcing System. We also consider the main interactions with the Manufacturing outsourcing System. In order to come up with a proposition of a model for the Design Outsourcing System, let us

first define the triptych of this system: the system ontology, the system functionality and the system genetics [18]. We will also describe the system teleology [1].
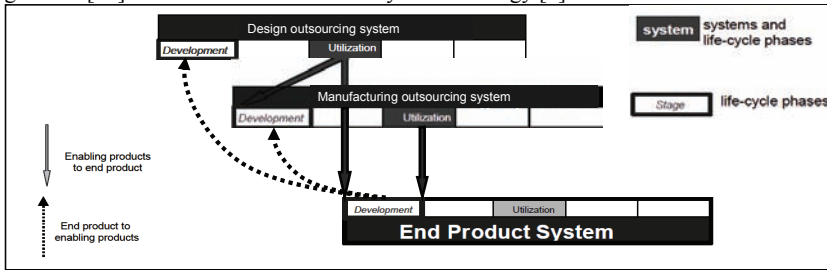

Figure 1. Interaction between design outsourcing, manufacturing outsourcing and end product systems adapted from [1]

6.1.1 Triptych of the Design Outsourcing System and its teleology

The system ontology

In the ontology of the system we will focus on the human resources and on the competence required from these resources. Due to their relative irrelevance, we do not take into consideration materials or other type of ontological components of the system. The competencies involved in the ontology of the design outsourcing system are designer engineers working on the product design. These engineers oversee decision making and specification of the needs. There are also supply chain competencies such as the definition of approved suppliers list, assuring certain information and data for designers about the sourcing strategy of the firm. In addition, there are technology specialists of the firm, whose role is to identify new technologies and work on existing technologies; they can be considered as the technical experts in the sourcing strategies.

The system functionality

The system function is to cover all the outsourcing activities of the firm in the design phase of the product, if the design is considered during the utilization phase of the system. This means that it will cover strategic activities related to outsourcing as much as operational activities of outsourcing. Moreover it will ensure a lean transformation of strategic views to the operation level of daily work. Reciprocally its function is to complete the loop by feeding back the project needs to be integrated in the firm strategy. This ensures a continuous update and alignment between the strategy and operational project needs.

The system genetics

The system genetics are characterized by the transformation from one phase to the other. The first phase is the development phase which is the current phase of our study. The second phase is the utilization phase. It is the phase where we implement the system inside the firm. During the utilization phase, the system is designed to be in continuous transformation thru the loops discussed in the system Functionality.

The system teleology

The system in the utilization phase aims to ensure a clear outsourcing management during the design of products, with the objective of optimizing the outsourcing in the design. Another goal is to take into account the manufacturing system constraints be it in prototyping or industrial manufacturing aiming again to optimize the product lifecycle.

6.1.2 Systemic model vs. classical model

The impact of adopting a systemic approach instead of a classical analytical one on the methods and results used to deal with outsourcing can be seen in two things:

- The decision to make or buy is not isolated from the other steps concerning outsourcing preceding or following it (implementation of the decision, management of the relation with the supplier…) all this is considered simultaneously.

- We take into account in our study more than the direct first level impact of action (make or buy) .The conditions considered in making a decision take into account the different interaction that the company can have with other elements of its environment, and the evolution of these interactions.

To illustrate this briefly, we will look at the outsourcing of a technology to a supplier firm:
 - First, the outsourcing decision depends on the type of relation that intended with the supplier(s).

- The decision to outsource this technology cannot rely solely on current available criteria. It must take into account possible evolution paths of this technology, be it in the market or in its application inside the firm. This evolution has a direct impact on how we want to manage this technology (in or out, and if out how and using what kind of suppliers)

6.2 The general outsourcing process model

As mentioned earlier, the approach adopted here is based on processes. The first process that we consider is the internal product development of a firm. This process is described in [17].

A process representation of industrial product development is proposed in [1]. This paper adopts Bocquet's representation of the development process. We propose in this study to superpose the outsourcing process to Bocquet's representation. Figure 2 shows that the outsourcing process is composed of two levels in the design phase: the strategic outsourcing process and the operational outsourcing process. Finally this model also considers the Supplier development process, which is activated when outsourcing decision making ends with a decision to buy.
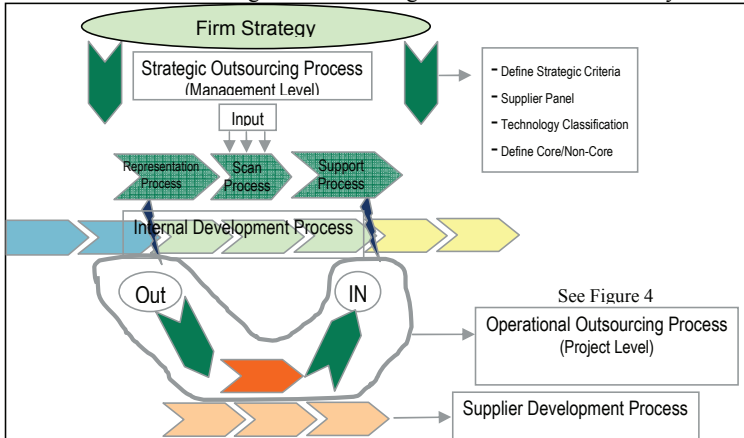

Figure 2. The general Design Outsourcing Process

6.2.1 The strategic outsourcing process

This process situated at the top level of our model relates to the other part of the model via inputs that it generates in order to feed the rest of the model. A feed back is given to this process through the supports process, which allows the engineers and manager at the project level to communicate their needs to the strategic level. The actors in the CF directly concerned by this process (the users) are members of the board of directors, the CEO i.e. the top management. This level is mainly a decision making level. These decisions involve issues such as whether to outsource or not, what type of management we will use for each technology, what is the organizational mode that will be adopted with each supplier etc… We utilized here a Multi Criteria Decision Analysis (MCDA) model. Using this kind of model with a constructive approach [27] will allow taking into account the client preferences on issues of almost any type, going beyond purely quantifiable point of views. We can include in the model qualitative points of view such as the capability of adaptation to changes of the supplier, the cultural compatibility between the supplier firm and the CF, etc… The advantage of this type of technique is that it will generate a model that is completely adaptable to the concerned client, since it can only be constructed through close interaction with that client. But on the other hand this means that in order to serve another client and context, this process should be reworked almost entirely. The only aspect that will require relatively small adaptation efforts is the methodology that lies behind the model.

6.2.2 The representation process

We propose a simple representation of processes in our work based on three main elements: Actor, activity and the deliverable. The "actor" is the human resource in charge of doing the activity. The "activity" is the transformation phenomenon that occurs at a certain level of the work advancement. The "deliverable" is the transformed object as a result of the activity. Each process element is

supposed to have an entry that is nothing but a deliverable of a previous process element. This simple representation is inspired by the systemic approach of Lemoigne [18], coupled with adaptation and pragmatism of the firm needs and working habits.

Using this representation will lead us to orient the outsourcing analysis on these 3 elements. After multiple discussions with managers inside the firm and researchers, we decided to exclude one element which is the deliverable, and study the outsourcing issue using the resource variable and the activity variable. To the resource variable we relate the competence and the tacit knowledge. To the activity variable we relate the technology and the experience accumulated. The idea is to make a more detailed analysis for outsourcing, and to start studying outsourcing of these elements. This way we have two possible extremes to study outsourcing. It can be considered as a scale, starting from outsourcing the actor (human resource) on the left side of the scale ending with outsourcing the activity (implicitly including the actor) on the right side of the scale (see Figure 3).
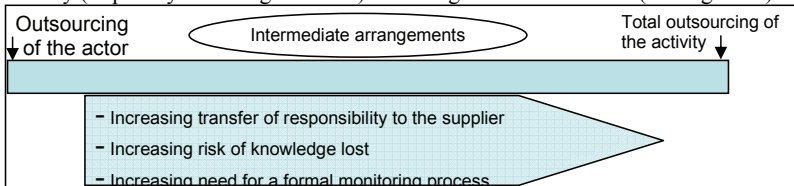

Figure 3. Outsourcing arrangements scale

As we move from left to right on the scale, the outsourcing firm hands more responsibility to the supplier. During some project meetings at the client firm, a lot of discussion occurred over the question of responsibility concerning the outsourced activity that we want to provide the supplier with. In the manufacturing phase, defects are the responsibility of the supplier, and each supplier's responsibility will differ depending on the task assigned to them. This could be applying a specified process or manufacturing a part with the supplier's own competencies. Another aspect of this question is the development that can be produced and the amelioration of the process while manufacturing. In design, similar issues exist such as the reliability of the solution proposed by the supplier, the intellectual property, and the formation of new knowledge and innovation during the development process.

6.2.3 The scan process

After formalizing the internal development process, we can now activate the scan process. This process uses input from the firm strategy. In this proposition we consider mainly technology classification as the strategic criteria. This classification must be realized through a study of the core competence of the firm and identify where its competitive advantage comes from. Another concept that is used in the process scan is the integration between process elements as mentioned earlier. This scanning of the internal development process will allow a better understanding of the stakes at each process step in terms of competence needed. It will allow grouping of process element into integrated blocks that can be further studied through the operational outsourcing process.

6.2.4 The support process

In this process we include all the activities that need to be taken in order to keep the strategic level in line with the designer's and project's needs. For instance if a new technology is needed in a new project development, this process will be activated in order to decide what sourcing strategy to adopt for this new technology i.e. whether to develop it inside or outside, which suppliers to work with, and what type of relation do we wish to have with these suppliers.

6.2.5 The Operational Outsourcing Process

In this paper we propose an operational outsourcing process that represents the lower part of figure 2. This process consists of seven sub-process elements as shown in figure 4. It is activated at the project level and is applied to the resulting element blocks of the scan process. The first step of this process is to define the project needs in terms of specifications. These specifications will be the medium of the communication with the supplier. After this step, we identify three very closely interactive sub-process elements. Henceforth, the process decision will be clear for the design team.

Moreover the nature of the relation with the supplier will be defined depending on the technology concerned and the corresponding sourcing strategy determined by the firm in the upper level of the

general process. This model will allow integrating issues related to series production and sustainability of a product in the early phases of design, by impacting the type of the relationship with the supplier. This is achieved by defining the relevant criteria to each project case. Issues such as the property of the product files when developed by the supplier will have direct impact on the possibility to change suppliers when we reach the manufacturing phase. It can even encourage adopting a multi-sourcing strategy for manufacturing. This model allows us to clarify these issues by integrating the product lifecycle in the early phases of outsourcing decisions of design. The final step in the decision here is the request for quotations (RFQ) where classic purchasing questions are addressed. The next step is to start the development at the supplier level with the order launch. This is done when we reach supplier development process in figure 2. The process next permits a follow-up on the work advancement of the supplier using the specified and agreed upon procedure in step 1 of the operational outsourcing process. Step 7 is a final validation of the deliverable after which we return to the internal design process of the outsourcing firm. This model identifies exit and entry points from the internal design process through the scan process.
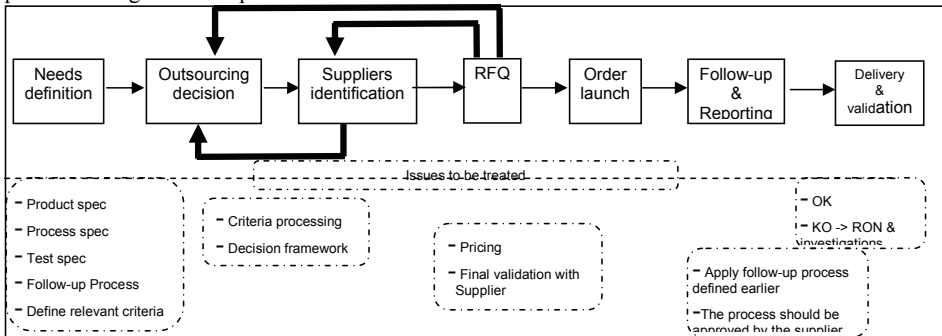

Figure 4. The Operational Outsourcing Process

6.3 How can all this be applied: an illustrative case

Here we will illustrate a real example of application of the model to the CF's design process. We consider a new technology (T) judged to have higher performance if applied to the product developed by the CF. In this example we will go through the design outsourcing process starting from the strategic level. For simplicity reasons we will only consider two strategic criteria:

• Technology added value: This criterion could in more detailed analysis be the aggregation of other criteria such as the increase in product liability, market added value, reproducibility to different internal projects, and non duplicability by competitors.

• Privacy: this applies to the information related to this technology.

The study of strategic criteria will allow the CF to assess the sourcing issue on a long term perspective (we are developing a MCDA model in order to rationalize this complex decision, see section 6.2.1). In the scan process we apply the integration concept of process elements which we consider inherent to the nature of the design activity and thus essential for the analysis. It will allow us to identify the process elements that are affected by the outsourcing issue at hand, here the technology T.

The board of directors along with the center's technology managers are responsible of the strategic analysis done by the application of the strategic process. After a market and technology analysis it was found that this technology can add competitive value to the products, and is likely to be used for other new projects and that it is important that the firm possesses the knowledge in house. Currently, the company does not possess the competencies within its staff. The CF can now determine its sourcing strategy at the upper level phase in figure 2. The CF decided to outsource to a single supplier that allows immediate access to this technology. The type of collaboration decide with the supplier will allow the CF's engineers to gain competencies. Using the representation and the scan processes with the first strategic input (decision to outsource) and the integration concept, the project manager will isolate blocks of process elements that can be outsourced. The project manager is also in charge of the OOP that will allow the daily management of outsourcing with respect to the second strategic input (the type of collaboration) by defining the different elements of the OOP (see Figure 4).

7 BACK TO THE RESEARCH QUESTIONS

In this paper we identify two pertinent levels at which the outsourcing decision should be studied. At the first level (strategic one) decisions impact the firm's whole organization and various projects. Issues should be addressed with a long term perspective. Decision makers at this level are members of the board of directors. The second level is situated at the single project level of a firm. Project managers treat project specific issues with respect to the strategic inputs.

The decision concerning which design process or technology to source in order to access external knowledge is to a large extent firm specific. In this paper we propose to tackle this issue using a MCDA model. We believe this will represent a rational framework that allows taking into consideration multiple and conflicting points of view.

Given that information leakage regarding product's configurations and robustness is one of the biggest CF's concerns in outsourcing design, this will be a predominant criterion when deciding about outsourcing and contractual features. If the decision of outsourcing is taken, the knowledge control will be under the responsibility of the day to day operational level.

Finally, as stated in section 4, we can look at the work presented here form an open innovation perspective. In parallel, we need to pay careful attention to two issues. First, the petroleum services industry is far from being compliant with full open innovation conditions as described in [26]. We note for example an absence of the Venture Capitals parallel to the low occurrence of the spin-offs phenomenon. But the presence of a rich and varied knowledge landscape leads us to the real objective behind our work, which is to allow the firm to benefit from this rich landscape. We do not address other aspects of the open innovation paradigm such as the alternatives paths to access existing or new markets. Addressing such issues would be an interesting complementary research subject to our work..

8 PRELIMINARY VALIDATION OF THE MODEL

We consider ourselves concerned by the validity of the model in the context within which it was developed. The validation should be looked at from two perspectives. The first is the applicability of the model. The second is the model's utility. The co-construction of the different parts of the model with the different actors of the company insured a first degree of applicability. Points of view and concerns of designer engineers, manufacturing engineers, projects and products managers along with technology managers were taken into account creating a common knowledge base and glossary. This interaction took the form of interviews or group meetings and workshops that allowed the advancement of the research work. Two of the company senior managers were assigned to follow-up the research project. Their role was to be the representatives of the board of directors and to of the CF from a client perspective. This allowed a step by step validation of the results and adjustments through monthly meetings. To date, utility perspective's preliminary validation is a paper based validation. Key outsourcing processes have been identified as well as decision making levels. In particular, the utility of the 7-steps process presented here (section 6.2.5) has been validated: Better identification of CF's and suppliers' responsibilities, improved formalization of CF and suppliers relation, and better definition of needed competencies and of knowledge sharing practices.

9 CONCLUSION AND FUTURE WORK

This paper describes a general process for design outsourcing and identifies the elements that constitute this general process. It explains the function of elements and their interaction. The systemic approach adopted in this study, which we referred to as the horizontal process allowed us to take into consideration the product lifecycle early in the design phase. The systemic approach that we adopted here for the model was on the other hand reflected by what we called a vertical process that aligns both strategic and operational issues related to outsourcing, and allows integrating different functions of the firm concerning the outsourcing issues. Finally, the immediate future work will focus on the MCDA model. We will then be able to put into work the two levels model. Then, the board of directors will take part directly in the entire model's validation. We expect this board will also validate the inherent logic. With the validation of the general process, we shall proceed to the implementation of the model to a broader range of projects.

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