A Methodology for Implementing a Product-Centred Bid Model for Suppliers

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ABSTRACT

Early phases of product development are critical for next phases and impact the product definition. During bid process, suppliers generate offers for a customer that must both meet customer's requirements and be realizable in terms of technical aspects, costs and due date. Our aim is to propose a methodology for implementing a generic bid model, composed of context parameters, customer's requirements, the product i.e. technical solution, its delivery process, and associated risks. Key Performance Indicators allow to evaluate different solutions. The bid model is exploited with two different approaches. First, we use Constraint Satisfaction Problems to formalize expert knowledge and identify variables/constraints and relations. Second, we use case database to reuse past experiences. This model and the methodology are applied with a company developing harbour cranes. An initialisation phase allows to define existing bid process. Then, the generic model is adapted through a specialisation phase, using specific knowledge from company's experts. Finally, the specific model is implemented and tested in an implementation phase. Future work will be focused on a software tool development.

Keywords: Knowledge management, Product modelling / models, Design methodology, Offer model implementation, Bid process

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1 INTRODUCTION

Early phases of new product development process (Bidault *et al*., 1998) mainly predetermine the results of the complete development process by impacting the quality and relevancy of the final product. When the product is developed by a supplier for a customer, they impact also the satisfaction of the customer and the expected benefits of the supplier. According to Petersen *et al*. (2005), the relationships between a supplier and a customer can be described by three different levels: support to the customer (white box), collaborative development (grey box), or sub-contracting of the entire product (black box). In this final situation, the supplier is responsible of the product development and must satisfy the requirements provided by the customer. Our works concern this black box situation.

During the early phases, the customer may have to select a supplier. To describe such process, Langner and Seidel (2009) propose a collaborative concept development process divided into three distinct phases: exploration phase, competition phase and engagement phase. The exploration phase allows customer to generate the requirements that will be used by the possible suppliers for formalising an offer during the competition phase. This phase is concluded by the selection of the supplier that will be contracted during the engagement phase. During this final phase the proposed product may be improved through direct exchanges between supplier and customer.

In this paper we focus on the competition phase and on the way that a supplier formalises an offer to respond to a customer request through call for tenders. Focusing on the supplier process, we can describe the bidding process during the competition phase as follows:

- First, the supplier got requirements elaborated by the customer during the exploration phase (Yager *et al*., 2015). The supplier starts analysing the opportunity to bid then takes a first decision: to answer or not to the call for tenders (Chalal and Ghomari, 2006).
- The second activity deals with the elaboration of the offer. Using the customer's requirements and context information, the supplier elaborates the technical offer. Most offers are built by choosing between existing elements already implemented in previous offers those who match the customer's needs. Thus, elaborating an offer can be associated to routine design (Chandrasekaran, 1990), or even configuration (Mittal and Frayman, 1989), rather than innovative design. This means that we are mostly in an Assemble-to-order situation, with a small part of new items to be designed (Engineer-to-order situation).

Finally, the proposal is sent to the customer, and the supplier waits for customer's decision.

Besides, to respond to bids, suppliers face a competitive environment and demanding customers. To be competitive, a supplier must develop offers consistent with requirements, attractive by their technical solutions and their cost, and feasible by controlling the delivery process and the associated risks.

Thus, our work focuses on the offer elaboration activities in order to propose models and tools that will support the bidding process for a supplier. In this paper, we describe a product-centred bid model, already detailed in Guillon *et al*. (2017), and the main contribution is a methodology to implement such model into a specific company. This paper is structured as follows. In section 2 we introduce the applied research method and the case study. Section 3 is dedicated first to a review of product and process modelling then on our offer modelling. Section 4 presents the implementation methodology which is illustrated by a case study. Then, a discussion and a conclusion are drawn in section 5.

2 RESEARCH METHOD

The work presented in this paper is part of the OPERA project (https://research-gi.mines-albi.fr/display/OPERA). OPERA is a R&D collaborative project funded by French Research National Agency (ANR) and labelled by both Aerospace Valley and Viameca competitivity poles. In order to help bidders during the response to call for tenders, the OPERA objective is to provide them a knowledge-based system (KBS) exploiting their expertise and good practices. The project has in November 2016 and involves four industrial partners which respond daily to calls for tenders: one from automaton engineering, one producing milling machines and two from service companies. Thus, we have structured our research work as follows:

1. Study of the industrial need: What is an offer? What information is needed to elaborate one?
2. Literature review: How to model an offer, a product, a process, risks?
3. Proposition of a generic bid model.
4. Formal validation of the generic bid model using uses cases elaborated on main offers of the industrial partners.

5. Consolidation of the generic bid model and KBS software specifications.
6. Proposition of a methodology for implementing generic bid model and KBS into a company.
7. Operational validation of the methodology based on software experimentations (to come up).
8. Consolidation of the implementation methodology (to come up).

Thanks to OPERA project, we interacted several times with industrial partners. First, during step 1, we achieved interviews within members of commercial and design teams to have a clear understanding of their needs: What kind of products do they develop? What limits are they facing during the bidding process? Then, during step 4, we made other interviews with same people to detail the content of an offer and improve our model, and to identify and formalise uses cases. During step 5, we worked with them for defining part of the functional requirements of the software to be implemented. Finally, during step 7, we planned to make tests and experiments with them to both validate the proposed methodology and tool. Moreover, steps 4 to 8 are included in a two-iteration loop, first iteration with models and use cases formalised before the implementation of the tool, and second iteration using the implemented tool.

In section 4 is presented a real case study that illustrates the proposed methodology: transformation of the generic model in order to validate its applicability. For confidentiality reasons, the real case has been simplified. We worked with one industrial partner of the OPERA project which is a small design office (six people) specialised in automatons engineering. This company works on the electric part of harbour lifting gear only, and work with an industrial partner for the mechanical part. The case study concerns the generation of a crane offer.

3 PRODUCT AND PROCESS MODELLING FOR BIDDING PROCESS

3.1 Review of product and process modelling

Modelling an offer refers to design knowledge modelling in the specific context of a bidding process. An offer is composed of the technical solution and the delivery process, so we need to extract expert knowledge to formalise a model of the product that the company is used to sell, then a model of the process that it is used to implement.

Several product models and process models have been proposed in the literature. Some authors show that integrated models should allow knowledge capture and reuse (Abramovici and Chasiotis, 2002) but also support decision making for design choices (Merlo and Girard, 2004), sometimes by using AI approaches (Klein, 2000). Product models can be categorised according to the objective of the model. For example, Eckert *et al*. (2017) distinguishes models for product visualisation, for product definition, for product evaluation or for product lifecycle management. During the bid process as part of the early design phases, the supplier needs to define the product to be proposed and to evaluate some parameters such as costs and risks, and visualisation or lifecycle dimensions are not useful at this stage. A lot of models for product definition are proposed such as ISF (Ahmad *et al*., 2013), or models based on Functions - Behaviour - Structure (FBS) concepts (Gero and Kannengiesser, 2014 or Bernard *et al*., 2006). Mainly all of them propose as part of their model to define components and parameters as a structural dimension of the product. Functions result from the customer's needs and their analysis by the company (specification).

A lot of process models were proposed too, either process modelling for process management purpose or integrated models combining process modelling to other dimension for specific purpose. In the first category have been proposed models generally used for describing business processes such as BMPN or SADT or for scheduling activities (PERT, GANTT). Such models shared generic concepts such as activities and their parameters (mainly start date, end date, duration, input/output, resources) and sequential links between activities with or without chronological purpose. Such concepts are useful for describing the process that will be implemented by the supplier if the bid is a success.

In the second category, we can notice Product-Process-Organisation model (Roucoules *et al*., 2006, Robin *et al*., 2010) which proposes to associate product model states as input and output to design activities, or the Design History System (Shah *et al*., 1996) which is available for assembly relations and configurations. Here also main concepts of the design process description are based on linked activities. Nevertheless, the interest of coupling product modelling to design process modelling is not a priority in the case of a bidding process. First design achieved during the bidding process is only a preliminary design for quotation, made in a short time. Moreover, design activities are considered as product configuration activities (Abeille *et al.*, 2010). Second, design to be achieved if the bid is a success is only identified as a global activity to quote its resources and costs, as well as other activities that the suppliers will have to achieve for the customer such as delivering, installing, teaching, maintain, etc (Sylla *et al.*, 2017). We conclude that product and process modelling during a bid process is based on main structural components of product and process, without integration between the two models.

Knowledge modelling requires to focus also on the way knowledge will be used or reused. Our research work aims at supporting suppliers to automate the generation of offers by providing a KBS to suppliers. Different techniques exist that can be used. Knowledge engineering approaches aim at capturing and formalising expert knowledge in order to implement specific KBS for a manual reuse (e.g. MASK method by Matta *et al.*, 2002) or for problem-solving expert systems: e.g. Tiger system implemented by Milne and Nicol, (2000), for turbine diagnostic). In such systems, business rules must be formalised for solving problems as proposed by Malatesta *et al*. (2015). Constraint Satisfaction Problems (CSP), as defined by Montanari (1974) are very often used in design then configuration problems for knowledge modelling (Felfernig *et al.*, 2014) and decision support. Another interesting approach for supporting suppliers is to consider the reuse of the experience, mainly by using Case Based Reasoning systems such as P-Race system by Bandini and Manzoni (2000) for tyre characterisation. Both types of approaches can be applied for improving the generation of an offer by suppliers. We propose in the next section the offer model and the way we will use it for proposing a KBS system.

3.2 OPERA product-process model for bidding process

For the generation of an offer by a supplier, Guillon *et al*. (2017) propose a product-centred bid model (Figure 1). To elaborate a relevant offer and allow feedback on similar cases, supplier has to (1) characterize the context of the bidding, (2) identify key requirements, (3) describe the proposed technical system, and (4) describe its delivery process and associated risks.

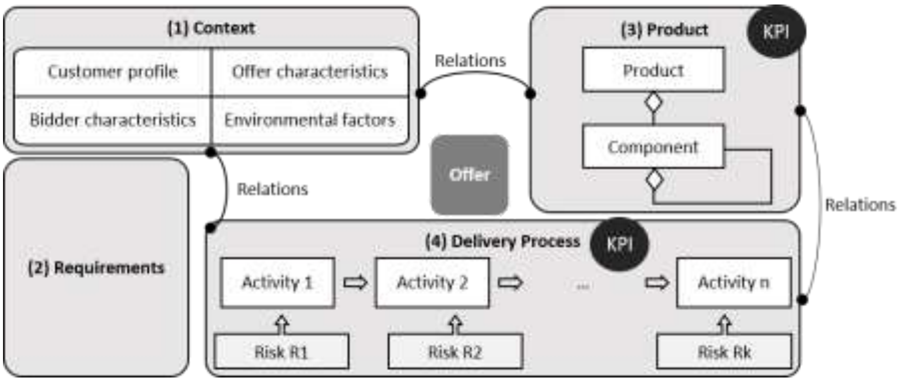

Figure 1. Generic product-centred model

(1) Context. Context information has an impact on the proposed solution and its delivery process. Four types of information have been distinguished, those characterizing:

- the customer profile (for instance, is it a new customer? Is it a strategic one?);
- the offer characteristics (for instance; is it a public or a private market? Are there late penalties?);
- the bidder characteristics (for instance, is the workshop overloaded?);
- the environmental factors (for instance, is here an important competitor present on the market?).

(2) Requirements. A set of variables allows to list key customer requirements, and if necessary resulting requirements / specifications. Functions of the product can be formalised this way to help to select righjt and existing solutions, but it is not mandatory at this stage since detailed design is out of scope. In this paper we do not develop the links between requirements and solutions.

(3) Product. The description of the technical solution is the key part of the model. It corresponds to an outsourced product, sometimes associated to services (e.g. support for installation or support for teaching dedicated employees). Product description is based on two types of elements as demonstrated in section 3.1: first, the description of the structure of the product formalized as a bill of materials (BOM) and, second, the description of each component key characteristics. The cost assessment of

this technical solution is a very important point in competition phase. Besides, the technical characteristics of the solution are of strong interest for the customer.
(4) Delivery process. To propose an accurate due date and eventually evaluate working loads, the supplier has to describe the delivery process as a sequence of activities (see section 3.1). The delivery process does not have to be detailed in this competition phase. The objective is to identify key activities to: evaluate costs linked to delivery process; propose a relevant due date; and identify major risks. Indeed, we propose to carry out a partial **risks analysis** to provide more realistic costs and due date.
Key Performance Indicators (KPI) are necessary to characterize the product and the delivery process and to compare different options or offers. It can be financial indicators (cost, price or margin for instance), duration or load indicators, but also confidence indicators (Sylla *et al*., 2017).
We point out that the generation of a bid is an iterative process with several improving iterations. Various reasons may exist: either the cost or due date does not fit the customer's requirements after having defined the technical solution or the delivery process; or risks are too high for the supplier with an important economic loss and they have to be reduced; or the specifications have changed due to customer's reorientation.
This product-centred bid model will be exploited with two different approaches. First, since offer elaboration during the response to call for tender is very close to configuration, we will use CSP. Second, to allow companies to reuse the knowledge of past cases and past experiences, a case database will be used. This implicit knowledge base is added to the explicit knowledge base (CSP) and thus a complete knowledge-based system (KBS) is built to help the response to call for tender. This KBS should help the supplier to build different bids on the same specifications, to compare them following relevant criteria (e.g. selling price or due date) and to select the one which suits the best both customer's requirements and companies' capabilities.

4 METHODOLOGY FOR IMPLEMENTING THE OPERA BID MODEL

This section is dedicated to the proposal of a methodology to implement the model proposed in previous section. This methodology is composed of three phases (Figure 2) and illustrated by the case study introduced in section 2.

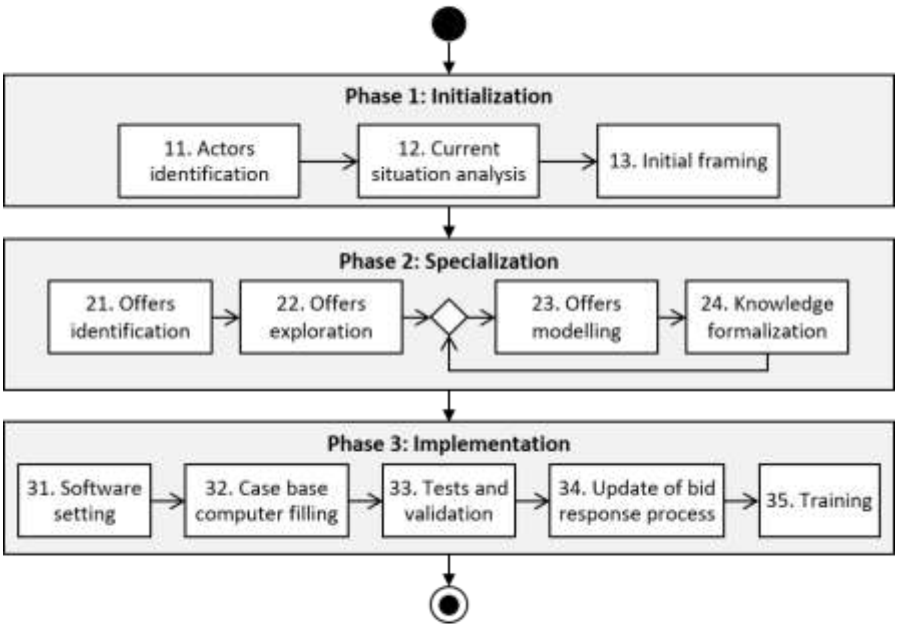

Figure 2. Methodology for bid model implementation

4.1 [Phase 1] Initialization

The objective of this first phase is to identify key interlocutors, to understand the expectations and the business of the company and to define the scope and the activities to be scheduled. This *Initialization* phase is composed of three steps:

(11) Actors identification: Identification of people who will step in throughout the deployment of the methodology: Who are the experts to interview? Who are the future users to train? Who will be the selected interlocutors? Etc.

Case study (CS): We have identified two types of roles who will use the software: one expert and several technical users. The expert (sales manager) and one of the technical users (international relationships coordinator) have been implicated all along the deployment of the methodology.

(12) Current situation analysis: What is an offer for the company? What are main bidding process KPIs? How many people are involved in a response? What are their skills? What is the response time? How many iterations does it take to submit a final offer? Etc.

CS: The company, which submits around 200 quotations per year, responds to 10 to 20 calls per year for new full harbour lifting gear, on public or private markets**.**

(13) Initial framing: Expectations validation and definition of means and provisional timetable. What are the expectations of the implicated people? Do they fit to the improvement linked to the deployment of OPERA software? What is the scope of study? What types of offer are considered?

CS: Our main interlocutors were the expert and international coordinator. It appears that the objective of the company is to increase the success rate by (1) reducing the response time and increase the response number and (2) elaborating relevant offers using expert knowledge.

4.2 [Phase 2] Specialization

The objective of this second phase is to formalize the knowledge of the company's experts. This *Specialization* phase describes how to "transform" the generic model proposed in section 3.2 to a model specific to the studied company, and is composed of four steps:

(21) Offers identification: Regarding the scope defined previously, identification of offers concepts and model restrictions specific to the company.

CS: Due to the company specificities and to reduce the complexity of the model for future users, some restrictions have been identified. First, the delivery process is a sequential process and, second, the BOM structure will be limited to three levels of decomposition. Three types of offers have been identified: new full harbour lifting gear, new part of lifting gear for retrofitting or repair/renovation. The first use case is limited to new full harbour lifting gear.

(22) Offers exploration: Understanding of the offers. This step is centred on the company. To gather the most information, we will use a vocabulary understandable by the actors. It is an iterative step, where four different activities may be carried out several times to approach the completeness of the collected information. The activities are the following ones: identification of context, product, process elements and their attributes; business rules description; risks exploration and offer validation.

CS: Six interviews and iterations - six days schedules periodically every two months - have allowed to gather all the information needed to elaborate the model proposed at the next step. Two past cases have been identified to complete the case database.

(23) Offers modelling: Modelling based on all information gathered previously that is formalised using CSP concepts of variables and definition domains. These new concepts may be defined for any of the 4 sub-models of the model, and at any level resulting from the implementation of product or process dimensions to represent the products and the processes of the selected company.

CS: Based on previous step collected information, we formalise key knowledge of the company using the generic model to obtain the corresponding specific model. Following example (Figure 3) illustrates this work:

(1) 3 variables have been identified to characterize the context: strategic customer, late penalties, bidder characteristics and partner confidence;

(2) 1 variable describe the requirements: business type (is the bid for a new crane selling or is it a renovation of an existing crane);

(3) The product sub-model has been implemented to become a 3-level BOM sub-model describing the product: crane; then electrical distribution, control and movements; then automaton, engine and transmission. Each component is characterized by one to several variables. The cost is the only KPI chosen for the product part. A constraint links the engines powers and the transmissions powers (described in step 24).

(4) The process sub-model has been implemented and proposes a sequential process of four identified activities. Two KPI (the cost and the delivery time) characterize this process. One risk R1, called « Out of spec component », has been identified. It can occur during the activity of

Procurement: if a provider delivers a component out of specification, then the company has to send back the component and wait for a new proper one.

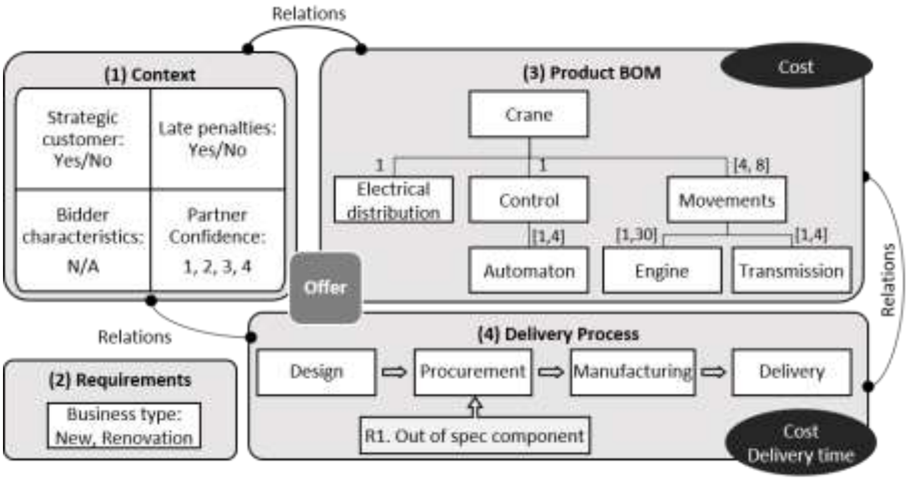

Figure 3. Specific bid model - application to a crane offer

(24) Knowledge formalization: Translation of business rules into constraints (CSP) and formalization of past cases.

CS: During step (23), we identified a constraint between the engines' power and the transmissions power. This constraint is defined by following rule:
"For a movement, for a given transmission *i*, the power of the transmission is greater than or equal to the sum of the power of the engines which are linked to it".
Rules linked to the risk "R1: Out of spec component" are also defined:
Probability = [1, 10] %
Duration impact = x days with $x \in [5, 90]$
Cost impact = 0 if Late penalties = No
Cost impact = $x \times y$ if Late penalties = Yes
with y the daily cost of the penalty
The preventive action "PA1: Supplier audit" is then identified to reduce the occurrence of the risk "R1: Out of spec component":
Cost = [1 000, 3 000] €
Duration = 1 or 2 days
Probability reduction = Less than 5%
No cost impact, no duration impact
These constraints will be managed by the future OPERA CSP module for controlling the definition of an offer by a company.

At the end of this second phase, a new model is obtained and is called the specific model. This model is composed of a CSP part and a "paper" database, which means the structure of the future database has been identified and past cases have been formalized.

4.3 [Phase 3] Implementation

The objective of this phase is to implement the model into the OPERA's software for the company.

(31) Software settings: Deployment of the software and configuration for implementing the specific model and managing the structure of the case database.

CS: This phase has been achieved for the first iteration but as OPERA software is currently in development it therefore could not be deployed yet for the second iteration. In the first iteration, the objective is only to validate the models and rules, as well as the completeness of the tests, so only steps (32) and (33).

(32) Case database filling: Using the past cases previously formalized at step (24).

CS: First with the expert and the international coordinator of the company, we analysed two past cases in order to characterise information given by the customer then the resulting offer from the company: this information corresponds to input data then output data.

(33) Tests and validation: Using pre-established cases, the software is tested to compare software's output and expected ones.

CS: We defined a scenario that corresponds to a theoretical sequence of activities for generating the offer. This scenario corresponds also to the way the company works. In this first iteration, we applied the scenario with the company to apply manually the specific model by other technical people in order to control the manual input and output all along the scenario. Results correspond to the expected output: given the initial customer's needs, a technician generates an offer respecting the specific model. Successful outputs consist of an offer that (1) respect CSP defined rules, (2) is similar to the predefined offer according to the variables' domains, and (3) has not generated restrictions in technician choices.

By this way we validated the tests composed of input/output data and scenarios to be implemented when the software will be available.

For future second iteration, the scenarios must be able to test all rules and all alternatives of these rules to control the behaviour of the CSP rules. If it appears too complex to evaluate all resulting rules combinations, it can be divided into several scenarios.

(34) Update of bid response process: Following the first uses of the OPERA software, the company former bid response process is updated with new practices and the new bid process is formalized.

(35) Training: Training adapted to each role of user profile: e.g. technical expert or sales agent.

Once these three phases are achieved, the company is ready to exploit the model to elaborate new offers.

5 DISCUSSION AND CONCLUSION

The results obtained by applying the proposed methodology can be analysed according three points of view: models, then methodology itself and finally the relevancy of the approach.

Concerning the offer model, all partners involved in the OPERA project validate the content and the structure of the model as they can represent all information they generate for an offer. The tests achieved during the 'paper loop' show that the generic model can be adapted as a specific model for any of the four industrial partners. The example, voluntarily simple, illustrates the mechanism to adapt the generic model into a specific one. Focusing on product and process models, our proposal is reduced at main concepts but compared with other product and process models, we consider that it can be extended in order to allow interoperability between an offer-centred software and a design-centred software: e.g. specifications as a list can be re-used as "functions" objects in a FBS-based tool; product BOM is one dimension of such a FBS-based tool; the activities of our process model can be re-used in a project management tool that would also beneficiate from the characterisation of resources, timetables and KPI; etc. Another limit is that the model has been built and experienced in a routine design context. But it may be extended to authorise innovation in some subsystems. All these points are perspectives for future work out of scope in the OPERA project.

During last years, service is becoming more and more important and, in many offers, the customer expects products and services, or even more services than products. It is then also important that our product model integrates service modelling. This work is presently developed with two of the OPERA partners, specialised in training or in consulting, and a more complex example of a specific model is under development, combining product and services.

Concerning the methodology, our proposal has a significant impact for the companies as they can implement a dedicated tool without any new programming phase. Nevertheless, the company must be able to adopt a knowledge-centred culture to be able to get a global overview of its process, and to train experts with unusual concepts and tools. The different steps of the methodology should help these experts to "change" (Argyris and Schön 1974) and to be supported all along this cognitive process.

Finally concerning the relevancy of our approach, we have presented in this paper first results that show its applicability. Presently, our research work is not yet achieved, and we cannot demonstrate if the generation of offers during a bid process is improved on several indicators: e.g. time of generation, effectiveness of the estimated costs, or convergence of the offer parameters compared to the real ones after customer's acceptation. More precisely, our methodology will have to integrate such validation phases to trace what happens during the project then to compare it to what was planned in the offer. This is the objective of the research work engaged through OPERA project and that will end in 2020.

To conclude, in this paper we focused on the preliminary phases of product development, studying the bid process of a supplier generating an offer for a customer. Our aim is to support this process by characterising a model of an offer and developing a Knowledge Based System. In this paper we present first results of this research which consists in a generic product-centred offer model, the formalisation of expert rules using CSP techniques, and the proposal of a methodology to implement model and tool for a specific company. The discussion of the results obtained through the case study show that several axes are still to be explored such as extending the offer model to services, implementing the KBS software, and applying final steps of the methodology.

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