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Abstract. This paper aims at describing a proposed Performance Indicators (PIs) Toolset, which has been developed to provide useful methodologies and tools to enterprises, especially Virtual Manufacturing Enterprises (VMEs), in order to support the management and evaluation of their service systems. Particularly, the identified PI Toolset helps VMEs to understand how well they are performing and contributing to their strategic goals and objectives.
Indeed, determining which activities should be monitored, controlled and measured through proper PIs is essential for a VME. In this context the proposed PI Toolset helps to select the significant activities, to manage governance processes, and to support the design and implement the specific PIs related to the precise use case objectives. Finally, the proposed Toolset defined a set of PIs that can be used to evaluate business processes related to governance issues.

Keywords: Virtual Enterprise, Service governance support toolset, Performance Indicators.

1 Introduction

Global industrial competition, current economic crisis and market turbulences have opened up more threats and also opportunities to enterprises both in manufacturing and service environment; furthermore, threats and opportunities generate exceeding pressure on enterprises to improve their capabilities. This paper investigates a key topic in management area based on the mutual interests of individual managers, decision makers, and also the capabilities of a network or supply chain: process evaluation through Performance Indicators (PIs). Therefore, enterprises need to employ different strategies with different context and circumstances in order to achieve a differentiated competitive advantage [1]. The competitive advantage will help enterprises to survive in an increasingly competitive context [2].

Despite the facts that individual enterprises gain the opportunities through its own internal Tangible and Intangible (T/I) assets such as knowledge management and progressive R&D process; nevertheless, individual enterprises need to get closer to their partners in supply chain network and optimize their relations through the outsourcing

process. Therefore, in order to be able to provide outsourcing process, individual enterprises need to participate in a collaborative network that has nowadays become crucial for any manufacturers and service providers.

With respect to the above mentioned context, individual enterprises need to shift from autonomous work toward collaborative network that can be defined as a common way by which all enterprises in supply chain are actively working together toward shared objectives. Consequently, collaborative networks are characterized by sharing T/I assets such as information, knowledge, risk and profits [2, 3 & 4].

Undeniably, enterprises need to provide some requirements in collaborative network environment such as restructuring their internal and external operating process; re-engineering the production and service system; redefine the roles and rules of members in network; employed multi skilled and flexible people and at last, but not at least preparing the proper IT tool in order to coordinate the relationship among the members. Therefore, collaborative networks need significantly to improve competencies in terms of dealing with new business models, strategies, organizational and governance principles, processes and technological capabilities [5] in order to be successful in a very competitive and rapid changing environment.

In this context, this paper aims to define and develop an overall Toolset to monitor VE based on Product-Service solution, through PIs and Product-Service oriented methods. Therefore, the proposed method should be applied to VE in order to efficiently control the product-service system within a Manufacturing Service Ecosystem. Meanwhile, in order to be able to produce significant results, an industrial case study is presented where the proposed PI Toolset is validated and adopted on it.

2 Research Background

A collaborative network can be defined as composed by various entities such as organizations, people and machines, and is characterized by geographical distribution, large autonomous and heterogeneity in terms of their operating environment and goals [6]. For its mature it needs to be supported by IT tools in order to set the interaction among the participants.

A relevant stream of literature mainly rooted that a collaborative network structure classified in classical and dynamic format. In classical format network is relatively stable with well-defined roles in organizational forms; nevertheless, nowadays more dynamic structure are emerging in industries. One of the most important organizational forms, which will be analyzed in this paper, is the so-called Virtual Enterprises (VE). VE is a temporary organization of companies formed to exploit fast changing opportunities. In this case, companies come together to share costs, skills and core competencies in order to address the business opportunities that they could not undertake individually [7, 8].

Although the combination of the core competencies of companies, the VE may become the best of everything enterprises and the key issue in order to fast reaction to market demands and business opportunities; Nevertheless, their practical implementation is still far from the expectations and also VE planning and creation, as well as several aspects of VE operation, are still difficult and need to be properly adapted even by advanced and competitive collaborative networks [7]. Some of the

lacunae include the lack of common reference models and appropriate support tools following by below observed points [9-12]:

- Partners search and selection;
- Monitoring and coordination of task execution according to contracts;
- Performance assessment.

In this context, understanding the VE formation process, modeling its processes and developing useful supporting tools are still open challenges [2, 9& 13]. In order to provide a meaningful analysis of the research background, the "Servitization" process is introduced. Indeed, it is accepted as one of the most successful structure which has been used to extend the after sale service activities. Meanwhile, it has been used frequently by manufacturing enterprises that would like to shift from a pure product sales structure towards after-sales services, and bundle their products with services to satisfy the customer needs [14]. In this context, Servitization process has been used to enhance the services that have been provided to support the manufactured products.

Use case plays an important role and leads the VE environment as a focal firm where it is responsible and allocates the manufacturing and service tasks among the partners (upstream level), and also sharing the costs and resources. Meanwhile, Use case (Focal firm) acts as a product integrator and also is responsible for the final product/service and relationship with the customer.

As far as the use of VE as an organizational form of a collaborative network is concerned, different Performance Measurement Systems (PMS) developed during the past decades in order to facilitate the generation and selection of most proper PIs. Consequently, PMS is used in order to be able to monitor the service performance effectiveness and efficiency through exploiting the suitable PIs. During the past decades, several PMS (Models, Tools, Methods and Frameworks) proposed and developed by various researchers and business managers. The most important are PMSs such as PRISM, ECOGRAI, Integrated Performance Measurement System (IPMS), Balanced Score Card (BSC), Six Sigma, European Foundation for Quality Management (EFQM), and Matrix and Brown's framework, which have been accepted and employed by various enterprises. [2, 15-23]. The basic idea behind PMS exploitation is to encourage the enterprises to continue improvement and also to support appropriate activities through the proper PIs exploitation. Furthermore, PMS is used as a key process in the management of VE and traditionally, is defined as a systematic process of gathering, assessing and reporting the predefined tasks and objectives status. In order to be able to have meaningful analysis a set of quantitative and/or qualitative indicators can be used to help the enterprises and decision makers to evaluate the collaboration benefits in this environment such as activities performed resources employed, and outcomes obtained [5].

Various authors expressed either positive or negative criticisms on the aforementioned PMS. For instance, EFQM and BSC highlighted in the literature as the most popular and employed by several enterprises today. Although, both models were initially designed for intra-organizational performance measurement in single companies and offer a measuring approach based on driver and outcome indicator to monitor and assess different perspectives in an enterprises; nevertheless, these models have a lack in terms of focusing on the strategy of collaborative network environment.

Additionally, BSC proposed a closer measure to predefined objectives and has a faster and more processed reporting especially based on financial measures. So, the relevant PIs make sometimes difficult in terms of comparison because indicators are contextual and need to be customized for each enterprises or objectives [5, 25-26].

A relevant stream of the literature rooted some other criticism included: the nature of PIs used, dimensions retained, lack of procedures for the choice of PI's and procedure for the PIs connections, etc. Even the BSC, perhaps the most popular and used method, was deeply criticized about the reduced stakeholders [15].

In spite of these criticisms, it turns out that aforementioned PMS's present many similarities and differences, advantages and inconveniences. With respect to the mentioned methods, ECOGRAI method will be selected in this paper in order to design and to implement proper PIs in VE domains. The basic idea behind of ECOGRAI selection is that it has the opportunity to link with modelling tools such as Graph with reference Active Interrelated (GRAI) GRID and GRAI nets and also applied with the implication of the decision makers [2]. The selected method has a clear vision about the decomposition and the coherence of objectives in comparison to other most well known PMS such as BSC. Meanwhile, in ECOGRAI method is easy to have a very detailed view of the performance and also control of the performance [2, 26-27]. At last but not at least, the selected method covers the various functions and the various decision levels such as Strategic, Tactical and Operational in order to present a coherent distribution of PIs. Also, in order to manage the monitoring processes and to define the objectives, GRAI method will be used according to its proper integration between the focus on results and the consistency of the decision process [28]. Meanwhile, the selected method has a good possibility to analyze and to correct the coherence of an objective system in order to ensure that the operational objectives contribute to the strategic objectives.

In particular with regards to service performance, two research methodologies have been investigated and compared: Action Research Methodology (ARM) and Collaborative Management Research (CMR). CMR and ARM have some similarities as well as distinct features [29]. A comparative analysis revealed that both methodologies focus on developing a deeper level understanding and their main purpose is the identification, modification and transformation of the studied system [30]. Furthermore, both are concerned with system improvement and added value to the management realm. However, CMR is more oriented to capabilities' improvement and it can be adopted for both improving the capabilities of VE or even the capabilities of individual managers and decision makers by addressing specific aspects of management such as specific managerial actions or coordinating mechanisms among collaborative networks. In this way, CMR can be defined as an inquiry process that, through multiple studies, the accumulation of knowledge over time about different aspects of management, and across types of systems will clarify when and how managerial actions can make a difference [29]. The inquiry process of experiencing, understanding, judgment and action, as captured by Coghlan, is likely to confirm or disconfirm assumptions and is likely to result in general accumulation of managerial wisdom and scientific knowledge that eventually influence how management is taught and practiced [31-32].

2 Research Questions and Methodology

This section presents the main research questions to satisfy the above-mentioned open challenges in VE realm, and indicates an overall method that combined a set of existing methodologies to achieve the research objectives. Therefore, the adopted research methodologies have been applied in an industrial case study to demonstrate its validity.

2.1 Research Questions and Objectives

In order to succeed in the modern turbulent and competitive climate, VEs require significantly improving competences in terms of business strategies, new governance principles and performance assessments. Moreover, in order to leverage the potential benefits, assessing the performance of the associated members in the VE through a proper set of PIs can usefully support the lifecycle of the designed and produced solutions, i.e. Product-Service.

In this context the authors identified the following research questions about performance assessment and governance in VE:

- Which specific performance assessments should be considered while monitoring VE (based on Product-Service) when numerous companies cooperate within a Manufacturing Service Ecosystem (MSE)?
- Which specific aspects related to performance indicators and methods should be applied to a VE in order to efficiently control the Product-Service system within a MSE?

Such questions decline the overall research goal in two specific objectives; in particular, to answer the two research questions, the following three objectives have been defined:

- Development of a new methodology that helps enterprises selecting the activities to be monitored, controlled and measured through appropriate PIs;
- Definition of functions and actions at decisional levels (i.e. Strategic; Tactical and Operational);
- Preparation of a guideline to design, classify, implement and maintain effective PIs related to a specific VE with respect with its internal goals and objectives.

Moreover, the scope of research is focused on the analysis of the Service VE lifecycle by itself and the assessment of service performance for Service. As a consequence, the present research is based on the selection of a specific Use case focusing on a Service VE and the characteristics of the Service Lifecycle Management (SLM). Given the relative novelty of the subject, the literature lacunas in VE in which both manufacturing and service practices and performances can be considered according to the Use case objectives and strategies.

The proposed method starts from the investigation of existing methodologies about performance and service management lifecycle assessment. It includes a brief literature review based on major methodologies that have been used in research and short explanation of adoptable methodologies that can be used in order to develop the concepts/approaches proposed and methodologies adopted to validate that the concepts/approaches are applicable.

With respect to performance assessment requirements for Service in VEs, the research methodology is structured in the following steps:

- Monitoring Framework for Service Virtual Enterprises;
- Generating a PIs model suitable for the specific purposes;
- Defining a list of PIs for service VE;
- Inserting this list in an ICT tool.

Furthermore, this paper considers that Use case seeking the transformation at all level of organizational life; consequently, Developmental Action Inquiry (DAI) also will be included. In the following table the research tools adopted in the proposed methodology to be used in on Use cases. In particular, it contains the list of tools for each step. With respect to the first step, the methodology has been developed starting from reference models available in the literature and using both selected tools from CIR and DAI approaches. The second step considers PMS tools for PIs generation models. The third step the list of PIs defined before will be shared with decision makers and study team in order to select the most proper PIs according to the use case objectives and main strategies. The fourth step will consist of insertion of PIs into an ICT tool according to Use case requirements according to the Process Modeling approach. Finally, a Use case is adopted to test the applicability of the model, as well as to refine the methodology itself.

	Research Methodology **Adopted**	
	Approach	Validation
Monitoring Framework for Service VE	Literature Review- CIR and& DAI	Use Case
PIs generation model	Literature Review & DAI	Use Case
PIs for Service VE	Literature Review- CIR	Use Case
Insert into ICT Tool	Literature Review- Process Modeling	Use Case

Tab.1. Research Methodology

3 PI Toolset

A PI Toolset has been created to support the managing and controlling issues of a VME. The stated Toolset includes various tools such as service governance framework, PI method and list of PIs that adopted together. By synthesizing the mentioned trio methods, PI Toolset will be able to create a coherent link between governance issues and the selection of specific PIs.

3.1 Service Governance Framework

The proposed service governance framework satisfies the first step fo the proposed methodology. It synthesized by GRAI model and Model Driven Service Engineering Architecture (MDSEA) within a VME environment in order to create a conceptual reference framework focusing on business objectives definition and governance issues.

Particularly, the GRAI model has been used to synthesize coherently various governance concepts (at detailed and global levels) into a unique generic model to facilitate integration between decisional levels and functions. On the other hand, MDSEA has been adopted with a conceptual framework in order to classify PIs into a different level of decomposition (i.e. decomposition by level of abstraction and decomposition by level of decision). The MDSEA has been used in order to facilitate the classification and implementation of PIs into a different level of decompositions; it means decomposition by level of abstraction (BSM, TIM and TSM) and decomposition by level of decision (Strategic, Tactical and Operational). In more details, BSM (Business Service Modeling) level has been used in order to elaborate high abstraction level model from users' point of view. TIM (Technology Independent Modeling) level gives detailed features of the service. TSM (Technology Specific Modeling) level insert a particular type of technology such as machine technology that is belongs to implementation options.

The conceptual framework has been used to lay down the foundations for governance framework which can be then linked with coherent monitoring and controlling activities; and to help the selection of highly exploitable PIs related to End User governance objectives. Table 2 provides an overview of the correlation between the stages considered for the Service Governance Framework and the MDSEA levels of decomposition.

		Service Governance Framework							
		IDEATION	CONCEPT	REQUIREMNTS	DESIGN	IMPLEMENT	OPERATION	DELIVERY	DECOMMISN
BSM	*STRATREGIC*								
	TACTICAL								
	OPERATIONAL								
TIM									
TSM									

Tab. 2. Service governance framework

3.2 PIs Generation Model

PIs Generation Model has been used to design, implement and classify the specific PIs related to the precise use case objectives. The (Fig. 1) Use case objective (i.e. Servitization) process has been modeled through the proposed framework and servitization characteristics have been specified such as functions and objectives at decisional levels. As described in Fig. 1 the following aspects can be observed: firstly, objectives at decisional level are defined through the proposed framework; secondly, a set of specific functions and actions have been defined through Value Reference Model (VRM) as decisional tools for supporting business processes; at the third level, an initial definition of specific PIs is carried out, and afterwards a personalized list of PIs is generated. At the end, the selected list of PIs is defined: they can be used to monitor and govern the service. VRM has been used deliberately in order to design and

implement the related PIs. Indeed VRM provides a supporting tool to define and prioritize the PIs that are needed to govern business processes.

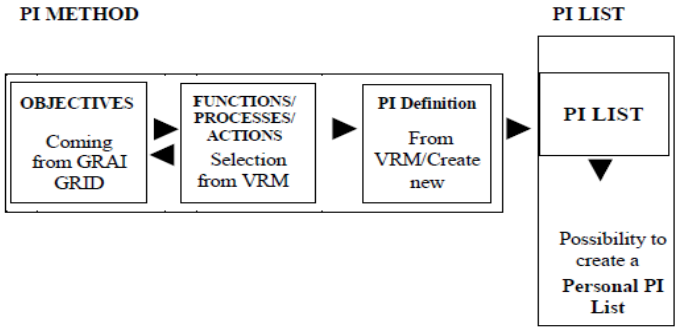

Fig. 1. PI Toolset: detail on PI Generation Model and PI List

3.2 PI List and ICT tool creation

The PI list has been used to evaluate business processes related to governance issues. In the Table, 3 proposed methods developed a "Tree" structure file in order to filter the selection procedure of PIs.

PI list classification in one side comes from VRM process categorization and on the other side comes from MDSEA. The PI List has been focused on VME creation with particular attention on BSM Level. Indeed the PI List is the results of service governance framework and PI Method. PI List is a supporting tool to assess service performances and manage the efficiency of enterprise resources. Meanwhile, a PI List structure has been created in order to facilitate the selection and the linkage of PIs to objectives and decision variables.

Finally, in order to support service design, management and evaluation within the manufacturing networks in an ICT environment PI Toolset has been implemented within the SLM Toolbox. By using the toolset the following points can be observed:

- Easy and coherent selection of highly exploitable PIs related to End User Governance objectives;
- ICT implementation of the support control toolset through the SLM Toolbox;
- End Users have the possibility to edit, change, save their PI List and share it with partners through the innovative ecosystem platform;
- Adequate measures for effectiveness, efficiency and productivity can be assessed in order to offer a satisfactory service system;
- The toolset can improve the efficiency of the service system by measuring the ability of a firm to reach its main governance goals within the VME perspectives.

MDSEA	VRM process Classification	PI field	Dimension	PI metrics	PI formula

Tab. 3. PI List structure

4 The use case results

In order to produce meaningful results and optimize the proposed PI Toolset, the approach has been applied to an industrial Use case. The company is one of the largest European manufacturing industries in the white goods sector, aiming at providing its consumers with advanced services; therefore, the proposed PI Toolset has been developed and modified through industrial case study creating a real servitization process.

The current Servitization level in the selected company is rather low and limited to selling the physical product and only few basic services have been offered in a traditional way such as warranty, technical support and service center. The basic idea behind of Servitization process exploitation is to increase the product selling through differentiate the services according to the company profile. In particular, the company aims at realizing a new service focused on supporting the customers' usage by personalized services such as personalized best practice, machine monitoring and tailored commercial offers [15]. In order to provide the new services, Use case has been provided a new VE environment and selected the partners according to the preexisting suppliers profile and also new members from outside of its own ecosystem with respect to new VE defined activities and main objectives.

In particular, the company framework is actually characterized by the manufacturing company itself and a group of partners: it is actually organized in a vertical supply-chain adopting a product-oriented development process. Collaboration between the manufacturer and its partners and suppliers is limited to design stages and components' supply. The leader company recently designs and produces a "Smart Washing Machine" enhanced with embedded items (e.g. sensors, Zigbee module, router Wi- Fi) and software components (e.g. web service, data repository, web/mobile application) as well as an infrastructure to connect the product to an external network. The Use case focuses on enabling new services for such Smart Washing Machines: it aims at realizing a new service, called "Carefree Washing Service", to provide the washing machine rent for free, a supply agreement comprising washing energy and detergent supply by paying an annual fee, and a web/mobile application for machine monitoring and customer training and coaching. Such Use case aims at enlarging the VEs by including also customers thanks to a direct relationship with them by facilitating the product use, educating the customers in a correct use and energy/cost saving practices, and collecting real-time feedback.

According to the Use case objectives, a set of functions has been defined and classified inside the framework of servitization (i.e. Customer decision, Customer ideation, Service product design, Service requirements). Then, according to the mentioned functions, main objectives have been defined at each stage (i.e. Strategic,

Tactical and Operational). Table 4 represents the results related to the proposed framework. Finally, PI list has been represented in the Table 5.

	External Information	Customer decision	Customer ideation	Service -Product design	Service -Product Implementation	Service -Product planning	Service -Product delivery	Internal Information
STRATEGIC H= 2 Years P= 6 Month	Existing Services in competitive companies	Customer expectation in terms of services	Business plan for service proposition	Selection of design methodologies and partners	Selection of targeted goods and technologies	Annual service planning	Partner relationship organization	Business Strategy and Master planning
TACTICAL H = 1 Year P= 1 Month	Existing HW & SW Implementation technologies	Feedback on customer satisfaction	Assessment of existing services	Definition of PSS functions and design specifications	Action plan to modify production process	Planning of the specific service actions	General planning of service delivery	In- house Available technologies
OPERATIO-NAL H = 1 Month P = 1 Week	Advertising	Customers orders; Customers claims	Brainstorming meeting;	Detailed design planning	Implementation of modifications	Service scheduling; Feedback measurement	Short term delivery planning	Status of service production and service system

Tab. 4. Service Governance Framework

MDSEA	Customer relationship	Service ideation	Product-Service System design	Product-Service system development	Product-Service system planning	Product-Service system delivery
STRATEGIC H= 2 Years P= 6 Month	ROI for each product-service (like the minimum ROI range); Net margin expected	Capability to implement cross-selling (through a CRM system)	Total cost of product-service system design	Global implementation costs	Amount of product-service sales for the next two years	Cost of delivery channels
TACTICAL H = 1 year P= 1 Month	Service Exploitation	Amount of sales per month	Time to design the PSS	Time to market	Turnover	Number of new customers/contracts
OPERATIO-NAL H = 1 month P = 1 week	Time to start up the service, Customer satisfaction rate	Increase of of the new ideas	Delay/advance in design	Checking of timing and costing (deviation in%) of master plan	% of WMs with Carefree Washing Service produced in time	Product-service frequency

Tab. 5. PI List

5 Conclusions and future works

In this paper a methodology to define a PI Toolset for performance assessment in the VE has been proposed as an instrument to support service management and VME configuration. Indeed, it allows defining and representing an open structure (i.e. Service Governance Framework) to share knowledge and sources among the members inside the service ecosystem. Meanwhile, the PI Toolset is used as a decisional supporting tool to generate specific PIs related to end users' core activities. Particularly, the output of PI Toolset will provide a source of information to be used, visualized and shared among VME partners through ICT tools. PI Toolset can support VME to control and monitoring their performances in order to improve their level of service quality and, therefore, manage better the service governance. Indeed the PI Toolset is able to provide, collect and manage necessary information for helping the VMEs in identifying and understanding the needs and requirements of the service system and assessing current and future organizational and process capabilities of the service. The method is

presented and tested on an industrial use case, whose preliminary results are shown and discussed. Obviously, this paper paves the way to a more detailed validation phase where the PI Toolset are improved through a huge number of use cases. Therefore, in order to generate additional positive results on use case servitization governance processes the following additional improvements such as visualization of performances, Internal audit and feedback on performances can be taken into account as further steps.

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