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iMAGiNE

Innovative end-to-end Management of Dynamic Manufacturing Networks

"Innovative end-to-end management of Dynamic Manufacturing Networks"

Deliverable D1.1.1

Compendium on virtual manufacturing management

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2.4	20th January 2012	UoP, INTRA	Minor refinements
2.5	24th January 2012	UoP, INTRA, EADS	Final improvements

Executive Summary

Deliverable D1.1.1 aims to accomplish two primary objectives:

1. To reach a common starting point for all partners of the IMAGINE project towards end-to-end Dynamic Manufacturing Networks (DMN) management
2. To identify suitable case studies for the deployment and validation of the IMAGINE innovative approach.

In order to provide an overview of the current industrial practice, identifying at the same time the shortcomings of available software tools, the following information is provided:

1. The current practices and the lowlights of the associated software systems in the area of supply chain and DMN management are indicated in Chapter 2.2.
2. The latest developments and advances from an academic perspective are presented in Chapter 2.3.
3. A clustered overview of the standards, regulations and technologies currently in use or already identified as relevant for the IMAGINE project is provided in Chapter 3.

Accordingly, suitable case studies have been identified for each of the five Living Labs that will be realized in IMAGINE. For each Living Lab (Chapters 4.2, 4.3, 4.4, 4.5 and 4.6), the following information has been provided:

1. The main objective and the expectations from IMAGINE.
2. The current practices and their specific shortcomings.
3. A set of business cases that can be examined in the context of each Living Lab.

The resulting deliverable is expected to act as a Compendium on Virtual Manufacturing Management, supporting the future project activities.

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1 Introduction

1.1 Purpose and Scope

The main objective of this deliverable (D1.1.1) is to provide the common ground for initiating the IMAGINE Project activities. Particularly, three main sub-objectives are identified as the core of the deliverable:

1. The presentation of the state-of-the-art regarding the dynamic manufacturing network management as well as the related software technology and tools
2. The regulation and standardization activities currently used in networked manufacturing
3. The description of the case studies that will be investigated in the project

These can also be identified as the primary objectives of deliverable D1.1.1 and related tasks T1.1 and T1.2.

1.2 Approach for Work Package and Relation to other Work Packages and Deliverables

One of the main requirements is to provide a background information framework - current practices and state-of-the-art approaches - to Task 1.3, which is planned to elucidate the novel methodology for the management of Dynamic Manufacturing Networks (DMNs).

Additionally, the regulation and standardization information recorded and provided by this deliverable is expected to be considered in the context of WP2 'Technology Foundation and Architecture Specification', aiming at resolving relevant architecture and interoperability issues.

Furthermore, the definitions of the five Living Labs that will demonstrate the results of the IMAGINE project are provided in this deliverable. These definitions are important since they will drive the IMAGINE future developments, promoting a case-driven implementation approach. Therefore, the definitions of the IMAGINE Living Labs are expected to be utilised by all future project activities and especially by WP2/T2.1, where the IMAGINE Platform use cases are defined in detail, and of course by WP4, which deals with the Living Lab demonstrations.

1.3 Structure of the Document

In relation to the aforementioned, the deliverable follows a structure pertaining to the identified main sub-objectives.

Chapter 1 provides a short introduction about the scope of this deliverable and is followed by Chapter 2, which focuses on the Virtual Manufacturing Management. Chapter 2 presents the current practices, the latest developments and recent advances from the academic perspective and an overview of the DMN lifecycle. Three DMN lifecycle phases are identified: 'Network Configuration', 'Network Processes Design' and 'Network Monitoring and Governance'. The latest developments in managing manufacturing networks are presented in these sections. The key points identified are indicated in the conclusions of Chapter 2.

Chapter 3 focuses on the regulations and standards used in networked manufacturing systems. A list of the most commonly used standards is provided, in order to provide a set of standards that could be used for addressing software architecture and interoperability issues. Technologies and guidelines have also been included in Chapter 3 to further support the development of the novel DMN methodology.

In Chapter 4, the IMAGINE Living Labs (aerospace and defence industry, industry agnostic, furniture manufacturing, car manufacturing and engineering sector) are described. For each of the five IMAGINE Living Labs, the primary respective objective along with the current practices and associated shortcomings are identified. The current process flow together with the eventual expectations of the industrial stakeholders is also described. The ultimate objective is to define the business use cases that will be tested and validated in the context of the Living Labs demonstrations in WP4.

Finally, Chapter 5 concludes the Deliverable D1.1.1, by presenting the findings and the directions to be followed by the IMAGINE project.

2 Virtual Manufacturing Management

2.1 Introduction

For many decades, cost and production rates were the most important performance criteria in manufacturing, and manufacturers relied on dedicated mass production systems in order to achieve economies of scale. However, as living standards improve, it is increasingly evident that the era of mass production is being replaced by the era of market niches. [1]

Commonly, in order to respond to this need, companies form virtual enterprises. In a Virtual Enterprise (VE), a company assembles a temporary consortium of partners and services for a certain purpose. The purpose could be a temporary special request, an ongoing goal to fulfil orders, or an attempt to take advantage of a new resource or market niche. The general rationale for forming the VE is to reduce both costs and time to market, while increasing flexibility and gaining access to new markets and resources. In principle, large companies or organisations, participating in a VE, focus on their core competencies and mission critical operations, outsourcing everything else to partners. One of the ideas driving the VE creation is that of processes dynamically constructed out of available Internet-based services as needed at runtime. [2]

Since the 1990's, the concept of virtual enterprises has gained more momentum, as it is based on "the ability to create temporary co-operations and to realize the value of a short unpredicted business opportunity that the partners cannot (or can, but only to lesser extent) capture on their own [3]". There is much debate regarding the formal definition of virtual enterprises in the bibliography, yet there are three fundamental features of the Virtual Enterprise concept that make up the fundamental difference between the virtual and the traditional enterprise, and that generate a number of consequences, making that paradigm shift [4] :

1. Dynamics of network reconfiguration
2. Virtuality
3. External entities as environments for enabling or supporting the VE integration, as well as a reconfiguration dynamics

The classification of a virtual enterprise may be carried out based on four types of "opportunistic aggregation": opportunity-driven, capability-driven, supplier-chain, and bidding consortia [5]. In the realm of time, various methods for managing virtual enterprises and collaborative networks in general have been proposed by researchers. An indicative set of approaches is presented in the following paragraphs.

2.2 Current Practices

Factories operate in networks and are parts of logistic connections with chains in design and engineering of the products, supply chains from customer orders to customers` delivery, supply chains for factory machines, equipment and tools [6]. Today's networked factories have to exhibit low production cost and high flexibility and adaptability to the dynamic change of demand as well as to other external factors.

Subcontracting a great part of the production activities is nowadays a common option, widely employed by many large organisations (e.g. 60% for Airbus' A380). Even more intense subcontracting plans are targeted for future projects (e.g. future long-range Aircrafts envision an 80% subcontracting). Tier-one sub-contractors are also relying on subcontracting their own production quite aggressively. As a result, the number of sub-contractors is increased globally for the whole supply chain from level one to the other levels. This trend can be referred to as "Virtualization of the enterprise". At every level of the supply chain there are companies working with different organization structures and different tools.

Software tools are often employed to assist these efforts. An indicative list of software vendors that provide software used in production networks is presented in Table 2-1: Supply Chain Management Software Suppliers [7].The table lists the following software tools:

- SCP: Supply Chain Planning
- WMS: Warehouse Management System
- MES/MRP: Manufacturing Execution Systems / Material Resource Planning
- TMS: Transportation Management Systems

Table 2-1: Supply Chain Management Software Suppliers [7]

Supplier	2010 Revenue	Web Site	SCP	WMS	MES/MRP	TMS
SAP	$1.317 billion	www.sap.com	x	x	x	x
Oracle	$1.21 billion	www.oracle.com	x	x	x	x
JDA Software	$362 million	www.jda.com	x			x
Manhattan Associates	$136 million	www.manh.com	x	x		x
RedPrairie	$94 million	www.redprairie.com		x	x	x
IBS	$83 million	www.ibsus.com	x	x	x	x
Lawson Software	$80 million	www.lawson.com	x	x	x	x
Descartes Systems Group	$75 million	www.descartes.com				x
Kewill Systems	$64 million	www.kewill.com				x
Retalix	$58.5 million	www.retalix.com	x	x		x
Servigistics	$58 million	www.servigistics.com	x	x		x
Epicor	$57 million	www.epicor.com	x	x		x
Infor	$54 million	www.infor.com	x	x	x	x
Totvs	$50 million	www.totvs.com	x	x		x
GTNexus	$48 million	www.gtnexus.com	x			x
Sterling Commerce	$43 million	www.sterlingcommerce.com		x		x
Aldata	$41 million	www.aldata-solution.com	x	x		x
e2open	$39 million	www.e2open.com	x	x		x
IFS	$37 million	www.ifsworld.com/us	x		x	
Logility	$37 million	www.logility.com	x	x		x

However, within the context of IMAGINE, and especially when considering the lifecycle of Dynamic Manufacturing Networks, other kind of software products will also be considered, such as:

- PDM tools: Product Data Management
- PLM solutions: Product Lifecycle Management
- SLM tools: Simulation Lifecycle Management
- MRO tools: Maintenance and Reparation Operations
- FLM: Factory Lifecycle Management

Despite the advances on the software platforms and tools used, a lot of effort has yet to be made, in order for the integration of suppliers to reach a high maturity level. According to [8] poor planning and integration of e-commerce and enterprise resource planning systems is costing major organisations up to £600,000 a month until problems are sorted out. Aside from poor planning and integration difficulties the heterogeneity of the various partners can also cause undesired effects. According to EADS the A380 program was delayed due to the heterogeneity of the PLM tools used inside Airbus, with important economic impact.

According to EADS, the A380 program was delayed partially due to the heterogeneity of the PLM tools used inside Airbus, with important economic impact. This led to an important PLM harmonization project inside the EADS Group[1]. It also led to the creation of an eBusiness PLM standards governance group for the whole Aerospace & Defense community[2], as the "digital break" problem is not Airbus specific, but shared by all the Aerospace eBusiness ecosystem, as illustrated by the objective of SEINE project[3]. Some industrial PLM Hubs platforms are currently emerging (such as BOOST Aerospace[4]), which are operated in some cases by external entities as environments for enabling or supporting the digital collaboration.

"On Boarding", for such platforms, could be defined as the process of acquiring the necessary knowledge, skills, and behaviours to effectively and efficiently participate in a partnership. Specifications and implementation of current hubs are really slow, and on boarding process could be difficult as such approaches are emerging. Therefore, the on boarding process is important since the maturity of the partners' community needs to be developed as fast as possible.

Besides the rather slow onboarding process, the cost of sophisticated software tools is also frequently prohibiting SMEs to adopt such efforts. By using open standards and modern technologies, such as web services technologies and service oriented architectures, the cost of the software tools is expected to be reduced and the on boarding process could be accelerated.

According to [9] when it comes to logistics management and supply chain management 58% of retailers are either constrained by a fragmented IT approach or are even using manual or spreadsheet approaches. As argued in [9], retailers need to address the lack of integration between

[1] EADS PLM Group strategy: Phenix harmonization programme, Mondon, 23/11/2007, http://www.virtual-plm.com/fr/brochure/download/file/345_0_EADS_PHENIX_Public_Pres_V22.pdf

[2] ASD Strategic Standardization Group, http://www.asd-ssg.org/web/asd-ssg

[3] SEINE project, http://www.ticpme2010.fr/projets/projet66/fiche_html/

[4] BOOST Aerospace, Collaborative Digital Hub, http://www.boostaerospace.com/Pages/AirCollab.aspx

software solutions such as Warehouse Management Systems, Order Management Systems, Transportation Management Systems and Inventory Management Systems. The importance of visibility is also highlighted by [9]. In particular, 50% of the companies surveyed do not have real time access to inventory and order data. At the same time, the today's dominant business model does not allow for the consideration of loosely coupled partnerships that could be built on the fly, addressing specific time-constrained demand requirements. Security and confidentiality aspects need both to be taken into account, while the processes for integrating diverse organisations in networked manufacturing enterprises will have to be less complex and expensive.

IMAGINE has identified these difficulties, as discussed in the previous paragraphs, and aims to tackle these issues by incorporating modern, yet mature technologies such as web services.

2.3 Latest Developments

According to [10], a supply chain can be viewed as a directed graph where the nodes represent functionality that must be provided and the arcs capture precedence constraints among the functions. A function might be the procurement of a raw material, the manufacture of an assembly, or the shipment of a product to a distribution centre. For each of these functions, there are one or more options available to satisfy the function. [10]

The latest developments in efficiently determining these nodes and arcs as well as the overall network performance are discussed in next paragraphs. The findings have been aligned to the key phases identified in the IMAGINE project DoW, namely Network Configuration, Network Design, Monitoring and Governance.

2.3.1 Network Configuration

Before selecting the right partners for an alliance, a company first needs to identify potential partners. Usually, many enterprises have a list of pre-approved suppliers that can perform work for them. Even though there are no formal criteria for the inclusion of companies in this list, it is generally populated with local suppliers that have already traded with the enterprise. However, because of the increased competitiveness in the global market, an increasing number of business and trade directories have emerged providing means for online partner identification. Examples of them can be found in regional portals, a series of representative examples follows:

- China Sourcing (www.chinasourcing.ch), which promotes the products offered by companies across China;
- Asia Trade Hub (www.asiatradehub.com), which lists companies across all major Asian cities;
- Alibaba International (www.alibaba.com), a manufacturing directory primarily serving SMEs, with one million registered users from over 240 countries;
- MFG (www.mfg.com), a specialized manufacturing e-marketplace that focuses on engineering SMEs;
- Enterprise Europe Network (http://www.enterprise-europe-network.ec.europa.eu), an EU supported business support network that specializes in supporting SMEs finding international business partners. In a broader sense it can provide searches to form manufacturing partnerships.

What is common to all these portals is the frequently limited information provided about the listed companies. Companies are usually classified according to their end products, as for example in China Sourcing and Alibaba, an approach that is insufficient for innovative, higher value added work. As argued by [11], it is the skills and assets that exist in a firm that result in the development of new successful products delivered in chosen markets. Products are only instances of what an engineering company is doing, and does not show all it can do. The importance of an individual's experience, know-how and skill has been noted in [12]. How far a manufacturing resource or a process can be pushed towards its highest level of performance is usually dependent on the skills of the individuals driving the process. The lack of relevant information on the existing portals points towards the need for a partner repository that could, for instance, capture key competencies and product descriptions and would provide information that can be verified or trusted by the members of a network.

The design of such a partner repository could provide a standard way to access partners' competencies and possibly the ability to compare them with the product manufacturing requirements. Additionally, it could enable access to dynamic information of partners, such as available resources and current manufacturing capacity. In the Virtual Enterprises (VE) environment, interactions between distributed, heterogeneous computing entities representing different enterprises, people and resources, take place. These interactions, in order to be both syntactic and semantic compatible, need to follow appropriate standards well understood by all the participants [13]. The identification of potential partners in this context would result in a list of potential partners whose competencies match the product manufacturing requirements. In principle, only a subset of these partners would be selected to actually form the Manufacturing Network. In the context of this document this final selection of partners is referred as Partner Selection. In today's challenging market conditions, companies need to take advantage of any opportunity to improve their performance. In this context, working closely with supply chain partners to optimize business processes is one of the main methods to achieve this goal. Therefore, a key step in the formation of any supply chain is that of partner selection [14].

Partner selection decisions change the global supply chain design problem in many ways because they are based on broadly defined criteria. Suppliers are typically selected based on the buyer's perception of the suppliers' ability to meet quality, quantity, delivery, price, and the service needs of the firm [15]. In some cases, purchasing managers consider an even broader set of criteria, defined as the total cost of ownership, to include the cost of carrying inventory, repair, training, disposal, etc. [16]. Supplier contracts also influence the design problem structure with additional factors such as minimum order quantities, restrictions on the number of vendors, geographic preferences, and limitations on supplier capacities [17]. Ultimately, purchasing managers try to summarize these factors so that candidate suppliers may be sorted and ranked for selection. An indicative list of information on which criteria can be based is presented at Figure 2-1.

Figure 2-1 Indicative Criteria for partner selection[5]

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[5] The compilation of this list has been influenced by the following works:

- Willems, S.P., 1999. *Two papers in supply chain design: Supply Chain Configuration and Part Selection in Multigeneration Products*. Ph.D. Dissertation. MIT.
- Huang G.Q., Zhang X.Y. and Liang L., 2005. Towards Integrated Optimal Configuration of Platform Products, Manufacturing Processes, and Supply Chains. *Journal of Operations Management*, 23 (3–4), 267–290.
- Mourtzis D., Papakostas N., Makris S., Xantakis V. and Chryssolouris G., 2008. Supply chain modeling and control for producing highly customized products. *CIRP Annals - Manufacturing Technology*. 57(1), 451-454.
- Meyer, M.H. & Utterback, J.M., 1993. The product family and the dynamics of core capability. *Sloan Management Review*, 34(3), pp.29-47.
- Slack, P.N., Chambers, D.S. & Johnston, P.R., 2009. *Operations Management*, Financial Times/ Prentice Hall; 6 edition.
- Efthymiou K., Sipsas K., Melekos D., Georgoulias K., Chryssolouris G., 2011. A Manufacturing Ontology Following Performance Indicators Approach. *7th International Conference on Digital Enterprise Technology, Athens, Greece.* 586-595.
- Leenders, M., Johnson, F. & Flynn, A., 2010. *Purchasing and Supply Management*, McGraw-Hill/Irwin; 14 edition.
- Burt, D.N., Dobler, D.W. & Starling, S.L., 2003. *World Class Supply Management The Key To Supply Chain Management [Hardcover]*, McGraw-Hill; 7th edition.
- Pan, A.C., 1989. Allocation order quantity among suppliers. *Journal of Purchasing and Materials Management*, (25), 36-39.
- Lin, C., Chiu, H. & Chu, P., 2006. Agility index in the supply chain. *International Journal of Production Economics*, 100(2), 285-299.
- Christopher, M. & Towill, D.R., 2000. Supply chain migration from lean and functional to agile and customised. *Supply Chain Management: An International Journal*, 5(4), 206-213.
- Gunasekaran A., Lai K.-H. and Chang T.C.E., 2008. Responsive Supply Chain: A Competitive Strategy in a Networked Economy. *Omega*, 36 (4), 549–564.
- Nepal B., Monplaisir L. and Famuyiwa O., 2012. Matching product architecture with supply chain design. *European Journal of Operational Research*, 216 (2), 312-325.

<u>What is primarily missing on partner identification and selection ?</u>

While there are several internet portals concentrating on companies and their products**, they do not seem to provide the sufficient functionality for appropriately identifying and selecting the potential partners for a manufacturing network**. Frequently, this is because they categorize companies based on their products and not their competencies and/or potential competencies. The results provided are also frequently inadequate for selecting the ideal partner by applying a set of criteria, since they do not provide the functionality to perform partner selection by applying sophisticated criteria. Sophisticated criteria could be applied if dynamic data –concerning, for example, available resources or present requirements- is available. However, a major drawback of current approaches is that they commonly provide static data and, thus, do not allow sophisticated selection. Another important issue is that they do not provide any means for the collaboration and orchestration of work among the companies.

2.3.2 **Network Design**

The design of network processes is composed of different elements: e.g. Structural network and supply chain design processes, functional network design process as collaborative factory engineering and design processes, followed by the implementation of interconnected IT architectures, networked production systems and end-to-end supply chains network processes from customer orders to product delivery. Figure 2-2 presents the main elements of the network process design types that have been identified in Literature. Each of these elements consists of various methods and applications, which could support the DMN design process. In the following paragraphs, the Structural and Functional Network Process Design as well as the Implementation of Network Processes in terms of Virtual Manufacturing and Information Technology are summarized. It should be noted that although these processes have been identified as relevant to the Dynamic Manufacturing Networks, they have not been implemented in an integrated software platform or tool and they still represent part of an on-going theoretical debate about how network processes may be defined and designed.

- Alexopoulos K., Papakostas N., Mourtzis D., Chryssolouris G., 2010. A method for comparing flexibility performance for the lifecycle of manufacturing systems under capacity planning constraints. *International Journal of Production Research*, 49 (11),3307-3317.
- Aksoy, A. & Öztürk, N., 2011. Supplier selection and performance evaluation in just-in-time production environments. *Expert Systems with Applications*, 38(5), 6351-6359.
- Crispim, J.A. & de Sousa, J.P., 2010. Partner selection in virtual enterprises. *International Journal of Production Research*, 48(3), 683-707.
- Weber, C., 1991. Vendor selection criteria and methods. *European Journal of Operational Research*, 50(1), 2-18.
- Che, Z.H. & Wang, H.S., 2010. A hybrid approach for supplier cluster analysis. *Computers & Mathematics with Applications*, 59(2), 745-763.
- Wang, Z.-J., Xu, X.-F. & Zhan, D.-C., 2009. Genetic algorithm for collaboration cost optimization-oriented partner selection in virtual enterprises. *International Journal of Production Research*, 47(4), 859-881.
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- Zhiping F., Tiansheng H. and Zhizhuang L., 2008. Selection of Suppliers Based on Rough Set Theory and Fuzzy TOPSIS Algorithm. *Knowledge Acquisition and Modeling Workshop, 2008. KAM Workshop 2008. IEEE International Symposium on*, 979-982.

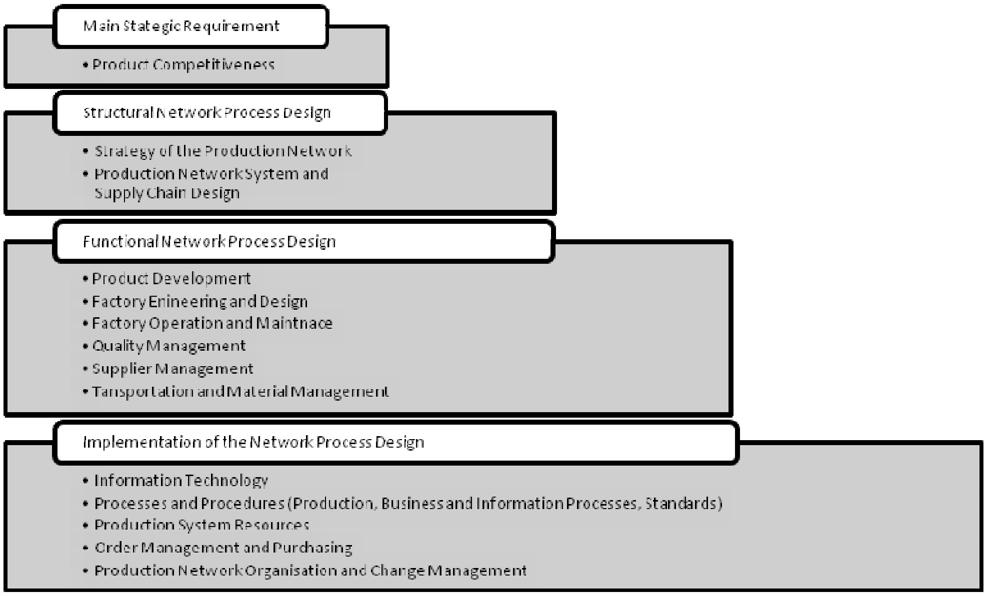

Figure 2-2: Strategy and Design of Network Processes – Main Elements [18]

The Structural Network Process Design

The strategy of the Production Network Design depends on the business models of the collaborating enterprises. For example, the centralised control of network processes is reasonable if a large enterprise is dominating the production network or interconnects their own production systems. In the case of interconnecting individual companies, the design and control of manufacturing network processes are often performed in a decentralised manner but in close connection and coordination with the joint production systems, as individual companies often try to be autonomous in terms of acting and decision making [19].

Functional Network Process Design

The functional network design process with its collaborative factory engineering and design processes have to cover all the phases and aspects of the Product and Factory Life Cycle within a DMN [20].

There are a few methodologies for product design that could in theory enable a systematic engineering of products. One of the most important documents in the field of methodical product design is the guideline [21] provided by the Association of German Engineers (VDI). Most standard works of engineering design refer to this guideline.

Implementation of the network process design

Digital production engineering is a complex procedure, since distributed engineering teams, using heterogeneous IT tools, should be able to collaborate in order to design and implement a production system [22]. The work of Alexopoulos [22] presents the theoretical groundwork of a workflow system for collaborative computer-aided production engineering. This prototype workflow system could support the execution of production engineering activities in the Extended Enterprise (EE) and it is built on the basis of web services and the BPEL (Business Process Execution Language). It also manages the electromechanical data exchange, using XML that conforms to the AutomationML format. [22]

According to the authors, the workflow of a production engineering project could be configured within the BPEL Engine layer and deployed as a set of coordinated web services. The engineering data become available to the appropriate cooperating partners in a native or an AutomationML open

format. Unlike many traditional PDM and PLM systems, the AutomationML Server approach does not need to be configured in-depth in order to match the current production engineering procedures. However, effort is required for interfacing with the legacy systems but this is expected to be achieved in a shorter time, due to the openness and the flexibility provided by the web-services API. [22]

End-to-End Process Design

Identifying a future vision for a plant network requires a pragmatic approach involving a careful balance of analysis, intuition and creativity. There are too many variables to model every aspect mathematically – and yet a systematic and clear process is essential, supported by valid data.

The Supply Chain Operations Reference (SCOR®) model provides a framework that links performance metrics, processes, best practices, and people into a unified structure. The framework supports communication between supply chain partners and enhances the effectiveness of supply chain management, technology, and related supply chain improvement activities. SCOR metrics provide the basis for an organization to measure how successful it is in achieving its desired objectives and are designed to be used in conjunction with supply chain performance attributes, making it easier to compare different supply chains and different supply chain strategies. SCOR also provides a common language for supply chain classification and analysis. Using a common language and framework makes it easier for teams to communicate, speeds benchmarking efforts, and enhances the evaluation of best practices [23]. Although the SCOR framework may provide the means for fostering the communication among DMN nodes as well as the evaluation of their performance, it has still to be tested and validated within the scope of realistic DMN cases.

Figure 2-3: SCOR Framework [23]

What is primarily missing on processes planning?

As it can be concluded from the previous paragraphs, different methodologies relating to process planning can be found in the literature. Although these methodologies provide a sound theoretical basis for modelling DMNs, they still have to be tested and validated in real dynamic manufacturing networks and distributed production cases. A few cases presented in the literature are related in principle to static supply chain configurations, and are most usually limited to addressing only a minor part of the DMN lifecycle.

2.3.3 Monitoring and Governance

This phase aims at managing and controlling in a continuous way the operations of the network, resulting either in "small and corrective" decisions towards the network's operation optimisation, or to "larger and structural" changes. These changes should in theory be fed back to the network configuration phase, for reconstructing the network in order to achieve better results.

Although research has delivered various methodologies for controlling plant operations and monitoring data coming out of the production systems, they do not yet seem mature enough for addressing the needs of dynamic manufacturing networks. Today, we find various platforms able to control intra-organisational processes (and even in some cases inter-organisational processes as part of static supply chains), but as noted in [24], there is a lack of approaches and tools specifically developed for dynamic networks that consist of distributed, independent, and heterogeneous members. Current approaches cannot deliver the same results without strong modifications and one has to investigate to what extent they can meet the different requirements set by such dynamic alliances.

The notion of a DMN includes the configuration of a network consisting of a large number of closely integrated and interdependent projects, which are executed over a wide geographic spread, across very different time zones, and involve large numbers of staff. As it is understandable, this whole process, apart from being very difficult to be executed, affects also a wide range of stakeholders whether they are members of the network or not.

This last phase claims the need for monitoring and governing end-to-end process performance and detecting events that may influence performance. A considerable collection of indicative KPIs can be found in the Appendix, specifically in Table 6-1: Indicative Key Performance Indicators.

In essence, the network evaluation could be split to the following four sub-phases:

a) **Real Time Data Collection and Network Monitoring**. This step would deal with gaining access on information regarding how the work progresses and raising alerts on early detection of issues that may influence the performance of the network's operation.

b) **Operational Level DMN Governance**. This sub-phase would constitute the logical step after an alert is generated and would deal with the immediate response of the system in order to fine-tune and optimise the network in order to avoid the consequences of the problem identified.

c) **Network Performance Measurement and KPIs Monitoring**. During this phase a cumulative analysis of various metrics of the network would be carried out and translated in KPIs, presenting the overall picture regarding the DMN.

d) **Network Performance Evaluation and DMN Reformation**. The last step would include the analysis and evaluation of the DMNs KPIs values towards deciding on whether a reconfiguration of the network is necessary in order to maximise the anticipated results.

<u>What is primarily missing on network evaluation?</u>

There are no approaches that can monitor, manage and control dynamic manufacturing networks without implementing strong and complicated modifications. Nevertheless, even after implying the necessary modifications, it has to be investigated to what extent these can meet the different requirements set by such dynamic alliances.

2.4 Conclusions

One of the top business pressures most frequently cited by today's enterprises is the need to react to demand changes in a more timely manner. Further to having to deal with the increase in year-over-year fulfilment and transportation per unit costs, companies have been attempting to improve the cross-channel supply chain flexibility in order to achieve a faster reaction to demand changes and improved supply chain responsiveness [9]. Manufacturing companies must be able to quickly restructure or transform the supply chain execution (source-deliver processes) in response to an evolving global, multi-channel supply chain scenario. However, many companies still don't have the ability to respond to dynamic demand cycles, while, at the same time, the increased globalisation pushes the demand uncertainty at even higher levels [9]. In the retail domain, for instance, the demand has been so uncertain in the last 18 months (mid 2010 – end 2011) that the volume of inventory has either been too high to too low [9]. The recent events of the volcano's eruption in Iceland and the nuclear disaster in Fukushima have reaffirmed the need for greater flexibility in order for manufacturing organizations to cope with the dynamic nature of the market and its fluctuations.

At the same time, current SCM software platforms and tools are too expensive to implement, deploy and use at a broader networked enterprise scale, including smaller companies with lower IT capacity, and are unable to a) cover all actual phases of a manufacturing network and b) cope with the highly dynamic and uncertain nature of demand. It is not enough for today's manufacturing enterprises to be 'networked': they have to be able to change and adapt to a continuously evolving environment and to form dynamic alliances with other companies and organisations in a fast and cost-efficient manner. In parallel, when considering collaborative networks utilizing supporting platforms and tools, such as PDM, PLM, SLM, MRO and FLM, it is also frequently found that these networks are difficult to change and to adapt to new, emerging requirements.

To effectively manage a Manufacturing Network in an integrated manner, the most appropriate partners have to be selected, an efficient network manufacturing process should be identified and designed and the appropriate monitor and govern strategies should be defined.

Identification of the appropriate partners is the first step in the process. In order to successfully identify potential partners it is not always sufficient to rely on identification based on their current product since they only provide a subset of their true potential. Efficient partner identification should take into consideration the network partners' competencies.

The filtering and subsequent best final choice of network partners has to face fuzzy, incomplete data and a big variety of criteria. Criteria formulation usually fall under 4 main classes of attributes: Time, Flexibility, Cost and Quality and use various data from potential partners. To cope with non-homogeneity of partners, fuzzy, incomplete and uncertain data various algorithmic techniques can be employed such as heuristic, stochastic optimisation, evolutionary programming, etc.

Although a few approaches for partner identification and selection may be found in the most recent literature, nevertheless, their integration into dynamic manufacturing networks management methodologies has not been tested or reported yet. Current practises are in principle limited to the utilisation of internet directories that categorize companies based on their products and in particular their textual description. The information, functionality and categorisation provided by these directories are insufficient for forming dynamic manufacturing networks. There is much more information that needs to be identified in order for key competencies to be revealed and utilised, taking advantage of multiple sophisticated criteria.

After selecting a group of partners the Dynamic Manufacturing Network must be designed efficiently at the Strategic, Tactical and Operational levels. In terms of structural and strategic network process design, analytical methods and applications can be employed in the DMN environment as part of the IMAGINE framework. Within such a common and consistent management and design framework, critical aspects and processes of a DMN can be analysed and optimised. Moreover, the network processes can not only be assessed analytically, but also be dynamically simulated and optimised to support the planning and design of a DMN.

While, different methodologies relating to process planning can be found in the literature that provide a sound theoretical basis for modelling DMNs, they still have to be tested and validated in real dynamic manufacturing networks and distributed production cases. The few cases presented in the literature are related in principle to static supply chain configurations, and are most usually limited to addressing only a minor part of the DMN lifecycle.

There are also no approaches that can monitor, manage and control dynamic manufacturing networks without implementing strong and complicated modifications. Nevertheless, even after implying the necessary modifications, it has to be investigated to what extent these can meet the different requirements set by such dynamic alliances and how well can they be integrated in a dynamic manufacturing network management approach.

Summarizing, the following points have been identified regarding the DMN lifecycle:

- The functional network design process with its collaborative factory engineering and design processes have to cover all the phases and aspects of the Product and Factory Life Cycle within a DMN.
- The network processes cannot only be assessed analytically, but also be dynamically simulated and optimised to support the planning and design of a DMN.
- If needed, the partner selection process can be repeated in order to select partner(s) that may lead to the desired network objectives in a timely and cost-efficient manner.
- When the network design has been completed the dynamically created manufacturing network can assume its operation. Governing the network requires access to near real time data that are used in conjunction with predefined KPIs to monitor the DMN operation, detect performance flaws and trigger correction actions.
- The quick reconfiguration or redesign of the DMN should be possible in order to avoid undesired performance flaws.

3 Manufacturing Systems Regulations and Standards

3.1 Introduction

Considering the creation of flexible DMN, standards are of outmost importance in order to ensure the compatibility of all partners involved in the planning process. The extensive list of standards that are either used or expected to be used by the Living Labs needs to be comprised in order to cluster it for the following examination of possible gaps and necessary enhancements or developments inside the IMAGINE consortium.

In order to enable the consortium to handle the complexity of the standards, regulations and technologies used for the IMAGINE project, first a framework is established to enable controlled processes. This framework is described in Section 3.2. Section 3.3 introduces a consolidated map and a clustered baseline overview of the standards, regulations and technologies currently in use or already identified as relevant for the IMAGINE project.

3.2 Framework for standards, regulations and technology

During the course of the project, it is expected that new standards, regulations and technologies will be identified which might be necessary or useful for the IMAGINE project or it might become obvious, that a previously not included standard, regulation and technology might be useful.

In order to handle the standards, regulations and technologies during the course of the project without creating any confusion in the consortium, a framework is established. This framework is comprised of three steps, "periodic overview", "inclusion process" and "decision process".

3.2.1 **Periodic overview**

To keep the table of standards, regulations and technologies, relevant for the IMAGINE project, up to date, the list will be updated periodically for each of the Living Labs. Step 1 "periodic overview" is detailed in Figure 3-1.

This periodic update of the list is then included into the deliverable D1.1.1. If any partner identifies a gap for a specific challenge in their Living Lab, he may first consult the clustered overview and map of the standards already in use by the consortium. If none of the included standards, regulations and technologies addresses his challenge, he is then able to trigger step two and if necessary step three of the standard handling framework. The created map of all standards, regulations and technologies useful for the IMAGINE project is also the basis for the evaluation of the necessity of the expansion of standards or the inclusion of new ones.

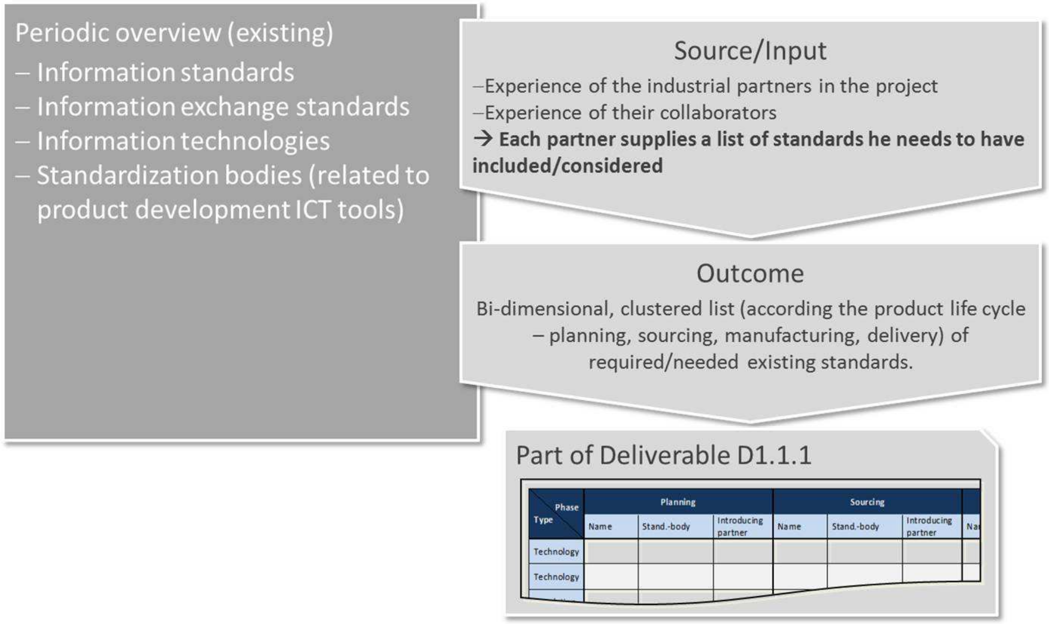

Figure 3-1: Step 1 "periodic overview" of the IMAGINE standard, regulation and technology handling framework

3.2.2 Inclusion process

In case a partner in the consortium identifies a new standard, regulation or technology or one that needs to be expanded for the IMAGINE project, he will trigger the inclusion process (Figure 3-2).

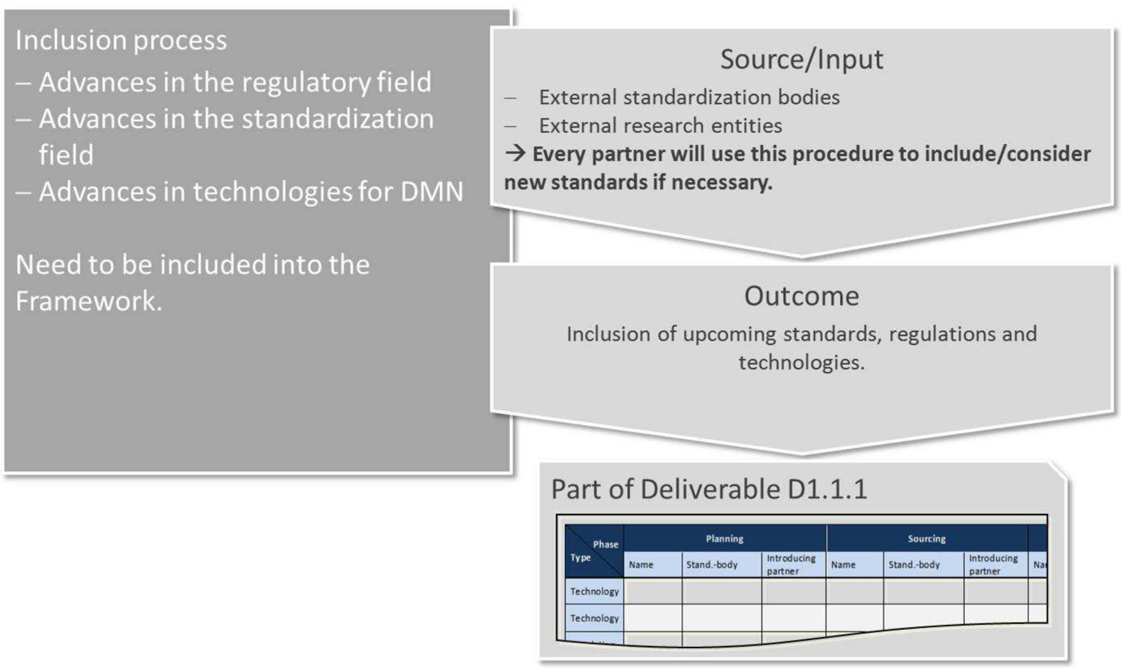

Figure 3-2: Step 2, "inclusion process" of the IMAGINE standard, regulation and technology handling framework

For this step, every partner is required to keep track of the standards, regulations and technologies relevant for his Living Lab. If he considers a new one or an extension is necessary, this step is used to determine the possibility to help him evaluate a useful substitution using the existing standards, regulations and technologies already in the consortium. At the end of this step, the partner introducing the new or extended standard, regulation or technology -which he considered necessary-, he can be now sure if the next, step three is required to trigger the inclusion or extension.

3.2.3 **Decision process**

In order to control the number of standards, regulations and technologies for the implementation of the derived methods to be realistic, the inclusion of new or the expansion of standards, regulations and technologies are controlled inside the consortium. This process is depicted in further detail in Figure 3-3.

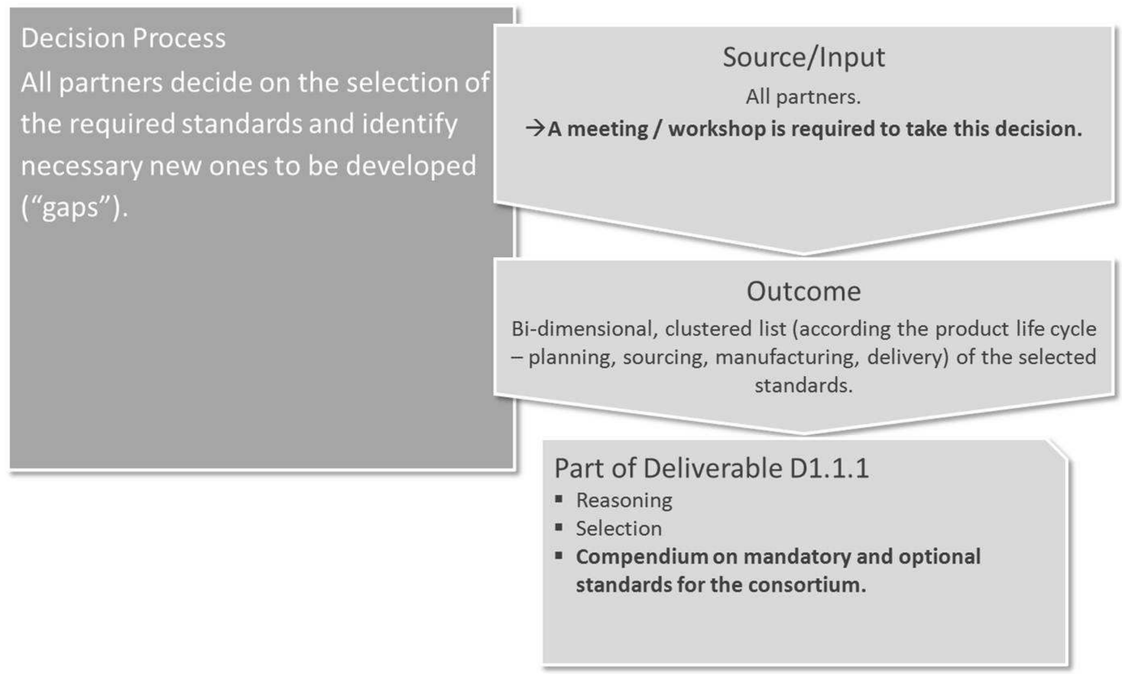

Figure 3-3: Step 3, "decision process" of the IMAGINE standard, regulation and technology handling framework

A committee is derived, that includes one person from each partner. This committee meets regularly in order to take decisions concerning the inclusion or extension, basing this decision on the map of standards, regulations and technologies created by step one of this framework. This step derives a compendium of standards, regulations and technologies mandatory or optional for everyone to use in the consortium and decides about the extension of this compendium to include new or expanded standards, regulations or technologies.

3.3 Clustered overview of existing standards and technologies relevant for IMAGINE

At the start of the project IMAGINE, each partner identified the standards, regulations and technologies that are either used or expected to be used in his Living Lab. This extensive list comprises standards, regulations and technologies both from the mechanical engineering as well as from the IT field.

3.3.1 **Standards, regulations and technologies relevant for IMAGINE**

In order to enable the consortium to have a common basis of standards, regulations and technologies in use by everyone, the consortium is asked to list the ones, relevant for IMAGINE in their specific Living Lab. In sum, more than only standards, regulations and technologies were gathered, in order to ensure the compatibility of the created IMAGINE platform for all Living Labs:

- Standards: Of course, the standards need to be gathered as most Laboratories are bound to them. If any technology, method or other gathered relevant input is described in an official standard, it is preferred to include the official standard instead of descriptions of the method itself.
- Regulations: In some fields of the mechanical engineering especially, regulations are very common. In difference to the standards, they are mostly not binding and are often more an understanding of how to approach certain topics.
- Technologies: In order to enable the consortium to be able to use the most modern technologies in use today and to ensure the compatibility, the used technologies are gathered.
- Methods: Some Living Labs are using specialized methods, especially in the field of optimisation. If they are not standardized, they were included in the table in order to methodically ensure the compatibility.
- Formats: There are formats which are not (yet) standardised, but are very common in certain fields. These formats might prove very useful in order to provide the consortium a list of exchange formats where there are already experiences in the consortium.

All partners identified the standards, regulations and technologies currently in use in their Living Lab or expected to be relevant to IMAGINE. These have been gathered Table 3-1: Overview over the standards, regulations and technologies, relevant for IMAGINE. This table will be the basis of discussion in the workshops of the standardisation group in order to identify gaps and decide on mandatory or optional standards, regulations, technologies etc. Some of them are gathered from several partners. This does not necessarily mean they are implemented identically for these partners. Standards especially can be very extensive and as such might be in use differently, when different sections of the standards are addressed. In order to prevent confusion, all gathered standards, regulations, technologies, methods and formats are classified according to the DMN lifecycle as well as the supply chain lifecycle, each described in the DoW of the IMAGINE project and clarified in Chapter 2. This information is not describing what the standards, regulations, technologies, methods and formats themselves are able to cover, but rather what the appropriate partner uses (or could possibly use) these standards, regulations, technologies, methods and formats for. It is therefore expedient to include some of them several times, if different partners use them to cover different parts of the supply chain or DMN lifecycle. This may especially be the case for standards, regulation and technology that encompass extensive fields (e.g. ISA95) and therefore have an extensive range of appliance.

	General information				Supply chain lifecycle			DMN lifecycle		
Phase / Type	Name	Standardisation body	Field	Intro. Partner	Planning	Sourcing	Manufacturing	Configure	Design	Monitor and Govern
Method	5s	-	Eng.	UoW			X		X	X
Method	6 Sigma	-	Eng.	UoW		X	X		X	
Method	8D	-	Eng.	UoW		X	X		X	
Technology	Advanced visualization on the Web	W3C	IT	EADS	X	X	X	X	X	X
Standard	ANSI/ISA95	International Society of Automation	Eng.	FhG-IPA			X		X	
Standard	ANSI/ISA95	International Society of Automation	Eng.	FhG-IPA			X		X	
Standard	AS 9100	European Association of Aerospace Industries	Eng.	UoW	X	X	X	X	X	X
Format	AutomationML	AutomationML	Eng./IT	FhG-IPA	X	X	X	X	X	X
Standard	AutomationML	Deutsche Kommission für Elektrotechnik Elektronik Informationstechnik	Eng.	UoP	X	X		X	X	X
Standard	AutomationML	Deutsche Kommission für Elektrotechnik Elektronik Informationstechnik	Eng.	UoP	X	X		X	X	X

	General information				Supply chain lifecycle			DMN lifecycle		
Phase / Type	Name	Standardisation body	Field	Intro. Partner	Planning	Sourcing	Manufacturing	Configure	Design	Monitor and Govern
Format	B2MML		Eng./IT	FhG-IPA			X	X	X	X
Format	BPEL		Eng./IT	FhG-IPA	X	X	X	X	X	X
Format	BPMN	OMG	IT	UoP	X	X	X	X	X	X
Technology	BPMN	Object management group/Business process management initiative	IT	UoP	X	X	X	X	X	X
Technology	Caching and load balancing		IT	EADS	X	X	X	X	X	X
Format	CAEX		Eng./IT	FhG-IPA				X	X	X
Technology	Cloud-Manufacturing		Eng.	FhG-IPA	X	X	X			
Format	COLLADA		Eng./IT	FhG-IPA						
Technology	Configuration and change management	ISO	Eng.	EADS						
Guideline	cPlatform documentation		IT	LOGO				X	X	X
Standard	DIN 8580	German Institute for Standardization	Eng.	FhG-IPA	X	X	X	X	X	X
Standard	Ean 128			LOGO				X	X	X

	General information				Supply chain lifecycle			DMN lifecycle		
Phase / Type	Name	Standardisation body	Field	Intro. Partner	Planning	Sourcing	Manufacturing	Configure	Design	Monitor and Govern
Standard	EDI	National Institute of Standards and Technology		LOGO	X	X	X	X	X	X
Guideline	Enterprise interoperability framework	EADS	Eng./IT	EADS	X	X	X	X	X	X
Technology	Enterprise modelling	Open group ISO OMG	IT	EADS						
Technology	Enterprise portal technology	OASIS W3C	IT	EADS	X	X	X	X	X	X
Technology	Federation Mashup Syndication	W3C	IT	EADS	X	X	X	x	x	x
Method	FMEA	-	Eng.	UoW			X			X
Technology	Grid-Manufacturing		Eng.	FhG-IPA	X	X	X	X	X	
GuideLine	GTIP/HS				X	X	X			
Standard	IDEF0	National Institute of Standards and Technology	IT/Eng.	UoP	X	X	X	X	X	X
Standard	IDEF0	National Institute of Standards and Technology	IT/Eng.	UoP	X	X	X		X	
Standard	IEC 62264	International Electrotechnical Commission	Eng./IT	FhG-IPA	X	X	X			X

	General information				Supply chain lifecycle			DMN lifecycle		
Phase / Type	Name	Standardisation body	Field	Intro. Partner	Planning	Sourcing	Manufacturing	Configure	Design	Monitor and Govern
Technology	IMDS	HP	Eng./IT	UoW						
Technology	Integration frameworks (.Net, J2EE)		IT	EADS			X		X	X
Standard	ISO 10303	International Organization for Standardization	Eng.	FhG-IPA			X	X	X	X
Standard	ISO 10303 STandard for the Exchange of Product model data (STEP)	ISO	Eng./IT	EADS	X	X	X	X	X	X
Standard	ISO 13485	International Organization for Standardization	Eng.	UoW				X	X	X
Standard	ISO 14001	International Organization for Standardization	Eng.	UoW	X	X	X	X	X	X
Standard	ISO 15489	International Organization for Standardization	IT	UoW	X	X	X	X	X	X
Standard	ISO 16739	Industry Foundation Classes	Eng.	FhG-IPA	X	X	X	X	X	X
Standard	ISO 17025	International Organization for Standardization	Eng.	UoW	X	X	X	X	X	X
Standard	ISO 27001	International	IT	UoW				X	X	X

	General information				Supply chain lifecycle			DMN lifecycle		
Phase / Type	Name	Standardisation body	Field	Intro. Partner	Planning	Sourcing	Manufacturing	Configure	Design	Monitor and Govern
		Organization for Standardization								
Standard	ISO 9000	International Organization for Standardization	Eng.	FhG-IPA	X	X	X	X	X	X
Standard	ISO 9000	International Organization for Standardization	Eng.	LOGO	X	X	X	X	X	X
Standard	ISO 9001	International Organization for Standardization	Eng.	UoW	X	X		X	X	X
Standard	ISO/IEC 20000	International Organization for Standardization /International Electrotechnical Commission	IT	FhG-IPA	X				X	
Standard	ISO/IEC 27001	International Organization for Standardization /International Electrotechnical Commission	IT	FhG-IPA				X	X	X
Standard	ISO/TS 16949	International Automotive Task Force	Eng.	UoW				X	X	X
Standard	ITIL	Office of Government	IT	UoW						

	General information				Supply chain lifecycle			DMN lifecycle		
Phase / Type	Name	Standardisation body	Field	Intro. Partner	Planning	Sourcing	Manufacturing	Configure	Design	Monitor and Govern
		Commerce								
Format	JT		Eng./IT	FhG-IPA	X					
Standard	Model Driven Architecture (MDA)	OMG	Eng./IT	EADS	X	X	X			
Format	OWL	OMG	Eng./IT	FhG-IPA	X	X	X			
Format	PLCopenXML		Eng./IT	FhG-IPA	X					
Technology	Product lifecycle management	ISO	Eng.	EADS			X			
Standard	Security assertion markup language (SAML)	OASIS	IT	EADS	X	X	X	X	X	X
Technology	Semantic cartography		IT	EADS	X	X	X	X	X	X
Technology	Semantic Web technology	W3C OASIS	IT	EADS	X	X	X	X	X	X
Technology	Single sign on and federation of identity		IT	EADS	X	X	X	X	X	X
Technology	SOA Technology	W3C OASIS OMG	IT	EADS						

	General information				Supply chain lifecycle			DMN lifecycle		
Type / Phase	Name	Standardisation body	Field	Intro. Partner	Planning	Sourcing	Manufacturing	Configure	Design	Monitor and Govern
Standard	Software & Systems Process Engineering Metamodel specification Version 2.0 (SPEM2)	OMG	Eng./IT	EADS	X	X	X	X	X	X
Guideline	SOSI (system of systems interoperability)		Eng./IT	EADS	X	X	X	X	X	X
Method	SPC	-	Eng.	UoW				X	X	X
Technology	System engineering	INCOSE ISO	Eng.	EADS	X	X	X	X	X	X
Format	UBL		Eng./IT	LOGO	X	X	X	X	X	X
Guideline	VDI 2209	Association of German Engineers	Eng.	FhG-IPA						X
Guideline	VDI 3633	Association of German Engineers	Eng.	FhG-IPA		X	X		X	
Guideline	VDI 4499	Association of German Engineers	Eng.	FhG-IPA		X	X		X	
Guideline	VDI 5200	Association of German Engineers	Eng.	FhG-IPA	X	X	X	X	X	X
Guideline	VDI 5600	Association of German Engineers	Eng.	FhG-IPA			X		X	
Technology	WEB server		IT	EADS			X		X	

	General information				Supply chain lifecycle			DMN lifecycle		
Phase / Type	Name	Standardisation body	Field	Intro. Partner	Planning	Sourcing	Manufacturing	Configure	Design	Monitor and Govern
Format	WSDL	W3C	IT	UoP	X	X	X	X	X	X
Technology	WSDL	W3C	IT	UoP	X	X	X	X	X	X
Format	XML	W3C/OMG	Eng./IT	FhG-IPA	X	X		X	X	X
Format	XML		Eng./IT	LOGO	X	X		X	X	X
Format	XML	W3C	IT	UoP			X	X	X	X
Technology	XML	W3C	IT	UoP	X	X	X	X	X	X
Standard	XML Process Definition Language version 2(XPDL2)	Wfmc	Eng./IT	EADS	X	X	X	X	X	X
Format	XSD	W3C	IT	UoP	X	X	X	X	X	X
Technology	XSD	W3C	IT	UoP	X	X	X	X	X	X

Table 3-1: Overview over the standards, regulations and technologies, relevant for IMAGINE

At the start of the project, the partners have identified 61 different standards, regulations and technologies relevant for IMAGINE. As this list is quite extensive and not an appropriate basis for discussion, it is further clustered in the following chapter.

3.3.2 Clustering of the standards, regulations and technologies

In order to enable the consortium to identify the gaps in the existing standards, regulations and technologies, the relevant standards have been clustered into a map (Figure 3-4). The categorization in this figure has been done by type while the sorting of the previous table has been done by the name of the standard, regulation or standard. It has to be noted, the formats are included as a subsection of the standards, as most of them are in use in a similar way.

The map will be updated according to the standards, regulations and technologies that will be further identified during the course of the project. It is the basis for the identification of possible gaps and will be used for the discussion of standards to be extended or derived by the IMAGINE project. Standards will be evaluated in more detail for deliverables D1.2 and D2.2.

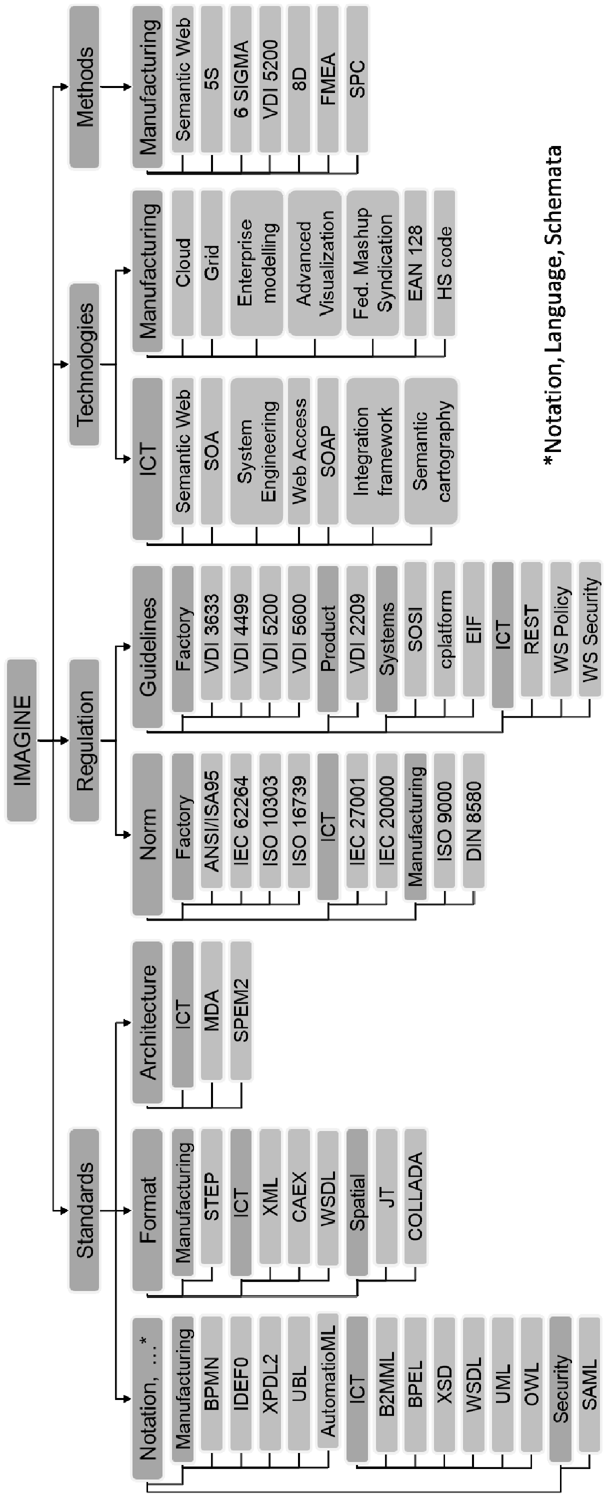

Figure 3-4: Map of the standards, regulations and technologies relevant for the IMAGINE project

3.4 Conclusions and Future Work

The standards, regulations and technologies relevant to the IMAGINE project have been identified and clustered. The listing and clustering of the standards could be subject to change as new standards could emerge and others standards could be overshadowed by future findings, as it is also discussed in Section 3.2.

This chapter will be used as a framework to ensure the compatibility of all partners involved in the planning process. A framework based on the use of existing information standards and reference models for the information needed in DMN management has been presented in this chapter. The framework includes standards regarding information, information exchange standards and standardization bodies related to the ICT tools commonly used during all product development phases. It describes how the consortium will create mandatory and optional lists of standards already available and identify -in several workshops over the course of the project- what gaps exist and need to be addressed by creating appropriate new standards, regulations or technologies or extending existing ones.

The framework has been completed by taking into account the standards used by industrial partners systems as well as the latest scientific advances.

The framework has been established on a new approach to standards use and standards development for the needs of the novel DMN management and provides a strong foundation for the standards-based integration of the IMAGINE platform with the participating production systems in the Living Labs in WP4.

In the course of WP2, the IMAGINE platform will be specified. During the course of this work the list of standards, regulations, technologies, methods and formats will serve as a base of existing experience when deciding the development of the IMAGINE platform. The selection of standards, regulations, technologies, methods and formats by the committee as described in Section 3.2.3, will be based on the requirements of the IMAGINE platform as they arise during the specification in WP2.

4 Living Labs Case Studies Discussion

4.1 Introduction

The IMAGINE Living Labs have been initially defined in this chapter. The main difficulties experienced have been identified and the initial expectations from the IMAGINE project results are indicated. This chapter aims to provide the first basic input and to support the detailed definition of the IMAGINE Platform use cases in Workpackage 2 and the eventual implementation and demonstration of the Living Labs in Workpackage 4. The IMAGINE case studies are discussed following the same structure for each Living Lab. Initially, the main objectives are indicated. The current practices are provided and the existing problems are described. Additionally, the process flow depending on each case under study is presented. Finally, the expectations from the IMAGINE Platform are discussed and related business use cases are defined.

4.2 Aerospace and Defence Industry

4.2.1 Objective:

The objective of this Living Lab is the collaborative digital product development within extended enterprise and networked organizations.

4.2.2 Current Practice and Existing Problems

Currently, the new trends are leading to a full reconfiguration of the Supply Chains within European Aeronautic and Defence, for various families of Products as illustrated by the following figure.

Figure 4-1: Large family of European Aerospace & Defence Products

New projects are reaching a high level of subcontracting (e.g. 60% for Airbus' A380) and are targeting even higher level of subcontracting for future programs (e.g. future long-range Aircrafts programs are targeting 80%). In addition, it is targeted to reduce the number of tiers-one sub-contractors, but as these are also sub-contracting a lot, there is a global increase of the number of sub-contractors for the whole supply chain from level one to the other levels. This trend can be referred as "Virtualization of the enterprise". This is illustrated by the following figure which comes from strategic communication in the area of PLM for Aerospace.

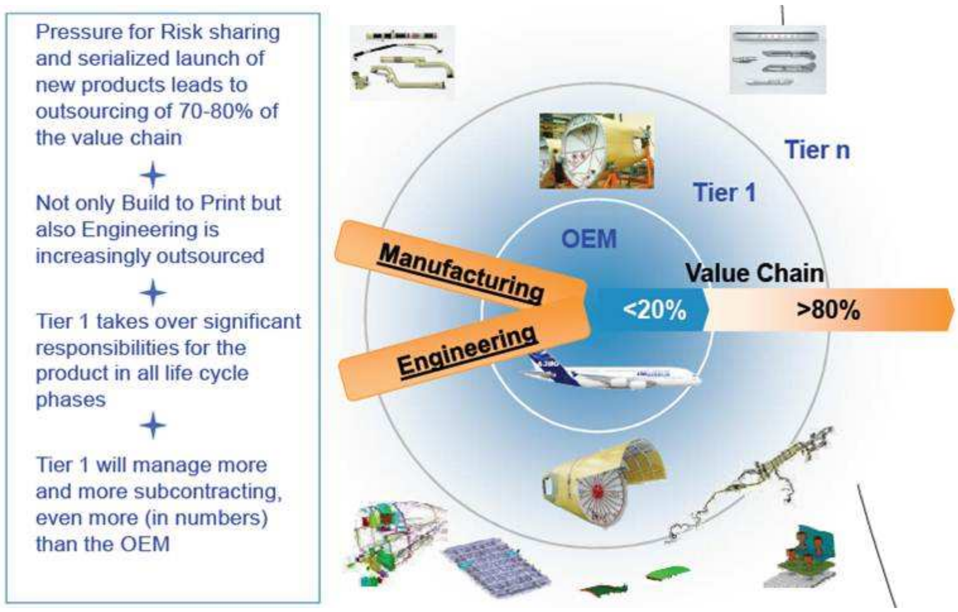

Figure 4-2: Current trends for the Supply Chain for Aerospace

In addition, another trend is the systematic usage of Computer and Modelling for growing set of Engineer disciplines and for collaboration, leading system usage of Model Based engineering, being for System Engineering or Product Life Cycle Management. This trend can be referred as "Virtualization of the Product".

The combination of both trends is leading to border effects in terms of interoperability for collaboration within extended enterprise implying interchange and sharing of digital model of the Product.

In order to respond to such needs, emerging eBusiness PLM Hubs within large groups (EADS PHC PHUSION) and for the European Aerospace & Defence (c.f. Boost-Aerospace Figure 4-3: BoostAerospace Hub) are being setup, with on one hand the systematic usage of COTS as components of the collaborative infrastructure and digital engineering chains, and on the other hand the identification of strategic importance of eBusiness PLM standards, as promoted by strategic standardization workgroup such as ASD Strategic Standardization Group or EADS Strategic Standardization Committee.

In such a context, some issues exist with the expected qualities of the cross organizational collaborative platform: interoperability, flexibility, robustness, security or other qualities of the platforms are to be adapted to support a continuously changing Supply Chain without endangering the Programs. It also appears that appropriate Methodologies and Requirement Engineering for setting-up such platforms are not available yet, and that on boarding process is facing heterogeneous maturity of the members of the Supply Chain when dealing with digital collaboration. Finally, organizational impacts of the strategy used in terms of Architecture, Security and Product Data Management are not always well assessed by involved organizations and stakeholders because of the complexity of these new environments and because of the lack of experience in deploying proposed approaches at this scale.

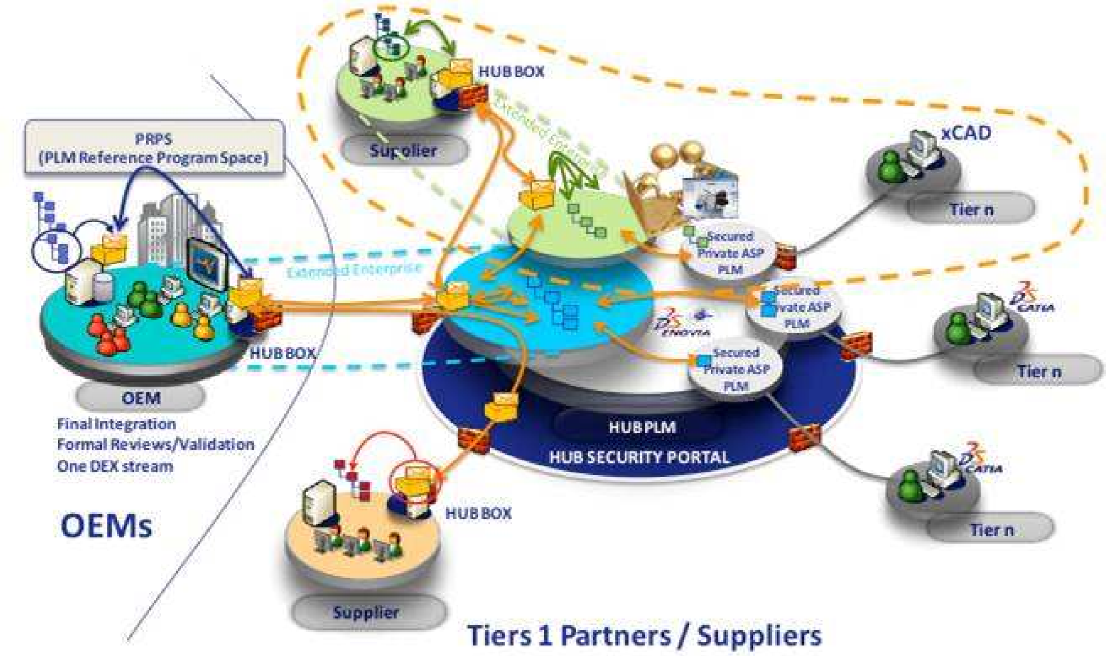

Figure 4-3: BoostAerospace Hub

In order to illustrate such situation with a concrete example, let's consider that the A380 program was delayed due to heterogeneity of the PLM tools used inside Airbus, with important economical impact. EADS PHENIX (PLM Harmonization) project was launched in order to face such a problem. In addition, EADS decided to be involved in Boost-Aerospace in order such harmonization also made inside the whole supply chain, and in order to avoid the digital break between huge OEMs, first level sub-contractor and SMEs, and in order to face border effect of virtualization of the enterprises. It should be stated that specifications and Implementation of current hubs are really slow, and on boarding process could be difficult as such approaches are emerging. On boarding process is important, and the maturity of the community has to be developed as fast as possible.

4.2.3 **Process flow**

So the process that is considered is the related to collaborative platform. Such a platform is dedicated to a digital eBusiness ecosystem (in our case Aerospace and Defence Industry within the area of PLM), willing to support networked Product Development within Virtual Enterprise.

The process associated to such a platform was defined in ATHENA (FP6 IST-507849) for Network Product Development platform:

P1- Set up of the platform (Design, development, deployment and enactment)

P2- Interconnection between Information system of a company and the collaborative platform

P3- Collaborating (several instances of collaboration processes)

P4 – Leaving the community (disconnection from the Collaborating platform

Here, it will be necessary for the operator of such a platform to be able to qualify:

- The network of organizations interconnected to the platform in order to support collaborative product development of digital product
- The network of applications that have to be interconnected in order to support cross-organizational collaborative processes

Qualification should be done related to different purpose:

- Effective interchange and sharing of product data between partners and CAD/Product Data Management systems involved (constituting what is called the "digital factory").
- Secured collaboration
- Maturity in terms of collaboration processes, in particular in PLM and System Engineering context
- Maturity in terms of interoperability of application for secured collaboration – in link with relevant standards elected by a Digital Business ecosystem (e.g. European Aerospace and Defence).

4.2.4 **Expectation from Imagine Platform:**

The expectation from the Imagine Platform is to provide

- Open, robust and evolutionary environment allowing to aggregate solution components provided by IMAGINE partners and interconnection with most of the legacy capabilities.
- Dedicated services, based on blueprints and dynamic network management, for the different stakeholders, such as collaborative platform operators (e.g. THALES for BoostAerospace) and OEM to be able to qualify interconnected companies and supply chain, all along the life cycle of the collaboration within a continuous evolving environment.
  Usage of blueprints should respond to identified issues such as:
  - Appropriate Collaborative eBusiness PLM and Engineering platform set-up within European Aerospace & Defence ecosystem, aligned with the Manufacturing ecosystem
  - On Boarding process and assessment/monitoring of the maturity of the Supply Chain Members in terms of digital collaboration and in terms of effective infrastructures and capabilities
  - Collaboration monitoring
  - Applicative functional chain monitoring
- Dedicated services for supporting stakeholders, such as ICT departments dealing with Technical Information Systems, Design offices dealing with methods and standard experts within the field of secured Product Data Exchange.
  Usage of Dynamic Networked Management should in particular respond to identified needs such as:
  - Appropriate Service Level agreement between
    - Supply Chain partners

- Applicative components and technical components providing services for the collaboration

– Robustness of the underlying reconfigurable infrastructure (Organizational, Functional, Applicative and ICT)

To be driven by Business needs and virtual lab infrastructure, in order to ensure cohesion of the activities of the IMAGINE partners, in order to build and prepare interoperability appropriately and in order to accelerate innovation and to respond to Business needs in terms of collaboration within the Supply Chain. In particular, it is expected that IMAGINE platform could rely on existing experimental cPlatform defined by EADS IW on the basis of an Interoperability Framework, in order not to reinvent the wheel, and in order to prepare and construct efficiently and effectively the interoperability within the IMAGINE project first, and within the targeted communities second (Aerospace but also automotive, furniture, etc).

As the targeted system is a complex system of systems, some focus should be put on precise components or aspects, leading to different business cases that will be extended and refined all along the IMAGINE project. The business cases are listed in the next section.

4.2.5 Business Use Case

Table 4-1: Aerospace Living Lab Business Case index

Business Case	Business Case Name	Reference
Aerospace_BC1	Digital Business Ecosystem with a set of common standards for PLM	EADS PHC (PLM harmonization)
Aerospace_BC2	Product data exchange, sharing and archiving manufacturing standards elected by ASD Strategic Standardization Group	ASD SSG Business cases
Aerospace_BC3	Networked Collaborative Product Development	ATHENA [DB43]
Aerospace_BC4	PLM collaboration	SEINE project
Aerospace_BC5	Functional modeling (SysML) within a SLM context (Simulation Lifecycle Management)	OpenDevFactory Project
Aerospace_BC6	Secured collaboration infrastructure for development of the Digital Behavioural Aircraft within integrated and extended enterprise	CRESCENDO
Aerospace_BC7	Selection of the good components, good standards for the CPlatform	

The listed business cases were to some extent defined in previous research or operational projects which should take advantage of new solutions that IMAGINE aims to define. Several other potential and relevant business cases will be investigated related to other research activities inside EADS IW/SE.

Other relevant Business Cases will be search within publicly available result of external European projects of interest for EADS IW.

Aerospace_BC1: Digital Business Ecosystem with a set of common standards for PLM	
As is situation	**Stakeholders**: Strategic standardization group (EADS SSC), EADS Business Units, their methods and ICT departments, Software product providers, standardization bodies and projects, EADS PHC project, EADS BUs' partners and supply chains **Objectives**: To be able to implement effectively a roadmap for PLM harmonization within the EADS group **Processes**: To identify and elect relevant common methods, services and tools **Targeted improvement**: To accelerate on boarding process
To be situation	**Problem to be addressed**: To assess simultaneous PLM maturity and global harmonization **Generic solution**: • Blueprint for development, implementation and usage of PLM capabilities of PHC • Collaborative experimental place for acceleration of specifications assessment, maturity of tools, validation of associated collaborative processes and feedback to methods and tools improvement **Specific solution**: To be proposed by the partners **Assessment criteria**: • Technical level: Robustness, performance, should be easy to use • Applicative/process level: – Quality of the developed services, tools and associated development process, better interaction between the stakeholders – Automatic generation and tuning of application interfaces • Organizational level: Usability for the different concerned decision makers and operational people
Aerospace_BC2: Product data exchange, sharing and archiving manufacturing standards elected by ASD Strategic Standardization Group	
As is situation	**Stakeholders**: Strategic standardization group (ASD SSG), Enterprises in Aerospace domain, their methods and ICT departments, Software product providers, standardization bodies and projects, PLM hubs **Objectives**: To be able to implement effectively a roadmap for standardization policies for the whole digital business ecosystem **Processes**: To identify and elect relevant standards, to support policies establishment and implementation by companies and tools **Targeted improvement**: To establish and measure maturity of the digital ecosystem member for collaboration through digital hubs
To be situation	**Problem to be addressed**: To assess simultaneous usage of standards, related implementations and concerned processes despite number of actors implied for development, implementation and usage of standards **Generic solution**: • Blueprint for development, implementation and usage of standards for digital eBusiness PLM standards • Collaborative experimental place for fasten standard assessment, maturity of interfaces of tools, validation of associated collaborative processes and feedback to standards for improvement **Specific solution**: To be proposed by the partners **Assessment criteria**: • Technical level: Robustness, performance; should be easy to use

	• Applicative/process level: Quality of the developed standards and associated development process, better interaction between users and standardization community; automatic generation and tuning of application interfaces • Organizational level: Usability for the different concerned decision makers
Aerospace_BC3: Networked collaborative Product Development	
As is situation	**Stakeholders**: Programs, Methods&Tools, ICT department, ICT integrators, **Objectives**: To be able to define easily collaborative space between functional and organizational boundaries at an acceptable price **Processes**: To define collaborative space, to set it up, to connect, to collaborate to disconnect **Targeted improvement**: To include new horizontal services for Networked collaboration, for Dynamic Networked Management, as the environment is continuously changing **Reference:** ATHENA As is and To be scenarios
To be situation	**Problem to be addressed**: To be able to aggregate easily Networked Product Development Collaborative Platform and new kind of services for Dynamic Network Management, with minimum integration effort **Generic solution**: Interoperability framework, blueprint **Specific solution**: To be proposed by Imagine partners **Assessment criteria:** • Technical level: Reduction of time to deployment – and other resources- for enactment for new service – with appropriate integration/aggregation • Applicative/process level: Agility and fast adaptation to process and capabilities evolution • Organizational level: Better robustness for digital collaboration infrastructures
Aerospace_BC4 : PLM collaboration	
As is situation	**Stakeholders**: Different industrial sector and domains that can be involved in a given program using PLM standards **Objectives**: To be able to defined common standards and practices for the industry which need PLM eBusiness standards for similar problems **Processes**: Multi-domain projects, networking, sharing experience, etc **Targeted improvement**: Manage the complexity, sharing roadmap and know **Reference:** SEINE project web site
To be situation	**Problems to be addressed**: • Providing Common blueprint based on implementation of standards (Methods & Tools) • Semantic preservation and global coherency of distributed Product Metadata • Qualification of the federated Interconnected Information systems within the Supply Chain **Generic solution:** • Dynamic Network Management facilities • Shared knowledge base and model of reference repositories for qualification • Data aggregation • Data transposition **Specific solution:** • Extended hypermodel services (EADS IW) • To be proposed by Imagine partners **Assessment criteria:**

	• Technical level: Easy collection and federation of data • Applicative/process level: Fast collection and easy maintenance of the knowledge base • Organizational/level: Easily find relevant information to help decision making
Aerospace_BC5: Functional modeling (SysML) within a SLM context (Simulation Lifecycle Management)	
As is situation	**Stakeholders**: Design office, method and tools **Objectives**: To define new methods in order to deal with Digital Behavioral Aircraft, taking advantage of Simulation tools and Simulation Life Cycle Management **Processes**: Selection of best in class tools for each company, creation of specific SLM systems, integration a posteriori with the partners within the supply chain, high cost for connection with other PLM tools and maintenance of the interfaces **Targeted improvement**: To prepare and build interoperability at the earlier stage, between partners **Reference:** Open Dev Factory, Crescendo Enterprise Collaboration
To be situation	**Problem to be addressed:** • Accelerate elaboration of standards , associated recommended practice by taking into account legacy solutions, and relying on legacy Dynamic Networked Management capabilities developed by other functions of the enterprises • Adaptation of the quality of service and service level agreement to support digital simulation within networked organizations **Generic solution:** To be proposed by IMAGINE partners **Specific solution:** To be proposed by IMAGINE partners **Assessment criteria:** • Technical level: Reduction of the development phase • Applicative/process level: Faster composition and reconfiguration of the applicative chain • Organizational/level: Reduction of resources required for establishment of collaboration
Aerospace_BC6 : Secured collaboration infrastructure for development of the Digital Behavioral Aircraft within integrated and extended enterprise	
As is situation	**Stakeholders**: Security officers, Partners in competition, standardization, solution providers, integrator, IT department, Design office, programs **Objectives**: Secured and effective digital collaboration **Processes**: Same than for collaborative platform with special focus on interoperability **Targeted improvement:** To facilitate security requirements and assessment of chosen policies and standards in terms of workability and interoperability **Reference:** Crescendo secured collaboration platform, Boost-Aerospace, PHC Phusion
To be situation	**Problem to be addressed:** To be able at an earlier phase to specify security requirements and to validate them on the basis of experimentation & To be able to create testbed for security components in order to validate interoperability, robustness, quality of services and price of their maintenance within an evolutionary context **Generic solution:** • SCM Networks monitoring • Auto-adaptation • Appropriate level of SLA

	• Interoperability Framework **Specific solution:** • LAAS: SLA framework adaptation to cPlatform that will constitute the infrastructure of the Aerospace Lab • Other IMAGINE partners to make proposals **Assessment criteria:** • Technical level: Selection, deployment and monitoring of appropriate software components for security – and appropriate tuning for appropriate quality of service and operational maintenance • Applicative/process level: Percentage of operational time • Organizational/level: Reduction of time for connection to cPlatform for appropriate secured collaboration
Aerospace_BC7: Selection of the good components, good standards for the CPlatform	
As is situation	**Stakeholders**: EADS IW, standardization bodies, research projects **Objectives**: to develop innovative framework and associated experimental environment supporting fast establishment of eBusiness PLM collaboration based on Computer Aided Engineering with extended and virtual enterprise **Processes**: Elaboration of component based infrastructure with continuous functional extension and **Targeted improvement**: scalability and robustness **Reference**: BootAerospace, PHC Phusion, EADS programs (in terms of amount of data and simulation of number of users)
To be situation	**Problem to be addressed**: How to ensure that collaborative platforms architecture is scalable? **Generic solution**: • Coupling of caching, load balancing, adaptive service bus • Blueprint for scalable networked organizations and applications in the Supply Chain • Monitoring and auto-adaptation **Specific solution:** • LAAS will adapt research on low level network and service auto-adaptation to an Enterprise Service Bus • Other IMAGINE partners to make proposal **Assessment criteria:** • Technical level: QoS for ICT infrastructure • Applicative/process level: OoS for business services • Organizational/level: Amount of resource required for obtaining and maintaining scalable infrastructure

4.3 Industry agnostic, Multi-site, Single Factory Context

Holistic and multi-scale product design, factory and process planning is a key factor to face the challenges that are created by shorter product life cycles, increasing number of variants and the need for an efficient integration of new technologies. The "*Grid Engineering for Manufacturing Laboratory 2.0"* (GEMLab 2.0) is the Fraunhofer IPA unique platform which provides suitable enabling technologies to meet those challenges. It is an innovative workflow-and grid-based planning environment, integrating self-developed and state-of-the-art commercial tools, for continuously integrated product design, factory and process planning along the whole factory life cycle [27]. It enables the collaborative sharing of resources and competences in engineering of factories and products and supports the integrated and continuous management of the entire Product and Factory Life Cycle [20].

Figure 4-4: Continuously integrated factory engineering and design

The innovative GEMLab 2.0 is an industry-agnostic, multi-site factory and process planning environment. It is characterised by the employment of innovative solutions and integrated state-of-the-art digital manufacturing tools. In sum, those properties enhance the quality, reduce the time and optimise the planning of processes, factories and production networks. A Change Propagation System guarantees the consistent propagation of data changes within the planning environment. This way a continuous integration of the information flow along the whole the planning process can be achieved.

The GEMLab 2.0 is comprised of current digital tools for planning and engineering of products, processes and factories. Integrated are two types of digital tools, commercially available (Siemens Industry Software GmbH & Co. KG; Parametric Technology GmbH) and in-house developed systems (Fraunhofer IPA). There is a plethora of hardware and software available, of which a complete overview is given in the next figure.

Hardware
1. GEMLab, FhG IPA
Stereoscopic 3D-Projektion-Wall[8]
• 10 dedicated PC Workstations • 12 High-End-PCs for 3D-Cube System • 14 further PCs as additional Workstations
Cooperative Planning Table
VR-Systems: ▪ SpaceMouse ▪ Nintendo Wii Control and Balance Board
2. Smart Factory IFF Uni Stgt.
Ubisense, different mobile terminals, RFID readers
3. Parts of IFF Learning Factory IFF Uni Stgt.
Physical Learning Factory and coupled Digital Learning Island

Software	
Planning Phase	**Tools**
Product development	NX[3], Pro/Engineer[4], AutoCAD[10], Inventor[10]
Product life cycle management	Windchill[4]
Investment and performance planning	**FLIP**[1]
Site and network planning	**vProNet**[1]
Process, equipment and workplace planning	Process Designer / Process Simulate[3]
Process simulation	Plant Simulation[3]
Layout planning	Cooperative Planning Table[1], Process Designer[3], FactoryCAD[3], SBFP[9]
Internal logistics	FactoryCAD[3], FactoryFlow[3], Plant Simulation[3], **Order Management System**[1,2]
3D visualization	GEM Factory Immersion[1]
Factory operation	**Failure Management System**[1,5] **Order Management System**[1,2] **Factory Cockpit**[1,2], **DataEngine**[1,2] ProVis.Agent[7], ProVis.APS[7], ProVis.Visu[7] **Total Energy Efficiency Management**[1]
Factory life cycle management	Teamcenter Manufacturing[3]
Planning workflow System integration	**GEMFlow** (workflow system)[1] Globus Toolkit[6]

1) Fraunhofer IPA
2) IFF Universität Stuttgart
3) Siemens Industry Software
4) Parametric Technology Corporation (PTC)
5) Skom Solvtec
6) GlobusAlliance
7) Fraunhofer IOSB
8) Eyevis
9) University of Malta
10) Autodesk

Figure 4-5: Hard- and software infrastructure of GEMLab 2.0

4.3.1 Objective

The objective of this case study is to enhance the state-of-the-art industry agnostic living lab called “GEMLab 2.0”, which is very well suited for factory level planning and optimisation, in order to enable the planning and optimisation of Dynamic Manufacturing Networks. Thus, an optimal factory and network planning and optimisation, considering stakeholders and dynamic changes in a production network can be achieved (Figure 4-6).

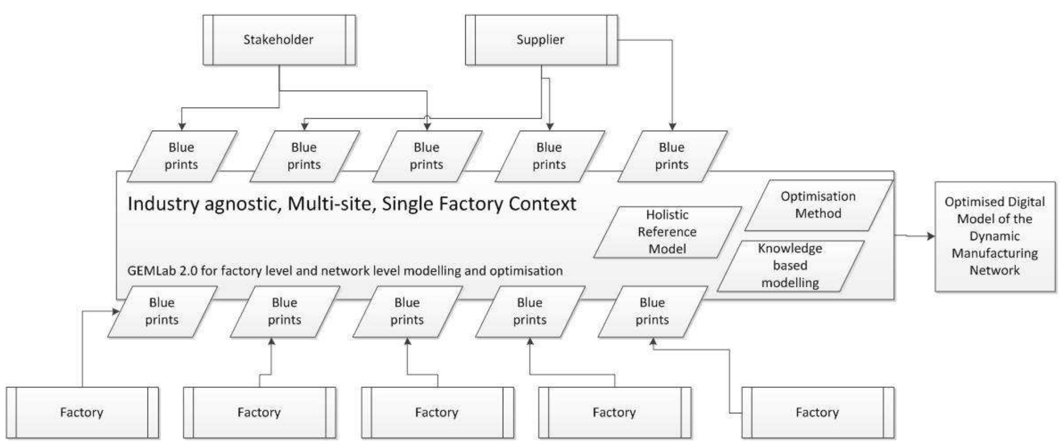

Figure 4-6: Use case scenario – Objectives

The main goals, which will be addressed in the use-case scenario, are:

- Reduction of effort for planning factories and manufacturing networks
- Consideration of dynamic changes in a manufacturing network
- Value added ideal dynamic manufacturing network planning
- Agile planning processes to handle order and engineering changes.

To achieve the overall objective, new methods and reference models have to be developed and integrated in the industry agnostic living lab. Thereby different aspects have to be considered:

- The enhancement of existing factory planning reference models, concerning rules and processes within manufacturing networks
- The development of blueprints to characterise supplier, stakeholder, factories and products of a specific manufacturing network
- The development of a method for knowledge-driven multi-scale modelling of existing manufacturing networks
- The development of a method for the optimisation of multi-site, multi supplier, multi-customer networks
- The analysis of specific "What if" scenarios

Thus, the modelling of factories as well as dynamic manufacturing networks and their subsequent optimisation will be supported through suitable methods and reference models, to ensure the competitiveness of the participating industry partner in a first step and in a second step for the whole European industry.

4.3.2 **Current Practice and Existing Problems**

Factory Planning

State-of-the-art reference models for Process Development and Factory Planning provide defined, structured and standardized workflows for different factory and process planning activities to over-come the current challenges in Manufacturing Engineering [26, 27]. The predefined standardized planning activities improve the communication between planning partners, interdisciplinary teams or stakeholders, who participate in different phases of a factory planning activity ([27], [28]). The first factory reference models were proposed as factory structure reference models. These reference models are targeted to a specific industrial sector or they are very generic and describe the structure of a factory without taking its life cycle or processes into account [29, 30, 31]. Today's reference models for Process Development and Factory Planning provide a various level of detail for each planning phase and support different phases of the factory life cycle [32, 33]. [34, 35] concentrate on the factory planning (investment, building, layout, logistics planning and ramp-up) without considering the manufacturing execution planning and the dismantling of the factory [33, 32, 35, 34, 36]. A more holistic view on the factory planning life cycle is provided by the VDI (Association of German Engineers) and Westkämper. There, the factory life cycle phase "manufacturing execution" is additionally taken into account ([27], [28]). However, the dismantling is not considered in those approaches. [37] provides a factory and process planning reference model, which concentrates on the factory planning phases up to manufacturing execution in a highly detailed way. An innovative point in the approach of [37] is that it also takes the relations and interdependencies between the planning phases into account [37]. The approach of [38] concentrates on the whole factory life cycle including manufacturing execution and the dismantling of the factory; also the information flow in the manufacturing execution phase is considered briefly [38]. The VFF (Virtual Factory Framework, EU

Project, available at www.vff-project.eu) reference model for Factory and Process Planning is a generic, modular, open and extensible reference model taking into account the factory planning phases from investment planning to ramp-up. Every planning phase is described through detailed, structured and standardized planning activities. The information flow between the planning phases is also considered (VFF NMP-4).

The methodology and reference models for Product and Factory Lifecycle Management are implemented in several existing commercial software applications, on which the table below gives an overview.

CAx-App.	Description	Software Application
PLM	***Product Lifecycle Management (PLM) is the process of managing the entire lifecycle of a product from its conception, through design and manufacture, to service and disposal.***	Teamcenter-Engineering Windchill; ENOVIA
FLM	***Factory Lifecycle Management (FLM) is the process of managing the entire life cycle of a Factory from its conception, through planning and operation, including maintenance and dismantling.***	Teamcenter-*Manufacturing*

Table 4-2 Commercial software applications for Product and Factory Lifecycle Management

[39] focuses on the knowledge-based integration of product development, process planning and the planning of the production system. At the same time economic instruments are considered. Recently, the CIRP working group SPECIES (SPECIES) highlighted how critical the modelling, integration and evolution (named co-evolution) of products, processes and production systems along their life cycles is. [40] addressed the co-evolution problem both from the industrial and academic point of view, by presenting industrial use cases and extensively analysing the scientific literature, respectively. Moreover, the authors presented a reference model to study the integration between products, process and production system in terms of requirements to face a specific industrial problem, constraints imposed by the internal and external Factory Environment, and capabilities offered by methodologies and tools. Finally, [40] identified a collection of future research priorities to be addressed: need of technical standards for evolving information related to product, process, production systems; development of co-evolutionary Design-for-X methodologies; new Business Models for co-evolving product, process and production systems; new production system architectures to support the changes in products and processes; reconfigurable process plans.

Thus, the state-of-the-art reference models mainly aim at decreasing the complexity of the planning activities and modelling as well as managing all the necessary information and communication flows. However, these reference models are not able to integrate the different planning life cycles of the product, the process and the factory in a knowledge based approach.

Network planning

The ideal distribution of a manufacturer's production sites is a crucial issue to assure their competitiveness. An early model which supports the managing of new production capacities in production networks is developed by [41]. Thereby the production network is divided into two levels, the production site level and the headquarter level. By dividing the network into these levels, [41] generated a simulation model to analyse the future changes in the production program. Based on the research activities of [41], [42] and [43] develop a three level production network model. This contains the network level, where production sites are chosen, the site level, where the production program of the single production sites is planned and the production module level, where the detailed planning of production processes is carried out. Other approaches in the field of network planning concentrate on mathematical optimisation. [44] developed a method for designing and evaluating global production networks based on a quantitative analysis of network costs. [45] and [46] focus more on the aspect of analysing costs at one production site and neglect the extension to production networks. Another approach pursues the value added ideal production network planning. Thereby the flexible and cost optimized simulation based distribution of the value creation in a production network is supported through the employment of a reference method consisting of seven [47].

Today's network planning approaches consider a high variety of aspects, while developing a model of a specific production network. However, the following optimisation is mostly based on static factors. Dynamic changes regarding stakeholder, supplier and factories in a production network are not considered properly. The knowledge-driven communication between the factory level (product, process and factory life cycle) and the network level (stakeholders, suppliers), is not supported by existing reference models, either. This reveals a lack of dynamic change consideration and knowledge-driven communication between the stakeholders, suppliers and the factory level.

Summary

In summary there are some issues that have to be addressed in this use case scenario to enable a holistic modelling and optimisation of a production network with its containing stakeholders, suppliers and factories. These are:

- Integration of the factory level and the network level in on holistic reference model
- Suitable consideration of dynamic changes within a complex Dynamic Manufacturing Network
- Suitable standards for communication and data/information exchange within a complex Dynamic Manufacturing Network
- Adequate optimisation methods for complex Dynamic Manufacturing Network

Thus, this use case scenario will enhance and integrate previously developed reference models, in order to develop a holistic, knowledge-driven, industry-agnostic reference model, which considers both, the integrated factory level (product, process and factory life cycle) and the network level (stakeholders). This concept allows the efficient modelling and simulation-based optimisation of complex Dynamic Manufacturing Network.

4.3.3 **Process Flow**

This chapter evaluates the needed process flow for the realisation of the planned use case scenario. Six steps have to be performed, in order to achieve the defined objects and goals. These steps, depicted in Figure 4-7, are:

1) The definition of the considered products.
2) The characterisation of the involved supplier.
3) The definition of the structure of the production network.
4) The following analysis of the production structure.

5) The definition of the production site.
6) The definition of the production modules.

Based on this, the ideal involvement of production sites and production modules, the production networks can be defined. Thus an efficient modelling and value added ideal manufacturing network optimisation is enabled.

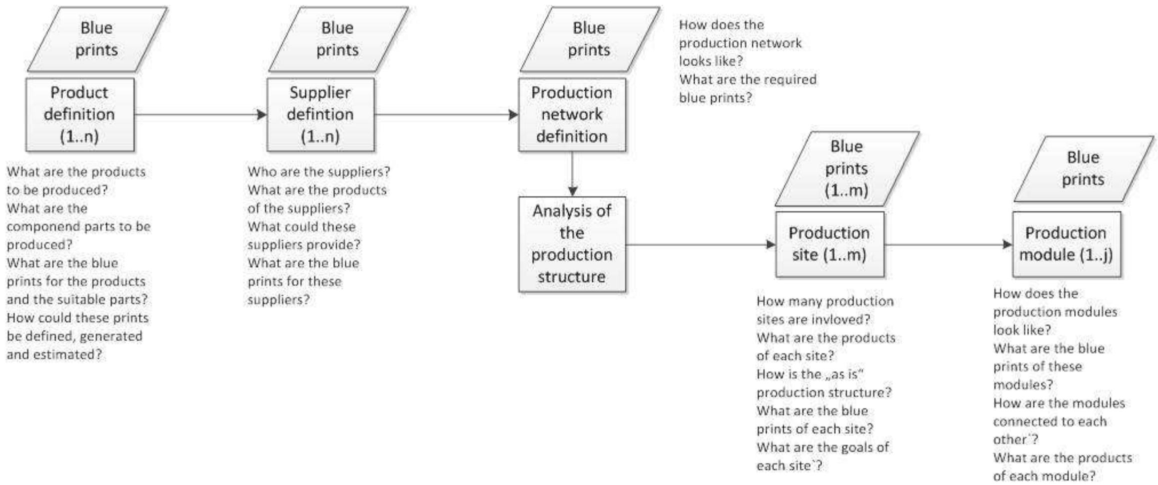

Figure 4-7: Process flow of modelling and optimising a Dynamic Manufacturing Network

Before planning and optimising a DMN, a clear understanding of the strategic goals, which will eventually determine the formation of the Dynamic Manufacturing Network, has to be defined. To get a clearer view on these processes, an example, based on an exemplary product, will be given on how this process can be applied. The exemplary product will be a desk set comprised of two existing components –a clock and a cup– and a new component –a lamp–. This exemplary product is depicted in Figure 4-8.

Figure 4-8: Exemplary product – Desk Set

First of all, the adaptation of the existing DMN has to be clarified. Will the lamp be built in an existing production site or in a new production site? Strategic goals should initially be defined. Based on these strategic goals, in the first step, the relevant product –the lamp– and its component parts are identified, keeping the modelling and optimisation of a DMN characterised by blueprints in mind. These are e.g. the inlay and the body housing. Additionally, involved suppliers, which will supply specific parts for the lamp, are characterised e.g. regarding their competences to manufacture the needed parts, their ability to deliver and their cost. Those input parameters, represented by key performance indicators, requirements and blueprints enable a detailed analysis of the whole existing production network and its restructuration. Relevant information e.g. transportation or capacity in different sites, considering the planning and further optimization are identified too. Based on this identification, performance indicators are defined and used to generate an accurate performance measurement framework for the following subsequent steps. This framework enables the evaluation of the production network regarding the ideal involvement of production sites and production modules in the production network. The result of this step is a rough Dynamic Manufacturing Network. This rough Dynamic Manufacturing Network shows where the parts of the lamp will be manufactured and assembled and brought together with the desk set.

Based on the results of the first step, a rough layout of the DMN can be developed, considering the layers of a factory down to sites, single machines and machine units. This rough DMN layout builds the basis for a detailed arrangement of machines and equipment using simulation as a basis, to enable the most efficient manufacturing and assembling of the lamp and the desk set regarding the material flow, energy efficiency and/or others. Furthermore, the performance of the whole DMN can be calculated by taking into account the defined performance indicators, requirements and blueprint. The results of this step are an optimized DMN down to sites, a factory performance forecast and optimized manufacturing lines to manufacture the whole desk set.

After the planning and optimization of the DMN, in a third step, the customer orders will be provided or generated – in the case the customer orders for the planned DMN are not identified. Based on these orders, the production sequence of the lamp and the desk set can be planned and the manufacturing line can be evaluated using the discrete event simulation as well as the closed loop simulation. The planning of the production sequence and the evaluation of the different production lines considering the different sites can be performed. The last step is the consideration of the factory operation. In this step the real data of the DMN will be used to enable the monitoring of the defined KPIs. Figure 4-9 shows the described planning phases within this Business Use Case and the different planning activities.

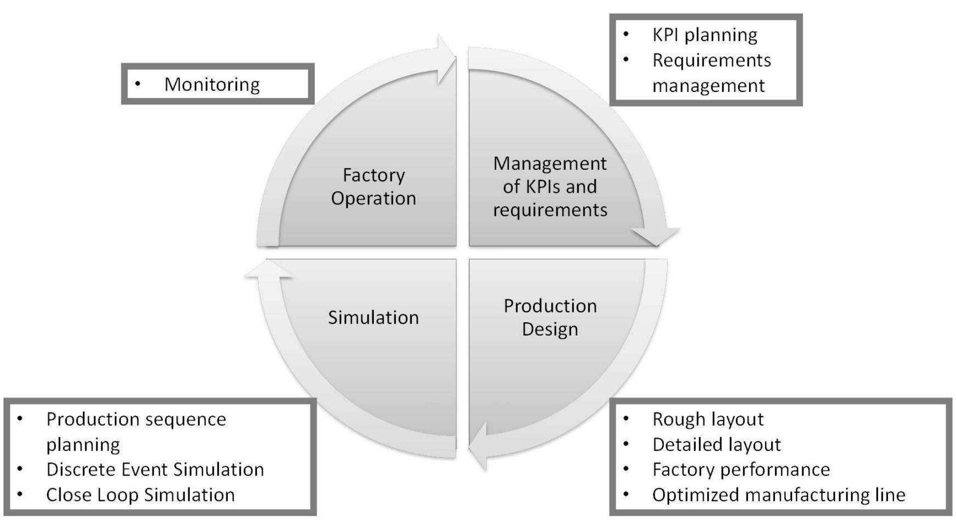

Figure 4-9: Living Lab method for the modelling and optimisation of a DMN

4.3.4 Expectation from Imagine Platform

The overall expectation of this use case scenario is an industry agnostic, multi-site, single factory context platform that enables a holistic and efficient modelling and optimisation of complex production networks. Thereby the evolving issues, which arise from multi-site, multi supplier, multi-customer networks can be addressed. Not just static optimisation methods can be applied, but dynamic optimisation methods, which enable a value-added ideal dynamic manufacturing network planning.

Additionally characteristics and KPI's to describe supplier, stakeholder, factories and products of a specific manufacturing network through blueprints, which will be used as valuable and suitable input for the method developed in this use case scenario, are to be developed for this scenario. This is then used to verify the proper functionality of the optimisation method and enables the analysis of specific "What if" scenarios. Thus, the modelling of factories as well as dynamic manufacturing networks (DMN) and their subsequent optimisation will be supported through suitable methods and reference models.

4.3.5 **Business Use Case**

The Business Use Case considering the Industry agnostic, Multi-site, Single Factory Context Living Lab consists of four different steps for the planning of Dynamic Manufacturing Networks (DMN).

Due to the detailed definition of the Use cases in WP2-Deliverable 2.1, a conceptual overview of currently practicable Use Cases for the GEMLab 2.0 will be given. These business use cases may consider a manufacturing engineering enterprise, which has to adapt its production network, because of different turbulent market influences.

These influences can be addressed by this Business Use Case:

- A Tier 1 supplier is insolvent.
- One or more Tier 1 or 2 suppliers are too expensive to contract them in the future.
- New customer requirements are propagated to the product development and new technologies are needed to fit them.
- The whole production network performance has to be improved by restructuring the existing international production network to increase the own competitiveness.
- A new site has to be built and the production system and layout have to be planned.
- New orders are placed with different requirements concerning focus on quality, price or production time.
- Existing manufacturing layouts have to be optimized.

With the method, described in Section 4.3.3, all these aspects can be addressed. By using blueprints of different suppliers a supplier can be replaced in a very short time and new suppliers, which meet the requirements considering the technology for the production an innovative product, can be identified. Furthermore the performance of an established production network can be evaluated regarding its product component manufacturing distribution in different sites and its network production sequence as well as throughput times. Also, new site projects can be evaluated in advance with the help of simulations.

4.4 Furniture Manufacturing Industry

4.4.1 Objective

Furnishing Living Lab will check the benefits of IMAGINE for the furnishing sector with a main scenario: on-demand supply and production networks, which is the most commonly used system in the furniture manufacturing industry and divided in two main fields (supply network and production estimation).

4.4.2 Current Practice and Existing Problems

It is quite obvious that the whole *Furniture Manufacturing Industry does* not work in a unique way and at every level of the supply chain there are companies working with different organization structures. Anyway it is also true that there is a mainly representative group of companies that share a common work system.

Therefore we will assume that there is a *most common system* and in order to describe the current practice we will use but it is important to state that in this sector, probably the most well known companies are not the most representative ones (for instance IKEA).

First of all we will show by means of the next diagram an overview of the supply chain, from the first supplier to the end customer.

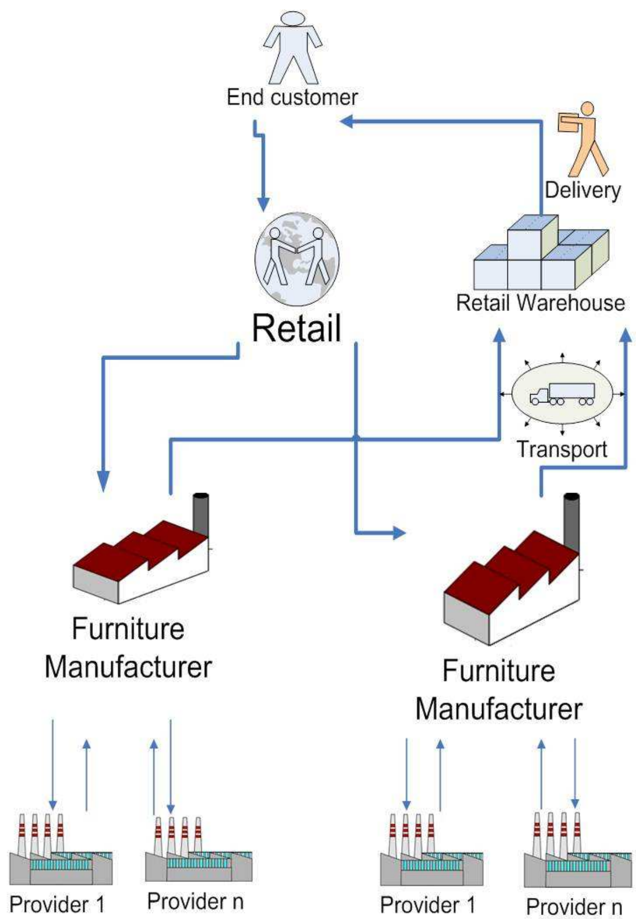

Figure 4-10: Furniture Living Lab end-customer

The above figure represents an end customer (any individual who wants to furnish a room) who gets in a furniture shop (retail) and after watching the showroom, orders a list of items.

Probably this order will be made of items from different manufacturers: for instance the sofa is made by one, table and chairs by another one and the shelves, and cabinets by another one. Then the retailer converts this order into several purchase orders to all those manufacturers.

On the other hand, each furniture manufacturer, in order to make these items, will group them with other orders and plan this manufacturing process. For this group of orders, he will also need to buy some raw materials or components to his provider.

Then, these materials will be sent to the furniture manufacturer, who at this point will be able to manufacture the components and assemble them. And once they are packed they will be sent to the retail warehouse.

When all the required components are at the warehouse, the retailer will call the end customer to agree a date for the delivery and at-home-assembling.

Involved Roles

In the next section every role is detailed.

End Customer

This role represents any individual who has the intention to furnish a room or a whole house and visits one or several showrooms to decide what he / she wants.

Retail

In this sector the retailer is commonly represented by furniture shops with a showroom where the customers can watch some proposals from different manufacturers. These shops may be independent or part of large chains of shops. Apart from these proposals they have a library of catalogues with all the possible options for every item and its price because it is impossible to show every product and every option. These catalogues contain technical information like dimensions, finishing or base material.

Normally the customer asks for several estimates for different possibilities assessed by the sales person. At the end he confirms one of them and is converted into a firm order.

Once the order is ready, the retailer converts that order into one or several orders to their suppliers (furniture manufacturers). They can be several because the list of products of the order can come from different catalogues from different manufacturers.

These orders are sent by FAX or electronic mail.

From this point, the retailer waits for the reception of the products from every manufacturer and for this purpose they work with warehouses. Sometimes, the retailer is also the owner of this warehouse and in other situations, they outsource this process. This process is called *orders consolidation.*

The last process is the delivery and at-home-assembly. It may be carried on order by order or grouping several orders when destination is the same.

Furniture manufacturers and suppliers also play an important role in the furniture manufacturing industry. Their roles are discussed in the next section.

4.4.3 Process Flow

Table 4-3: Software Tool Commonly used in Furniture Industry

ERPs (Company)	CAD / CAM	3D Furnishing (Company)
Purpose: insight management	**Purpose:** design of catalogue, parts and generating manufacturing instructions	**Purpose:** Showing (at the retail) to the customer the look of a room with the selected items and generating the order to the factories.
Gdp (AIDIMA) Teowin (Simsa) SPIWood (2020) expertMueble (Datadec) **Note:** commonly well known ERPs like SAP, Navision, Axapta, Oracle, etc are not very popular in this sector.	Inventor +Alphacam Autocad (only CAD) Topsolid (CAD + CAM) Cabinet vision + Alphacam	S-Planner (AIDIMA) Teowin (Simsa) Planit

Profiles for Products

In the furniture industry, we can classify the products according to many different criteria, but in order to define them for the IMAGINE platform, we must consider a sorting that allows us to define them in a unique way. With these criteria we find two main kinds of products:

- Furniture. For these products (chairs, tables, cabinets, sofas, etc) there is a specific way to identify them based on a reference and a list of properties. This way solves the problem of the huge amount of features available for every part of every product which combined enables a very wide range of choices for everyone. Then to identify a product we need a data structure like this:

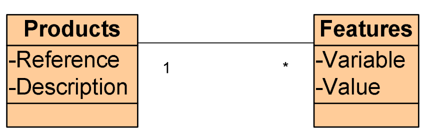

Figure 4-11: Products - Features

- Components. These products are the ones that are required by the furniture manufacturers in order to make their products. They can be identified just by a reference and some additional information. Then in order to identify a product we need a data structure like this:

Products
-Reference -Description -Length -Width -Height -Quality

Figure 4-12: Furniture Products

Profiles for Manufacturers

Furniture Manufacturer

For the furniture manufacturer the process starts when they receive an order from a retailer. They never sell directly to the end customer but when there are specific situations with family, etc.

Every order is registered as most of them work with some kind of sw. program, at least for the sales department. There are others, but cannot be considered a standard, that have integrated information systems like ERPs. Independently of the IT solutions they have implemented, these manufacturers manage to review and plan the manufacturing process along the different shop floor departments. Commonly this is made grouping these orders by some criteria according to their needs. Most common criteria are:

- Geographical delivery area, when they need to optimise transport
- Colours, when they need to optimise the finishing line and they don't need to optimise transport
- Delivery date, when they must accomplish with this date (this is not often a must)
- Order reception date, when the priority is the lead time

According to these grouping criteria, the manufacturing process starts with the final objective that orders need to be sent complete.

The furniture manufacturer is not a simple assembler of parts that they buy. They usually manufacture most of the wood components from the motherboard, if required they polish them and finally they assemble and pack them.

One of the main difficulties for a manufacturer is to get the required materials on time so that they can avoid delays in the delivery terms. In order to get this they usually have an oversized warehouse for the most common materials but for others that are expensive or not very common it becomes a difficult task. Here we show a list with the typical materials that are supplied to a furniture factory:

- Wooden or melamine Boards
- Edges
- Glue
- Varnish
- Pulls
- Glass parts for different purposes: doors, shelves, etc.
- Several types of iron fittings.

In the next diagram you can observe one of the common production flows:

- Material reception. Normally stored in organised warehouses, not chaotic ones.
- Cutting from board. Standard size boards are bought and the cutting process tries to optimize the waste of board by means of a program that uses an algorithm to achieve it.
- Edge banding. It is the process that adds a nice edge to the cut part.
- Machining. This process can drill or shape the parte to fit the needs. This is the technologically most advanced process and uses CNC programs.
- Polishing. Depending on the type of base material and finishing the parts may be polished. Two main groups: wooden parts are always polished and melamine parts are only lacquered in some cases.
- Assembly. Both manufactured and bought parts are assembled.
- Packing. Every product is packed, using one or several packs.
- Grouping order. As orders need to be sent complete, but they are not made all at a time there is a necessary process to store items while the others are being made. This is usually done by metallic structures with wheels to be moved easily.

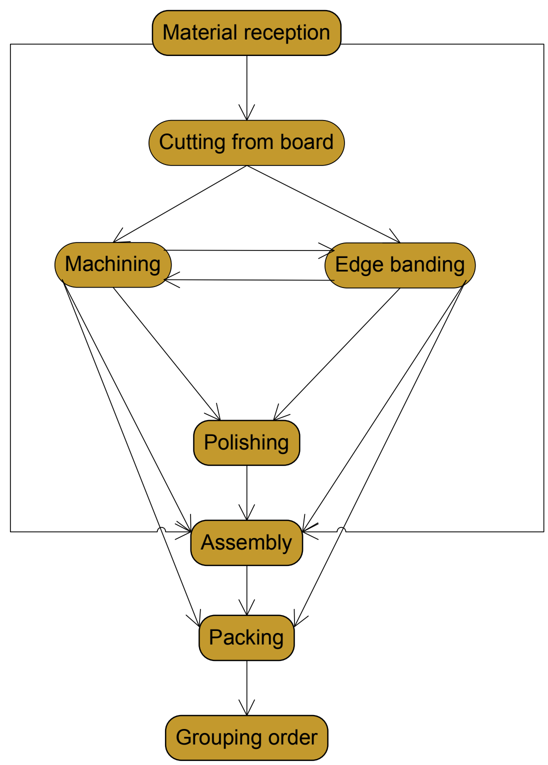

Figure 4-13: Furniture Industry Common Production Flow

The manufacturer is also responsible for the transport till the retailer and for this process, different situations occur:

- Carriers and trucks own to the manufacturing company
- Delivery agencies are outsourced
- Self-employed workers are outsourced to cover specific routes.

Supplier

The supplier plays a very important role in this supply chain because as described above it becomes a difficult task for the manufacturer to be able to plan what they will need because there is a very wide range of materials and it makes that some of them have to be ordered on demand.

As the supplier is actually a manufacturer that provides raw materials or components we can assume that they work with a similar system than described for the furniture manufacturers but, obviously with different production processes.

4.4.4 **Expectation from IMAGINE Platform**

From the Furniture Industry Living Lab there is a matching from the user requirements of the furniture scenarios to the three phases of IMAGINE.
In the following figure there is a representation of such matching:

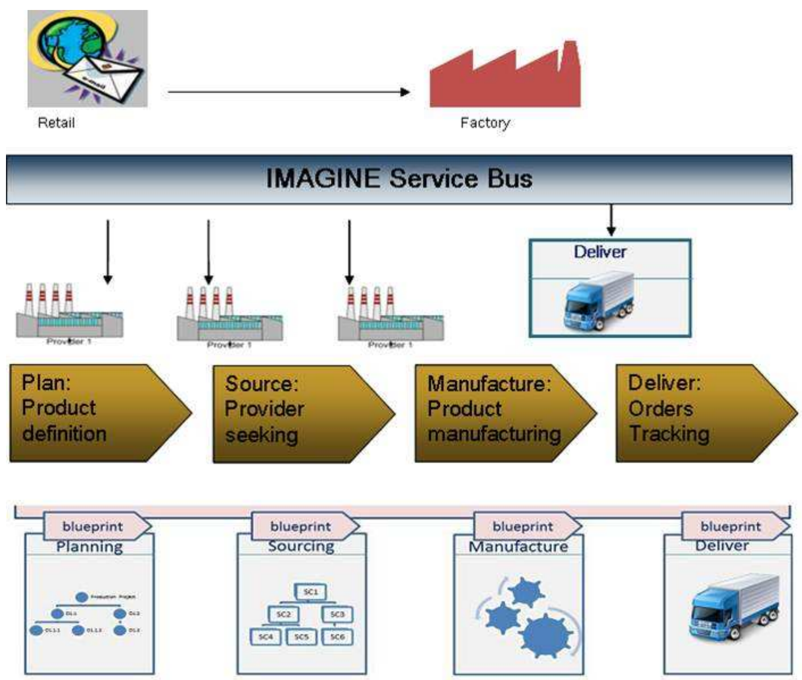

Figure 4-14: Furniture Industry - User Requirements Matching to IMAGINE Phases

1. Phase 1: Configure → Product, services and suppliers definition. This phase will be carried on when a new catalogue is being designed. At this stage it is necessary to design every component and also to find providers for the new materials. Even though commonly providers are normally the same from one catalogue to another, this phase of IMAGINE will be specially interesting to search providers for innovative materials like novel iron fittings, novel types of boards made of lighter panels, etc.

2. Phase 2: Design → Offering/Bidding for new products. After products/services and providers have been defined by means of their respective *Blueprints*, at this phase the user of IMAGINE will select the most appropriate suppliers within an Offering/Bidding process. In order to help the user in his decision making process, some kind of simulation process may be utilized to show the complete lead times at every situation.

3. Phase 3: Monitor & Govern → Orders management and tracking. Once a product is defined and the required suppliers have been selected, this phase will be focused on the tasks involved in the entire process to produce and serve an order (it is assumed that the MRP process knows the required materials and terms kept at *factory level*).

4.4.5 Business Use Case

Figure 4-15 shows an overall overview of the Furniture Business Use Cases and the standards and possible services that may be used.

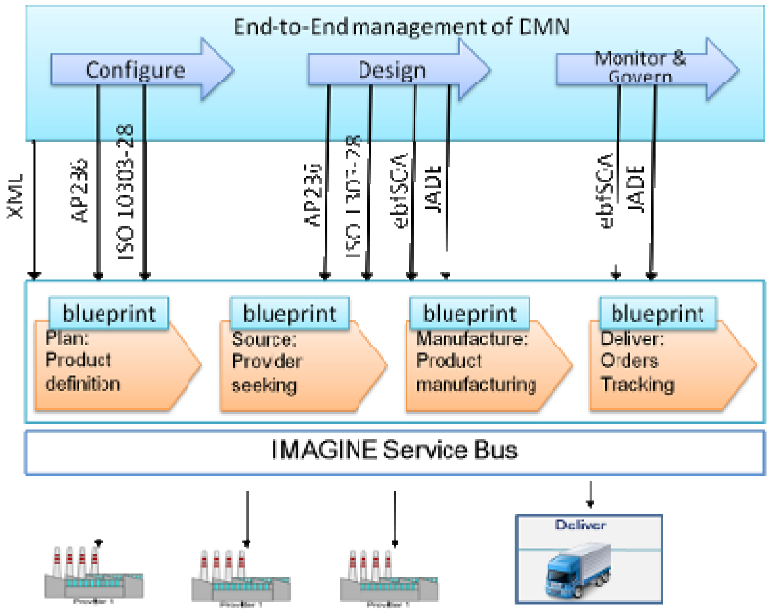

Figure 4-15: Furniture Industry Living Lab business case overview

All the communication between the blueprint and the DMN will be made by XML files, since it is a widely-used format for sharing structured information.
These are the 3 proposed Business Use Cases:

Table 4-4: Furniture Industry Living Lab business index

Business Case (acronym)	Business Case Name
Furniture_BC1	Configuration of Product, services and suppliers definition
Furniture_BC2	Design by Offering/Bidding for new products
Furniture_BC3	Monitor & Govern: Orders management and tracking

Table 4-5: Furniture Industry Living Lab Business case overview

<table>
<tr><th colspan="2">Furniture_BC1: Configuration of Product, services and suppliers definition</th></tr>
<tr><td>As is situation</td><td>Stakeholders: Manufacturers, Retailers, Transports. All stakeholders in furniture value chain. ICT department.
Objectives: To be able to manufacture a product under any supply service problem.</td></tr>
<tr><td>To be situation</td><td>Problem to be addressed: To be able to re-configure a product under any supply problem finding a fast supply agent.
Generic solution: Interoperability framework. Blueprint for configuration on products, services and suppliers.
In the "Configure" phase, which includes the design of the new products, it is necessary to design every component and also to find providers for the new materials. The standard ISO 10303-236 (AP236) will deal with the product data information for the furniture industry, then the ISO 10303-25 is needed to specify the mappings between the EXPRESS data specification language into the Object Management Group's (OMG) Unified Modelling Language (UML).
It will be necessary:
• Specification for every product to manufacture. This specification should include information not only about the end product, but also for every part of it: dimensions, machining, finishing, etc. The intention is to make use of the ISO 10303-236 standard which deals with the product data information for the furniture industry. Furthermore, it has to consider a multi-attribute management, which is a specific requirement at this industry (for example any cabinet has different choices meaning colours, knobs; in a sofa the choices are mainly the textiles which combined generate a very wide range of options for it).
• Specification for every purchasing component. These components may be standard or innovative. In the first case, just a reference would be necessary but in the second one, it would be necessary to attach some technical (probably CAD/CAM) files to define them. Products will be defined using some kind of multi-layered categories, so that they can be structured. Some typical examples for this purpose could be transportation or polishing which are usually subcontracted.
• Specification for every required service. For this definition, it will be used technical information by means of technical files. Services will be defined using some kind of multi-layered categories, so that they can be structured. Some typical examples for this purpose could be transportation or polishing which are usually subcontracted.
• Specification for every provider in order to ease the search of providers some kind of multi-layered categories will be used (the same one than for services and components). In this way it will be possible to find providers at the next phase
Specific solution: To be proposed by the partners
Assessment criteria:
• Technical level: Very easy to use by SMEs
• Applicative/process level: Quality of the developed services for a better</td></tr>
</table>

<table>
<tr><td></td><td>product configuration between the stakeholders
Organizational level: Usability for the different concerned decision makers</td></tr>
<tr><td colspan="2">Furniture_BC2: Design by Offering/Bidding for new products</td></tr>
<tr><td>As is situation</td><td>Stakeholders: Manufacturers, Retailers, Transports, all stakeholders in furniture value chain.
Objectives: Find new providers in other value chains for new product manufacturing.</td></tr>
<tr><td>To be situation</td><td>Problem to be addressed: to be able to bid/offer the manufacturing of a new product to new suppliers.
Generic solution: Interoperability framework. Blueprint for provider seeking to offer a bid for manufacturing a new product.
In the “Design” phase, there is the same issue regarding the product data information, so both AP236 and the ISO 10303-25 will be used in the blueprints definitions. The ebfSOA is responsible of the documentation of the blueprints, in particular the documentation related to the administrative and commercial tasks (RFQs, Invoices, etc.) . The JADE is a Multi-Agent Systems (MAS) that will be responsible for searching new suppliers, as JADE enables the creation of a short list of suppliers that have the raw materials available, making the search faster.

From the point of view of a company which has developed a new product:
Sending information by the DMN to the suppliers whose blueprint matches the product definition so they can bid for providing it.
Sending information by the DMN to the suppliers whose blueprint matches the service definition so they can bid for providing it.
Receiving information from the potential suppliers about the terms of service: lead time, terms of payment, price.
Selecting suppliers for those products or services at a test-mode.
Simulating the whole process according to the information received. This simulation must provide information about:
- Complete lead time
- Total cost
- Terms of service.
Selecting suppliers for those products or services and sending them a confirmation
From the point of view of those suppliers:
Receiving information about the requirements of the products or services
Sending their bids with:
- Prices
- the appropriated SLAs (Service Level Agreements)
- Lead time
Joining “the consortium” once they have been confirmed
Specific solution: To be proposed by the partners
Assessment criteria:
Technical level: Robustness, performance; easy to use for SMEs
Applicative/process level: Quality on selecting and searching new possible providers
Organizational level: Usability for the different concerned decision makers</td></tr>
</table>

Furniture_BC3: Monitor & Govern: Orders management and tracking	
As is situation	**Stakeholders**: Manufacturers, Retailers, Transport,… All stakeholders in furniture value chain, ICT department. **Objectives**: To know the situation of any order at manufacturing level as well as at delivery level.
To be situation	**Problem to be addressed**: To be able to monitor any order traceability. **Generic solution**: Interoperability framework (ebfSOA), blueprint for order tracking for: • Sending to the DMN the Bill of Materials and services required from the orders. Some kind of automatic process should redirect every order to its previously selected supplier. • Sending / receiving confirmation of the reception of the order and the lead time. • Tracking at any moment the status, not only of an order of a component, but also of the whole process to achieve the actual target: serving on time the whole order, i.e. comparing the estimated shipping terms with actual date and having the option to see how a delay affects the whole process. • Tracking the delivery status of the order once it has been sent The "Monitor & Govern" phase uses ebfSOA once again for all the documentation pertaining to orders, tracking the delivery and order status. Also, here in this phase, JADE may be utilized to help in the monitoring of the documents, to search for changes and warn the user. **Specific solution**: To be proposed by Imagine partners **Assessment criteria** • Technical level: Robustness, performance; easy to use for SMEs • Applicative/process level: Quality on finding and searching an order • Organizational level: Usability for the different concerned decision makers

4.5 Car Manufacturing Industry

The Car Manufacturing Industry Living Lab is a replicated automotive production network reproducing in test environment the actual layout of a manufacturing chain along its main lifecycle phases with a detailed focus on inbound flows and spare parts management.

4.5.1 Objective

The objective of this Living Lab is the collaborative digital product execution to ensure business continuity in large organizations.

4.5.2 Current Practice and Existing Problems

Current practices

The automotive production network includes the OEM plant and its main part suppliers. In the Living Lab, order, manufacturing and provisioning of parts are performed, towards the OEM plant (inbound use case) and to the spare part dealers (spare parts use case), as displayed in the Figure 4-16 below.

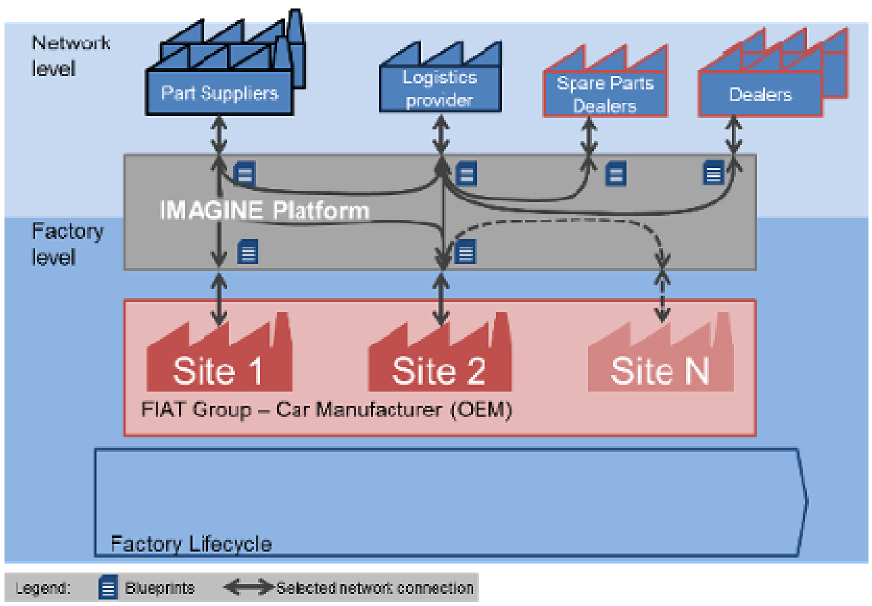

Figure 4-16: Automotive production network

On top of that, many other users are involved, such as:

- global supply chain management, for the design and coordination of the network;
- procurement and material management, for the identification of suppliers, contracting and execution phases
- production planning and warehouse management, at the plants level
- spare part and car dealers, which can be independent from the OEM

The ERP (Enterprise Resource Planning) system implements all the order management for incoming parts and connects to the MRP (Manufacturing Requirements/Resource Planning), the MES (Manufacturing Execution System) and the Click WM for the management of inbound/spare parts.

Click WM is the dedicated system which provides visibility on the level of stock in the warehouses, as shown in Figure 4-18. All systems are interfaced one each other throughout the supply chain.

The suppliers are involved through a collaboration portal that will be simulated by using a customizable social networking platform for B2B called TamTamy. This platform is already in use by FIAT Group companies for interacting among dealers and manufacturing.

The customization will enable, through usage of APIs, to post a request to the suppliers' community in real time, manage a bid among them based on response parameters (time, cost, quality, shipping terms etc.) and drop an order.

The suppliers subscribe to the collaboration portal based on their interest in supply categories and size/quantity of the supplies.

Current shortcomings

The risk visibility, and thus the potential to ensure business continuity is only ensured in very specific cases:

- When the supplier actually belongs to the same group as the OEM and thus can provide complete visibility on the operation risk and the relative mitigation strategies.
- When the part can be supplied by multiple vendors without involving the co-design of the part itself.

Cases of business interruption in the automotive sector are well known, such as the "1997 Aisin fire" involving a Toyota-subsidiary[6].

4.5.3 Process flow

As described above, the target process is the digital collaboration for ensuring the business continuity, in particular for the manufacturing of vehicles. The collaborative platform has to address the following steps, described in the figure below:

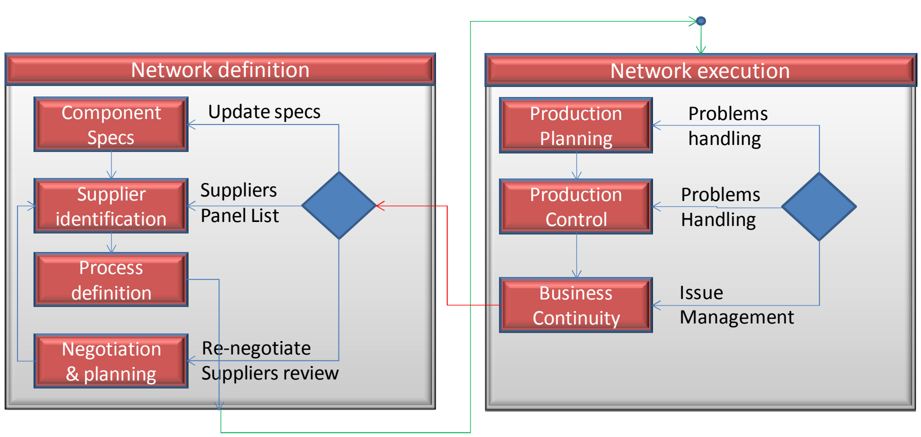

Figure 4-17: Production network definition, execution and exception management

[6] See http://en.wikipedia.org/wiki/1997_Aisin_fire

P1- Specifications definition

P2- Identification/ Selection of supplier from panel, through marketplace

P3- Manufacturing, execution and control

P4- Exception management and re-definition of network

4.5.4 Expectation from Imagine Platform

The objective of the Car Manufacturing Living Lab is to determine, design, develop and simulate the key elements of the IMAGINE concepts highlighting the potential impact on existing and future business models regarding the car production processes.

The final goal of the Living Lab is to demonstrate which parts of the factory and supplier network levels could be improved in terms of robustness and performances by using the DMN concepts and technologies on the virtual enterprise business model.

The Living Lab will reproduce in a certification/test environment the main ICT architecture and production strategies of the real production system chain

The Living Lab will exploit a cloud-based system environment able to scale up the computing powers and loads to provide flexible, on demand and pay-per-use resources. The cloud computing system will be hosted in the Reply data center and accessible from the outside for public demonstrations.

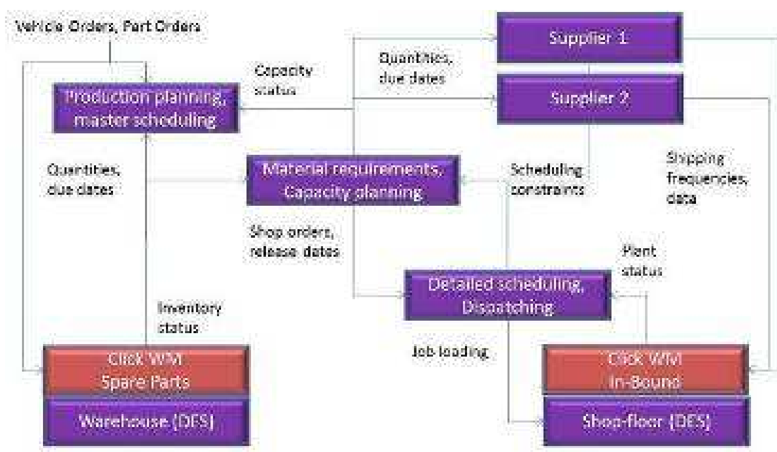

Figure 4-18: Technical infrastructure, with actors and data flows

If the part can be supplied by multiple vendors without involving the co-design of the part itself, the IMAGINE platform can help in finding alternative suppliers and ensuring the business continuity, which is increasingly important in case of a business interruption due to unexpected failure of a supplier e.g. in case of natural catastrophic events or quality drawbacks.

The Living Lab will use the IMAGINE platform to perform simulation and what-if scenarios: the simulated production environments, as described above, will simulate the XML messages generated currently by the ERP, MRP, MES etc. as input for the Click WM – replica (inbound/spare parts management system) and evaluate the resilience of the network (or business continuity performance) through specific KPIs.

4.5.5 Business Use Case

The use case is expected to be finalized in WP2 and specifically in T2.1. However, a preliminary business use case has been identified and is provided hereafter.

Car Manufacturing Industry Living Lab Use Case	
As is situation	**Stakeholders**: Manufacturers, suppliers, spare part and car dealers **Objectives**: In case a supplier is unable to deliver as promised, it is difficult to reconfigure the network without business interruption.
To be situation	**Problem to be addressed**: To be able to quickly find new suppliers for a given part, without, if possible, involving the co-design of the part itself; and to quickly reconfigure the network with minimal business interruption. **Generic solution**: Interoperability framework. Search functionality for suppliers able to provide the required part. • The Living Lab will use the IMAGINE platform to perform simulation and what-if scenarios: the simulated production environments, will simulate the XML messages generated currently by the ERP, MRP, MES etc. as input for the Click WM – replica (inbound/spare parts management system) and evaluate the resilience of the network (or business continuity performance) through specific KPIs. **Specific solution**: To be proposed by the partners **Assessment criteria**: • Technical level: Robustness, performance • Applicative/process level: Business interruption minimization. • Organizational level: Usability for the different concerned decision makers

4.6 Engineering Sector

4.6.1. Objective

The European Collaborative networked Organisations LEADership initiative, ECOLEAD, aims to create strong foundations and mechanisms needed to establish the most advanced collaborative and network-based industry society in Europe: This four year, 26 member, 15.2 million euro project (project ID 506958) had as its vision:

"In ten years most enterprises will be part of some sustainable collaborative networks that will act as breeding environments for the formation of dynamic virtual organizations in response to fast changing market conditions."

The UoW living lab, called WMCCM, is one of the few working platforms that's demonstrates the EcoLead vision actually working with real businesses conducting real trade. WMCCM currently implements most of the collaborative working platform vision that has been articulated by a range of EU Projects such as Athena, etc. It does not currently cater for the functions conceived for IMAGINE. There is currently no way for the partners from a consortium created by WMCCM to then undertake the actual manufacturing supply chain co-ordination and management activity.

This living lab will help define the requirements for IMAGINE and test the resulting IMAGINE platform in the context of a breeding environment for virtual organisations in the engineering sector.

4.6.2. Current Practice and Existing Problems

The UoW has a large knowledge transfer and engagement activity working with SMEs and large Engineering sector partners such as Jaguar – Land Rover, BAE Systems, JCB, and Arup. For the IMAGINE project we propose utilising our existing Living Lab which provides services to Engineering related SMEs. This lab is an online system used by companies to promote their capabilities, find opportunities, select partners and undertake projects. The process flow for it is shown in Figure 4-21: The WMCCM workflow.

The WMCCM living lab currently has 10,000+ registered user companies. These are mainly SMEs, and address all sectors and levels. Many are support businesses to the 2nd, 3rd tier component business. The sectors covered include automotive, aerospace, retail, rail, construction, IT and more. Of these 10,000+ companies around 400 have been visited and validated via a competence profiling process to capture what they CAN DO, as well as what they DO NOW. An example competence profile is shown in Figure 4-19.

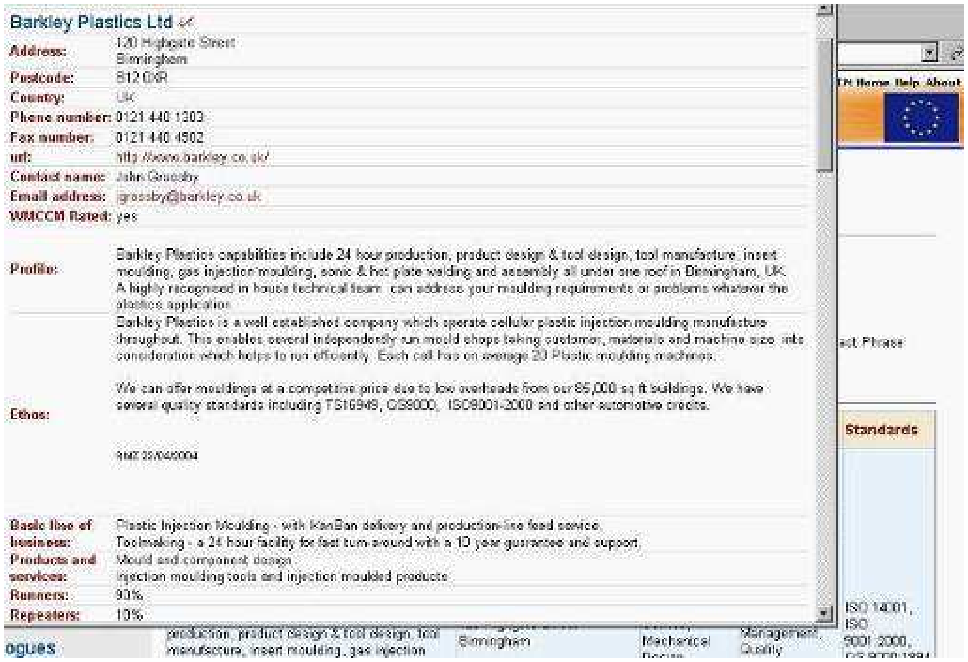

Figure 4-19: Competence Profile for a WMCCM Company

Only competence profiled companies are considered for partnership when WMCCM members use its team formation (supply chain building) function. These partnerships are usually formed in response to a new tender opportunity that WMCCM has notified its members of. See Figure 4-20, for a screen shot of a suggested team to address the needs of a particular tender.

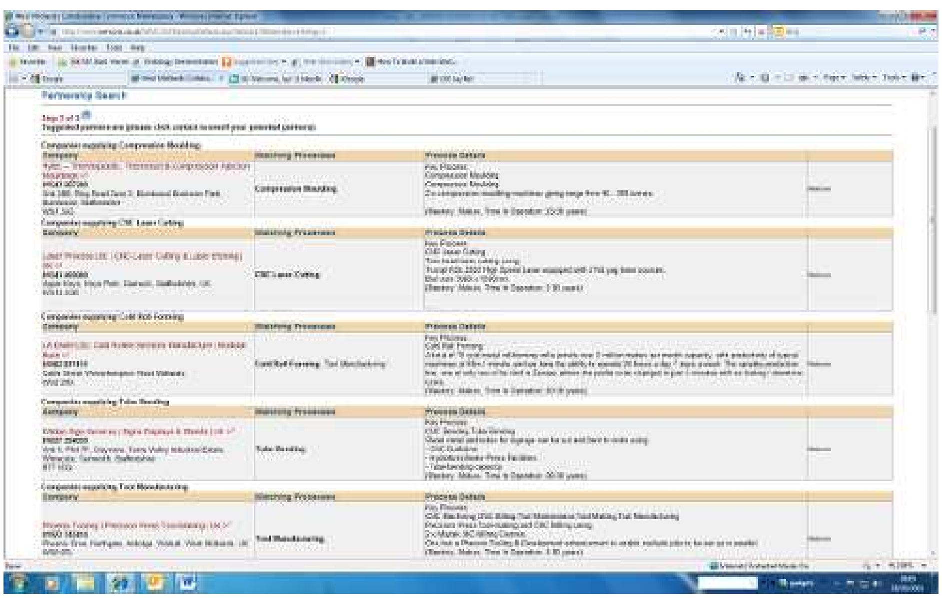

Figure 4-20: WMCCM Consortium/Team suggestion to address tender Opportunity

Once a consortium/team has been formed the WMCCM platform provides secure collaborative work spaces for collaboration co-ordination. These collaborative spaces do not provide any kind of functionality to assist in the planning and coordination of the manufacturing activity. Thus WMCCM achieves Ecolead's goal of breeding new virtual organisations in response to opportunities, but then has no tools to help the virtual organisation undertake the resulting tasks of planning and execution.

4.6.3. Process Flow

WMCCM is designed to support the following key workflow processes as shown in Figure 4-21. The workflows, as illustrated from left to right in Figure 4-21, are described below:

1. Sourcing new business from varied e-tender external online sources including a range of both public and private sector contracts. Firms can also generate tenders for their own needs.

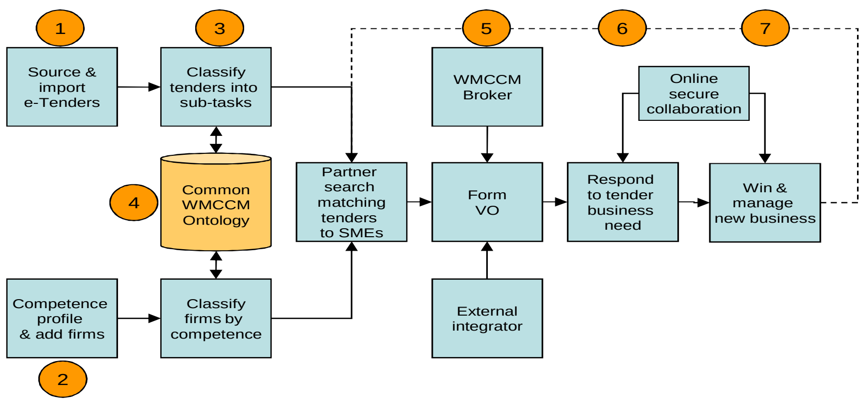

Figure 4-21: The WMCCM workflow

2. Competence Profiling of SMEs. This is a structured process that measures capability within firms using a standardised formal questionnaire with the objective of generating trust and giving easily comparable information. The focus of the questionnaire is to discover what the firm can do, rather than what they are doing currently. The competence profile also captures a range of hard and soft factors so that firms with similar cultures can be identified when forming effective collaborations and virtual organisations.

3. The classification of tender requirements and SME capability using a common ontology. Tender requirements are automatically classified by process, skill need, and location and quality standards by the WMCCM system and then compared against the needs and capability of Competence Profiled SMEs. Therefore when tender requirements and SME requirements match, the SME is automatically alerted by a daily email giving detail about the tender opportunity.

4. Match tender to individual or group of SMEs using WMCCM online Partner Search System. The Partnership Search system is used when a tender requires a competence, which interested SMEs cannot provide individually. It is a two-stage search process. The first stage matches against an absolute need or hard factors. The second stage is a preference or soft factor scoring

process. The system scores matching marks for each eligible company and then suggests a best-fit partnership based on the highest matched scores.

5. The results of the partner search suggest an initial best fit grouping of SMEs who collectively have the potential capability to bid for the tender contract. At this stage the VO starts to take shape as members undergo a stage of team forming through a number of initial face-to-face meetings. It is important that best practice virtual teaming principles are followed in order to ensure that good team performance is achieved.

6. Respond to tender (business need) and collaborate online in secure project spaces. These can be generated within the portal by SMEs to support low cost and speedy collaboration. Default functionality includes document storage, simple project and task allocation management and discussion forums with associated knowledge management tools.

7. If the bid is successful and the contract won, further collaboration tools can be used such as an integrated supply chain visibility facility.

In summary, rather than just measuring current operational capability, competence profiling seeks to determine transferable capability. SMEs that are competence profiled are matched against a dynamic ontology, which allows their capabilities to be matched against the tasks of any online tender. This is the matching of tasks (tender requests) with resources (the SMEs capability) with the view of stimulating innovation.

4.6.4. Expectation from IMAGINE Platform

As described in section 4.6.2, WMCCM living lab provides a breeding environment for establishment of virtual organisations. Therefore as illustrated in figure 4-22, functionalities of WMCCM platform correlates with the configuration stage of IMAGINE framework. However there is no mechanism in WMCCM for actual collaboration between companies or for integration of their ICT tools.

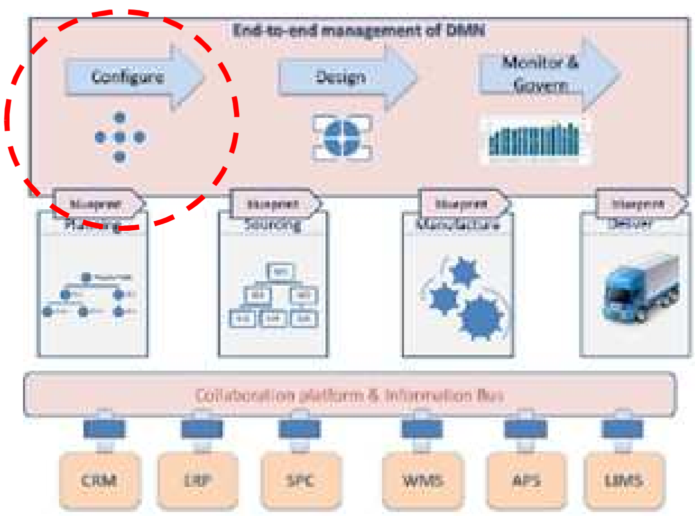

Figure 4-22: IMAGINE Framework

Therefore the UoW living lab places demands on the IMAGINE platform in the following ways. Some of these are complementary to the other living labs but others are contradictory.

1. The WMCCM members employ a broad range of processes and tools. These are usually not the high end automated machinery such as that employed by tier 1 supplier in Automotive and Aerospace. Some WMCCM members are tier 1 suppliers to automotive, aerospace companies, rail, but they tend to supply a number of customers and are not exclusively orientated towards a particular sector. The majority of the WMCCM companies supply to three different sectors. Automotive, Aerospace and Retail are the most common. Thus there is a very diverse base of machinery and processes.
2. There is often no strong end customer to drive integration. Thus decisions on the level of coordination and integration are driven purely by the benefits derived by the members themselves.
3. There is a belief that integration will reduce flexibility and autonomy.
4. Better integration and coordination of the supply chain will bring about a more optimal operation overall for the supply chain. However individual members may have to "lose" for the overall system to gain. Selling the benefits will be a lot harder.

4.6.5. Business Use Case

As formation and deformation of virtual organisations at WMCCM are exclusively based on companies' interest new tender opportunities, therefore at this stage of the project, it is not possible to describe a particular case study that could be used in the final stage of the project to test the functionalities of the IMAGINE platform. However, the following case study will describe a project in which WMCCM's functionalities has been used to meet a particular tender's requirements.

Case Study Description

The DSTL tender was an opportunity to apply automotive industry best practice to form a VO, comprising of multi-disciplinary SMEs in order to meet future DSTL engineering requirements. Due to the scale and complex nature of the DSTL technical requirements and scale of the contract value at over €15m, it was accepted that a typical engineering SME within the West Midlands, UK could not provide the wide range of competencies nor realistically expect to navigate the intricate tendering procedures independently.

Thus a collaborative VO was established through utilising the WMCCM to address the specific requirements of the DSTL contract. Aspîre Consulting, a Defence based SME and WMCCM member, was used to act as a conduit between the automotive and military industry sectors, to facilitate the long and intricate DSTL procurement process and in the future to act as a potential prime contractor.

When the DSTL tender was received by WMCCM, it was automatically processed by the in-built dynamic ontology, which splits the tender into a number of sub-tasks including industrial market, technical skill and geographic location.

The online partner search selection tool was run to identify a short list of potential consortium members covering each area of technical expertise. This matching of capability is a key part of grouping potential members, in order to build a dynamic VO. Each company was then contacted and invited to form part of the collaborative consortia, attending a number of face-to-face briefing sessions. The VO structure of the DSTL bid can be seen in Figure 4-23.

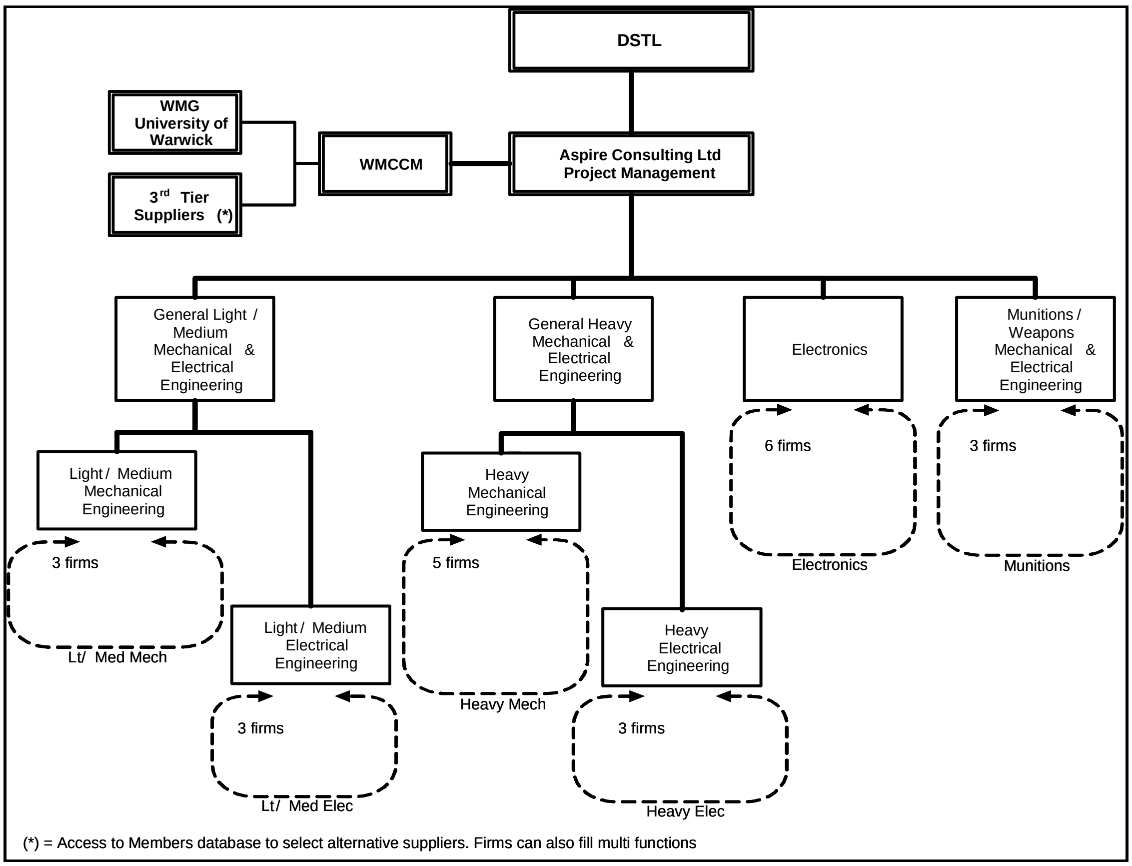

Figure 4-23: Proposed DSTL response VO structure

The collaborative bid aimed to provide DSTL with a "one-stop-shop" for all of the engineering service disciplines detailed in its competitive tender call. In addition to the membership of WMCCM and its approach seeks to give a number of further benefits:

•The ability to address all of DSTL's needs both from a capability and capacity perspective without any additional investment in tooling, machinery and software.

•The ability to offer additional services from other SME members of WMCCM to meet DSTL additional service options. WMCCM has a wider membership of 4,000 SMEs, each with a brief business or detailed competence profile. Consequently if the combined capability and capacity of the companies identified in this proposal are unable to meet the task requirements set by DSTL then within a short time period an alternative supplier can be identified from the WMCCM membership to join the team.

4.7 Living Labs Summary

A high level of complementarity can be identified by the IMAGINE Living Labs. We may note that some Living Labs focus on the configuration phase of the network while others focus on the operation phase of the network or follow a more holistic approach. Additionally, we can prefatory identify the important aspects for the IMAGINE Living Labs, such as partner selection, interoperability, reconfiguration, monitoring, network transparency and more. As a next step, these will be investigated in detail within the context of Task 1.3 and Work package 2, in order to design end eventually implement a platform able to tackle these issues.

Finally, the main objectives and expectations of the IMAGINE Living Labs have been examined and an effort to extract and summarize this information is provided in Table 4-6: Living Labs Summary.

Table 4-6: Living Labs Summary

Living Lab	Objective	Expectations from IMAGINE
Aerospace and Defence Industry	Collaborative digital product development within extended enterprise and networked organizations	Provide open, robust and evolutionary environment allowing to aggregate solution components provided by IMAGINE partners and interconnection with most of the legacy capabilities.
		Provide dedicated services, based on blueprints and dynamic network management to the different stakeholders in order to be able to qualify interconnected companies and supply chain, all along the life cycle of the collaboration within a continuous evolving environment.
		Provide dedicated services for supporting stakeholders, such as ICT departments dealing with Technical Information Systems, Design offices dealing with methods and standard experts within the field of secured Product Data Exchange.
Industry agnostic, Multi-site, Single Factory Context	Enhance the industry agnostic living lab called “GEMLab 2.0” to enable the planning and optimisation of Dynamic Manufacturing Networks	Realize an industry agnostic, multi-site, single factory context platform that enables a holistic and efficient modelling and optimisation of complex production networks.
		Characteristics and KPIs to describe supplier, stakeholder, factories and products of a specific manufacturing network through blueprints.
Furniture Manufacturing Industry	On-demand supply and production networks	Efficient matching of the user requirements in the furniture scenarios to the three identified phases of IMAGINE ('Configure', 'Design', 'Monitor & Govern').

Car Manufacturing Industry	Collaborative digital product execution to ensure business continuity in large organizations	Examine the key elements of the IMAGINE concepts highlighting the potential impact on existing and future business models regarding the car production processes.
		Demonstrate which parts of the factory and supplier network levels could be improved in terms of robustness and performances by using the DMN concepts and technologies on the virtual enterprise business model.
Engineering Sector	Breeding environment for virtual organisations in the engineering sector, especially within an SME context.	Support the existing Living Lab to cover the 'Design' and 'Monitor & Govern' phases.
		Fine tune partner search; provide the infrastructure needed to replace Face to Face meetings; to orchestrate end-to-end process.
		Better integration and coordination of the supply chain will bring a more optimal operation; support integration but without reducing flexibility and autonomy.

5 Conclusions

5.1 Discussion of Results

The findings of this deliverable indicate that while there are some approaches that partially cover some aspects of network manufacturing there is no end-to-end dynamic manufacturing network management approach available. The study of the current practices and latest developments has also helped in deriving important findings that will help in the formation of a novel methodology for the end-to-end management of dynamic manufacturing networks.

In particular, partner identification and selection is currently facilitated only by the companies' internal lists of known suppliers' ratings and/or by internet directories. However, internet directories categorize companies based on textual descriptions of their products and do not adequately consider their current and/or potential competencies. In parallel, they do not seem to provide the sufficient functionality for appropriately identifying and selecting the potential partners for a manufacturing network. Another important issue is that they do not provide any means for the collaboration and orchestration of work among the companies.

In terms of process planning most methodologies tend to focus on static manufacturing networks and do not properly address dynamic manufacturing networks, able to efficiently change in a regular basis. Finally, it can be noted that there are no approaches that can monitor, manage and control dynamic manufacturing networks without strong modifications. In addition, when analysing the huge list of tools, applications or processes which have to deal with Dynamic Manufacturing Networks, one difficulty that can be identified is to define DMN services and capabilities that can be shared and used in a coherent way, together with the whole set of heterogeneous applications, processes and tools that are interconnected within an eBusiness environment.

5.2 Final words

Three main sections are provided in Deliverable D1.1.1:

1. The presentation of the current practices in virtual manufacturing management.
2. The identification of the regulation and standardization activities currently used in manufacturing.
3. The description of the case studies that will be investigated in the project.

Based on these, Deliverable D1.1.1 will facilitate the development of the methodology for efficient end-to-end management of Dynamic Manufacturing Networks, a work that will take place in Task 1.3. The current, unstructured practices in virtual manufacturing management are described in Chapter 2, while specific problems have been analyzed and targeted in Chapter 4. The identified drawbacks in current practice and the problems experienced will provide the basis for developing the required solutions. Additionally, an overview on the lifecycle of Dynamic Manufacturing Networks is approached in Section 2.3. This overview provides the initial guidelines for the segregation of the methodology to specific, different sections of the DMN lifecycle: 'Configure', 'Processes design' and 'Monitor & Govern'. This categorization has been done in order to promote exact solutions for specific problems during the DMNs lifecycle and eventually providing focused solutions. Additionally, a preliminary set of parameters that can be investigated during the construction and operation of manufacturing networks has also been provided in Section 2.3. The key findings are provided in Section 2.4. The final aggregation of the developed solutions will be realized by the IMAGINE Platform that will be implemented in later stages of the project. Finally, in order to further support the work in Task 1.3 and WP2, Deliverable D1.1.1 provides an outlook on the latest academic approaches supporting efficient network manufacturing management.

The regulation and standardization activities in Chapter 3 provide –among others- the partners with a reference point that can be exploited during the whole duration of the project in order to, depending on each case under study, resolve related problems that may be encountered (e.g. interoperability issues). Furthermore, the provided information will be particularly considered in WP2 in order to decide on and structure the technology foundation and the IMAGINE Platform architecture.

Finally, the Living Labs have been described in detail in this deliverable. The as-is and the to-be situations have been specified for all five IMAGINE Living Labs. The main objectives are made clear and the shortcomings of the current practices are reported. The expectations from the IMAGINE Platform and preliminary business use cases have been identified. The provided information will be examined in order to derive the individual tools that will solve the reported issues and which will eventually be integrated in order to realize the IMAGINE Platform.

Based on these conclusions, we can expect that deliverable D.1.1.1 will successfully accomplish its main objectives, to provide a common starting point for all partners in the IMAGINE project towards end-to-end DMN management and to identify suitable case studies for the implementation of the project.

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6 Appendix

6.1 Indicative KPIs

A selection of KPIs is presented in the following table, divided into categories concerning the business processes they are mostly related to. These KPIs will be examined during the development of the novel methodology for DMN management, in order to eventually decide on which KPIs should be considered during the configuration, design and monitoring of DMNs. Of course, this table can only be considered as an example collection of indicators which are, according to [25], most commonly used in manufacturing and engineering enterprises.

Business Processes	Indicative KPIs
Production & Supply chain	Cost variances, Manufacturing cost, Fixed production cost, Variable production cost, average Production cost of the goods manufactured during the period budget ratio, order processing cycle, production cycle times, downtime, % outsourcing, PLER, budget ratio, STR, capacity utilisation, logistics cost, SPC, load utilisation, failure rates, return on plant, space utilisation, set up time, waste rates, pollution levels, emergency delivery, out of stock %, obsolescent stock %, recycling%, back order %, JIT% energy efficiency ratio, peak capacity %, supplier ratio, partnering, obsolescent stock, EOQ, number of suppliers, supplier spread ratio, number of components, emergency call out, delivery failures, productive hours %, E-enablement, vendor rating, project success, internal service satisfaction levels, effective headcount, % mentoring
Product Development	Product age spread, R&D%, ideas, strategic fit, budget ratio, protocol score, total cycle time, project review, team creation, testing, % outsourcing, NPDER, budget ratio, license fees, IPR%, IPR infringements, IPR maintenance costs, royalty rate %, time, productive hours %, budget, specification, project success, internal service satisfaction levels, effective headcount, % mentoring
Administration	PEST elements, budget ratio, high impact/ high probability assumptions and boundary conditions (strategic risk assessment),CGAL, RSM, contractual, portfolio risk levels, % hurdle rate, insurance costs/sales, BEV, capital spread ratio, cost per sqm or cost per employee for facilities total space, productive hours %, % meeting time, BS index, utility cost, noise, accidents, % outsourcing, complaint resolution speed, complaint resolution cost, average meetings/ month, utility cost/ market cost ratio, premises cost/ market cost ratio, space utilisation, whistleblowing, temperature, noise, health and safety breaches, security breaches, document loss, pension cost, theft, AER, budget ratio, KFR, project success, certification, wages ratio, litigation, internal service satisfaction levels, effective headcount, % mentoring
Personnel	Productivity, budget ratio, turnover, absenteeism, % outsourcing (temporary staff ratio), PER, budget ratio, labour cost%, wages ratio, CNCER, employee satisfaction levels, CH/WH ratio, overtime%, skills, training, discipline, disputes, appeals, timekeeping ratio, apprenticeship, recruitment costs, training days, productive hours %, whistleblowing, span of control, appraisals, wages ratio, diversity index, PDP,

	project success, internal service satisfaction levels, effective headcount, % mentoring
IT	Management information system functionality, productivity, budget ratio, stability, web hits, access speed, site downtime, site click through, productive hours %, Intranet, Extranet, % outsourcing, ITER, budget ratio, security breaches, data storage, EDI, web position, quality of data, information overload, project success, internal service satisfaction levels, effective headcount, % mentoring
Finance	Financial ratios, budget ratio, % outsourcing, FER, BEV, BEV/EBITDA, debt age, cost of finance, capital allocation ratio, capex, EFT%, CER, tax charge, SPT %, gross yield, P/E,PEG, EPS, project success, DER%, BDR, FCF, overdue accounts, productive hours %, market dynamics capital allocation, EBITDA currency/ debt currency ratio, sales tax rate %, cash interest rate%, depreciation %, internal service satisfaction levels, effective headcount, % mentoring
Sales and Marketing	CLV, budget ratio, market share by segment, trial rate, competitive score, sales by channel, % repeat purchase, average sales value, sales productivity, market share, advertising productivity by channel, cost per lead, cost per converted lead, bid success rates, range sale%, average discount, service call out times, productive hours %, enquiry response time, seasonality ratio, price index, customer satisfaction, advertising awareness, % branding %, customer investment review, customer transition rate, value chain, % outsourcing, MER, budget ratio, EGMG ratio, customer investment return, customer churn, complaints, warranty claims, project success, channel members, product positioning variance, SER, AER, pricing, price elasticity, country spread, seasonality ratio, customer spread, product spread, product age spread ratios, segmental leadership, TDA's, project success, CIR%, competitive bidding success %, internal service satisfaction levels, effective headcount, % mentoring

Table 6-1: Indicative Key Performance Indicators