PLM adoption in SMEs context

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ABSTRACT

The increasing market needs and technologies evolution, push companies to develop competitive advantages based on adequate and intensive use of information technology and communication (ICT). However, SMEs do not realize the importance of ICT adoption, which becomes vital for the development, and are not always well equipped to adopt and integrate them to their activities.
The paper focused on issues regarding the ICT adoption, especially PLM solutions by SMEs. By analyzing the PLM definitions and works done, we explored indicators that impact positively or negatively ICT and PLM adoption. This paper proposes a model, currently theoretical, with empirical validation proposal through a survey.

Keywords: PLM, SMEs, ICT adoption.

1 INTRODUCTION

The ICT is one of the ways, at the disposal of a company, to increase its productivity. Large companies have already realized it long time ago, but SMEs have discovered the opportunities offered by ICT recently and they still have difficulties to understand all the potential of these technologies [64]. Effectively, if you go back 10 years, ICT solutions, PLM, accounted for very high costs and long and costly internal resources deployments. This is one of the reasons that many SMEs are struggling to adopt these technologies.

Recently several researchers were interested to enterprises ICT adoption; [14] has used statistical tools to improve the adoption process of PLM tools and systems. The work focuses on PLM introduction strategy, and its effect on the organization. In [31], authors investigated the adoption process of ICT in the Italian manufacturing sector; the survey was done around of 1500 firms with more than 50 employees. Work indicates that size, human capital of the workforce and the presence of large firms in the local environment has an impact on ICT adoption. Another investigation based on an empirical analysis was conduct in [13]; authors highlight the importance of firm manager and quality assurance system in the ICT adoption. Always in terms of strategy, in [51] author proposed a model of adoption based on 3 relevant issues: Perceived benefits, organizational readiness and external pressures, used to test IT adoption.

In [58] authors considered the adoption of PLM as a selection of information advanced technology, which requires an evaluation of several competing alternatives. They considered PLM software as a complex, expensive, service-depended software initiative; and the challenge is solving the costs related with IT technology and infrastructure investment.

The Information Society concept was addressed in [9]; where author focuses on initiatives and programs that promote it. In [9] author made a vast study on ICT according to SMEs from regions of Spain, Portugal and Poland. The work is based on the "material access", "skills access" and "usage access" supporting for owner-managers and employees of SMEs, especially the older ones. Author shows that the Digital Divide in small and medium-sized enterprises is due to owner-managers' and employees' knowledge and not to money or technology.

There is another aspect of work, where author, in [26], makes a survey with 73 owner managers of SMEs in the west Midlands UK, and examines issues that are relevant to successful adoption in ICT companies. He concludes that companies whose main business is in ICT would have no difficulty in adopting new technology. Some of these companies are not aware that some of the latest technologies can provide high efficiency in their business processes. This work may has limitation due to the disclosing of information from own manager.

PLM incorporates a product centric vision enabled by the adoption of advanced ICT solutions fostering collaboration among many actors and organization [69]. Appeared in the late 90s, the acronym "PLM" Product Lifecycle Management concept has succeeded the "PDM" ("product Data Management", in order to draw the product information in the industry [15]. A journey on the Internet (Google) of "Product Life Cycle Management" identifies more than 9.200.000 various links and information overload ... This deserves some clarification.

The literal translation of the Product Life-Cycle Management is the management of a product throughout its life cycle. This life cycle includes the initial customer requirements from concept design including the manufacturing design (industrialization product / process), operational life and end of life (recycling) [27].

PLM is an integrated approach including a consistent set of methods, models and IT tools for managing product information, engineering processes and applications along the different phases of the product lifecycle. PLM addresses not only one company but a globally distributed, interdisciplinary collaboration between producers, suppliers, partners and customers [4].

(IBM) defines PLM as "…a strategic approach to creating and managing a company's product-related intellectual capital, from its initial conception to retirement".

For the analyst CIMData [21], PLM is defined as: "a strategic business approach that applies a consistent set of business solutions in support of the collaborative creation, management, dissemination, and use of product definition information across the extended enterprise from concept to end of life – integrating people, processes, business systems, and information."

For the PLMIG (PLM Interst Group), PLM includes research, management of customer requirements, product development CAD, CAM, simulation, rapid prototyping and virtual concurrent engineering, product / process design, sourcing of components, machining digital control, collaboration via the web with customers and suppliers. PDM is the IT Platform for PLM, the terms 'PLM System' and 'PDM System' mean the same thing, and are interchangeable.

Despite the conferences / Journals [32], [18], [64], [48] books [27], [62] websites (PLM Interst Group) [43], [74] meetings, and especially industrial needs, there is a really need to map the PLM. Especially, when it goes through the literature and see the words often associated to PLM, see Tab. 1.

Terms related to PLM	*Author*
Collaborative Mode	[21], [53], [43], [3]
Strategic approach	(CIMData), (IBM) [2], [62], [5]
Requirement management	(PLM Interst Group)
PLM Process	(PLM Interst Group) (CIMData) [62], [33], [63]

PLM Architecture (IT tools)	(CIMData) [62], [33], [53], [1]
Integrated Business approach	(CIMData) [53], [1]
Integrated management	[63]
Product structure	(PLM Interst Group) [66]
Concurrent Engineering	(PLM Interst Group)
Engineering process management	[1]

Tab. 1: Terms listed in PLM definitions, adapted from [48], [18].

Beyond these terms listed in different definitions, we find a multitude of acronyms and other topics associated to PLM. The combination of all these terms/topics and acronyms is mainly due to the vast field that PLM is trying to cover. Today, PLM aims to address several concerns, via tools and resources often based on standards such as:

- Design Tools / Manufacturing / simulation of product data (CAD, document management ...)
- Means of collaboration, management and sharing product data.
- Standards and practices for the unification of data formats, languages, sharing and services.

Following the various definitions and areas related to PLM, we noted that we could combine these terms along defined axes by grouping keywords/terms according to their areas.

Next paragraph will introduce our vision about PLM which is used as a reference throughout the paper. Third paragraph is on the need of SMEs for PLM especially for improving collaboration. The fourth paragraph proposed the model of PLM adoption based on quantitative KPIs. The fifth paragraph highlights the existing links between different KPIs through an oriented graph. Finally, we conclude and discuss future work on how to improve and deploy our model.

2 THE PROPOSED PLM AXES

PLM is a complex phenomenon in which several dimensions and disciplines use their contributions [68], "bringing together products, services, structures, activities, processes, people, skills, application systems, data, information, methods, techniques, practices and standards" [65].

The opinion paper, [23], provides an approach based on 4-Pillars of integrated PLM in order to alleviating the multiple dimension of PLM complexity. The foundation of the approach is a process view put across four pillars of PLM that are to be integrated in a holistic sense. Based on best-practice experience from industries with higher PLM-maturity level (automotive, manufacturing industry), the model includes 1) PLM Process and Organization, 2) PLM Meta-Model, 3) PLM IT-Architecture and 4) Lifecycle Value Management. They expected that PLM will support value creation in following areas: Technical (user's need, product function optimization), economical (creation of value), Social (comfort, security and satisfaction to product), and environmental (focuses on resources, energy consumption).

In [69], authors proposed their vision for future steps of PLM, based on 3 lifecycle phases BOL (beguiling of lifecycle), MOL (middle of lifecycle) and EOL (end of lifecycle) adapted from [45] work. For this vision they proposed a fundamental element of PLM: Process for PLM, Methodology for PLM and ICT for PLM (tools).

For our approach, we made a literature review synthesis, mainly based on some PLM definitions and terminologies, and terms assigned to the PLM by different authors (Table. 1). Our initial analysis leads on drawing four axes (levels) grouping terms often associated with PLM (Table 1). These axes are: the strategic level (Integred Business approach, Portfolio Management, Virtual Enterprise, ...), level (definition) process (Requirements Management, Corporate Management, ...), the organizational level (collaborative mode, concurrent engineering, ...) and finally the tools implemented (ICT Architecture, product Structure, ...).

The following figure, Fig. 1, shows these four axes which will serve as a reference in the rest of our work. Strategy is the highest level, where important decisions are taking and in this level we define the kind of organization and make decision on processes. The organizational level describes the shape of structure based on different processes in different departments. Tools level is the implementation of processes and the support for the organization.

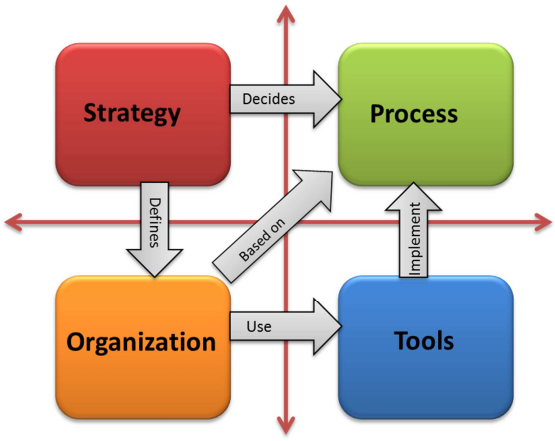

Fig. 1: PLM axis.

The following table, Tab. 2, summarizes the proposed axes: Strategy, organization, processes and Tools, and shows the main actions under each level.

Strategy	• Defining general guidelines • External/internal Evaluation STEEP, SWOT • Business model supporting product/service • Product portfolio
Organisation	• Change management: CR, ECR, ECO • Standards, Data mining • Capture, Dissemination, Transformation, sharing • End of life decision making
Process	• Specification of the operational organization/ Structure • Skills, motivation, turnover management • People and culture management
Tools	• 3D Model, CAX (CAD, CAM, …) • Requirements tools (Doors, etc.) • PDM, ERP, CRM, SCM, MES, … tools • Product models

Tab. 2: Again, short captions should be centered under each table.

In summary, product lifecycle management, (management) is the act of bringing people together to accomplish common goals. Therefore, there are at least five questions that must be taken into account in the management of the life cycle of the product [48]:

- When: the step where management occurs (Strategy / Process)
- Who: people, organizations involved in PLM (Organization)
- What: objects to manage in the PLM (Process)
- Why: challenges, motivations and objectives of PLM (Strategy)

- How to: the features and technologies that support PLM (Tools)

3 PROBLEM STATEMENTS

The main goal of BENEFITS project is to improve OEM-SMEs collaboration via PLM. One of important actions is to understand the barriers that discourage SMEs from taking advantage of ICT, especially PLM. From this point, we have chosen to go further and to review indicators that impact, positively or negatively, the SME's adoption of such technologies.

4 SMES NEED FOR « ICT » TOOLS

Enterprises, especially SMEs are not ready to make investment unless the benefits are seen behind. The benefit of PLM adoption fit into this framework, and is often not well evaluated by SMEs, and not easily transferred to monetary benefits [65],[28]. In the other hand, we have an interesting investigation in [39] where authors identify barriers to ICT adoption. They find that mostly barriers (for SMEs) are related to costs and skills rather than problems with the technology. Only a minority (about 25%) of firms reported technical problems sufficient to act as a barrier to future investments. Moreover, in recent years, companies have had to review their work following a number of evolutions:

- Contracts for outsourcing have increased
- Automation in industry has grown significantly
- Customers have more opportunity to influence the product
- The product portfolio has been expanded

PLM was initially adopted by large company in the field of automotive and aerospace industries. However, offers are changing and more and more solutions are adapted to SMEs. For example, PTC PLM On Demand Standard (service provided and hosted on a server offline by IBM) is a solution for SMEs, designed to prevent disadvantages according to initial investment, ICT resources and their slow deployment [19].

For more comprehension, and according to certain specifications, we can distinguish SMEs from large companies and to better understand the concept of SMEs. For [44], SMEs present five main features:

- Small size, characterized by lower hierarchical distance, promoting direct contacts and working relationships rather informal. SMEs differ from large enterprises characterized by anonymous relations, strongly hierarchical and formalized;
- Centralization/customization, management around the owner (Leader);
- low specialization, both in the direction or resources (employees and equipment);
- an intuitive and little formalized strategy;
- Less complex and poorly organized internal and external information systems cede place for dialogue and direct contact (while large companies are forced to establish a formal mechanism for all transfer of information).

PLM systems control critical product information that must be shared with other enterprise systems, such as ERP, CRM and SCM. Likewise, PLM systems need to leverage information that is managed in other enterprise systems. This bi-directional connection between PLM and other systems is critical for enabling a seamless flow of information among the different functional groups involved in product development, particularly engineering and manufacturing. The earlier supplier's integration in the life cycle can foster innovation [52]. The biggest benefits, by implementing PLM, can be realized through faster product development time and faster time to market [4],[64]. PLM systems adoption allows the organizational learning improvement, and the knowledge accumulation [6]. According to [65],[64], [47],[48] general benefits from PLM are identified as:

- effective management and use of corporate intellectual capital,
- effective communication among different groups at dispersed locations,
- better access to customer need information,
- increased (more innovative ideas) and quick innovation,
- improved sales process, and quicker delivery,

- utilizing distributed development,
- better possibilities for make-buy decisions,
- improved user support,
- less product defects, minimized manufacturing costs, and high quality
- reduced project failure rates,
- utilizing accumulated knowledge for service and maintenance,
- More effective re-use of product parts, and disposal of products.
- Mass customization,
- More environmentally aware.

The organization of outsourcing (according to vertical cooperation) is seen as a pyramidal structure, where; the top of the pyramid is occupied by the OEM and the bottom by suppliers [37]. At the highest level suppliers of the first rank, these are enterprises that have a special relationship with the OEM. It is possible in this kind of relationship, that the OEM who adopts a new technology requires it to its suppliers in order to facilitate coordination and exchange (as happens often in the automotive sector and aeronautics), thereby facilitating the adoption of a new technology standard [37]. In the case of suppliers of first rank, we can expect a positive relationship between suppliers and the adoption of new technology. By cons, when dealing with a subcontractor (suppliers of low rank) at the very bottom of the pyramid and whose contribution to the value chain is marginal, we can expect a negative relationship between suppliers and adoption of new technology.

5 PLM ADOPTION BY SMES

In the early 2000s, with the emergence of the extended enterprise and integration of suppliers and partners in the product lifecycle, the PDM changed [61]. So, new concepts have emerged such as the PLM. With the adoption of PLM, enterprises can gain many benefits.

The concept of adoption may be defined as a process composed of a certain number of steps by which a potential adopter must pass before accepting the new product, new service or new idea [34]. We have two kinds of adoption, the individual adoption and organizational adoption. The individual adoption focuses on the behavior of the user according to new technology and impact the strategy related to the investment in information technology [49]. The organizational adoption follows two phases: initiation and implementation where the organization, forms an opinion of the new technology and assesses it, then makes the decision to purchase and use this new technology [49].

Introduce the PLM in an organization can help to challenge existing processes. The importance of the organizational dimension is reinforced by the fact that PLM is based on the cooperation of various businesses; collaboration that takes place at different levels (Informal collaboration, project/process collaboration and extended collaboration). So, introduce the PLM in an organization has an intrusive aspect that may affect the existing organization [29].

Many researchers have studied the impact of the adoption of ICT on business performance [10]; [11]; and [71]. They demonstrated that there was indeed a close relationship between ICT use and productivity gains or any other measure of performance of enterprise.

However, although the ICT-productivity link is proven, SMEs do not feel the need to adopt the PLM. Based on our analysis of PLM axes and works done on literature review, we will explore the ICT adoption according to 4 axes proposed, see Fig. 2.

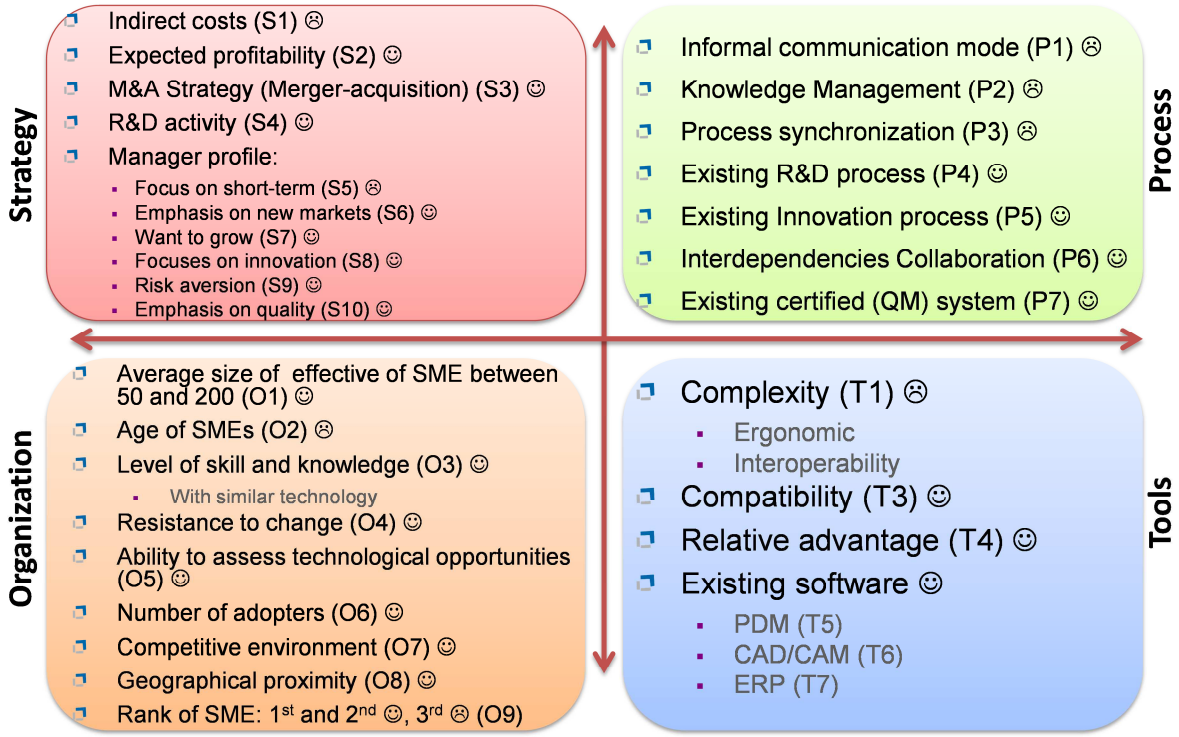

Fig. 2: The model of PLM adoption for SMEs (☺: Positive impact; ☹: Negative impact).

Adoption model, Fig. 2, shows the main element for adopting ICT (especially PLM) technology according to the forth axis: Strategy, Organization, Process and Tools. These elements are presented according to SMEs. For example, we can see the negative aspect (represented by sad smiley) of "Informal communication mode" in the process axis. It's related to SMEs practices, because in the most cases SMEs have an informal communication mode (according to their small size) and this kind of communication impact the PLM adoption.

According to [41], skills and competencies held by the enterprise are an essential element of its absorption capacity. The "Absorption capacity" was defined by [22] as the ability of a company to evaluate new external information, assimilate it and use it for commercial purposes.

5.1 Strategy

SMEs with greater financial capacity will be more likely to adopt ICTs technologies. They can more easily recruit qualified staff, which will facilitate the assimilation and diffusion of new technologies within the company [46]. Enterprise which has a large R&D budget and implements a strategy of acquisitions and fusion increases its absorption capacity, which promotes the adoption of new technologies [16]. These enterprises are more likely to reduce the risk associated with the adoption of a new ICT [22]. Enterprises that have a capacity of self-financing will easier adopt new technology [67].

The role of leader is crucial in the development of a strategy for the use of information technology. The introduction of information technology depends on the knowledge that had managers and their ability to understand the potential of these technologies [17]. The introduction of information technologies requires the development of new forms of organization and only leaders can effectively carry out these organizational changes over time [50]. The owner-managers' and employees' knowledge and skills play the crucial role in bridging the Digital Divide between SMEs and large corporations [8].

Enterprises that operate in highly competitive markets are likely to adopt an innovation may be necessary to maintain their market position and can enable for maintaining of “barriers to entry” [59], this factor is applicable to SMEs.

5.2 Organization

Traditionally, in the literature review we found that the adoption of a new technology is more likely for larger sized companies; this is due to the high risks and also the costs of early adoption [7]. Several empirical studies have shown that the size of the company had a positive impact on the adoption of ICTs technologies [46],[20]. In [41],[31] , authors argues that the size of SME is positively correlated with rapid adoption and intensive use of ICT; they suggested an optimum size (from 50 to 200 employees) [42]. SMEs have an advantage, according to large company, considering the small number of services and people involved, the implementation of PLM will not face to hard resistance to change [41]. In the other hand, SMEs with younger employees is able to have less resistance to changes [37]. Young workers might be more able and or willing to adapt to the changes induced by the new technologies [7]. Also, Age of SME can have a negative influence on the PLM adoption.

The integration of ICT requires strong retraining of workers; it is plausible that companies that already have a higher human capital, measured in terms of training and experience of workers, are more likely to be the first adopt [7],[31],[9]. The presence of skills and accumulated knowledge within the enterprise is important for the adoption of information technology [20].

Enterprises exporting are more likely to adopt new technologies to improve their internal organization and their production processes in order to remain competitive in international markets [40]. The diffusion of new technologies may be influenced by local industry influenced by interactions between companies. New technologies are characterized by a degree of uncertainty as to their profitability, decisions of other enterprises adoption could be an important influence source [7].

International competitive pressures increase the probability that a firm adopts such technologies [7]. Also, the local industrial structures have effects on the adoption patterns. The number of enterprises has two contrasting effects on adoption patterns. Having more enterprises in the local market will accelerate adoption, due to the circulation of information between them [38] and increases the competitive pressures, inducing a faster diffusion of new technologies [55].

In collaboration, especially vertical cooperation, we find the OEM at the highest level, and then there are the suppliers of 1st rank and so on. In this type of relationship, the principal who adopts the new technology requires its subcontractors to facilitate coordination and exchange, facilitating the adoption of a new technological standard.

5.3 Process

The new technologies adoption, such PLM, requires a standardization of procedures and information, which penalizes SMEs for which the exchange, either internally or externally, stood mostly informally [37].

Companies, including SMEs, are forced to redesign their products more frequently to meet the rapidly changing demands. R&D department is responsible, not only to develop new products, but also to change the information technologies that support the production process to make it more effective, and to develop effective and user-friendly applications to operate the assembly. The presence of an R&D department facilitates the adoption of new technologies [46] which can be seen as an existing R&D process and an ability to develop new products.

New organizational practices such certification process and product quality tend to reinforce the interdependencies between the company's members and between them and their external partners (OEM, suppliers), strongly favor the use of ICT by these companies [35]. Thus, interdependencies promote ICT adoption. In the other hand, Companies use ICT, in order to monitor production process, through quality management systems. A quality systems need to invest in ICT solutions. The implementation of quality control systems is positively related to ICT adoption [36].

5.4 Tools

The adoption of a new ICT, PLM, depends on its characteristics, but also on the context, especially technology already present in the company. They determine the compatibility of the new technology, but also the level of technological experience acquired through the use of older versions. In [70] authors show that the adoption of new technology depends on its advantage, compatibility and complexity. Also, the existence of an ERP, PDM and the use of software CAD/CAM within the company could facilitate the PLM adoption.

In [25] author studies the determinant factors in the adoption and use of ERP systems in SMEs which is conditioned by budget and tax. So, in [31], according questionnaire analysis, authors identify three different types of organizational software, namely MRP, ERP and EDI that impact the ICT adoption. They constructed a synthetic indicator of the degree of adoption of such technologies. The introduction of CAD/CAM, for example, requires suitably qualified employees to use it effectively [46] knowing that PLM integrates such tools. An enterprise may adopt a new technology only because other enterprises, having relationship with it, have already adopted [60].

A new (radical) innovation is likely to have a positive impact on the perceived advantage, but will reduce the level of compatibility with the existing structures of the organization [56]. If we consider PLM as an innovation for SMEs, the compatibility with other existing tools will have a positive impact on the adoption. In the same way, we assume that the complexity of PLM tools influences negatively the adoption.

6 TOWARD SMES ADOPTION EVALUATION IN TERMS OF PLM

Once adoption KPIs have been identified, we need to know if there are an interdependencies or links between KPIs. To choose the method of classification or prioritization of indicators, we must build a graph that represents the adoption model and interconnects indicators by validating sense relations.

The company size indicator(O_1) : The larger companies have more financial resources for a thorough KM implementation. Therefore, authors in [73] expect larger companies to have a higher KM (P_2) maturity than smaller companies.

Innovation activities(P_5): Here we expect that incremental innovations require a higher KM(P_2) maturity concerning processes and technologies whereas radical innovations require a higher KM maturity with regard to the key process area people [73].

Existence of a certified quality management (QM) system(P_7): As the certification of a QM system requires a thorough process management and documentation, we expect companies with a certified QM to have a higher KM (P_2)maturity, especially with respect to the key process area “processes”, than companies without a certified QM system (for the relationship between QM and KM see [57],[73].

Modules of Business Intelligence can be interfaced to the ERP(T_7) system to improve the decision making of managers ($S_{5,6,7,8,9}$) and provide useful knowledge relative to enterprise positioning, market trends and information on competitors [24]. The introduction of CAD/CAM ($T_{5,6,7}$)software, for example, requires suitably qualified employees (O_3) to use them effectively [40]. Existing certification process and product quality, strongly favor the use of ICT by companies [13].

Authors in [73] shows that there is no obvious relationship between the R&D spending and the industry or the size of the company.

Fig. 3 shows links between KPIs of adoption found in literature review. A directed graph is a good way for modelling KPIs. If we have a link, we will show it by a directed edge; the model allows multiple edges from one node to another; but no loops allowed. Continues lines represent links found in literature review, and Dashes represent links supposed.

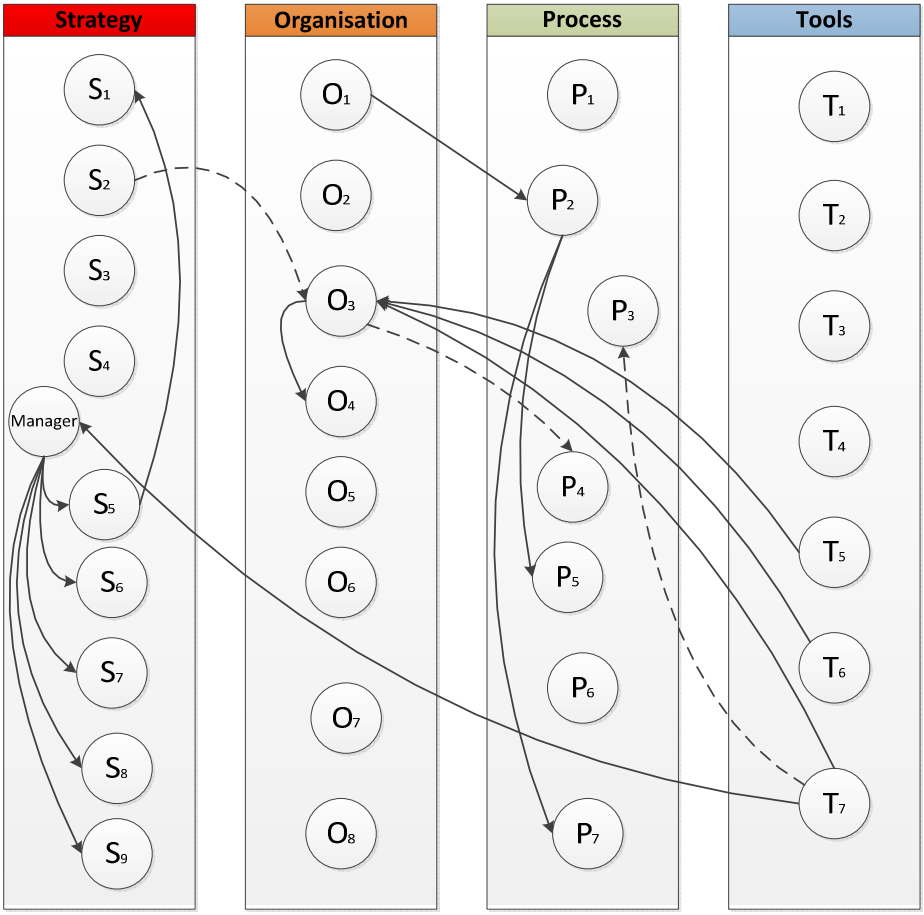

Fig. 3: Directed graph of PLM adoption KPIs.

The graph needs to be completed, by searching other links. We envisage conducting a survey with SMEs in order to validate and to improve the adoption model. Secondly we will validate and complete the directed graph.

7 CONCLUSION

ICTs adoption can be a source of competitiveness and sustainability for SMEs. In the other hand, the introduction of new ICT technologies, PLM, is a complex process that involves challenging the existing organization, not only in terms of information flow but also the human resources management and OEM/Suppliers relationship level. As seen in literature review, there are a number of factors that facilitate the adoption of ICT technology, but we also identified a number of obstacles that will need to act as the adoption takes place.

Through literature review we identify factors that impact PLM adoption, e.g. empirical results show that firm size and human capital are important variables related to ICT adoption. A work such [14], presented four statistical tools that can be used to improve the organizational adoption of new PLM systems and tools.

Note that the optimized model is the one without indicators correlation, and where indicators (KPIs) are independent. As future work, the average ICT adoption can be presented by the $PLM_{Adoption}$ function, for a first approach we will explore the regressive models (an alternative to hidden Markov models). This kind of approach was explored in [30] in order to find existing correlation.

$$PLM_{Adoption} = \sum_i^n \alpha_i S_i + \beta_i O_i + \gamma_i P_i + \sigma_i T_i \quad (1)$$

$\alpha, \beta, \gamma, \sigma$: represent parameters and will be estimated through a survey.

S, O, P, T : represent consecutively Strategic, Organizational, Process and Tools KPIs.

For such approach, it's important to be careful about other relevant variables that may have an impact on factors. It is therefore important to think about some control variables, such industry sector [72], that may influence results. We envisage for the future survey to have quantitative and qualitative evaluation. The quantitative evaluation will be on responses related to adoption KPIs, e.g. do you have R&D activities in your enterprise? Response can be "Yes" or "No" or another kind of question; from 0 to 5 where is located your R&D activity? Concerning qualitative evaluation, we may consider adding a comment to questions which will highlight pertinent remarks and / or control variables.

8 ACKNOWLEDGEMENT

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