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A Methodology for Developing Service in Virtual Manufacturing Environment

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Abstract: Developing services to support manufacturing industry in a context of virtual manufacturing environment and Ecosystem is a complex servitization process that needs support of appropriate models, methods and tools. This paper proposes a methodological approach to follow in the creation of service and service system during the whole service life cycle. The proposed approach is developed under the frame of an ongoing FP7 European Integrated Project MSEE. The methodology relates and integrates a set of frameworks, models, modelling and simulations tools by providing a structured approach. The added value of the approach is the gain of time and consistency in a complex servitization engineering project.

1. INTRODUCTION

European manufacturing enterprise will progressively migrate from traditional product-centric business to product-based service-oriented virtual enterprise and ecosystems (Thoben 2001). During this migration process, service system that will provide desired services around the product will have to be modelled, designed, implemented, tested and managed along its entire lifecycle.

It has been considered that ***service-orientation*** *for EU manufacturing industry* is a sustainable measure to improve the competitiveness of Europe in the global market arena, by keeping physical goods production/assembly (or even in-shoring it back from other Countries) and considerably improving their attractiveness and user-orientation by intangible added value services (MSEE 2011). This will contribute to develop sustainable business ecosystems in EU states.

This paper presents the result of a research work performed in the frame of the European FP7 MSEE Integrated Project (Manufacturing SErvice Ecosystem) (MSEE 2011). The project aims to create a new Virtual Factory Industrial Models, where service orientation and collaborative innovation will support a new renaissance of Europe in the global manufacturing context. The vision hold by MSEE is by 2015, novel service-oriented management methodologies and the Future Internet universal business infrastructure will enable European virtual factories and enterprises to self-organize in distributed, autonomous, interoperable, non-hierarchical innovation ecosystems of tangible and intangible manufacturing assets, to be virtually described, on-the-fly composed and dynamically delivered as a Service, end-to-end along the globalised value chain (MSEE 2011). This vision stems upon two complementary pillars, which have characterized the last 10 years of research about Virtual Organizations, Factories and Enterprises: Service Oriented Architectures (SOA) and Digital Business Ecosystems (DBE) (Homburg , 1999), (Spath, 2008), (Camarinha-Matos, 2008).

The paper is structured as follows. After a brief introduction in section 1 on the background and objective of the approach, basic concepts and definitions will be given in section 2. The structured approach of the methodology and the Bag of assets will be presented in section 3. Then section 4 will detail the methodology with possibly some examples and illustrations. Finally section 5 concludes the paper and discusses on future perspectives.

2. BASIC CONCEPTS AND DEFINITIONS

The proposed methodology aims at supporting the servitization process from traditional manufacturing enterprise to service in virtual enterprise and ecosystem.

Generally speaking, a service is a provider/client interaction that creates and captures value. A manufacturing service is an optimal combination of products and services to generate more income and better satisfy customers (Alter, 2008).

The servitization is a migration process wherein product companies embrace a service orientation and/or develop more and better services, with the aim to offer total client solutions (Baines, 2009).

Figure 1 shows the difference between a traditional product centric manufacturing company and a service oriented virtual manufacturing enterprise.

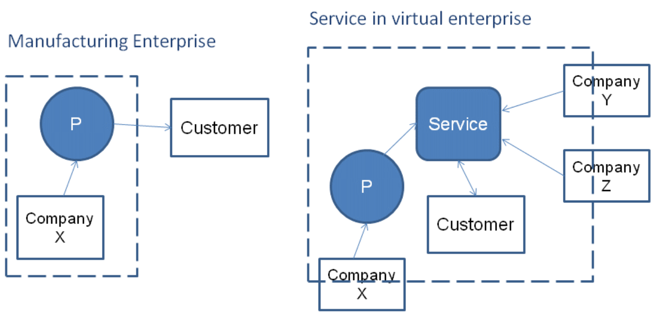


Fig.1. Manufacturing enterprise / service in virtual enterprise

3. OVERVIEW OF THE METHODOLOGY

The state-of-the-art considered that no mature service engineering methodological approach exists in the market.

There exist many different SLM (Service Lifecycle Management) models. However those existing models (1) mainly focus on IT related services, (2) deal with the management of services after its implementation, (3) not related to PLM activities. Furthermore existing service models, methods and tools are developed in uncoordinated ways. There is no complete methodology to support service engineering. Existing models, methods / tools don't cover the whole SLM phases.

In this part we present a global view of the methodology which will complement and provide added value to the state-of-the-art. It has two parts: (1) bag of assets; (2) structured approach.

3.1 Bag of assets

The bag of assets contains the models, methods and tools developed in SP1 (sub-project 1) of MSEE project as scientific and technical research and development results. They are assets elements that are used in the methodology to support service engineering activities along the service life cycle phases. They are categorized in five parts as shown in figure 2.

M	Service Modelling Methodology	
	M1	MDSEA architecture
	M2	Service Modelling Language (BSM, TIM, TSM)
	M3	Model Transformation method
E	Service Engineering Methodology	
	E1	Service Engineering Framework
	E2	Assessment of servitization level (Product, Process, Organisation)
	E3	PLM / SLM interaction model
	E4	Role Model for Service engineering
	E5	ServLab
G	Service Governance Methodology	
	G1	Service Governance framework
	G2	Service PI method
	G3	MSEE PI list
S	SLM Framework	
	S1	MSEE 3D space MSE
	S2	MSEE Servitization 2D plane
	S3	SLM 3D framework
T	SLM Tool Box	
	T1	Service Modelling tool
	T2	Service Engineering tool
	T3	Service Governance tool (MSEE PI Toolset)

Fig. 2 Bag of assets

- Service Modelling Methodology: This methodology is based on the proposed MDSE (Model Driven Service Engineering) Architecture which is adapted from MDA/MDI approaches. A service modelling language is defined at the three levels of abstraction of the MDSE architecture. BSM (Business System Model) aims at elaborating high abstraction level model from user point of view. TIM (Technology Independent Model) gives service system specifications independently of technology for implementation. TSM (Technology Specific Model) adds necessary technology specific information related to implementation options. Model transformation method is proposed to transform service model from one level to another till the implementation (Pandit, 2009)..

- Service Engineering Methodology: Service Engineering Methodology gives a guideline how to organise service departments, how to develop single services on a systematic way and how to create the interaction between Product and Service Life Cycle Management (Burger, 2010) as well as to define roles and assign them to various engineering activities.

- Service Governance Methodology: This methodology consists in a service governance framework, service PI method and a service PI list. Service monitoring and controlling activities are defined, with the aim of efficiently using KPIs and SLAs, to control enterprises within a MSE (Manufacturing Service Ecosystem). Interactions with data and information within the existing ICT systems allow a smooth integration of methods and tools for governance. This toolset is based on both design and runtime phases, to support service management, exchange and evaluation of Enterprises within manufacturing networks.

- SLM Tool Box: The application provides several graphical editors to model manufacturing services and service systems from a "business perspective" (BSM) and a "functional perspective" (TIM) for service engineering activities. It also includes model transformation methods. Other functional modules to support service engineering methodology assets and service governance methodology are also developed as part of the tool box.

3.2 Structured approach

The structured approach defines the process of using assets to carry out a set of service engineering activities along the service lifecycle phases. Figure 3 shows the proposed structured approach of the methodology with the indication of assets to be used for each of the steps.

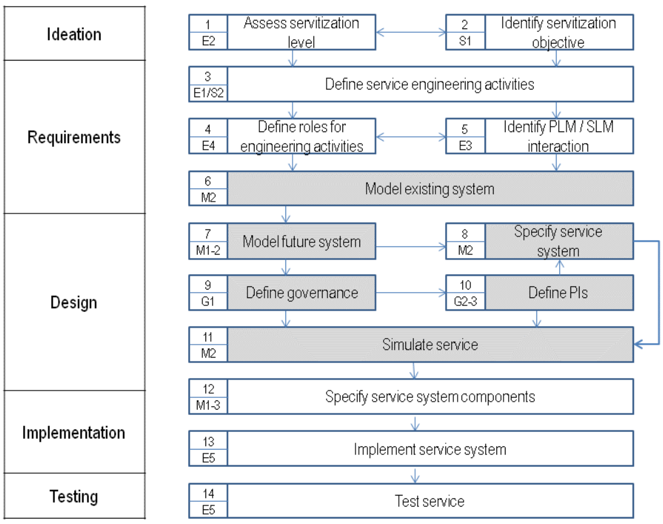


Fig. 3 Structured approach

The shadow parts of the engineering tasks in the figure 3 are supported by a computer tool called SLM Tool Box. This tool is developed under MSEE project using open source platform. It is based on MDSEA three modelling levels and allows to integrating existing modeling and simulation tools. Besides, it also interoperates with USDL through its model repository. Figure 4 shows the architecture of SLM Tool Box.

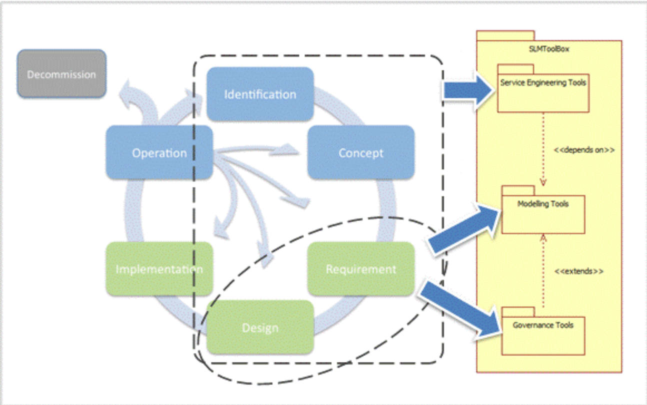


Fig. 4 SLM Tool Box architecture

It is to note that the methodology is used when initial service innovation and its concepts to implement have been already defined. Generally speaking the later phases of service lifecycle such as delivery and operation are not concerned by the methodology.

The sequence of the structured approach represents a normative servitization project situation. It should be adapted accordingly to the specificities of each individual servitization engineering project. Some steps are optional.

It is also to note that this structured approach is not straightforward. Iterations between steps may take place whenever necessary.

4. THE METHODOLOGY IN DETAIL

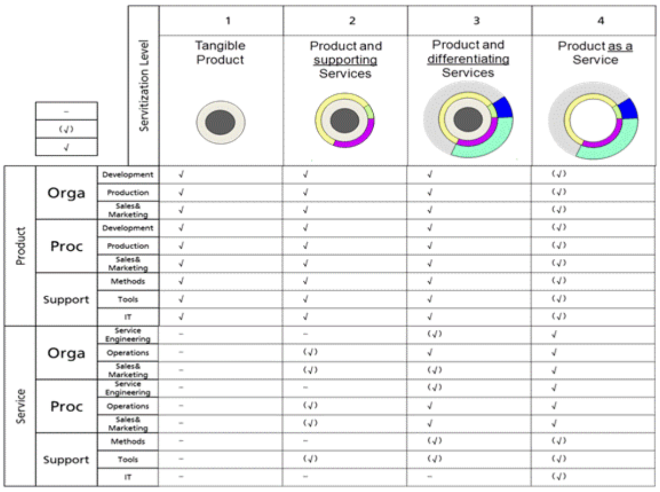
This section presents in detail the specification of the methodology. It describes the rationale and purpose of each of the steps defined in the structured approach and assets used with possibly an illustration example.

4.1 Assess servitization level

Before to start a servitization project, it is necessary to know the current servitization level or state of the enterprise. This will allow enterprise to know the needed changes to perform in order to reach the servitization objective and to put more effort on the critical points.

This step consists in assessing the strengths and weakness of existing system in relation to the servitization objective. The assessment is done from three points of view: Product, Process and Organization.

The asset (E2) used is a matrix form table to fill as shown in figure 5 and a questionnaire to help collecting information.



		Servitization Level	1 Tangible Product	2 Product and supporting Services	3 Product and differentiating Services	4 Product as a Service
Product	Orga	Development	√	√	√	(√)
		Production	√	√	√	(√)
		Sales& Marketing	√	√	√	(√)
	Proc	Development	√	√	√	(√)
		Production	√	√	√	(√)
		Sales& Marketing	√	√	√	(√)
	Support	Methods	√	√	√	(√)
		Tools	√	√	√	(√)
		IT	√	√	√	(√)
Service	Orga	Service Engineering	–	–	(√)	√
		Operations	–	(√)	√	√
		Sales& Marketing	–	(√)	(√)	√
	Proc	Service Engineering	–	–	(√)	√
		Operations	–	(√)	√	√
		Sales& Marketing	–	(√)	√	√
	Support	Methods	–	–	(√)	(√)
		Tools	–	(√)	(√)	(√)
		IT	–	–	–	(√)

Fig. 5. Assess the strength and weakness (E2)

4.2 Identify Servitization Objective

This task aims at identifying the migration path of a servitization from current situation to target one allowing an enterprise to know possible intermediate situations and steps and consequently better assess difficulties and challenges.

The purpose of this first step is to identify the as-is situation of the enterprise before a servitization project and the to-be situation to reach after the project has been done. The asset used is the MSEE 3D Space (S1) (see figure 6) to position in a graphical framework the as-is situation and to-be situation of the enterprise

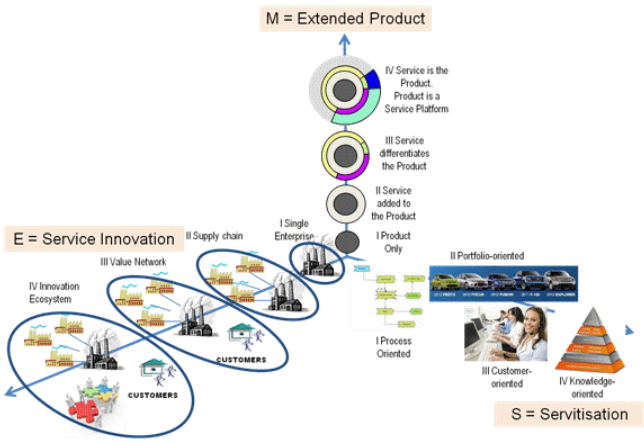


Fig. 6. MSEE 3D Space (S1)

4.3 Define service engineering activities

Before to start a servitization project, it is also necessary to define what engineering tasks to perform taking into account the specificities of the enterprise and project. This is to initialize a servitization project in an enterprise. The purpose is to identify a set of service engineering activities according the needs of the project. The asset (S2) is used. At first, a set of suitable engineering tasks can be selected using MSEE 2D plane as shown 7. This is done according to the service type that enterprise aims to develop.

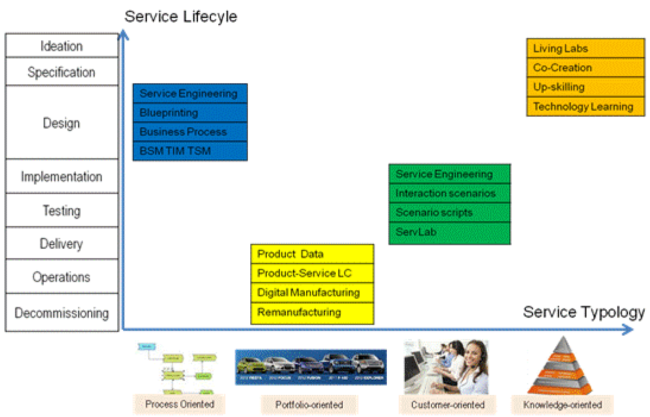


Fig. 7. MSEE servitization 2D plane (S2)

Another asset to be used is the MSEE engineering framework (E1) shown in figure 8. This framework provides complementary activities to define according to the objective of the project. It can be considered as a reference model to particularize by users.

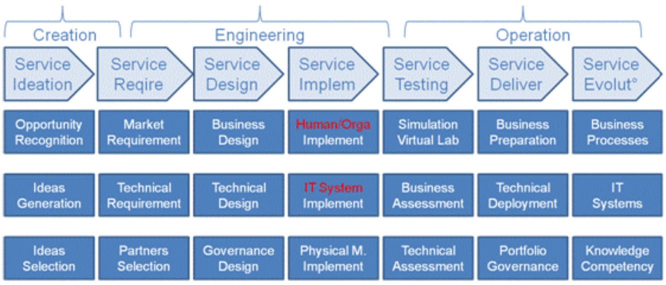


Fig. 8. Service Engineering Framework (E1)

4.4 Define roles of engineering activities

Service engineering activities involve various stakeholders and engineers who often play different roles in different activities and circumstances. This engineering task aims to define role(s) played by all actors involved in designing service system in a servitization project.

The asset (E4) used is a role model for engineering activities (see figure 9). Internal roles as well as external roles are to be identified and assigned.

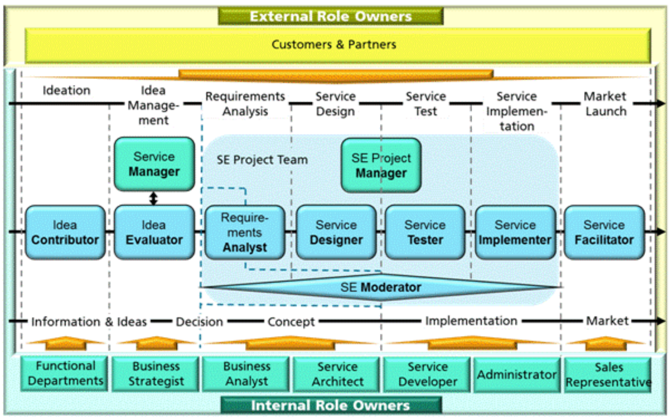


Fig. 9. Role Model for engineering activities

4.5 Identify PLM/SLM interactions

During service engineering project, some service engineering activities may be closely related to product design activities. The purpose of this task is to identify possible coupled PLM and SLM activities so that they can be properly grouped and synchronized. The asset (E3) used is the PLM/SLM matrix with PIM and SLM lifecycle phases as shown figure 10.

Fig.10. PLM/SLM interaction (E3)

4.6 Model existing system

Before to start service design, it is necessary to model existing system in order to understand it, to detect its strong points and weakness. According to the interest of the project, the modeling can be done from various views resulting in various models. In MSEE project, focus is on the modelling of decision-making and process.

The asset (M2) is used. To perform this modeling, Service Modelling Methodology is to be used. This modeling methodology is developed under MDSEA (Model Driven Service Engineering Architecture) which is adapted from MDA and further extended in MSEE project. Figure 11 shows the modeling constructs defined at Business Service Modelling (BSM) level. The precise modeling methodology asset at BSM level adopted in MSEE project is GRAI grid/net, Extended Actigram.

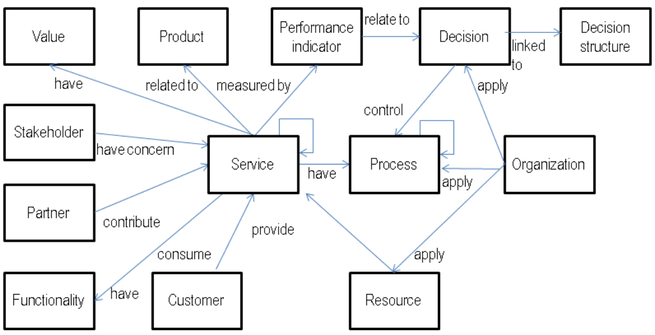


Fig. 11. Service modelling constructs at BSM level

4.7 Model future system

Before to perform detailed or technical design, business users and service stakeholders may wish to describe the target service (system) for the purpose of assessment, communication and validation.

This step consists in modeling future service system from business user perspectives. The asset to be used is the same as in the precedent step to model existing system (M1-M2). Use BSM level modeling language can build a conceptual description of the TO-BE system without specifying technologies (IT, Human, Machine/ Physical means) to be used for the implementation. Figure 12 shows a modeling example of MSEE use case using SLM tool box.

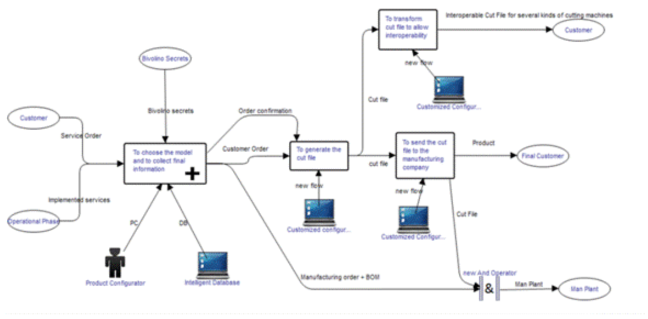


Fig. 12. MSEE use case service process example

4.8 Specify service system

At this step in a servitization project, the desired service and its system can be globally and conceptually specified before to move to detailed design. The purpose is to obtain a global picture of service system and to document necessary information in an integrated way. The BSM modeling language and its associated templates (Asset M2) can be used to specify and document a service system.

4.9 Define service governance

In order to correctly monitor and control service and its performance, it is necessary to define and implement a set of governance activities.

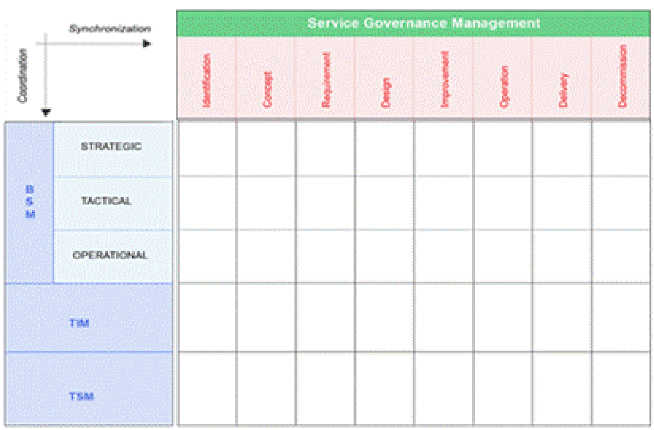


Fig. 13. Service governance framework (G1)

The purpose of this engineering task consists in identifying and defining service governance in terms of service operations monitoring and control actions. The asset (G1) used is a governance framework. It specifies strategic, tactical and operational levels; identifies SLM functions and objectives; facilitates the integration between decisional levels & between functions (see figure 13).

Remark: The proposed MSEE service governance framework is also implemented in SLM Tool Box.

4.10 Define Key performance indicators (KPIs)

Appropriate performance indicators (PIs) are to be selected according to the strategy and objective of a particular enterprise. Those PIs take an important part in the service governance. The purpose of this engineering task is to select/ define a set of PIs according to the objectives of the service enterprise. Selected PIs need to be related to decision/action variables in order to be able to reach targeted performance.

The asset (G2-G3) used is MSEE performance indicator method with the approach shown in figure 14.

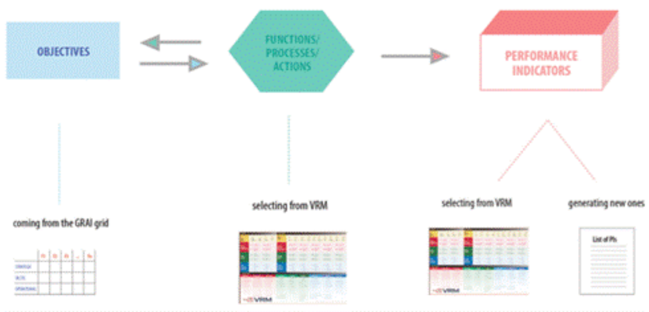


Fig. 14. MSEE PI method (G2-G3)

Remark: The MSEE PIs method is also supported by SLM Tool Box. According to the objectives defined, a filtered list of PIs will be submitted to the User (which fit best with Use case requirements). It is possible for a user to modify, copy, delete, save the PIs and create a personal PI list.

4.11 Simulate service

Simulation can be done during the design phase to assess if designed service meets the requirements. Simulation can be performed using various models according to the interest of design engineers. In MSEE, the simulation focuses on the business process. The purpose is to simulate the execution of a process in order to detect possible inconsistencies and assess its performance (time, cost, …). The asset (M2) used is a simulation tool defined and implemented in SLM Tool Box.

Figure 15 shows the overall approach of the modeling and model transformation paradigm from Extended Actigram, through BPMN to simulation.

Remark: The simulation tool is not developed under MSEE project but directly integrated to SLM Tool Box using an existing one.

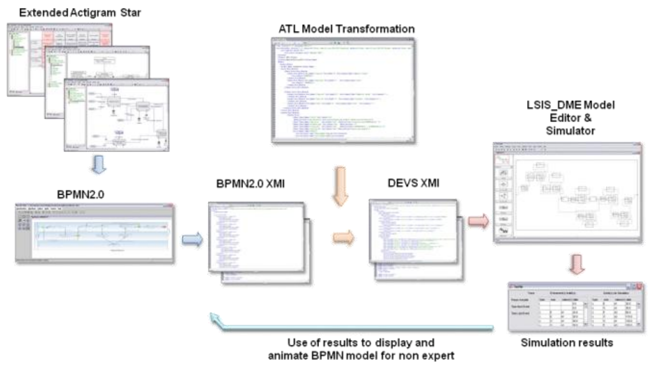


Fig. 15. From Extended actigram, BPMN to simulation

4.12. Specify service system components

A service system that provides desired services is composed (in its most general form) of three types of components: IT related components (hardware and software applications), Human related components (including organization structure), and machine / physical means components. This step consists in modeling in detail the three types of components. The result is detail technical specifications that allow to: (1) buy those components from the market, (2) develop those components (for example software applications).

The asset used (M1-M2-M3) is the Service modeling language defined at TIM (Technology Independent Modelling) and TSM (technology Specific Modelling) levels will be used to model and describe the specifications as well as the model transformation method (to transform BSM models to TIM models and TSM models).

4.13 Implement the service system

This step consists in building the service system with all its components (IT, Human and Physical means) that are either purchased/recruited from the market, either developed for this specific system.

4.14 Test service system

Testing service can be done before or after implementation depending on the type of the service in question. In MSEE project the focus is to test interaction between service provider and service consumer during the course when a service is delivered to the customer. The asset used (E5) is the ServLab developed by IAO which is experimented in some use cases. Figure 16 shows a service testing example.

Fig. 16. Service testing example using ServLab

Remark The test is based on the observation and analysis of behavior of both service provider and customer in order to assess the quality and satisfaction of customer. ServLab is used for the testing

5. CONCLUSIONS

This paper presented the proposal for a servitization engineering methodology to support the transition from traditional product based manufacturing enterprise to service oriented virtual manufacturing environment. The methodology contains the bag of assets which organises the MSEE R&D results and a structured approach defining a coordinated way of using those assets in a servitization project. The added value of the methodology is the gain of time and consistency in a complex servitization project. The methodology has been experimented in the use cases of the industrial partners of MSEE project. In the future, more testing and experimentations outside MSEE consortium are necessary to improve and complete the methodology.

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