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iMAGiNE

Innovative end-to-end Management of Dynamic Manufacturing Networks

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

Deliverable D1.1.2

Methodology for end-to-end DMN Management

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Executive Summary

The IMAGINE methodology for DMN management revolves around the DMN lifecycle that assists in the creation, design, and management and monitoring of DMNs to meet dynamic market demands and end-to-end performance (KPI) requirements. In particular, the DMN management methodology is structured as an iterative closed-loop, human assisted DMN lifecycle that enables automation of repetitive steps, while retaining the flexibility to allow product variants, value adding network re-configurations, and, end-to-end processes customisations.

This deliverable concentrates on the IMAGINE lifecycle of a manufacturing network which ranging from planning and sourcing, to manufacturing and delivery. It describes the phases in the IMAGINE lifecycle model, and associates them with similar activities in Product Lifecycle Management and supply chains.

To support the manufacturing network lifecycle, IMAGINE proposes a knowledge-enhanced model-based approach on the basis of its blueprint model. This model gathers, consolidates and integrates manufacturing data and processes from firms in a manufacturing network to develop actionable insights that help maximise the performance of facilities, assets and their global workforce. To achieve this goal, IMAGINE connects through its lifecycle and blueprint model disparate systems and platforms as well as people and equipment to enable information sharing, collaboration, enterprise-wide visibility and interoperability. The two main tenets of this deliverable, namely the DMN lifecycle and the blueprint model are specified formally by using information and business process modelling techniques.

The manufacturing lifecycle and blueprint model contents have been developed on the basis of standards such as SCOR, ISO 10303 – STEP, ISA95 and B2MML as well as a thorough analysis of the outcome of interviews with industrial - especially Living Lab - partners involved in the project to identify their needs, scope and requirements of potential improvements on current methods of networked manufacturing management. The analysis of the user needs resulted in specifying the phases of the DMN management lifecycle, the involved blueprint structures, their activities and their inter-dependencies.

In addition, this deliverable exploits existing benefit studies in virtual manufacturing and DMNs to provide a complete presentation on the, already recognised but also potential, benefits of participating in DMNs and, hence, provide high-level business incentives to the proposed novel methodology for the DMN management and monitoring. Potential risks that may accrue when forming or becoming a member of a DMN, such as security and trust in information sharing in manufacturing networks, as well as proposed mitigation and avoidance strategies are also considered.

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1 Introduction

1.1 Overview of the Situation

Manufacturing companies are facing many new challenges today, as they need to operate in a highly complex, distributed, and fragmented environment. We can distinguish at least two broad types of challenges:

1. Manufacturers in sectors such as aerospace and defence, and automotive companies are all required to track, trace, and create genealogy of their products from so called "cradle to grave", i.e. from raw materials to finished products. In many cases they must trace not only their main product produced through its entire life cycle with end customers but also their secondary or incidental products deriving from the core manufacturing process.
2. Manufacturers normally use of many different tiers of suppliers to manufacture the end product. Increasingly, OEMs are using more pre-assembled parts from a globally distributed network of suppliers who come and go rather quickly. In order to maintain profitability, companies need to seamlessly and securely integrate their IT systems to suppliers' in order to track product, supplies, schedules, and respect product deadlines.

The above points imply that since manufacturing is increasingly performed in a global setting, information silos cannot be accepted and information can no longer be locally owned. Indeed, manufacturing-related data, manufacturing operations and processes should be integrated within and along a manufacturing supply chain or network to link network partners toward a shared manufacturing goal. This can have direct impact on the shop floor, by, for instance, connecting and networking dislocated assembly lines, and directly relating them to manufacturing management processes, such as production planning and control. This requires cross-functional integration by connecting people, processes and information at every phase of the production lifecycle and across all manufacturing network participants.

In IMAGINE, we reserve the term *dynamic manufacturing network* (DMN) to denote a permanent or temporal coalition comprising production systems of geographically dispersed SMEs and/or OEMs that collaborate in a shared value-chain to conduct joint manufacturing. Each member in the network produces one or more product component(s) that may be assembled into final service-enhanced products under the control of joint production schedule, while keeping its own autonomy. Production schedules are monitored collectively to accomplish a shared manufacturing goal. In dynamic manufacturing network, products are composed, (re-) configured and transformed on demand through dynamic and usually ad-hoc inter-organisational collaborations that can cope with evolving requirements and emergent behaviour.

Manufacturing network integration enhances network visibility and avoids information delays and distortions. Insufficient manufacturing network visibility makes members vulnerable to quality and service level problems from manufacturing partners, e.g., second tier suppliers, and therefore subject to risks. Therefore, information sharing and manufacturing process integration are major contributors to effective manufacturing network management.

1.2 Purpose and Scope of this Deliverable

IMAGINE plans to leverage industrial experience and knowledge to develop better process models, knowledge-based production methods and smart manufacturing operations [12],[13] and product quality metrics that will assist the manufacturing network lifecycle (which is the subject of this deliverable). To this end IMAGINE will monitor closely techniques and recent advances in manufacturing such as those achieved by the Smart Manufacturing programme launched by programme by the National Institute of Standards and Technology (NIST) and the American Society for Testing and Materials (ASTM). This initiative seeks to develop and integrate the measurement science and relevant technologies enabling smart machining. In a workshop organised by NIST recently [44], the following major drivers for smart manufacturing were identified, among others: increasing pace of technological change; increasingly rapid product and process innovation; continual push for higher quality, better performing customised products; increasing productivity and reducing costs; and highly efficient unit-of-one production. Some of these topics are also central to the research work conducted in IMAGINE.

To support the manufacturing lifecycle and develop a community-accessible platform that ensures interoperability and plug-and-play capabilities IMAGINE leans heavily on service technologies and Service Oriented Architecture (SOA) [46],[47]. When these are used in combination with appropriate industry standards and continuous improvement methods they allow for a plug-and play type of architecture for manufacturing systems [39]. The modularisation and service enablement of manufacturing practises is one of the leading causes for the predominance of the service sector in the world economy and the business innovation of seamlessly integrating production with services [5],[51].

The DMN Lifecycle is an innovative method and supporting technologies to manage the entire lifespan of a manufacturing network ranging from planning and sourcing, to manufacturing and delivery. This is achieved by engaging manufacturing partners, and product-related information into a joint manufacturing network (during the *network analysis and configuration phase*), by integrating network manufacturing processes in an end-to-end fashion by combining wide diversity of manufacturing and physical processes, e.g., machining, forging, casting, and injection moulding, (during the *network design phase)*, and finally by monitoring and managing the network execution (during the *network execution management and monitoring phase*).

Figure 1-1 places the DMN Lifecycle, which is the topic of Deliverable D.1.12 in context. It shows that the IMAGINE Framework encompasses two main ingredients: the DMN Lifecycle and supporting ICT-based IMAGINE Platform (vis. Manufacturing and Enterprise Service Bus, see Figure 1-1 and Figure 7-1). The IMAGINE Framework is the instrument to help create, design, monitor and manage networked production systems able to respond to emerging manufacturing business models, which require continuous change of processes, service-enhanced products and production volumes. The IMAGINE Framework manages the discrete PLM processes of the disparate networked production systems through the phases of the *manufacturing network lifecycle* described above, while providing the ability to networked enterprises to adapt to dynamically changing market demands.

The cornerstone of the DMN Lifecycle is the importance it places on visibility along networked production systems for achieving effective and efficient manufacturing network management. To address this challenge, IMAGINE links information from disparate IT systems by fusing two worlds that were until recently largely isolated, vis. Enterprise Computing (ERP/MRP) and Manufacturing Execution Systems (MES) [40].

Figure 1-1 illustrates that the IMAGINE Framework uses the IMAGINE Platform to support the functions of the DMN Lifecycle (configure, design, monitor and manage a manufacturing network) by means of blueprints. The objective of the IMAGINE Platform is to orchestrate manufacturing operations and processes that transcend external partners rationalising processes, operations and data, and piecing them together a to create a unified picture of the manufacturing network and ensure manufacturing network visibility.

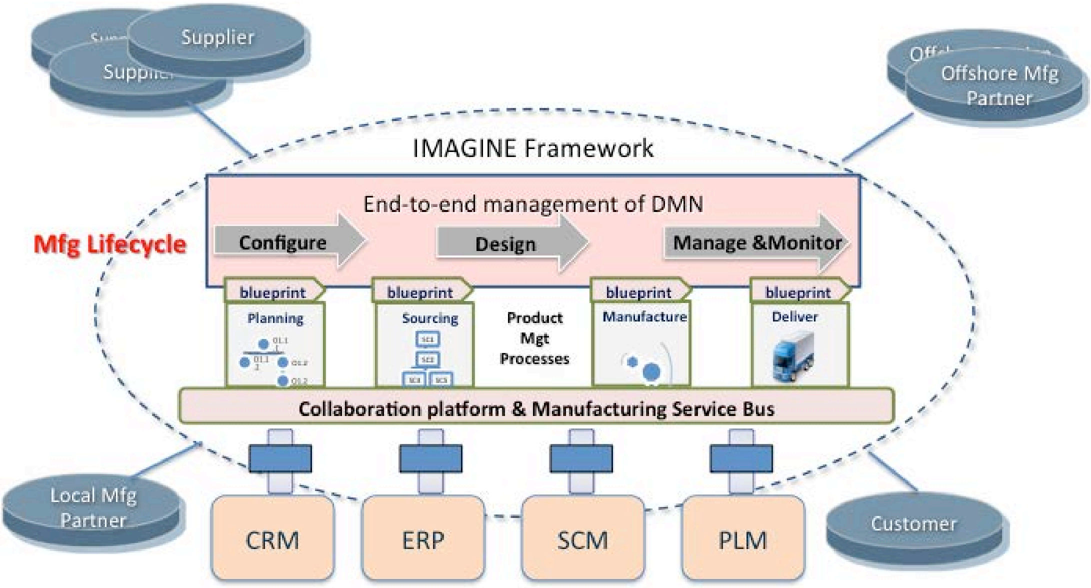

Figure 1-1: IMAGINE Framework

An essential instrument in support of the DMN Lifecycle are the IMAGINE manufacturing network *blueprints*, which are also the subject of D1.1.2. These serve as a central knowledge-based instrument of the DMN to apply and manage its lifecycle (see Section 4.3). Manufacturing blueprints rely on model-based design techniques to manage and inter-link product data and information (both its content and context), product portfolios and product families, and manufacturing assets (personnel, plant machinery and facilities, production line equipment) and, in general, help meet the requirements (functional, performance, quality, cost, physical factors, interoperability, time, etc.) of an entire manufacturing network. They provide the necessary information and knowledge to orchestrate a manufacturing network (network configuration phase), pool processes, resources and equipment, control KPI-driven end-to-end manufacturing processes (network design phase), and monitor and manage their execution in a repeatable and predictable manner (network execution management monitoring phase).

Additionally, IMAGINE recognises that the formation and operation of such a complex organisation like DMNs comes with a large number of potential benefits, but also of potential risks. To this purpose, a bottom-up approach was followed: possible benefits and risks (as well as mitigation and avoidance strategies of these risks) were recognised in an enterprise level and the analysis was escalated in a DMN level. Link between the identified benefits and risks and the IMAGINE methodology and blueprints constitutes the next logical step.

The main objective of this deliverable (D1.1.2) is twofold:

1. Firstly, this deliverable provides the specifics of the phases of the DMN Lifecycle based on the elicitation of needs and requirements of the industrial partners, considering improvements and extensions to existing methods of network management, including Product Lifecycle Management (PLM) and Supply Chain Management (SCM) aspects. The analysis of the industrial partner needs and requirements resulted in specifying the phases of the DMN management lifecycle. In this way, this deliverable captures an information model and associated process and material flows as well as scheduling and timing data relating to manufacturing, which will constitute the basis for constructing a consistent set of blueprints. This is covered in sections 2, 3, 4 and 5 of this deliverable.
2. Secondly, identify the benefits for enterprises' participation in efficiently managed and monitored Dynamic Manufacturing Networks and to reveal the business incentives for using the proposed methodology for DMN management and monitoring. Potential risks that may accrue when forming or becoming a member of a DMN, such as security and trust in information sharing in manufacturing networks, as well as proposed mitigation and avoidance strategies are also considered. This is covered in section 6 of this deliverable.

1.3 Action Plan

To develop the first part of this deliverable (sections 1 to and including 5) described in item-1 above, we created the lifecycle and the blueprints in transparent, tractable and repeatable manner on the basis of a methodological approach action plan described in this section. Our methodological approach and action plan is depicted in Figure 1-2.

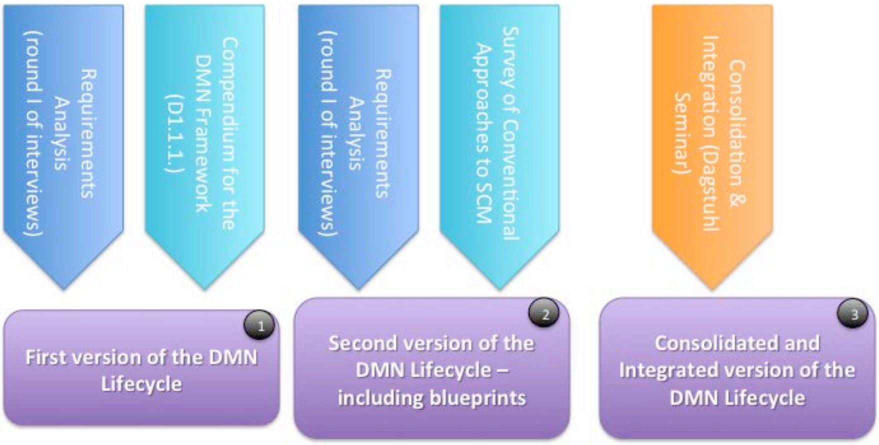

Figure 1-2: Action plan for Designing the DMN Lifecycle and Blueprints

Our action plan may be summarised as follows:

- **Step 1: From Survey round I to Configuration, Partner & QA Blueprints**: During the first step in our action plan, we have studied the Compendium on virtual manufacturing management produced in Deliverable D1.1.1 that summarises the latest developments in DMN management, and surveys related standards, regulations and policies. In addition, the Compendium introduces the use cases for the living labs. We have exploited both the literature survey and introduction to the living labs to design a first round of surveys to elicit the requirements of industry partners with regards to the DMN Lifecycle and specific blueprints. The first round of surveys addressed high-level requirements of the DMN Lifecycle, focusing on the configuration phase, and the initial definition of the Partner and Quality Assurance (QA) blueprints.

- **Step 2: From Survey and Interview round II to Design & Product/End-to-End blueprints:** The second step of our action plan concentrated on extending and refining the results of Step 1. In particular, we have studied conventional SCM approaches as well as approaches for formalising all the blueprints in the standardised general-purpose modelling language UML. The insights from the more focused literature survey in conjunction with the preliminary definition of the DMN Lifecycle and partner- and QA blueprint achieved in step 1, provided the basic ingredients for the second round of surveys. The result of the surveys – in combination with open questions asked during various (telephone) interview meetings and a round of consultations during a plenary meeting in Valencia (February 2012) led into the second version of the DMN Lifecycle including not only improved versions of the partner- and QA blueprints, but also a first sound version of the manufacturing- and end-to-end blueprints.
- **Step 3: Consolidation of Results:** In preparation of the second plenary meeting on the DMN Lifecycle and blueprints, industry partners were asked to deliver detailed descriptions about the way in which they currently conduct DMN management, and the information they use. This has led to a third and final iteration of the DMN Lifecycle and consolidation of earlier findings during a second plenary meeting in Dagstuhl, Germany (2 and 3 April 2012). To achieve this, opinions, remarks and additional requirements on version 2 were gathered, integrated and confirmed in the consolidated version of the DMN Lifecycle that we will introduce in section 4 of this deliverable.

Regarding the second part of the deliverable (detailed in section 6) which deals with the identifications of benefits and risk in order to give a clearer picture to enterprises that are interested in joining a DMN, the methodology that has been used in order to identify the benefits and the risks surrounding the participation of an enterprise in a DMN followed the following steps:

- Identification of typical industrial & organisational operations of SMEs belonging to several sectors.
- Grouping of operations by department and type (internal/external).
- Identification of the operations that get re-organised or indirectly influenced by a DMN
- Tracking down possible benefits of adopting the DMN methodology – classification by operation type and by department.
- Identification of problems and risks imposed per industrial operation and department and identification of risk avoidance and mitigation strategies and proposed solutions.
- Consolidation of the enterprise specific benefits and risks on a higher, network level perspective in order to present the overall critical factors that influence the decision to participate in a DMN.

1.4 Outline of the Deliverable

This deliverable is structured as follows. In the next section, we introduce the results of the requirements analysis amongst the IMAGINE industry partners and provide a brief summary of existing management approaches for conventional supply chains that provide the key building blocks on which the DMN Lifecycle and blueprints will be grounded later in sections 3 and 4.

Section 3 concentrates on demand-driven manufacturing techniques for IMAGINE as well as explains how to create manufacturing network production schedules.

Section 4 brings together the results of the requirements analysis and the concepts, methods and mechanism for DMN management extracted from literature, and introduces both the DMN Lifecycle model and its associated four blueprints: the partner blueprint, the product blueprint, the end-to-end process blueprint and the quality assurance blueprint. Several examples are given on the basis of SCOR and other manufacturing standards.

Section 5 outlines examples of use of blueprints in living labs for automotive and aerospace sectors.

The different benefits and business incentives that result from the proposed DMN methodology and the IMAGINE Blueprint Model for enterprises to participate in a DMN, alongside with a first level risk analysis is presented in section 6.

Lastly, section 7 concludes this deliverable with a summary and outlook to future work that will be conducted in WP-2.

2 Requirements Analysis & Conventional Approaches

Section 2 introduces the results of the first two rounds of interviews and surveys with the industry partners. In particular, we outline the key requirements underpinning the consolidated design of the DMN Lifecycle and blueprints that will be introduced later in section 3. In addition, this section overviews briefly notable reference models and standards (such as SCOR, BPMN and ISO STEP) that are used as building blocks of the DMN Lifecycle.

2.1 Requirements Analysis: Interviews with stakeholders

This section summarises and merges the interviews, surveys and findings of the consolidation session with the stakeholders (see section 1.3).

The key requirements that follow have been instrumental in helping shape the structure of corresponding blueprints. The key requirements from the interviews were used as recommendations for improving and extending the characteristics and attributes of blueprint structures. The findings have been systematically assessed and analysed and can be found in section 4.3.

2.1.1 Key requirements for the Partner Blueprint

The partner blueprint is intended to provide business and technical information to facilitate partners to be chosen by a specific contractor, e.g., OEM. The aim is to establish a unique Dynamic Manufacturing Network comprising partners and their resources that can collectively address a request from a customer. This happens during the Manufacturing Network Analysis and Configuration phase of the DMN Lifecycle. In particular, the partner blueprint captures unique skills and capabilities in the DMN and makes them available to potential partners to help address opportunities in new network configurations. The requirements analysis revealed that this blueprint must include the following important sections:

PB-req1: Low cost way of collecting partners blueprint information reflecting the process of engagement

PB-req2: Allow faster, rigorous, flexible configuration and reconfiguration of the network.

PB-req3: Allow integrating Virtual Organisations (VO's).

PB-req4: SLA establishment.

PB-req4: Support Configuration Stage 1: eliminate “non-compatibles”.

PB-req5: Support Configuration Stage 2: remove undesirables.

PB-req6: Support Configuration Stage 3: weighted scoring.

PB-req7: Associate information with that in Product blueprint.

PB-req8: Up to date (and possible real-time) partner information.

PB-req9: Inspire partner trust.

PB-req10: Include historical information, e.g., track record.

2.1.2 Key requirements for the Product Blueprint

The product blueprint contains all the components necessary for producing a standard or configurable product, such as machines, tools, personnel skills, materials, other equipment, and other entities that are necessary to start and complete manufacturing work. It contains both variant as well as non-variant parts. It is used to provide valuable product information for all DMN Lifecycle phases. The requirements analysis revealed that this blueprint must include the following important sections:

PRB-req1: Provide support during the lifecycle of a product.

PRB-req2: Capture the bill-of-material including mechanical/electrical/digital components of the product and sub-components.

PRB-req3: Provide understanding of the requirements of the DMN for employees, materials used (that can be digital), production steps and equipment that are needed to produce a particular product.

PRB-req4: Provide information with regard to the Manufacturing Bill-of-Material.

PRB-req5: Ensure compliance with standards such as ISA95 and in particular the STEP standard that is used in automotive and aerospace and defence.

PRB-req6: Provide visibility with regard to the shop-floor production of a particular product, manufacturing operations and related quality requirements (KPIs).

PRB-req7: Contain scheduling information giving insight on what to produce within a time-frame, and which material and personnel resources and equipment to use.

PRB-req8: Provide working instructions for the shop floor – who, what and when.

PRB-req9: Allow for global visibility of production routings.

PRB-req10: This blueprint should be lined to the end-to-end process blueprint, partner blueprint (e.g., to link personnel resources to the partner blueprint), and QA blueprint.

2.1.3 Key requirements for the end-to-end Process Blueprint

The end-to-end process blueprint ties together the many discrete processes associated with all aspects of product development while providing the ability to adapt to changing conditions and environments. This blueprint defines how actions are executed and decisions are made, and where responsibility is handed off between functions and partners. It is heavily used during the design as well as the execution management and monitoring phases of the DMN Lifecycle. The requirements analysis revealed that this blueprint must include the following important sections:

E2EPB-req1: Help establish the manufacturing network and a corresponding production schedule.

E2EPB-req2: Align network needs with end-to-end processes.

E2EPB-req3: Define network functional requirements with respect to partners, processes, information and material flow requirements.

E2EPB-req4: Ensure global manufacturing network visibility and visibility into critical network components, e.g., processes, equipment and people.

E2EPB-req5: Achieve effective manufacturing network partnerships based on precise and timely information, shared visibility and collaborative planning on manufacturing processes.

E2EPB-req6: Establish primary process roles and responsibilities.

E2EPB-req7: Establish and agree upon target process performance.

E2EPB-req8: Use process decomposition techniques to bring about more operational details and context for end-to-end processes.

E2EPB-req9: Ensure process interoperability by making use of standard sector-centric core processes.

E2EPB-req10: Ensure process privacy by ensuring participant access to shared profile-configured workspaces.

2.1.4 Key requirements for the Quality Assurance Blueprint

The Quality Assurance blueprint is used to structure data collections as regards metrics for operations analytics and associates these with end-to-end manufacturing processes. It is used mainly in the design and execution management and monitoring phases of the DMN Lifecycle. It helps enforce end-to-end process metrics for manufacturing operations and measure and control production status and performance across supply relationships between and within individual partners. The requirements analysis revealed that this blueprint must include the following important sections:

QA-req1: Constraints and deadlines regarding the Production Schedule Information in the Product blueprint – This may contain start or completion times, and it may define the resources (personnel, equipment, and material) to be used in production.

QA-req2: Production Performance KPIs – This contains production KPIs, defined in terms of equipment, and material used per production segment, per product or scheduled item.

QA-req3: Production Integrity KPIs for measuring the integrity of a product.

QA-req4: Production Compliance with standards and desired specifications.

QA-req5: Production Compliance with stipulated costs.

QA-req6: Process compliance with maturity levels.

QA-req7: Continual improvement of processes.

QA-req8: Partner interoperability with regards to conventions, standards and regulations in the manufacturing domain.

QA-req9: Capacity utilisation that manifests itself in the form of effective use of planning, design, production or delivery capacities.

QA-req10: Environmental KPIs to address production aspects such as CO_2 output, energy conservation, pollution prevention, and so on.

2.2 DMN Building Blocks

Building blocks for the DMN Lifecycle rely heavily on concepts and techniques found in the SCOR reference model whose neutral core processes can be used as a basis for designing end-to-end DMN processes. Process specification in IMAGINE also largely relies and extends the modelling constructs and conventions developed for the Business Process Modelling notation (BPMN). Another important building block is the Standard for the Exchange of Product model data. These are briefly summarised below. A more detailed synopsis of SCOR and BPMN is also given in Annexes C and D for reasons of completeness.

2.2.1 Supply Chain Operations Reference Model

The Supply Chain Operations Reference Model embodies the approach proposed by the Supply Chain Council[1] who combined the expertise of supply-chain professionals across a broad cross-section of industries to develop best-in-class business practices and design a specific methodology tailored to the analysis of supply chain processes [59].

SCOR is a business process methodology built by, and for, supply chain analysis and design designed to link best practices, technology, benchmarks, standardised metrics, and business processes in an effort to increase efficiencies in supply chain management operations. The SCOR-model provides a unique framework that links business process, metrics, best practices and technology features into a unified structure to support communication among supply chain partners and to improve the effectiveness of supply chain management and related supply chain improvement activities. The SCOR-model is widely adopted to supply chain companies that seek standardised methods for representing business processes and process interactions and easy communication with their partners.

SCOR is flexible and configurable to the specific needs of an organisation as the processes that are used to describe an organisation is dependent upon the role conducted in the network. SCOR as a process reference model contains:

- Standard descriptions of management practices.
- A framework of relationships among the standard processes
- Standard metrics to measure process performance
- Management practices that produce best in class performance
- Standard alignment to features and functionality.

The model spans all customer interactions, from order entry through paid invoice, all physical material transactions, from the supplier's supplier to the customer's customer, including field service logistics, and all market interactions, from the understanding of aggregate demand to the fulfilment of each order. SCOR does not attempt to describe every business process or activity. Specifically, the SCOR model does not address: sales and marketing (demand generation), product development, research and development, and several elements of post-delivery customer support.

[1] http://www.supply-chain.org

SCOR contend that the core processes that are directly involved in the execution of a supply strategy could be made up of a combination of five primary management processes: plan, source, make, deliver and return. By describing supply chains using these process building blocks, the model can be used to describe supply chains that are very simple or very complex using a common set of definitions. As a result, disparate industries can be linked to describe the depth and breadth of virtually any supply chain.

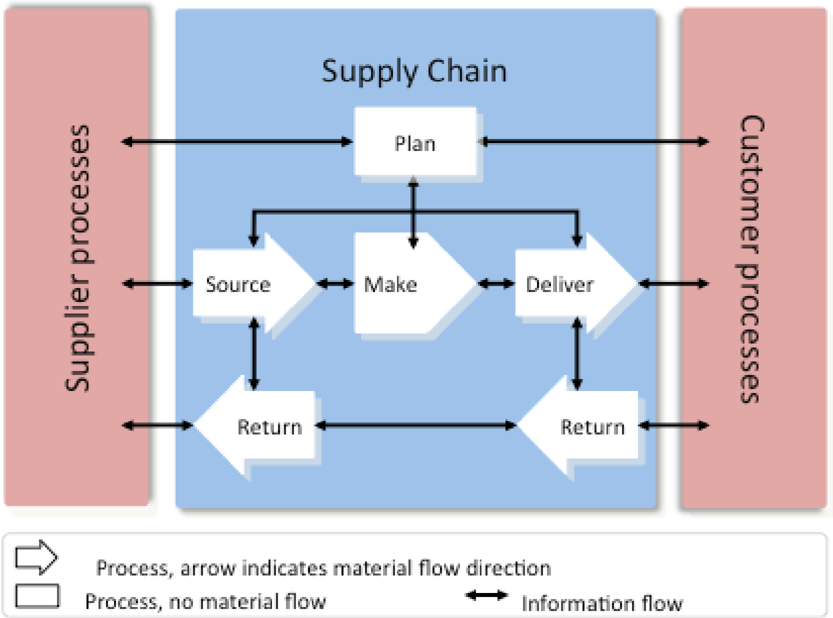

Figure 2-1: Elements of the SCOR Model

As Figure 2-1 illustrates, the SCOR modelling approach starts with the assumption that any supply chain process can be represented as a combination of the five following basic processes [59]. These are explained in some detail in Annex C: SCOR.

Plan: this process targets Demand/Supply Planning and Management and its purpose is to balance demand and supply to best meet the sourcing, manufacturing and delivery requirements. In particular, the process:

- Balances resources with requirements and establish/communicate plans for the whole supply chain, including Return, and the execution processes of Source, Make, and Deliver.
- Manages business rules, supply chain performance, data collection, inventory, capital assets, transportation, planning configuration, regulatory requirements and compliance, and supply chain risk.
- Aligns the supply chain unit plan with the financial plan.

Source: this process procures goods and services to meet planned or actual demand. This process targets Sourcing Stocked, Make-to-Order, and Engineer-to-Order Product and procures goods and services to meet planned or actual demand. The process:

- Schedules deliveries; receive, verify, and transfer product; and authorise supplier payments.
- Identifies and selects supply sources when not predetermined, as for engineer-to-order product.

- Manages business rules, assess supplier performance, and maintain data.
- Manages inventory, capital assets, incoming product, supplier network, import/export requirements, supplier agreements, and supply chain source risk.

Make: this process transforms a product to a finished state to meet planned or actual demand. It targets Make-to-Stock, Make-to-Order, and Engineer-to-Order Production Execution to achieve its purpose it transforms product to a finished state to meet planned or actual demand. The process:

- Schedules production activities, issue product, produce and test, package, stage product, and releases product to deliver.
- Finalises engineering for engineer-to-order product.
- Manages rules, performance, data, in-process products, equipment and facilities, transportation, production network, regulatory compliance for production, and supply chain make risk.

Deliver: this process targets Order, Warehouse, Transportation, and Installation Management for Stocked, Make-to-Order, and Engineer-to-Order Product. The process:

- Provides all order management steps from processing customer inquiries and quotes to routing shipments and selecting carriers, including warehouse management from receiving and picking product to load and ship product.
- Receives and verifies product at customer site and install, if necessary.
- Manages invoicing customer.
- Manages delivery business rules, performance, finished product inventories, capital assets, transportation, product life cycle, import/export requirements, and supply chain delivery risks.

Return: this process targets Return of Raw Materials and Receipt of Returns of Finished Goods. This process is associated with returning or receiving returned products for any reason. It extends into post-delivery customer support. Particularly, the process:

- Is associated with returning or receiving any returned defective or excess products from source.
- Manages return business rules, performance, data collection, return inventory, capital assets, transportation, network configuration, regulatory requirements and compliance.

SCOR processes exhibit the following characteristics [59]:

- They provide a balanced horizontal (cross-process) and vertical (hierarchical) view,
- are designed to be (re)-configurable,
- are used to represent many different configurations of a similar process, and
- can aggregate a series of hierarchical process models.

The SCOR framework has been widely used to model supply chain network structures and operations for strategic planning purposes. However, it is seldom leveraged for the design and implementation of collaborative manufacturing networks. Furthermore, while performance monitoring is critical to the measurement and improvement of supply chains, there have been little efforts focused on performance monitoring systems for collaborative manufacturing networks. These are explored in the context of the DMN Lifecycle in section 4.

2.2.2 Business Process Modelling Notation 2.0

It is evident that business process modelling requires a notation that is readily understandable by all types of users. This includes the business analysts and modellers who create the initial drafts of the processes in an SOA-based application to the technical developers responsible for implementing the technology that will perform those processes, and, finally, business people who will manage and monitor those processes. A major improvement would be if the business process modelling activity would lead to the execution of the modelled business processes in some standard business process execution language such as, for example, BPEL. In this way, a standardised bridge can be created for the gap between the business process modelling and design and process execution. These are precisely the primary goals of the Business Process Modelling Notation (BPMN) effort.

Business Process Modelling Notation is an attempt at a standards based business process modelling language that can unambiguously define business logic and information requirements to the extent that the resultant models are executable [45]. The goal of BPMN is to provide a business process modelling notation that is readily usable by business analysts, modellers, technical developers and business people that manage and monitor these processes.

In essence, BPMN provides a standard visualisation mechanism for business processes defined in an execution optimised business process language. BPMN provides a rich set of semantics that provide a tool for capturing the complexity of an information rich SOA development project. This modelling notation contains notations and semantics for capturing workflows or sequences of activities, decision points and prerequisites, information transformation and flows, collaborations among multiple entities and actors. BPMN is a compelling choice for modelling and document SOA development projects for the following reasons:

- It is an intuitive and expressive process-centric visual notation, which has precise semantics.
- BPMN is supported with an internal model that enables the generation of executable Business Process Execution Language processes. It also maps to other process notations such as XPDL[2].
- Its event and temporal notation lends itself naturally to SOA's event-driven design.

An important characteristic of BPMN is that it not only a modelling notation but also provides a mapping that generates execution definitions in BPEL that can used to implement the modelled business processes. As such BPMN positions itself as a bridge between modelling and execution and between business analysts and systems developers and programmers that support the business.

More details and examples of use of BPMN 2.0 can be found in Annex D.

[2] XPDL Support and Resources, available from: http://www.wfmc.org/xpdl.html

2.2.3 The ISO 10303 – STEP Standard

In this section we provide a brief description of the STEP standard, which stands for "Standard for the Exchange of Product model data"[3]. STEP is used to manage technical product data and serves as a foundation to define the data exchanges as regards the product blueprint. Since this standard is widely accepted by a large number of industries, we deem that reusing the constructs that are already put available is beneficiary for later interoperability purposes. Thus, by using STEP, it is easier to assess partners and see whether they respond to the preconditions and constraints set up by this blueprint.

The overall objective of STEP is to provide a mechanism that describes a complete and unambiguous product definition throughout the lifecycle of a product. STEP provides both broadly useful data modelling methods and data models focuses on specific industrial uses.

The STEP standard contains several dozen separate documents. The purpose of STEP is to specify a form for the representation and unambiguous exchange of computer-interpretable product information throughout the life of a product. It also includes the related elements involved in the development of the product such as resources.

Due to its complexity, STEP is divided into individual documents called "Parts". These Parts are numbered so that all Parts of the same type fall in the same number range. For example we can list:

- Application protocols (201-299) – These are the Parts intended for implementation in industry. Each application protocol includes several documents.
- Application modules (1001-1999) – These are similar to miniature application protocols. An application protocol can be built by including usually a large number of application modules. Using application modules is a more recent architectural approach.

For building the product blueprint we use customised elements extracted from the AP 236 and its related parts.

[3] SCRA Step Application Handbook ISO 10303 Version 3, North Charleston, June 2006, http://www.uspro.org/documents/STEP_application_hdbk_63006_BF.pdf

3 Demand-driven Manufacturing and Production Schedules

Traditional manufacturing simply starts with the manufacturing regardless of the requirements for that product, and then pushes to the next step, which could be the selling in the market. The disadvantage of this approach is the overproduction because the production is carried out without an actual consumer requirement. At the end of this process, manufacturers might have a large stock of products for which there may be no actual demand in the market [27]. This section describes the notion of demand-driven manufacturing for networked firms and its association with the DMN lifecycle model.

3.1 Demand-driven Manufacturing

In contrast to the standard manufacturing approach described above, pull, or *demand-driven, manufacturing* requires that manufacturing be performed when demand is confirmed, i.e. being pulled by demand. The customer demand will pull the products from the manufacturing facilities in a manufacturing network. Demand-driven manufacturing reduces overproduction. Only the required amount is produced in every stage. Altogether this makes a manufacturing system with very high flexibility and no waste. Manufacturing system will be very highly responsive to the customer requirements and will be closely related to the market dynamics. Demand-driven rather than supply-driven manufacturing meets the needs of a dynamic marketplace by building products to order rather than investing in large inventories, building products to stock and attempting to create customer demand. The advantages of this approach can be summarised as follows [1]:

- reduced inventory levels (raw materials, work in process and finished goods);
- reduced shop-floor space;
- reduced lead times;
- increased productivity;
- smoother production flow;
- reduced total costs;
- higher production visibility.

Demand-driven manufacturing by its very nature necessitates rethinking traditional manufacturing methods in favour of lean manufacturing principles, a highly efficient and collaborative supply chain, rapid order turnaround, and the efficient deployment of resources. In this environment, the focus shifts from individual partners to a holistic approach that emphasises throughput of the entire manufacturing network.

IMAGINE leverages the concept of lean manufacturing, which is the very foundation of the demand-driven manufacturing concept. Such a move to a lean manufacturing environment necessitates a re-thinking of manufacturing processes and the better utilisation of all available assets especially in the context of geographical distribution of manufacturing partners. This is necessary to ensure that greater efficiency and control are applied over manufacturing processes in order to streamline them. The objective must be centred on integrating the demands of the customer and translating these to a specific production schedule (see next section), which is then executed in a configurable manufacturing network while eliminating waste and optimising resources. This enables a coordinated and performance-oriented manufacturing enterprise that quickly responds to the customer and minimises energy and material usage while maximising environmental sustainability, health and safety, and economic competitiveness.

The concept of on-demand manufacturing is greatly assisted by the DMN Lifecycle and the blueprint model for manufacturing, which is a model-based, knowledge-enabled environment that addresses a full spectrum of enterprise product, operational and management life cycles and helps manufacturers to have production systems built to support production agility that responds to individualised demand-driven customer requirements (please refer to section 4.3 for a definition and description of the IMAGINE blueprint model).

3.1.1 Manufacturing Network Production Schedule

To maximise the chances of success, a DMN needs to ensure that products deliver the specific capabilities defined not only by customers but also by how the product will operate as a system. Understanding the product in the context of a system will produce a set of requirements that will determine what the production system does and how it does it.

An essential element of the DMN is a detailed *network production schedule* produced on the basis of a consumer demand taking into account the capacity of production lines and focusing on the efficiency of the production process. The network production schedule is the central control instrument of production and contains information about needs to be produced and when it is going to be produced, such as a production plan. In it the individual steps of production are defined for each production article in the form of work sequences involving resources, humans, and operation-equipment combinations [40]. It also contains production performance information about what and how much has been produced and which people and resources need to be used to achieve so.

The production schedule produces a work plan that determines "what" is going to be produced and "how" *it will be produced*. In addition, the production personnel, resources needed, i.e., with "what" the product will be carried out, and time data - in other words "when" (vis. production time) individual parts of the production will be produced and work scheduling, i.e., how production parts will be sequenced and assembled into a concrete product.

The general functions of production scheduling typically include [23]:

- the determination of production schedule;
- the identification of long-term raw material requirements;
- the determination of the pack-out schedule for end-products.

Frequently occurring influencing factors for a network production schedule may include [40]:

- Customer order attributes:
- Delivery date
- Delivery quality
- Product attributes:
- Actual work plans and part lists
- Alternative work plans and lists
- Production process attributes:

- Minimum or maximum intervals between the process steps
- Transport times
- Waiting times (e.g., cooling or maturing process)
- Production resource attributes:
- Current resource allocation
- Availability or resources
- Availability of quality assurance resources (e.g., test stations, laboratory practises, etc.).

Consider as an example a production request to an OEM for 200 painted mid-market sedan panel doors and the shop floor production schedule corresponding to this request as described below.

The production schedule may specify that robots must be used on an assembly line to fix interior door panels to the exterior door sections by applying a thin bead of adhesive to the exterior section and then compressing the interior section onto the exterior panel. It may also specify that operators must load the door panels onto a track where they are then assembled by the robots. The production schedule may specify that the assembly line consists of three process segments[4]: edge-wrapping, laser trimming and ultrasonic welding performed as follows [57].

Assembly starts with a flexible edge-wrapping machine for the upper door panels. A robot must apply a bead of adhesive and then pull and push a vinyl cover stock over the substrate. Pneumatic actuators hold the cover stock under pressure for an adjustable time period to wet out and set the adhesive.

Next, the panel's head to the flexible laser trim cell. This cell has a two-station rotary indexer and two six-axis robots, each equipped with 500-watt fibber lasers. The robots must work in tandem to trim the periphery of the product, as well as the inner openings where mating components interface to the panels. The indexer allows an operator to load and unload parts, while the robots are working in the opposite station.

The final process segment is ultrasonic welding. This cell also features a two-station rotary indexer. Using ultrasonic spot welding and staking, the cell joins the upper panel with the rest of the door trim, including the lower panel, map pocket and two sets of energy-absorbing foam.

Production and performance requirements for this production schedule must specify that:

- The upper panel is moulded from polypropylene and wrapped with a vinyl cover stock. The vinyl is bonded to the polypropylene with a moisture-curing hot-melt adhesive. The lower door panel is also polypropylene.
- To minimise cycle time, the assembly system must maximise the number of points that can be welded in a tight area. The front door has 37 welding points; the rear door has 29.
- Each cell should be equipped with sensors to ensure that parts are present before a machine cycle is started.
- The recommended production rate is two parts per minute, to match the moulding cycle time.

[4] See section 4.2.2 and 4.3.3 for a definition an examples of a process segment.

Production schedules such as the one considered above are closely associated with the product blueprint (see section 4.3.3) and help with:

- *Process and Operations Scheduling and Synchronisation*: this includes the functionality of providing the sequence and the timing of operations based on priorities, attributes, characteristics, and production rules associated with specific production equipment and specific product characteristics, such as shape, colour combinations or other requirements that, when scheduled properly in detail, will tend to minimise set-up time and effort. Operations and detailed scheduling take into account the finite capacity of resources and consider alternative and/or overlapping/parallel operations when detailing the timing of equipment loading and the particular adjustments to accommodate shift patterns. It aims at synchronising the process chain by means of the parameters in the work plan to minimise processing time. This means, among other things, avoiding idle times and waiting times (e.g., minimising storage costs for the production warehouse) while simultaneously considering resource requirements.
- *Achieving collision-free planning of a production request:* this is achieved by taking into account the specified equipment, staff or resource allocation priorities and rules.

Production scheduling functions interface to the manufacturing operations and control system functions through a production schedule, actual production information, and production capability information stored in the product and end-to-end process blueprints (see sections 3 and 4). This information exchange is presented in the production control functions. This includes the listing of the raw materials consumed, materials produced, and materials scrapped. It also includes the discussion of how long segments of production take and how much material can be produced and consumed by specific segments of production. This information is can be generally used to track actual production against production requests during execution time (phase-III of the DMN Lifecycle).

4 Bringing it all together: the IMAGINE Lifecycle Model

4.1 Introduction to the DMN Lifecycle

Product manufacturing is a value-creation activity that is realised by means of a controlled production workflow. The trigger for the development is normally an individual customer demand. To understand the DMN Lifecycle we must first understand the phases in Product Lifecycle Management and relate with the phases in the DMN Lifecycle. This is explained below. Following this we shall first describe the DMN Lifecycle and then the IMAGINE Manufacturing Blueprint model.

4.1.1 Brief Overview of PLM Phases

When we look at PLM we find that it is traditionally broken down into five broad phases: planning, design or definition, realisation, support and retirement [50],[58]. These can be summarised as follows:

- In the planning phase, data from brainstorming sessions, collaborations, and meetings is stored and associated to the relevant product(s) for quick and easy retrieval. Retaining such information can prove useful for developing the current and future product lines.
- In the design phase, the requirements and specifications generated from the previous phase can be easily retrieved and be used to further define the product. The product may be modelled in CAD software and the 3D computer models built in CAD can be stored in a data management application (e.g., PDM) that is part of the overall PLM software solution.
- During the realisation phase of the product lifecycle, manufacturing engineers, machine shop floor managers, fixture designers, quality engineers, etc., will use CAD data stored in the company's PLM software solution to perform their duties, such as determining how to build the product.
- In the support phase, marketing and sales use any product information to promote and further describe the product and all product issues, while complaints, and suggestions are stored in a PLM application to ensure that they are managed and dealt with appropriately. Some fixes and upgrades will be incorporated into the current product, while others may be postponed until the next generation of products is designed; regardless, that valuable information can be retained for present and future use all within the company's PLM applications.
- Finally, in the last phase, retirement, information about the material composition of a product, for example, can be stored and retrieved in a company's PLM software to help determine how the physical product can be safely disposed of and possibly recycled.

4.1.2 Characteristics of the DMN Lifecycle

The DMN Lifecycle operates in an analogous manner. Its central element is an entire manufacturing network and its associated manufacturing processes as opposed to a product - as in the case of the PLM lifecycle.

The combination of Service-oriented and Business Process Management technologies with manufacturing principles – as championed by IMAGINE – emphasises placing the actual focus on manufacturing processes and viewing them end-to-end, not as disconnected single-function procedures.

The IMAGINE lifecycle takes an end-to-end process centric view where processes cross functions, departments, partners and actors within a DMN. It pulls together hitherto separate or silo-ed processes and associated support systems, such as product development, quality, procurement, supply chain, manufacturing and service operations. These can now evolve to deliver significant incremental value to DMN partners by achieving seamless system and process integration with their extended supply base, suppliers, trading partners and 3PLs. Bringing all of these activities together under the auspices of a single operational framework is critical to providing product development teams with the ability to access pertinent manufacturing information end-to-end for decision making in order to improve product development, eliminate delays and reduce development cycle times and cost. Such concerns are the cornerstone of Manufacturing Enterprise 3.0 guiding principles [36] which promote the use of a holistic, process-centric management approach across the extended enterprise/value chain using precisely defined and supported business processes.

To support its DMN Lifecycle phases that will be described later in this section with sources of knowledge, IMAGINE has developed a product blueprint model that includes diverse views on partners, products and quality aspects of manufacturing. The blueprint model, although generic in nature, can be tailored specifically to the way in which a DMN works for a particular sector, e.g., automotive, aerospace, furniture construction, etc. The blueprint model is divided into a suite of standard industry processes and sub-processes, products these processes manufacture, assets such as plant machinery, production line equipment, intellectual capital, as well as a suite of Key Performance Indicators (KPIs) that govern the quality of the final products, to provide a holistic view of an entire DMN. In this way, it is possible to use the blueprint model as a springboard for creating and supporting effective DMNs targeting diverse industry sectors.

4.2 The DMN Lifecycle Model

The DMN Lifecycle model leans on a stratified architecture to manage a dynamic manufacturing network in a controlled and well-organised manner. This architecture encompasses five conceptual layers that are interlaced with the DMN Lifecycle. Figure 4-1 captures the basic fabric of this architecture.

The top three level layers address the management of manufacturing operations, whilst the two bottom level layers represent the shop floor manufacturing operations. At the highest level in this architecture the dynamic manufacturing network is managed as a structured network of interconnected nodes with predefined inputs and outputs that may reflect material and information flows between network partners. The network is managed through a series of end-to-end processes that not only comprise manufacturing operations, but also other processes including inbound and outbound logistics. These end-to-end processes are coordinated through choreographies that specify exactly when a particular party in the network has to perform a particular manufacturing operation, providing end-to-end visibility of their progress against predefined performance objectives. Where choreographies are used to control global processes, orchestrations manage operations at the level of discrete nodes in the network, e.g., production sites or manufacturing lines. Such orchestrations may either plan or control local manufacturing operations, or other business processes such as logistics and planning. Process segments sit between (and connect) the manufacturing operations management strata with the shop floor work units. They are used to control tools, machinery, equipment and people at the shop floor level to manufacture the requested product on time and in coherence with other agreed-upon quality criteria.

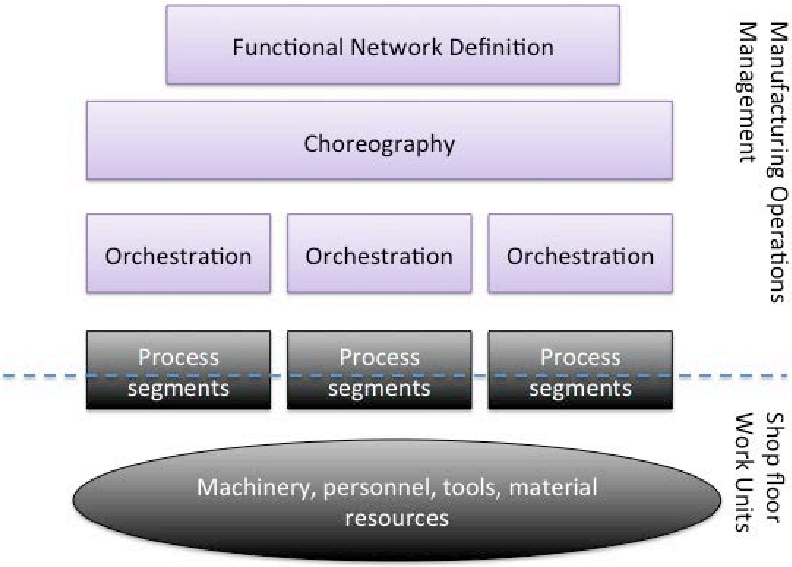

Figure 4-1: Anatomy of a Manufacturing Network

As explained in section 3.1, the DMN Lifecycle and subsequent formation of a manufacturing network is triggered usually by a consumer request and takes into account appropriate manufacturing resources and infrastructures, involving human actors, organisations, production systems and manufacturing processes that need to be pooled together to implement the required end product.

The DMN Lifecycle encompasses the following three main phases:

- Network Analysis and Configuration
- Network Design
- Network Execution Management and Monitoring[5]

The above three phases and their steps have been organised into the DMN Lifecycle model, which is depicted in Figure 4-2. Indeed, these phases collapse some of the broad phases in PLM. For instance, the network analysis and configuration phase is inspired by the PLM planning phase, whilst the design phase synthesises parts of the PLM design and realisation phase. Lastly, the network execution management and monitoring phase amalgamates and extends some elements of the PLM support and retire phases.

[5] The term execution management replaces the term governance in the DoW as it more faithfully represents the key activities in this phase. This decision was based on the literature review that was reported in D1.1.1 (Compendium).

Figure 4-2 illustrates the three phases and their respective steps and inputs. The manufacturing network lifecycle is initiated by a customer request (see left-hand side of this figure) that outlines the number of products that need to be produced, and the timeframe in which the product(s) should be ready.

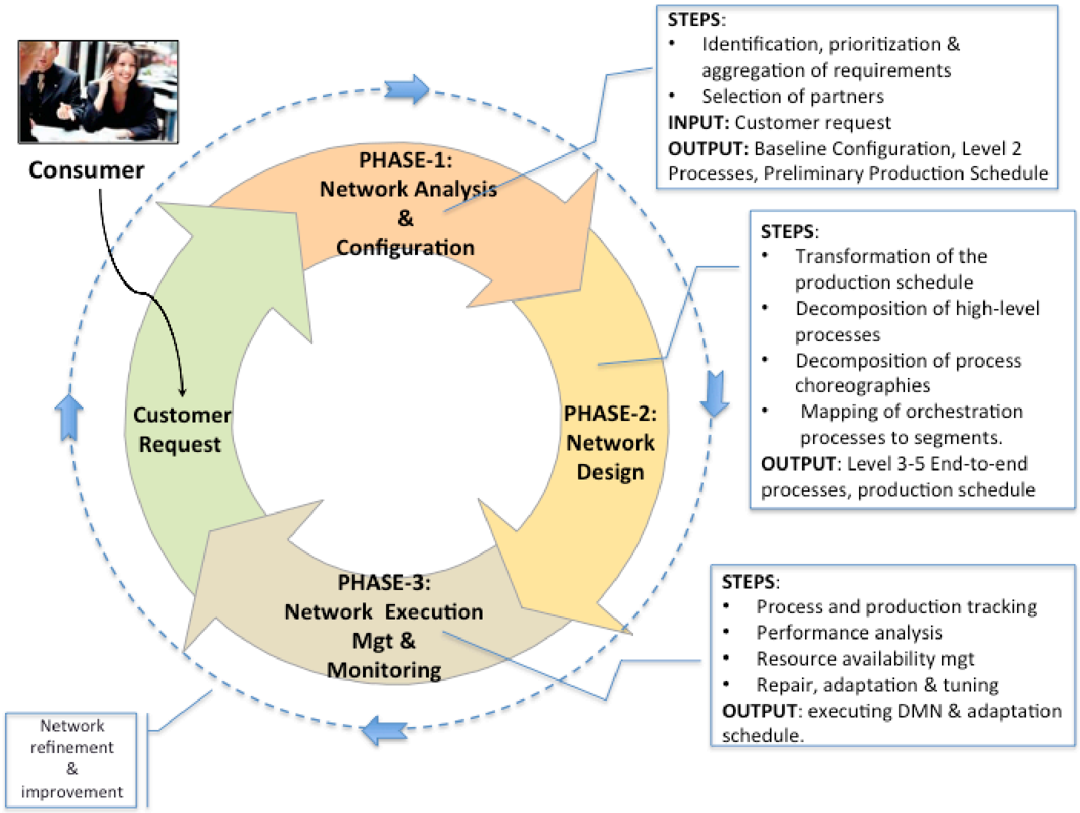

Figure 4-2: Synoptic view of the DMN Lifecycle phases & their steps

The following table describes the DMN Lifecycle phase inputs and outputs.

Table 4-1: The DMN phases and their inputs and outputs

DMN PHASE	INPUT	OUTPUT
Manufacturing Network Analysis & Configuration	• Customer request	• Baseline Network Configuration • Level 2 Processes (Functional Network definition in Figure 4-1) • Preliminary Production Schedule
Manufacturing Network Design	• Baseline Network Configuration • Level 2 Processes • Preliminary Production Schedule	• Final Network Configuration • Level 3 Processes (choreography), • Level 4 Processes (end-to-end orchestrations) • Level 5 Processes (end-to-end process segments) • Final Production Schedule – including scheduling and coordinating resources, equipment, personnel, materials
Manufacturing Network Execution Management & Monitoring	• Final Network Configuration • Level 3, 4, and 5 processes • Final Production Schedule	• Executing DMN • Adapted/improved Network • Adapted/improved Production Schedule

4.2.1 Phase 1: Manufacturing Network Analysis and Configuration

This phase involves the planning of a manufacturing network (i.e. network of those service providers whose composition of services delivers the final product) on the basis of a customer request and network available expertise and resources, including equipment, processes and products ensuring increased manufacturing flexibility, optimal manufacturing and market responsiveness. This phase allows for partners who have shared interests to inter-link with each other and work more closely to:

- Share each other's resources, e.g., specialised equipment, human expertise, and competencies.
- Avoid the vulnerability of carrying business costs in areas of incompetence.
- Partner to overcome weaknesses in areas with deficient competence.
- Leverage the areas in which they have core competence.

The network analysis and configuration has many similarities and parallels with supply chain planning. Supply chain planning means the activities that focus on evaluating demand for material and capacity, are considered together with the processes of formulating plans and schedules to meet demand and company goals [19]. This mechanism includes the essential features to improve the balance between demand and supply, as has been described by other authors, e.g. [31], and [68].

There are two basic types of supply chains [14]: *effective*, which aims at cost effectiveness and lean operations, and *responsive*, which aims at adapting the supply chain according to customer demand. In this model products can be considered to be functional, requiring efficient supply chains, or innovative, which are best managed in a market-responsive supply chain.

Supply chain planning solutions were considered in the framework presented in [28] who proposed that planning capability and production capability need to be synchronised. They suggested that both planning and production capabilities should support each other. If planning reacts more quickly than the production capability, the supply chain is in a mismatch situation; resulting in frequent plan changes, which wastes planning resources. On the other hand, resources are wasted, because unnecessary physical capabilities are maintained in the supply chain. These may be in the form of flexible production capacity that cannot be utilised due to inadequate information.

Several studies argue that supply chain planning techniques are hugely affected by technology choices. For instance, the choice of implementing the right technology in the supply chain is a topic examined by Singh et al. [55] who propose that technology decisions should be aligned with the nature of processes, the use of technology and nature of supply chain technology. Using a similar line of argumentation Jonsson et al. [26] provide a comparative case study of how the use of advanced planning systems impact planning effects.

From the previous studies it can be seen that the determinants that affect the choice of a planning approach in supply chains are related to market and product characteristics. Demand and product variability, and customisation appear to be crucial determinants for the selection of a supply chain strategy and supply chain-planning solutions. These become also crucial determinants of the IMAGINE manufacturing network analysis and configuration phase.

In IMAGINE the purpose of the network analysis and configuration phase is to identify and aggregate all sources that can serve as a basis for forming an integrated manufacturing network. Such sources (called *network partners*) are involved in the delivery of parts of a product at the appropriate quality level, production times and delivery dates. Figure 4-2 shows that outputs of this phase include: a Baseline Network Configuration, Level 2 Processes (which correspond to Functional Network definition in Figure 4-1) and, a Preliminary Production Schedule. These are described below.

During the network analysis and configuration phase in the DMN Lifecycle a *baseline configuration* of the virtual production network is achieved by selecting appropriate network partners on the basis of their profiles, material and preliminary products, product components they produce and the partners' competencies. Such information is captured in a partner and product blueprints (see section-4.3.3 below). Baseline configuration of the network includes a high-level description of the partner processes (corresponding to Level-2 of the SCOR model) and the way in which they are interconnected through information- and material flows.

In addition, this phase describes a preliminary production plan and schedule including material planning to guarantee availability of products between partners, and capacity planning to allow for an overall sufficient capacity. The preliminary production plan considers issues such as material requirements, calendar, production capacities constraints, warehouse capacity, and quotas. This rough-cut production plan is further refined into a detailed planning, e.g. a detailed shop floor resource planning, in phase II of the DMN Lifecycle.

Main steps in this phase concentrate on the following (see also Figure 4-2):

- Registration of interested enterprises which need to fill out partner blueprints. Potential partners may register themselves in a Partner Blueprint Registry, stating basic information such as their key competencies and track record, which can be evaluated by other partners.
- Identification and prioritisation of DMN requirements that result from the customer request. During the second step, the customer request is decomposed into a set of high-level requirements for the DMN. These involve requirements for the production resources, timing and scheduling. These requirements are then prioritised. The prioritised list of requirements serves as the basis for the selection of partners in the following step.
- Selection of partners. This means identify, assess, and aggregate DMN partners on the basis of profiles / resources offered. The selection of partners follows a three-step approach during which information available about the network partners grows, whilst the number of potential combinations of partners in a network coalition converges from many to one. Selection comprises the following three stages:
    - Long-list of potential network partners (Qualification) based on the product requirements, a rough pre-selection is made of potential partners that could contribute to the production of the requested product, e.g., on the basis of industry sector, financial stability and global capabilities. This activity is related to sorting rather than ranking, based on a minimal set of generic criteria, and results into a moderate initial set of partners. Techniques that may be used include: data envelop analysis models, cluster analysis models, categorical models and artificial intelligence models [73].
    - Short-list of potential network partners (Pre-Selection): based on the prioritised list of DMN requirements, a short-list of potential partners is created. Various compositions of potential partners will be created- e.g., three to five different configurations of the

network. This activity is related to ranking rather than sorting taking into account many criteria.

  - Final selection: this will involve the final selection of network partners. Final selection will be based on DMN Living Lab scenarios, and the drafting of Service Level Agreements reflecting the business strategy at the level of the partners and the network as a whole. Techniques that may assist in decision-making revolve largely around simulation relying on discrete event simulation or system dynamics models.

- Creating a DMN baseline model. During this step, high-level material- and information flows between the trading partners will be analysed and modelled. This baseline model conforms to models at SCOR-level II. In addition, this model will contain a description of the KPIs at the level of the network and partners. IDEF-0 is an example of a modelling notation that is catered for modelling DMNs at this level of abstraction.
- Deriving the preliminary network production schedule. The final step in this phase is to create a DMN production schedule that schedules all the high-level partner processes, modelled during step 4. This production schedule helps the DMN partners obtain information about when certain processes should start and end, which resources are needed (including, tooling, human, labour and material constraints). This production schedule will help in simulating the network in the long run, and across the entire network- thus over various partners and production sites, and to judge whether the network will be able to support the strategy of partners as expressed in KPIs.

Network configuration and analysis is performed mainly on the basis of partner and product blueprints (see section-4.3.3 below). The partner blueprint basically captures key competencies, product descriptions and resource capacities of potential network partners that are stored in a partner blueprint repository. The product blueprint provides complete knowledge of the product's to better understand the product manufacturing process, its characteristics and supply situation.

4.2.2 Phase 2: Design of Manufacturing Network

The infrastructure required to support DMN manufactured products is typically complex. It requires a modelling and design strategy that supports the entire production system and flows - not only the physical product but its connection with its environment. By modelling the entire production network early in the DMN Lifecycle partners can simulate various product and architectural alternatives early in the development process when changes are much less expensive.

From the manufacturing network and production models, partners can perform trade studies to determine which design choices make the most sense and predict behaviours of the network and its structures and processes. Having determined a set of behaviours, we can then create logical structures (vis. blueprint) to support those behaviours and map product capabilities to specific processes and parts of the manufacturing network. This may require a variety of models to help with understanding of the configuration and inter-linking of isolated core manufacturing processes into an end-to-end chain. With an overall design of an entire manufacturing network and the processes it supports in place, a DMN can then be deployed to achieve production.

To the above end, IMAGINE DMN modelling and design provides modelling and simulation mechanisms that allow an understanding of the manufacturing network as a whole, preventing situations in which the overwhelming network complexity can obscure the big picture. This allows architectural decisions to be made intentionally while providing a sound mechanism to ensure that the product addresses customer requirements at all stages of development. This is the main thrust of the second phase in the DMN Lifecycle.

The network design phase is where approved processes are designed and architected to ensure that they deliver the agreed capabilities to its users. It is during this phase that end-to-end processes must be architected correctly to achieve the agreed warranty and utility of the entire manufacturing network. The design phase of the manufacturing network concentrates on streamlining manufacturing processes by modelling, simulating and mapping the process flow to reveal optimal paths from beginning to end, which is then followed by analysing and measuring process performance on an end-to-end perspective.

As described in Table 4-1, the design phase in the DMN Lifecycle takes as input the configuration layout of the DMN and the preliminary schedule as a starting point for the design of detailed end-to-end manufacturing processes. This phase involves the profile-driven design of manufacturing networks, providing control over processes and data content delivered by diverse network participants, including stipulating network performance, accessibility, resource utilisation, etc. and preventing risks. Aim of this phase is to design a manufacturing network comprising well-defined standard end-to-end processes, the movement of product information and material exchanges between processes, as well as KPIs that govern the execution of processes.

Typical manufacturing processes considered during this phase may include:

- Production processes: Process routings and recipes; weighing, mixing, manufacturing, processing and packaging; standard operating procedures; assembly work instructions.
- Supply chain processes: Orchestration of enterprise manufacturing processes, including collaboration with departments and trading partners.
- Warehouse processes: Material receiving procedures, material replenishment of production lines and other warehouse and inventory management processes.
- Maintenance processes: Maintenance procedures and work instructions, such as periodic device control and calibration.
- Business IT-centric processes: Information integration workflows, such as reporting production (good quantity, scrap quantity, machine time) against order to ERP.
- Kanban processes: Controls production and material flow and of material in work in process (WIP) that can be kept between any two operations in a process based on the actual stock quantity in production [2]. Replenishment or the production of a material is only triggered when a higher production level actually requires the material.

As component manufacturing (batch production) and assembly (flow production) pose different operational requirements [53], we shall concentrate mainly on two types of manufacturing processes that exhibit different characteristics:

Batch production processes: The term batch refers to a specific group of components, which go through a production process together. As one batch finishes, the next one starts.

- Batches are continually processed through each machine before moving on to the next operation. This method is sometimes referred to as 'intermittent' production as different job types are held as work-in-progress between the various stages of production. These are particularly suitable for a wide range of almost similar goods, which can use the same machinery on different settings.
- *Flow production processes*: Flow production is a continuous process of parts and sub-assemblies of fairly standardised products passing on from one stage to another until completion. Units are worked upon in each operation and then passed straight on to the next work stage without waiting for the batch to be completed. To make sure that the production line can work smoothly each operation must be of standard lengths and there should be no movements or leakages from the line, i.e. hold-ups to work-in-progress.

In the network design phase processes are modelled, simulated prior to execution in rapid fashion, to mimic actual operating conditions to truly evaluate potential improvements and benefits. Service technology can accelerate this undertaking by coordinating and synchronising resources and materials; routing tasks to people; machines and backend business IT systems; integrating data across the stovepipes; responding to events; and monitoring process performance.

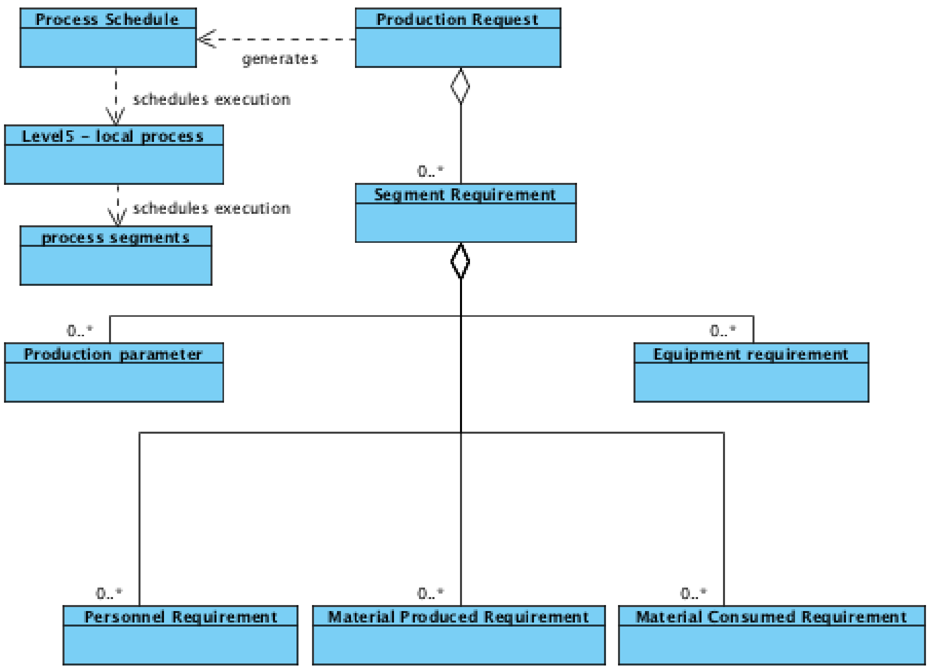

Figure 4-3: The network production schedule meta-model in UML

As Table 4-1 illustrates, this phase helps transform the production schedule into a sequence of end-to-end processes and production flows that take place between different partners in the network to fulfil a consumer need for a specific product. As already explained in section 3.1.2 production schedules are triggered by consumer driven production requests or orders. As a minimum, production requests have start/end times, identification of the product to produce and the amount to produce. Information is often included in a production schedule (shown in Figure 4-3). The granularity of a production request is application specific. Examples of production schedule granularity are:

- A production schedule may contain high-level production orders for an entire manufacturing network, a process or process segment.
- A production schedule may contain production orders which are subdivided into multiple parts where each part may address production requirements for a component in a plant or process segment.

Figure 4-3 depicts how a customer-driven production request – shortly referred to as a customer order - is instrumental in production scheduling. The production schedule plans the timing of the execution of local processes that conform to level 5 SCOR processes and that may contain shop-floor working instructions. The production request in itself may contain personnel, material produced and consumed, and equipment requirements, as well as production parameters.

The design of the DMN has different levels of interest. The driver of the DMN design is the strategy the network partners have agreed to follow. On this level, the partners agree on a strategy (e.g., prioritisation of products and customers) and controlling issues (e.g., processes and common performance indicators). These decisions are the drivers of the design of the other levels. For instance, on the level of material flow, physical properties of the network are designed, i.e., decisions upon the existence of plant sites, warehouses and distribution centres, the transportation links between these components and their capacities are made.

Main steps in this phase concentrate on the following:

- Creation of a detailed network production schedule on the basis of the baseline network configuration that was produced during phase I.
- Transformation of the production schedule into corresponding production orders that are performed by high-level processes (corresponding to SCOR level 2) that span multiple network partners and are used to move information and materials from network partner to partner.
- Decomposition of high-level process created during the previous step to SCOR level 3 end-to-end processes (choreography) at functional and non-functional level. This involves balancing partner resources with respect to QoS requirements.
- Decomposition of process choreographies from the previous step into more detailed processes (orchestrations).
- Mapping of orchestrated processes into detailed process segment implementations to define inputs-, outputs- and functionalities of the process segments.

Many of the above issues affect distributed resources across physical and logical sites. They can include remote production sites, distribution centres, wholesalers, carriers, brokers and suppliers. Therefore, to have effective manufacturing network solutions, these manufacturing aspects need to be properly designed and instilled into production and distribution functions by means of end-to-end process formations that are designed during this phase. Then manufacturers can control the fulfilment process according to the most cost-effective and efficient approach that best serves their manufacturing network and customers.

Network design is performed mainly on the basis of the product, end-to-end process and Quality Assurance blueprints (see sections 4.3.3, 4.3.4 and 4.3.5,) which ties together the many discrete processes associated with all aspects of product development, inclusive of mechanical content, electrical content, embedded software, engineering calculations, and service procedures.

4.2.3 Phase 3: Manufacturing Network Execution Management and Monitoring

The DMN must track the use of resources and execution results to report on material consumption, labour utilisation, equipment utilisation, completion of customer orders, and other important measures of manufacturing performance.

The execution management and monitoring phase involves the realisation and actual deployment of a manufacturing network and the monitoring of its execution, e.g., detection of abnormal conditions, machine failures or KPI deviations, and its consistent adaptation to changing consumer demands, laws and regulations (e.g., carbon emission). Its aim is to monitor production processes and either automatically corrects or provides decision support to operators for correcting and improving process activities. It provides activity monitoring and analytical capabilities that enable some human agent to watch over manufacturing operations, diagnosing problems as they occur so as to ensure that the processes supporting a given manufacturing task are performing in accordance with service-level objectives. It aims to provide end-to-end visibility and control over all parts of a holistic manufacturing (production) process that spans multiple partners in a DMN.

To assist network execution a production schedule describes the information required to help execute production involving diverse network partners, resources on the basis of the sequence in which materials are processed and products are assembled and constructed. Of course, during execution of the production schedule passed forward from the design phase, the information used to create the schedule might change. Indeed, this is a common occurrence in several industry sectors. This phenomenon relates to what is known as *reactive planning* [18]. Reactive planning refers to the creation of a practicable DMN production schedule that has been designed to meet the conditions known at the time of network design. However, things may change at execution time. For example, customers might subsequently change their orders or the result might differ from the plan, perhaps in terms of the produced quantity or of the characteristics of the produced material. The DMN must react to deviations of this kind, and the reaction must occur at different partners and levels.

Overall the execution management and monitoring phase oversees the deployment, effective execution, monitoring and management of production schedules and associated end-to-end processes in DMNs. This phase uses information which is generated or modified on the basis of the production schedule that has been created in the design phase (see Table 4-1) and produces:

- An improved production schedule;
- Details about the actual production versus the planned production;
- Details about the production capacity and resource availability;
- Details about the current order status and execution of processes.

To effectively manage the manufacturing processes, a number of manufacturing key performance indicators (KPIs) need to be compiled (e.g. those proposed by various associations of the manufacturing industry [67]). Among these are:

- plant productivity KPIs, that may include equipment utilisation, lead time/cycle time, etc.;
- costs that may operational and inventory costs, and,
- product quality that may include audit grades, scrap rates and values.

In particular, this phase has the ability to monitor and manage end-to-end process performance by analysing such KPIs, and detect events that may influence performance. Analysing process efficiency and effectiveness and aligning process improvement with enterprise goals and objectives involves reacting to critical business events, correlating event data and updating KPIs, which were captured during the network design phase.

When this functionality is interlaced with KPI-designed dashboards, network managers can visually monitor and thus better manage the progress of individual work items in real time. Examples of KPIs that should be considered and accurately maintained during this phase include: capacity utilisation (a measure of how intensively a resource is being used to produce a good), internal manufacturing capacity, constraining processes, direct labour availability and key components/materials availability, and, lastly schedule achievement (the percentage of time that a plant achieves its production schedule), and so on.

Main steps in this phase concentrate on the following:

- Process and production tracking: this step includes the functionality of providing the status of production. Status information that may monitored during DMN execution may include personnel assigned to the work; component materials used in production; related to the product. This step provides the capability of recording the production information to allow forward and backward traceability of components and their use within each end product.
- Performance analysis: this step includes providing up-to-the-minute KPI reporting of actual manufacturing operations results along with expected results. Performance results may include such measurements as resource utilisation, resource availability, product order cycle time, conformance to schedule, labour needed to meet current demand and conformance to standards.
- Resource availability management: this step delivers functionality of maintaining equipment and tools. The functions ensure the equipment and tools availability for manufacturing. They also may include scheduling for periodic or preventive maintenance as well as responding to immediate problems.
- Repair, adaptation and tuning: The step contains two main functions: repair, adaptation and relocation of resources, which have the following characteristics:
    - Repair: This step involves discovering, diagnosing, and reacting to potential manufacturing process disruptions. It can detect process malfunctions and initiate corrective action without disrupting the existing DMN. Corrective action could involve altering a manufacturing process or effecting changes in partners in the environment.
    - Adaptation: This phase can also adapt to changes in the manufacturing environment, using configuration actions. Such changes could include the deployment of new partners or the removal of existing ones or changes in the process characteristics and network configuration.
    - Tuning: Finally, the tuning actions could mean reallocating resources – such as in response to dynamically changing workloads – to improve overall resource utilisation, or ensure that particular manufacturing processes are completed in a timely fashion.

Network execution management and monitoring is performed mainly on the basis of the product, end-to-end process and Quality Assurance blueprints (see sections 4.3.3, 4.3.4 and 4.3.5,) which ties together the many discrete processes associated with all aspects of product development, inclusive of mechanical content, electrical content, embedded software, engineering calculations, and service procedures.

4.3 The DMN Blueprint Model

4.3.1 Blueprint Model Overview

To support its lifecycle IMAGINE employs a manufacturing blueprint model, which is a source of knowledge central to its lifecycle that makes creative use of manufacturing "intelligence" gathered from every point of the manufacturing network. This knowledge may range from product information and consumer preferences through manufacturing, production and delivery mechanisms and can be used to improve decision-making and product portfolio management thus leading to shrinking development times and better quality for products. Purpose of the blueprint model is to improve product quality, and enhance the ability of manufacturing plants to collaborate to produce new products according to customer demands.

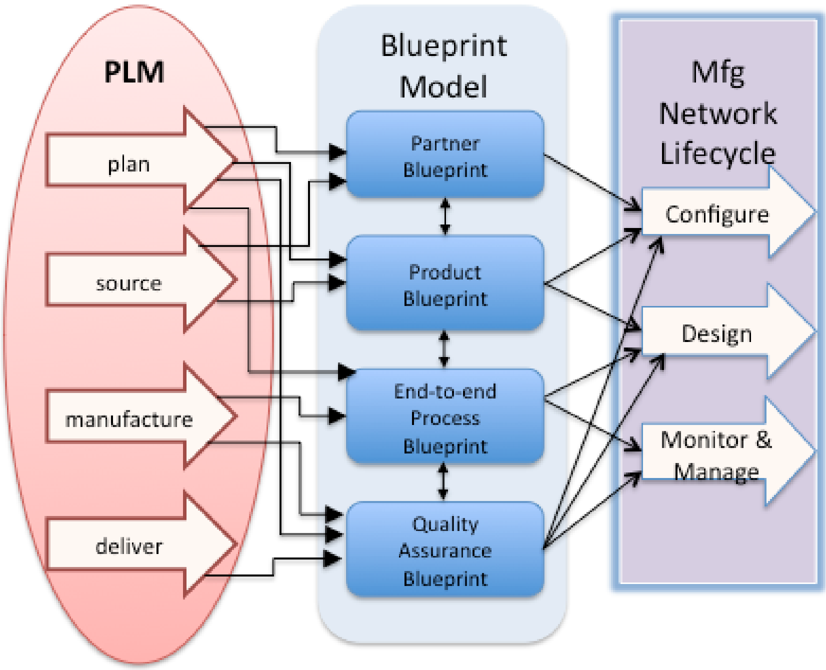

Figure 4-4: The IMAGINE blueprint model and its connection with the PLM and DMN Lifecycle phases

The key purpose of the blueprint model is to accumulate and modularise the knowledge needed to help manage enterprise resources, product life cycles, supply chains, partner relationships, operational planning, manufacturing process execution, compliance regulations and safety issues for the DMN Lifecycle. It is a container of any information, plans and processes needed for manufacturing production and support. This may include material specifications (such as composite structures), bill of materials, process specifications, and inspection data, which is critical to the model-based approach.

The blueprint model comprises blueprints for different aspects of manufacturing which assemble, distil and structure operational, manufacturing process information from the four Product Lifecycle

Management processes (plan, source, manufacture and deliver) as well as product and partner related information from a single site or multiple manufacturing sites. This information can be collated and put within a broader context to facilitate successful integration of manufacturing networks by allowing them to be knowledge-rich with "intelligence" applied to the point of need. This is shown in Figure 4-4.

The blueprint model helps for unrestricted specification of available component choices for variant type items, and allows creation of user-specific variant blueprints. Each component can be created with default values, which can later be modified, and complex variants can be created using highly specific rules.

Blueprinting will provide "intelligence" and improved visibility for an integrated supply chain in a variety of ways, e.g., providing valuable new or enhanced capabilities, increased regulatory compliance, improved asset utilisation and improved alignment of operations with business goals and metrics.

By connecting people, processes, and information at every phase of the production and manufacturing lifecycle and across all manufacturing network participants, the blueprint model helps:

- Reduce manufacturing cycle time
- Improve on-time delivery rates
- Increase production accuracy

To achieve its purpose, the blueprint model relies on a pool of industry-specific production information, process descriptions and closed-loop, industry-specific workflows based on best practices distilled from popular Manufacturing Integration Standards such as ISA-88 and ISA-95 specifications [23], [24], the Open Applications Group Integration Specification (OAGIS), the ISO STEP standard, reference models such as the Supply Chain Operations Model (SCOR) [59] and the Business-to-Manufacturing-Markup-Language - B2MML. These standards reinforce the practice of Lean Manufacturing and Six-Sigma techniques for manufacturing[6].

Essentially, the blueprint model is a declarative meta-model that aggregates and modularises manufacturing production, manufacturing operations management and logistics information by specifying four types of inter-related blueprints used to drive the manufacturing and production course of action: partner, product, end-to-end process and quality assurance blueprints (Figure 4-5).

Figure 4-5 provides a high-level overview of the IMAGINE blueprints, and their relationships. The graphical model in Figure 4-5 is defined in a class-diagram grounded on the Unified Modelling Language (UML) that is widely adopted in industry, and is underpinning with a concise, formal foundation. In particular, Figure 4-5 depicts the four key IMAGINE blueprints that are all associated to each other through the Blueprint Kernel definition, representing the Blueprint Master document. Each blueprint – or a combination of blueprints – may be extended and customised into blueprint extensions, e.g., to accommodate domain-specific and/or living lab specific meta-data requirements. The blueprints are defined in this section are defined at the "meta-level"/"language-level" meaning that for their actual use they need to be "instantiated".

[6] Six Sigma Systems. "What is Six Sigma and Lean Manufacturing", http://www.sixsigmasystems.com/.

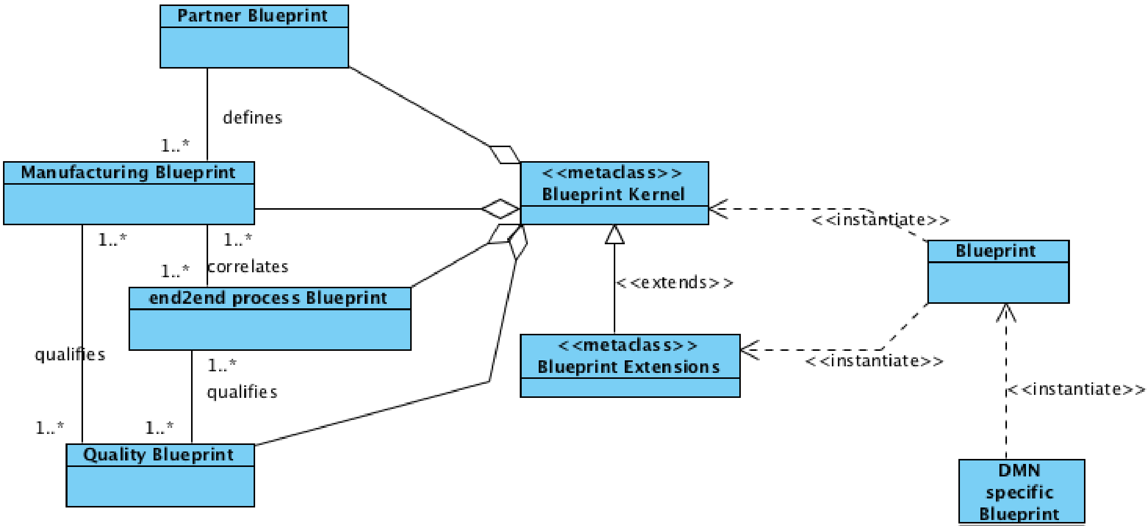

Figure 4-5: The IMAGINE blueprint meta-model in UML

Using a model-driven approach to manufacturing, such as the one epitomised by the IMAGINE blueprint model, we can more clearly analyse requirements, define design specifications, test manufacturing network concepts using simulation, and automatically generate code for direct deployment of manufacturing processes on the target hardware. Stakeholders can standardise processes and automate repetitive tasks to improve productivity and personnel efficiency while reducing time to value and enhancing operational compliance to customer requirements.

The various parts of the blueprint model are summarised below.

4.3.2 Definition and Structure of Partner Blueprint

The partner blueprint captures unique skills and capabilities in the DMN and makes them available to potential partners to help address opportunities in new network configurations. Focused searches for skills & capabilities among other regional SMEs can then be easily performed giving the tools to form virtual teams and partnerships to address, undertake and sustain new business (see PB-requirements 1 to 3 in section 2.1.1). However, the partner blueprint is also exploited during the other phases of the DMN Lifecycle to augment information to other blueprints with regards to organisation and human entities in the network, and identify (and design) connection mechanisms that are required to link not only the local processes into end-to-end processes but also the underlying enterprise information systems, including ERP and PLM systems.

With regards to organisation entities the partner blueprint combines static information and dynamic data. The list of static elements of the partner blueprint includes (not excluding unnamed elements):

- Company Background Information: size, annual reports, reference customer, financial growth and annual turn-over.
- Connection mechanism:
- Website/Portal,
- Telephone,
- Fax,
- Physical addresses,

- Service connection points (end-points/URI).
- Organisation type (e.g. Listed company, consortium, department, etc.)
- Products / Services: types of product and services, market, industry sector, geographical region, type of material (BOM)/information needed (e.g., CAD data), (see PB-requirement 7 in section 2.1.1).
- Skills: capabilities of the partner, track record (see PB-requirement 10 in section 2.1.1).
- Processes: key processes, key process skills.
- New Potential: potential new products, case histories of other network collaborations,
- Qualifications: name of standards awarded, patents, references to customers.
- Locations and facilities
- Local/global SLA: this item frames mutual promises and covenants regarding manufacturing processes (see PB-requirement 4 in section 2.1.1). Typical information includes, but is not restricted to:
- Work License: a partner promises to do his best efforts to conduct the work pursuant the purchase order;
- Forecast: the partner shall provide on a weekly/monthly/bi-monthly basis provide weekly/monthly/bi-monthly forecast;
- Purchase Order: a client partner will issue orders in accordance with order forms, while a provider partner may reject any order that is 60% less than the prognosed order, or that does not fulfil the order form criteria;
- Capacity reports: partners will provide network-manufacturing information for unique custom components as mutually agreed.
- Up-to-date information about current mean delivery times
- Up-to-date information about current mean production times
- Up-to-date information about available stock.

Next to static organisation data, the partner blueprint also captures and displays dynamic data that may be either pulled from a backend system (e.g., ERP) on demand and at real-time, or refreshed at regular intervals using a batch-transaction system. Dynamic elements of the partner blueprint include:

- Up-to-date information about current mean delivery times
- Up-to-date information about current mean production times
- Up-to-date information about available stock.

With regard to the person-related information in the Partner Blueprint the key items required are:

- Name (first, last, given, Initials, etc.),
- Relation to role/function definitions,
- Relation to connection mechanisms (telephone, email, etc.),
- Relation to qualification definitions,
- Relation to responsibility definitions.

Person information in the partner blueprint is used during the Manufacturing Network Analysis and Configure phase of the DMN Lifecycle identifying and defining only the initial contact person within the organisation. In later phases of the DMN life cycle it is consulted to define and identify the key (responsible) roles (and persons) in the end-to-end-processes, and/or process segments.

In the partner blueprint materialises and formalises the partnership in the DMN, by means of the Agreement (SLA), as stipulated during the configuration phase of the DMN Lifecycle. This information of the blueprint is exploited during the Monitoring and Management phase as the baseline to assess the performance of the DMN.

Note that the partner blueprint will be instrumented with view-based mechanisms for reasons of security. Particularly, more information about partners will be revealed along the three phases of the partner selection process (cf. PB-requirement 10 and section 4.2); partners commence with revealing high-level contact information in step I, whilst for example in phase III of the selection process detailed information will be made available on how to technically connect to the IMAGINE platform (see PB-requirements 4, 5 and 6 in section 2.1.1). This view-based mechanism will be further designed and implemented in the context of IMAGINE Platform in WP-2 (see section 7)

4.3.2.1 Formal Model in UML

Figure 4-6 defines formally the partner blueprint using UML. At the top of this figure, you see the Service Level Agreement (SLA) that defines the Service Level Objectives (SLOs) between two or more partners in the DMN, as set forth in the Quality Assurance Blueprint. The SLO describe quantifiable agreements in the SLA, regarding issues such as availability, agility, price, and responsiveness (see section 4.3.5).

We distinguish between two types of SLAs: local SLAs and global SLAs. Local SLAs stipulate contractual agreements of manufacturing process end-points that are local to a specific partner. Global SLAs on the other hand define global agreements over end-to-end processes governing one or more local SLAs. In other words, global SLAs are defined over one or more partner blueprints while local SLAs are associated to one, and only one, partner (profile) blueprint.

Now the partner profiles may store both static and dynamic meta-data; the class “Dynamic Resource Capacity” in Figure 4-6 captures the dynamic information. Static information is packaged in the “Static Profile” class in the same figure. This class composes information about the key skills, processes (referring to level-II processes in the end-to-end process blueprint), products/services, qualifications, connection-information, and company background (cf. the “Company While Page” class). Note that the static entities are logically correlated through associations, e.g., the class Skills is logically associated to one or more core Processes).

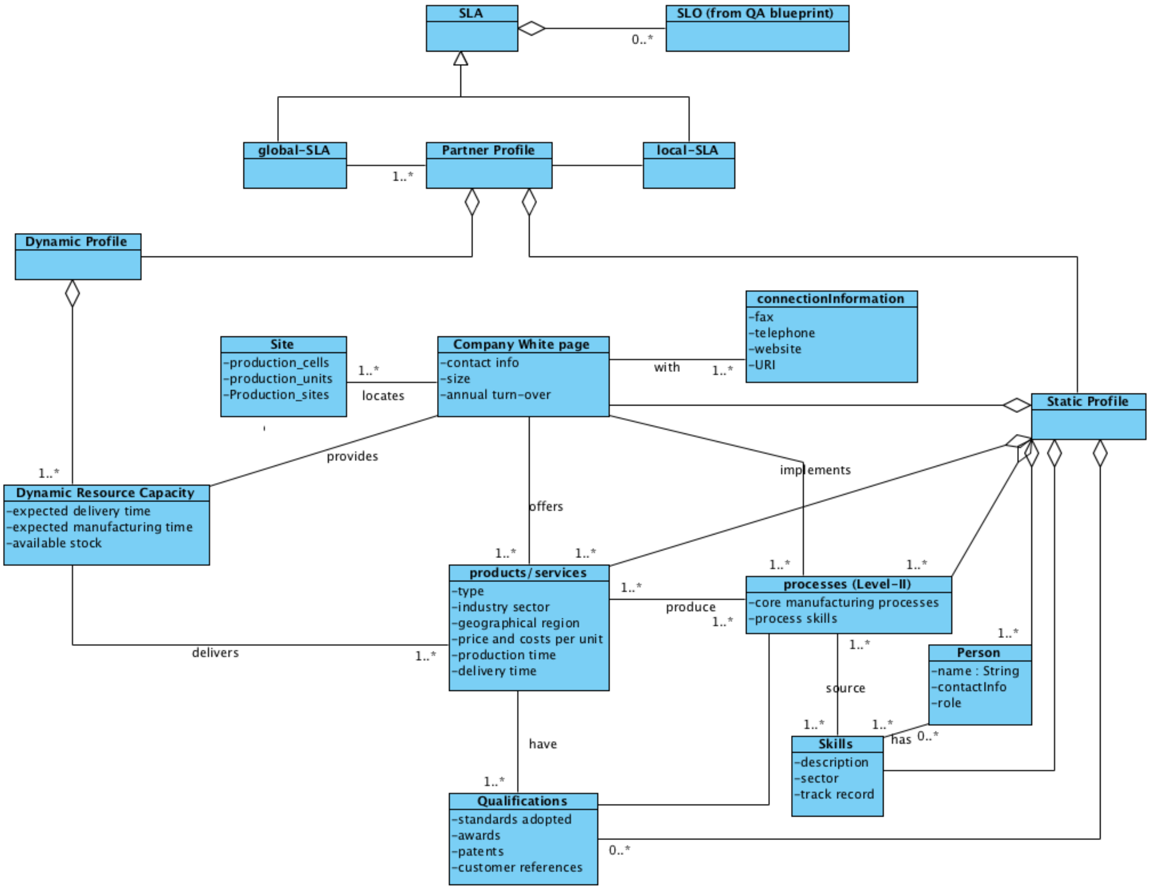

Figure 4-6: UML Meta-model of the Partner Blueprint

4.3.3 Definition and Structure of Product Blueprint

The product blueprint is a meta-model that defines the basic concepts necessary to assess whether a partner has the required capabilities in terms of human resources, material resources and skills to join the DMN. It provides a detailed definition of the process segment that could be carried out by a certain partner to achieve the production of a certain product. In a nutshell, the product blueprint sets up the constraints and the preconditions with respect to the construction of a product that a partner should respond to. It helps interface the manufacturing network configuration and the design phase of the DMN, therefore it constitutes a building block for the end to end blueprint.

This blueprint enables a company to create, maintain, re-use, and share core product information and make the information instantly available on-line to any member of their network partners. It will provide network partners with immediate access to the latest information and enable them to (see MB-requirements MB-req 1 to 4 in section 2.1.2):

- Locate preliminary and released information about any product and production line.
- View, and redline a bill of material.
- Identify where multiple product parts or materials are used.
- View the process segments and associated material, personnel and equipment capabilities.
- View which items would be affected by a change.

The product blueprint contains all the components necessary for producing a standard or configurable product. It contains both variant as well as non-variant parts and is largely based on and appropriately extends the ISA-95 4x4 manufacturing resource and information model [23] that is shown in Figure 4-7 below (see PRB-requirement PRB-req 5 in section 2.1.2). The resource and manufacturing operations models in Figure 4-7 is at the heart of the product blueprint.

The resource model is shown to include resources such as machines, tools, personnel skills, materials, other equipment, and other entities that are necessary to start and complete manufacturing work. A *process segment* in this figure is a logical group of equipment, personnel, and materials required to carry out a specific part of a manufacturing process. For instance, a semi-automated process segment may define the class of materials, personnel, and equipment needed. Examples of process segments are mixing, sawing, and painting. To mix, a manufacturer needs an operator (Personnel), a mixer (Equipment), and raw ingredients (Material). The capabilities may specify specific capabilities needed for the process segment. The management of these resources may include local resource reservation to meet production-scheduling objectives. Process segments are also examined in the context of end-to-end blueprints in section 4.3.4.

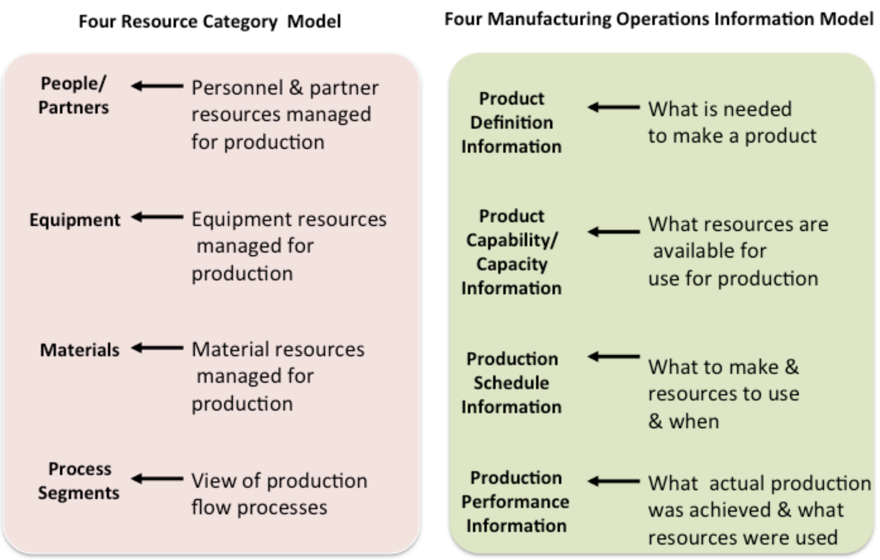

Figure 4-7: The 4x4 manufacturing resource and information model

The manufacturing operations model in Figure 4-7 divides production operations management information according to the following four categories:

1. Information about the capability to produce a product. This includes:
   - Production information on a specific product with the product definition and detail required for actual production.
   - Bill of material information on a specific product, including information not related to production (e.g. shipping materials).
   - Scheduling information on a specific product, including information that is not related to production (e.g. material order lead times).
2. Information required to produce a product. This includes information for scheduling, material information, and production rules.

3. Information about schedules for production of the product in terms of the personnel, equipment, material, process segment, and product definitions. It may define priorities, due dates, latest start dates, etc., what materials to use, what equipment to use, and what personnel to use.
4. Information about actual production of the product. This contains information about what was produced, what was consumed, what consumables where used, what personnel was used, and what equipment was used.

When describing BOMs the product blueprint allows for where-used lists, which simplify identification of subcomponent usage within other products, component substitution, BOM decomposition, and retrospective analysis. This allows high performance product trees can be graphically displayed to be created, used and maintained.

The product blueprint helps define production routings captured by the end-to-end process blueprint as it documents how the parts to be used in the manufacturing process are to be assembled and processed as part of a production schedule (see PRB-requirements PRB-req 6 to 10 in section 2.1.2). For each bill of material, it may define a corresponding high-level routing - from simple, using minimal labour information, to complex, focusing on move and queue time. For materials with accompanying routing information, we can then automatically create the necessary production network plans. The product blueprint also provides fulfilment designation, which allows defining production methods such as “make-to-order” or “make-to-stock.”

As an example consider the equipment element in the product blueprint. This element contains information about specific equipment used and the definition of capability test results. Equipment may be made up of other equipment, as defined in equipment hierarchy model. For example, a production line may be made up of work cells with each cell defined as a separate equipment element with separate properties and capabilities. Equipment capability contains references to equipment or equipment classes and may identify the capability type (available, unattainable, and committed) and the time associated with the capability (e.g. third shift on a specific date).

4.3.3.1 Formal Model in UML

Figure 4-8 provides the formal definition of the product blueprint in UML. As noticed before, this meta-model is largely grounded on STEP AP 236. Even if the AP 236 is designed to be specific to furniture industry, nevertheless, one can notice that in the diagram of Figure 4-8, the concepts are generic enough to be applied to other fields.

The product blueprint in the UML diagram includes the components, the equipment (or work resource), elements of work procedures and associated required resources needed to accomplish the various production requests (or orders) to be completed.

The product definition class plays a pivotal role in this blueprint. This class provides a description of the product to be manufactured in the DMN, and includes detailed information about the Manufacturing Bill of Material, which basically defines all the assemblies, parts and (sub-) components, defines their sequencing/routing layout during actual (networked) production (cf. the association between MBOM and Process Segments).

The equipment class in this figure transposes the equipment hierarchy model. The personnel class represents a set of personnel with similar properties -thus playing similar roles in the production process- for the purpose of scheduling and planning. Lastly, the material resources and digital resources classes store the actual total quantity or amount of material available, its current state, and its specific property values.

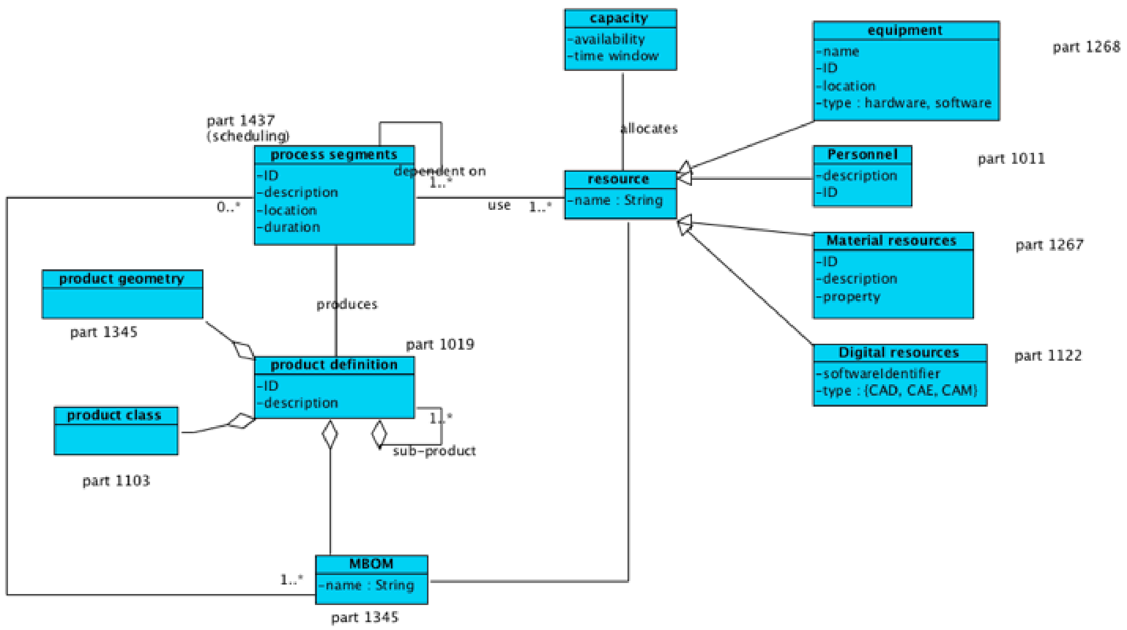

Figure 4-8: UML Meta-model of the Product Blueprint

4.3.3.2 Product Blueprint for the Construction Sector

In this subsection we present an example of how the product blueprint can be used to model aspects of the furniture construction sector. This Product blueprint example represents the production work necessary to manufacture a table, composed of two main pieces: a tabletop and the legs. A simplified blueprint is shown in Figure 4-9.

The production process begins with the verification of the necessary raw materials to make the table, such as the wood board, and other materials, namely iron fittings and packaging materials.

At the manufacturing location, the wood board undergoes various manufacturing processes, such as cutting, veneering, varnishing, etc., in order to produce the table top and the table legs. It is also during the various manufacturing stages, that particular product features of the final product emerge, such as colour or other finishes.

The final stage involves the assembly of the product and then packing it for delivery to the buyer.

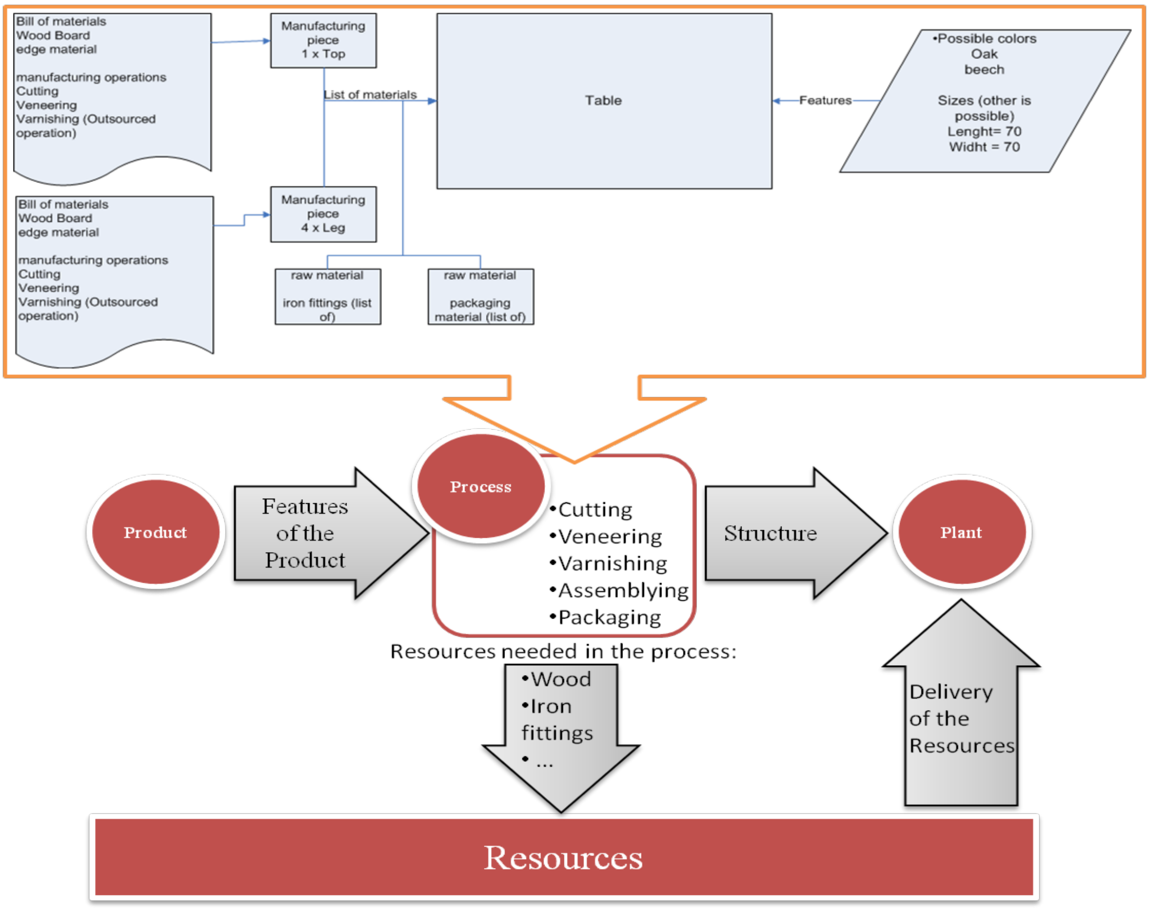

Figure 4-9: Furniture Product blueprint Example

4.3.3.3 Technical Data Package Message Scenario

In this subsection, we illustrate the product blueprint in the context of the Technical Data Package (TDP) message scenario illustrated in Figure 4-10. In this scenario, the Original equipment manufacturer (OEM) develops a certain product (e.g. an aircraft) and sometimes it externalises a certain number of development activities to an external partner (e.g. the activities related to the manufacturing of the engine). For this reason, the two partners need to exchange data relative to the product in a secure way. In this case, the OEM extracts the product data from its Product Data Management (PDM) tool. A PDM is an application that stores all the products data and offer a set of services and interfaces to access those data. In our scenario these data are a set of CAD and CAE files describing certain aspects of the engine to be manufactured by the partner. These files are exported by modelling tools used by the OEM. The TDP message is a package of these files; it can be decomposed into two layers:

- The first layer which contains metadata on the product models to be exchanged, such as the description of the models in natural language targeted for engineers, product identification within the database etc.
- The second layer contains the models exported from the modelling software applications.

Once these product data are available, they are packaged and then encrypted using specific encryption algorithms of choice. The result is the TDP message, and then the OEM sends this message to its partner. When the partner receives this message it deciphers it and extracts the metadata and the files representing the models to use them locally. The whole collaboration process between the two partners is performed this way in several iterations.

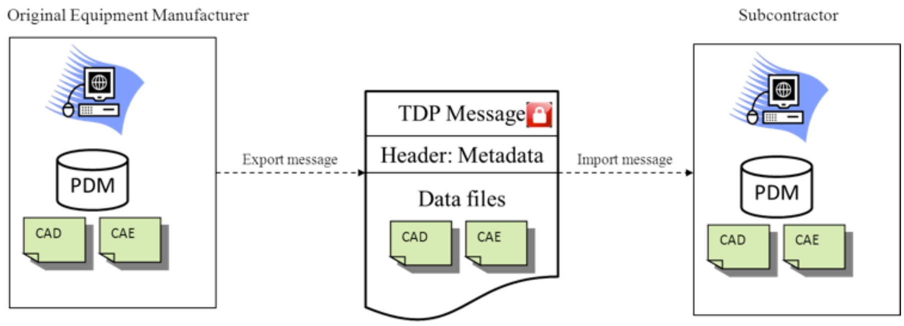

Figure 4-10: The TDP message process

Using the concepts defined in the product blueprint, describing such a TDP message is rather straightforward. The result is illustrated in Figure 4-11. In Figure 4-11 the TDP message exchange process is considered as a segment of the whole collaboration process that deals with secure data exchange. To accomplish such a process the OEM and the engine manufacturer should use a set of resources; we have identified human resources that include mechanical engineers, software resources that include AutoCAD to build 3D engine models and PDM applications that help the partners to automatically manage their product data.

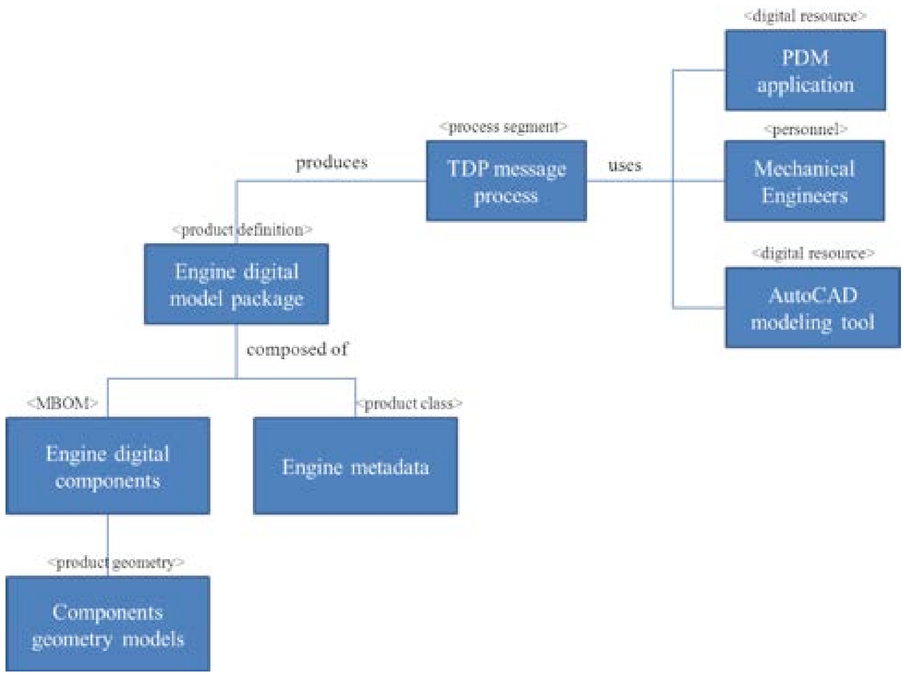

Figure 4-11: The instantiation of the product blueprint for the TDP message

The message exchanged between the two parties constitutes a partial definition of the engine, so it corresponds to the product definition. It includes several files describing the geometry of the engine and also metadata adding information to the engine models. In Figure 4-11 all this information is annotated with the corresponding concepts defined in terms of the product blueprint.

4.3.4 Definition and Structure of end-to-end Process Blueprint

End-to-end processes in manufacturing networks inherently cross functions, departments and actors within a manufacturing network. Bringing all of these elements together under the umbrella of a single blueprint is critical to the operational performance of the DMN.

The end-to-end process blueprint aims to tie together the many discrete processes associated with all aspects of manufacturing and product development while providing the ability to adapt to changing environments. This blueprint defines how actions are scheduled and executed, how decisions are made, and where responsibility is handed off between functions and partners. It also provides a more flexible and accurate description of equipment setup, materials acquisition, as well as activity control, information flow and materials flow.

The end-to-end process blueprint can help streamline the management, control and change of manufacturing operations to ensure the processing of raw materials, creation of components, and assembly of components into subassemblies and finished products. This blueprint spans customer interactions (e.g. order entry), manufacturing operations, production lines, and physical material transactions (supplier’s supplier to customer’s customer, including equipment, supplies, spare parts, bulk product etc.). This blueprint will be used in order to aggregate all these elements into a concise workflow model of the considered collaboration process, including data exchanges and quality requirements (see requirements E2EPB-req 1 to 5 in section 2.1.3). Note that due to reasons of project scope all activities that relate to returning products –thus reverse logistics- will not be considered.

There are two kinds of flow within a manufacturing process: material and information flow that are considered in this blueprint. Material flow is concerned with all the materials used to create the products and goods, while information flow is concerned with information about orders, activities being executed, products in-production, products made, personnel, work process etc.

- The material model defines the actual materials, material definitions, and information about classes of material definitions. Material flow information includes the inventory of raw, finished, and intermediate materials.
- Information flows support the material flows and are the connector between material flows and decision makers. Typical information flows contain incoming order, production-from-plan, production capability, production performance and cost, short and long-term material and energy requirement, product and process requirement, as well as quality assurance information flows.

Processes end-to-end process blueprint may include various roles and responsibilities, which as a brief example, may include (see requirements E2EPB-req 6 in section 2.1.3):

1. Product engineers who specify and validate product data (service, warranty, accruals for design specification, etc.) and the standard communication process for plants for design and engineering changes.
2. Manufacturing engineers who are primarily responsible for [54]:

- designing production lines or processes (i.e. line design);
- developing production methods, machinery, and/or equipment (method development);
- preparing the production of new products, such as setting up new production machinery/equipment, making jigs/tools/dies, managing trial production, writing operations manuals, instructing workers on production operations, and stabilising mass production (production preparation); and
- improving existing production lines, processes, machinery, equipment, jigs, tools, and/or dies for productivity increase, such as the increase on product quality, cost, and delivery (production improvement).

Other roles may include product assemblers, parts manufacturers, material providers, suppliers and so on. Roles and responsibilities of manufacturing processes will be described in detail in deliverable D2.2.1, which describes the use cases of the IMAGINE Framework.

The end-to-end process blueprint allows a shift from a data-centric view of manufacturing applications to a process-centric view of the how higher impact manufacturing is accomplished through the collaborative processes spanning of a network of original equipment manufacturers, manufacturing service providers, and parts suppliers. It is concerned with the design of end-to-end manufacturing processes and production flows, which includes and sequences all necessary resources, such as raw materials, equipment, human expertise, and order data, production data (e.g., production status data, operative order data, machine status data, etc.), equipment and machine data targeting a solution at operating sequence level. The production data is directly related to the complete description of the desired product, the resources expertise, and equipment, required for production as described in the product blueprint (see section 4.3.3). The end-to-end process blueprint also contains performance data furnished by the Quality Assurance blueprint (see requirements E2EPB-req 7 in section 2.1.3 and section 4.3.5). Influencing factors with regard to this blueprint are:

- Customer order: this includes delivery date and quality.
- Product: this includes alternative work plans and part lists, and setup costs depending on the sequence
- Production process: this includes minimum or maximum intervals between the process steps, transport and waiting times.
- Production resources: this includes current resource allocation, availability of means of transport and other resources, cleaning and maintenance times, and availability of quality assurance resources.

We expect to have different instantiation of the end-to-end process blueprint in accordance to the specific requirements of the living lab (e.g. different standardised collaboration and manufacturing processes and associated protocols for data exchange).

To combat interoperability issues this blueprint specifies standard naming and terminology conventions (according to standard ontologies the ones used by ISA-95 and B2MML). It provides tested and proven standard core processes; it describes the right level of granularity for processes; standard protocols; and other conventions that allow manufacturing processes to interoperate on a large scale. The previous satisfy requirement E2EPB-req 9 in section 2.1.3.

The end-to-end blueprint makes use of reference models and best-practices that govern and steer end-to-end manufacturing processes, such as ISA-88/95, SCOR, ISO 15928, PLCS and STEP. This blueprint helps:

- Achieve enhanced manufacturing network partnerships based on precise and timely information, shared visibility and collaborative planning on manufacturing processes
- Ensure important functional areas have access to precise and timely manufacturing and product information.
- Share information and mage participant access to shared profile-configured workspaces.
- Achieve shared visibility across the entire production lifecycle for manufacturing network partners and avoid numerous hands-offs with limited coordination, which reduce accountability and increase delays and risks.
- Track current status across all partners, product lines and production runs.

4.3.4.1 Hierarchical Decomposition of Manufacturing Processes

Processes in the end-to-end process blueprint are organised as a model of different levels of functional hierarchy. We have identified the four SCOR Level 1 core processes *plan, source, make* and *deliver* as the basis of the end-to-end process functional hierarchy. The processes described in this blueprint can be progressively decomposed from the highly abstract SCOR Level 1 core processes (plan, source, make and deliver) into detailed process descriptions until we reach well-defined process segment descriptions (along with their implementations). This is shown in Figure 4-12, which provides more definition and context for the end-to-end processes and defines the configuration level through which a DMN operations and strategy is implemented. This satisfies requirements E2EPB-req 8 and 10 in section 2.1.3.

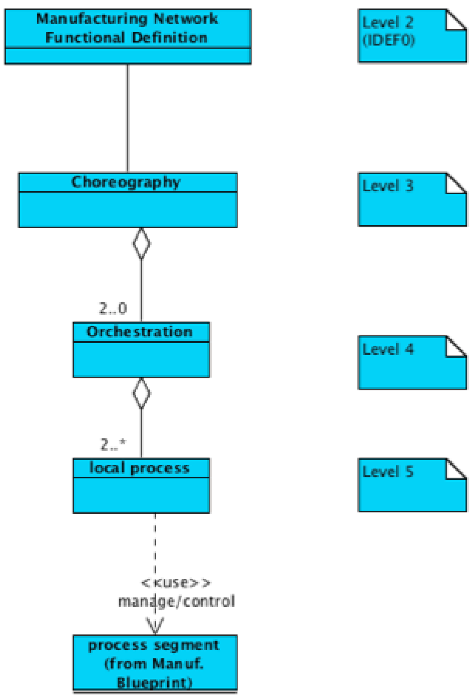

Figure 4-12: Manufacturing process levels of functional hierarchy

The levels of SCOR model we are considering in Figure 4-12 are Level 2 and below, as Level 1 is far too general. Level 2 models the relationship and interactions among manufacturing network members at a high-level of abstraction. This conceptual specification can be extended to describe the process workflow through Level 3 and Level 4 modelling in increasing levels of detail.

Level 2 provides variations in the way high-level processes can be implemented by modelling the broad functional aspects of a manufacturing network. At Level 3 processes can be decomposed into process element interactions, inputs, outputs, process performance metrics (reflected in the Quality Assurance Blueprint), and best practices to "fine tune" a firm's operations strategy. In particular, Level 3 captures the process choreography that manages the interactions between partners that participate in a specific end-to-end process (see Figure 4-12). Choreography is typically associated with the public (globally visible) message exchanges, rules of interaction and agreements that occur between multiple network partners, rather than a specific business process that is executed by a single party. It is described from the perspective of all network partners (common view), and defines the complementary observable behaviour between partners in end-to-end processes. A process choreography may be decomposed into two or more orchestrations (Level 4 process).

A process orchestration focuses on the activity flow and describes how partners deliver their part of the networked manufacturing process, defining the business logic and execution order of the interactions from the perspective and under control of a single network partner. The orchestrations are defined from the meta-data that is captured in the Partner and Product blueprints, particularly, the process segments.

While at the orchestration stage we focus on the activity flow of the complete DMN executable design which must also specify enforcement of policies and rules - associated to Service Level Objectives - performance metrics, and QoS properties that are logically structured in the Quality Assurance Blueprint. Often an event such as a vehicle arriving in an assembly line will trigger interaction between different manufacturing and/or business systems. These specify interconnection of both backend systems (ERP, PLM, etc.) and controllable machinery achieved using service technologies and Services Oriented Architecture (SOA). When SOA is employed as an integration strategy, it brings about a set of self-describing, atomic services used together to create a manufacturing process [39].

Local processes are used to model aspects of production. These are used to describe how operation schedules developed by a particular enterprise are sent to the shop floor and how they aggregate into the execution of operations workflows that invoke process segments. Local processes provide [17]:

- Operation schedules which are used by detailed production and operations scheduling activities that define detailed production and operations schedules containing production and operation work-orders.
- The production and work-orders are dispatched to work-units and shop-floors based on time, scheduling decisions, and availability of resources.
- Operations definition information about the procedures, BOM, and work routing needed for production is managed according the product definition management activities on the basis of the product blueprint.
- Process segments that can be executed by physical equipment or machines to produce part of a product. Process segments should connect easily with other such segments to assemble, or manufacture product parts.

Process segments are similar to those defined in the ISA-95 standard and carry out the "physical" manufacturing tasks necessary work to produce the product. A process segment is the collection of capabilities needed for a segment of production, independent of any particular product at the level of detail required to support business processes. This may include material, energy, personnel, or equipment capabilities. For this purpose, they use a logical grouping of personnel resources, equipment resources, and material or software resources required to carry out a production step. This definition is realised through the associations between Process segments class, and an abstract class representing the resources, which is extended by concrete classes Personnel, Equipment, Material resources, and Digital resources.

A notable difference with the SCOR model is that it emphasises process orientation (a horizontal focus) and deemphasises organisational or functional orientation (vertical focus). The end-to-end blueprint places emphasis on both processes as well as organisational roles responsible for executing the processes.

4.3.4.2 Formal Model in UML

The definition of end-to-end process constructs using UML follows the levels described in the hierarchical process structure in Figure 4-12.

Level 2: Network Scope & Cross-Functional Alignment

At this level we use a function modelling method for analysing the functional perspective of a manufacturing network and associating network partners with manufacturing activities. Here, we identify what functions are performed, what flows of information and materials are necessary to perform these functions, and who performs these functions across a manufacturing network. To achieve this we identify the key nodes within a DMN. A node represents a partner entity in the network, e.g., suppliers, distributors, intermediaries, etc. We then link the nodes to reflect material and/or information flows. Recall that materials flow within a manufacturing network is the movement of materials through a defined process or a value stream within a factory or an industrial unit for the purpose of producing an end product.

At this level we rely on simple IDEF0-like mechanisms as the primary means of a modelling a manufacturing network at a high-level of abstraction. IDEF0 (Integration Definition for Function Modelling) is a function modelling methodology for describing manufacturing functions [43]. Activities can be described by their inputs, outputs, controls, and mechanisms. Here we rely on the hierarchical nature of IDEF0 that facilitates constructing abstract models that have a top-down representation and interpretation and grouping together activities that are closely related.

The objective is to identify the high-level operations required in a manufacturing network, identify and locate the data sources and convert these to operating processes spanning organisations by following a progressive process decomposition approach through the layers in Figure 4-12. This approach facilitates accountability and reconciliation between plant, process, resource and product configurations and collectively supports consistency and reconciliation as the product construction lifecycle evolves in a DMN.

Level 3: End-to-End Process Choreographies

As mentioned above, Level 3 end-to-end process definitions focus on the specification of publically visible message exchanges between the partners in a DMN. A process choreography in our approach relies on standard level 3 SCOR processes such as, M1 Make-to-Stock, M2 Make-to-Order, M3 Engineer-to-Order, etc.

The BPMN Choreography meta-model definition is shown in a simplified manner in Figure 4-13. The Choreography class plays a central role in this type of diagram. This class brings together a message flow with Orchestration participants. Message flows and participants intersect during choreography tasks. Choreography tasks involve at least two network partners; one initiating and one (or more) providing partners.

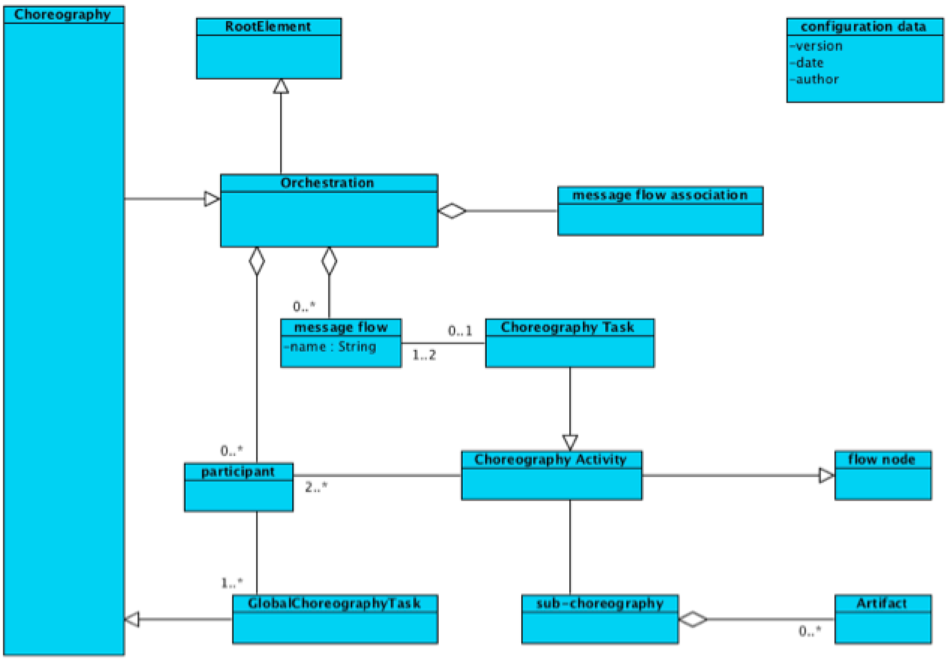

Figure 4-13: Definition of end-to-end process choreography in UML

To describe processes at the choreography level, which is more collaborative than process orchestrations, we will appropriately extend the BPMN 2.0 choreography diagram. BPMN2.0 allows defining messages exchanges during the execution of a choreography task. Choreography tasks can be defined recursively, and their interdependencies (e.g., sequencing and timing) can be defined relying on the FlowNode class.

Level 4: End-to-end Process Orchestrations

Figure 4-14 depicts the definition of partner processes in the end-to-end Process Blueprint. Again, we use BPMN 2.0 notation (c.f. Annex D: BPMN-2) to define the Level 4 Partner Processes. In a nutshell, the meta-model as defined in Figure 4-14 allows to model Activities as part of a Orchestration (Process), their sequencing (FlowElement) and message (Event) exchanges between them.

In addition, we provide several modelling constructs allowing to capture data flow, with distinction of workflow relevant data, message body for a message based data exchange (e.g. using SOAP) and digital assets flows. Digital assets could be documents or models. The digital assets can be used sometimes as resources, they can be sometimes considered as digital artefacts.

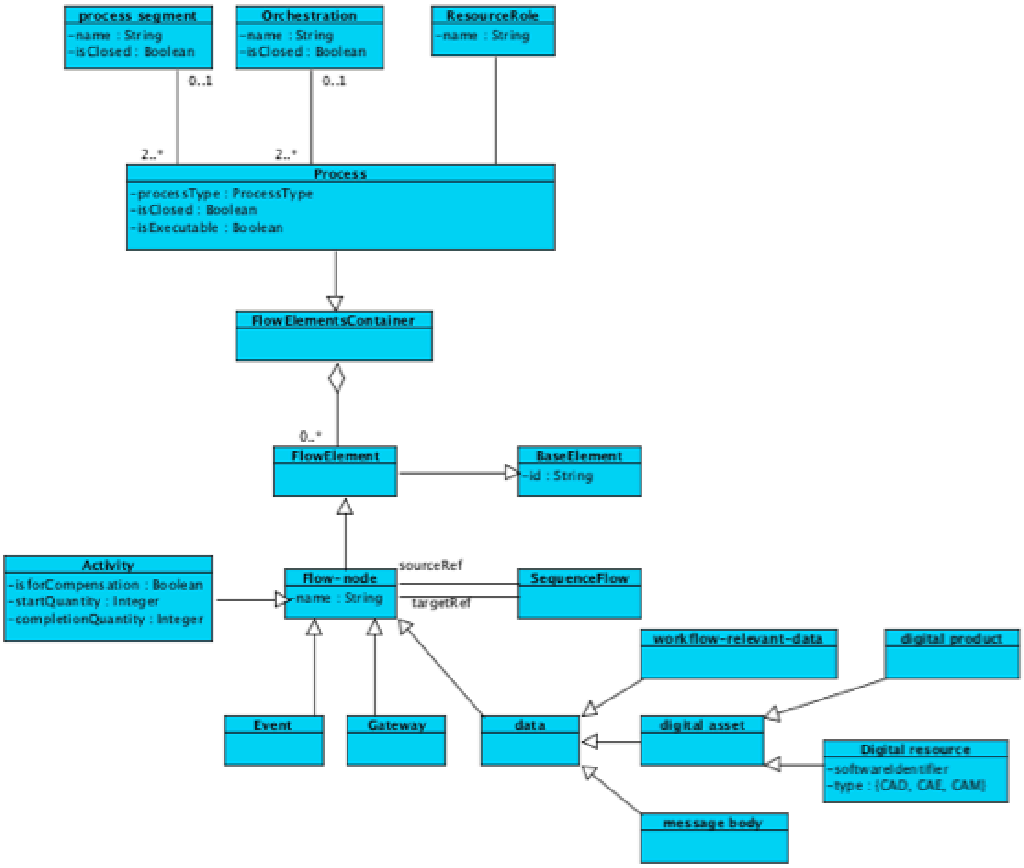

Figure 4-14: Definition of process orchestration in UML

The Level 4 Partner Process definitions are defined relying on the Business Process Diagram (BPD) in BPMN-2.0. This diagram is explained in depth in Annex D: BPMN-2. In a nutshell, the Business Process Diagram as defined in Figure 4-14 allows to model Activities as part of a orchestration (Process), their sequencing (FlowElement) and message (Event) exchanges between them. In particular, the formal model defines three basic types of flow nodes, vis., Event, Gateway and Data. An event signifies the instantaneous occurrence of something, e.g., a trigger the start of a process, or a timer. A gateway represents a control point in a flow, such as an XOR or AND-split. The data flow node represents messages that can be routed in the control flow, such as data-objects storing workflow-relevant data (e.g., the process state) and digital assets such as CAD or CAM designs that are streamed through the flow.

Local processes and process segments in Figure 4-12 are described in the following sub-section, which gives a concise example of the use of an end-to-end process blueprint.

4.3.4.3 End-to-end Blueprint Exemplified

As an example of an end-to-end process we shall concentrate on a Make-to-Order (MTO) manufacturing process inspired from [7] who present a SCOR example for the construction industry. An MTO signifies a production environment where manufacturing, assembly, or configuration of make-to-order standard/configurable products begins only after the receipt and validation of a firm customer order. Products of this type include products that are built to a specific design and the products that are manufactured, assembled, or configured from standard parts or subassemblies.

In this example we assume the existence of a production schedule corresponding to a production request to an OEM for 200 painted mid-market sedan panel doors and the shop floor production schedule as described in section 3.1.2. The steps followed when designing an end-to-end manufacturing process blueprint for the production of panel doors are described below and follow the hierarchy decomposition depicted in Figure 4-12.

4.3.4.3.1 Defining the Abstract Functional View of the Network Topology

To define the manufacturing network and its functional properties we transform the production schedule into corresponding high-level processes (corresponding to SCOR Level 2 processes) that span multiple network partners and are used to move information and materials from network partner to partner.

Figure 4-15 shows the SCOR Level 2 model for a typical DMN for make-to-order standard/configurable products. We assume that the products can be delivered directly from the manufacturers to the consumer's construction site e.g., automotive, aerospace or furniture construction site. Further, we assume that direct procurement to manufacturers is not possible. The Make-to-Order process is concerned with the making of standard or configurable products for unique customer orders. Customer orders determine what, how much and when to make and can be traced throughout the Make process.

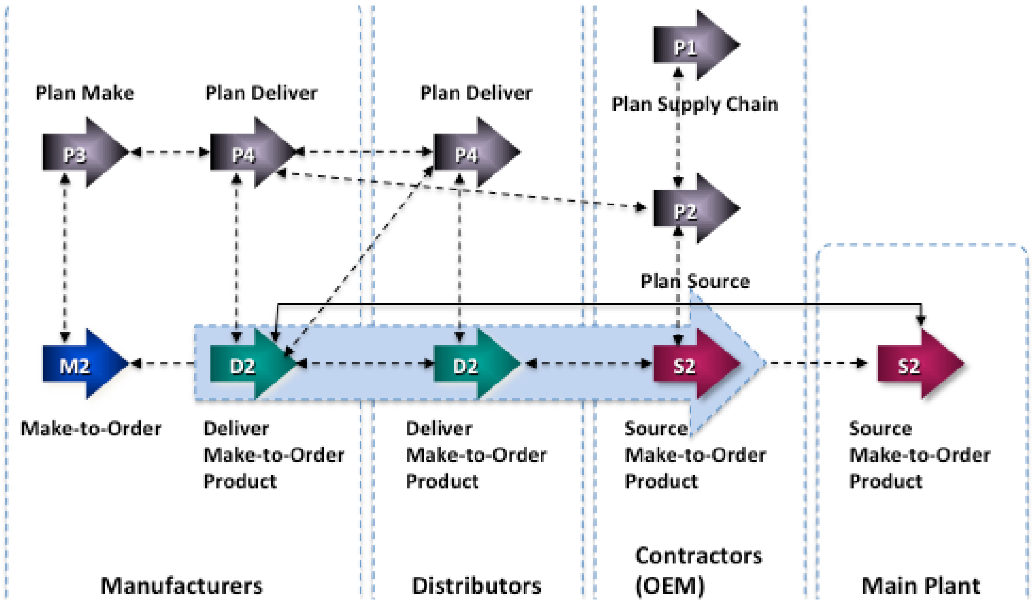

Figure 4-15: SCOR Level 2 model for a typical manufacturing network for make-to-order configurable products

In Figure 4-15 distributors serve as brokers between subcontractors and manufacturers, coordinating the procurement, production, and delivery in the supply chain. In addition to the distributors, we assume that subcontractors also communicate directly with their manufacturers to check the production and to schedule the delivery to minimise risks as in this way they can notice any material delay or shortage and mitigate the impact at an early stage.

The SCOR Level 2 model in Figure 4-15 provides a high-level functional view of the core SCOR processes and an overview of the information flows and material flows along these processes. Figure 4-15 gives a list of configurable high-level process templates (e.g. "Plan Make", "Make-to-Order" or "Deliver Make-to-Order Product") that can be chosen when modelling an application for typical manufacturing network for Make-to-Order configurable products. The dotted lines and the solid lines represent the information flows and the material flows, respectively. The information flows start from the contractors' headquarters, where purchase orders are sent. The material flow path shows that products are delivered to the main (construction) plant at the time designated by the contractor.

4.3.4.3.2 Defining a Process Choreography and Process Orchestrations

SCOR Level 3 and 4 models specify the processes involved in the manufacturing network in increasing level of detail. They specify a process choreography and process orchestrations, respectively. At Level 3 the model links different SCOR Level 3 supply chain processes into a process map that contains process element definitions, process element information inputs, and outputs as well as process performance metrics attributes and definitions. Figure 4-16 shows the decomposition of the high-level functional elements in Figure 4-15 (the shaded area encompassing processes D2, D2 and S2 – which are performed by diverse actors) to SCOR Level 3 and 4 processes. This involves a process choreography and orchestrated end-to-end processes, respectively.

The manufacturing subnet in Figure 4-16 connects a manufacturer with distributors and subcontractors. The manufacturer and distributors perform standard Deliver Make-to-Order Product (D2), while the subcontractor performs Source Make-to-Order Product (S2) Level 3 SCOR processes. Level 3 is represented using the Business Process Modelling Notation. The D2 process delivers a product that is manufactured, assembled or configured from standard parts or subassemblies. The S2 process procurement and delivery of product that is built to a specific design or configured based on the requirements of a particular customer order.

At SCOR Level 4 the model further decomposes a Level 3 processes and specifies the necessary process orchestrations and business operations to implement Level 4. These are organisation specific processes and not supplied by SCOR. Figure 4-16 illustrates this concept. This figure illustrates the BPMN representation of a SCOR Level 4 model at the bottom of the diagram corresponding to the Level 3 process "Mfg D2.2 Receive, Configure, Enter & Validate Order" performed by manufacturers, which is highlighted in the figure.

When performing the Level 4 process model, the manufacturer processes the purchase order received and checks the order consistency and validity. If the order is not valid, the manufacturer will return the order and ask for clarification; otherwise, the manufacturer will check its inventory status and production plan concurrently. After evaluating the order, the manufacturer will either send a confirmation message if the order is accepted, or notify a rejection on the purchase order otherwise.

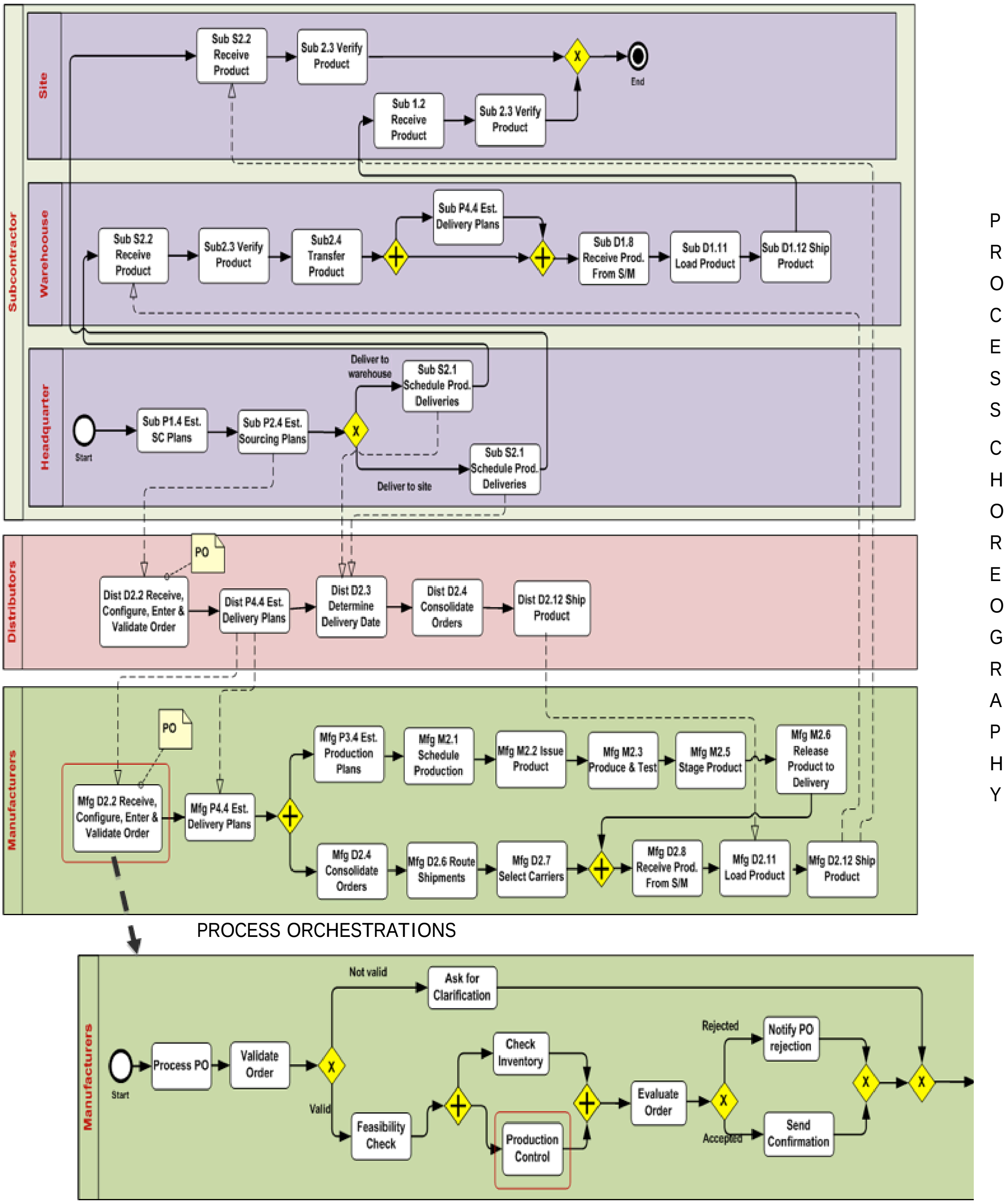

Figure 4-16: BPMN representation of the SCOR Level 3 and 4 process for make-to-order products

4.3.4.3.3 Defining Local Processes and Process Segments

The final step in the design details the implementation activities associated with the implementation of the Level 4 process "Production Control" at the bottom part in Figure 4-16 employing a local process. This process is shown Figure 4-17. The "Production Control" process in that figure involves the complete implementation of a process segment at SCOR Level 5, which may communicate with shop floor resources.

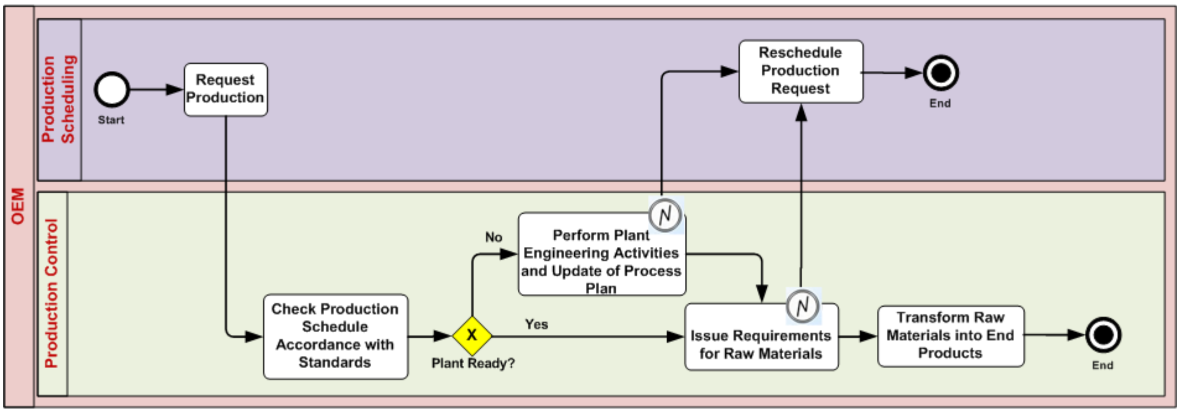

Figure 4-17: BPMN Representation of SCOR Level 5 Process for "Production Control"

Finally, Table 4-2 provides for completeness some typical service interface details associated with the implementation Level 5 process "Check Production Plan" (Production Control) represented Figure 4-17. This table specifies the operations and input/output parameters of this process and is based on the ANSI/ISA-95 standard core functions for production control.

Table 4-2: Production request services

Create Production Request		
INPUT	Production Request Information	Product Type ID
		Product Rule ID
		Production Line ID
		Quantity
		Storage Warehouse
OUTPUT	Production Request Order Information	Production Request Order ID
Create Product Rule Not Found Alarm		
INPUT	Product Request Information	Product Rule ID
		Product Type ID
OUTPUT	Alarm Information	Alarm ID
Create Not Enough Raw Material Alarm		
INPUT	Material Information	Material ID
		Quantity
OUTPUT	Alarm Information	Alarm ID
Reschedule Production Request		
INPUT	Production Request Order Information	Production Request Order ID
		Error Type

Finally, it is important to understand that the previous example considered an end-to-end blueprint in isolation. In reality, information which is contained in the end-to-end blueprint should be connected to the partner, manufacturing and quality blueprint to provide a holistic view and navigation paths between the diverse manufacturing artefacts and process elements.

4.3.5 Definition and Structure of Quality Assurance Blueprint

The integration of quality management in production management is an important aspect of the DMN Lifecycle. Current manufacturing practises focus on managing by department metrics, not by end-to-end process metrics. Current manufacturing operations management (MOM) systems unfortunately are too departmentalised and based on dissimilar information models with custom interfaces, reports, and misaligned metrics. The resulting communication breakdowns not only reduce the efficiency of the make-to-stock (MTS) plant, but make the effectiveness and profitability of changeover for make-to-order (MTO) job orders financially unjustifiable by traditional labour-intensive methods.

To surmount these problems the QA blueprint is used to structure data collections of the real-time operations metrics for operations analytics and associate these with end-to-end manufacturing processes. This blueprint helps:

- Enforce end-to-end process metrics for manufacturing operations
- Measure production status and performance across supply relationships and within individual partners
- Monitor on-time delivery, order fulfilment accuracy and manufacturing cycle times.
- Track execution status, production milestones and operational events with full audit trail.

The purpose of the Quality Assurance is to keep the production/manufacturing processes stable and reliable through systematic monitoring and repair methods so that the maintenance of defined KPIs is continuously ensured. Accordingly, this blueprint is the foundation for activity-based metrics for manufacturing operations, logistics, and costing such as those mentioned in the Manufacturing Enterprise Solutions Association (MESA) metrics report [38] and the SCOR metrics model (see Annex C), which promote a set of standardised requirements for a quality management [59].

The Quality Assurance blueprint maintains precise management control of mission-critical information for key manufacturing and production parameters, e.g., KPIs, like effective dates for finished goods and components, revision levels, shrinkage factors, issue-from and issue-to sites, and make/buy status. They also provide a list of comprehensive KPIs for end-to-end tracking of manufacturing, including shipping weights as well as units of measure. It also includes metrics that facilitate stronger adherence to regulatory and compliance edicts (quality and regulatory compliance).

The following requirement tree describes the category metrics in the QA blueprint as stipulated in section 2.1.4. Product requirements (QA-requirement 1 to 5) are only considered to the extent that product qualities have an impact on the network configuration and process design and, conversely, that product qualities are affected by insufficient process quality and network performance. Process requirements focus on process maturity, improvement and compliance to specifications (QA-requirements 6 and 7). Partner requirements (QA-requirement 8 to 10) mainly play a role during network (re-) configuration phases but are not continuously monitored, as changes are less frequent. Some of the requirements concerning the operation of a network take a global perspective as opposed to requirements concerning only the interface or information flow between network nodes.

1. Product- As stated above the product quality aspects are crucial for the overall quality of the DMN. The following are important attributes of product quality for a DMN:
    a. Integrity: The metrics for measuring the integrity of the product very much depends on the specific product. Examples are aesthetic aspects of a product like the colour of a car or intangible aspects e.g. depending on the current fashion.
    b. Conformance to standards. For almost every product more than one standard is relevant. This provides usually a good mechanism to control the quality of the product. Thus the metrics is the compliance with a concrete standard. As in many cases clear procedures how to measure the compliance to a standard is part of the standard definition, these can be used to define the measurement.
    c. Complies with specification. It is essential that every product has a clear specification, which is understood by an expert. Thus the metrics is the compliance to a concrete specification such as the product geometry, which can be at least manually checked.
    d. Cost. Cost is a very general quality measure, which can be applied to almost all aspects of the DMN. We consider it especially relevant as a product quality attribute.
2. Process - Processes are at the core of the complete DMN. They are very relevant on different levels and for different phases. Thus the quality attributes for them have to be chosen very carefully, balancing the benefit of a quality attribute with the effort and complexity to measure the corresponding metrics. The following are important attributes of process quality for a DMN:
    a. Process parameters: e.g. Lead Time to make (KPI). It is possible to define many process parameters as quality attributes. Many of them are related to the timing of results of process steps. A very relevant one is “Lead Time to make”, which means the time duration to execute successfully a concrete production process.
    b. Documentation of a process: We have a broad view on documentation. This concerns the technical documentation including design, requirement specification, user manual, and all administrative documents about process and the product.
    c. Process maturity level: The maturity of a process is a quite complex quality attribute. A clear definition depends on the specific type of a process and the reference process framework. For example, in a production process mechanisms for continuous improvement must be included.
    d. Security: We consider with security a set of quality attributes. They include privacy, sensibility of data, and resiliency of the information flow at the network level.
3. Partners - The following are important attributes of partner quality aspects for a DMN:
    a. Reputation: the reputation of a partner with respect to its intended role in a network contributes to the reliability of this partner. A reputation factor is assigned to a new partner based on proper evidence about its reliability.
    b. Certification: The certification by independent authorities, e.g., ISO 9000 or … provides evidence for a partner’s reliability.
    c. Organisation quality: This requirement addresses how the supplier organises responsibilities and their relationships into departments.

   d. Logistics: Logistical capabilities of an organisation such as staging areas, packaging flexibilities, numbers of delivery per period, transportation capacities, or ability to work just-in-time substitute the asset management efficiency.
   e. IT Systems Efficiency: The availability and production-related category of certain IT systems and services (ERP, MRP, etc.).
   f. Tooling capability: an organisation's provision with task-specific tools and the ability to adapt its tooling provision to changing requirements.
4. Operation of the Network. The following are important attributes of network operation quality for a DMN:
   a. Partner interoperability: The requirement for partner interoperability can be broken down to sub-requirements such as all partners are familiar with the conventions, standards and regulations in the manufacturing domain, they use compatible governance mechanisms, and can handle domain-specific parts. These aspects contribute to agility qualities.
   b. Network complexity: If a network is overly complex, it can reduce the responsiveness and the agility of the whole network even if the responsiveness and agility of individual network nodes lies within the required range. To detect such defects, a well-designed calculation method must be defined that takes into account the individual responsiveness of network nodes and the structure and typical profile of business processes.
   c. Environmental requirements: These requirements address production aspects such as CO_2 output, energy conservation or pollution prevention.
   d. Capacity utilisation: The effective use of planning, design, production or delivery capacities like fill rate.

As already stated above the QA blueprint can be used as a source of analytics to optimise manufacturing networks. For example, by analysing production and partner locations, order quantities, transportation costs and delivery times, a manufacturer can determine the right number of distribution centres and their ideal locations. The optimised network reduces warehousing and transportation costs, while still maintaining high service levels.

Monitoring the QA blueprint metrics results in notification and diagnosing performance issues, identifying deviations, trends and dynamic changes, taking preventive and corrective actions, and improvement of production goals. For example, the QA blueprint allows to monitor inventory and work-in-progress using back flushing inventory deductions. The production entry can explode subassemblies into component requirements, helping ensure that one can meet KPIs such as accurate inventory levels for component, subassembly, and finished goods items.

4.3.5.1 QA Blueprint Assumptions and Caveats

- The product qualities have been described in detail in the agreement with suppliers, therefore in the current QA blueprint the product quality parameters are those potentially impacting on the operations network. This means that the QA blueprint contains the evaluation of the compliance with standards and product specifications.

- Process and Product quality requirements are linked: in the product requirements the focus is on the final product quality while in the process requirements we focus on time and on supporting supplementary performance data.
- The environmental KPIs are a measure on the impact of the production on the earth environment, such as CO2 footprint, energy savings, pollution reduction, waste production, recycling capabilities etc.
- The QA blueprint contains many suppliers' data; those data are provided at KPI level as results targeting the quality of the networks. The KPI's should be specified in a format to protect privacy and sensibility of data as well as to prevent any leakage of company secret. The monitoring collection of data takes place in full compliance with international regulations.
- The Partner quality attributes such as reputation, certifications, organisation etc. are strongly linked to the Partner blueprint and perhaps these could be updated by fetching them whenever the partner blueprint is updated.

4.3.5.2 Formal Model in UML

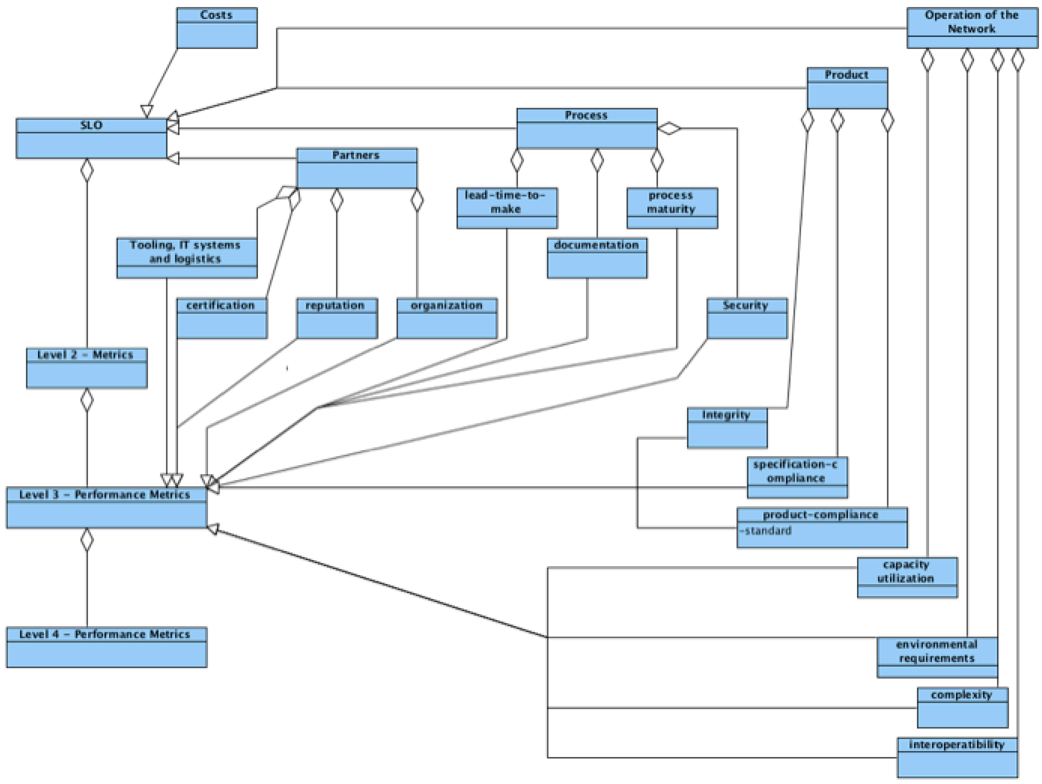

Figure 4-18: UML Meta-model of the Quality Assurance Model

The QA Blueprint is formalised in the UML meta-model graphically depicted in Figure 4-18. This meta-model is similar to the SCOR metric model and follows the three top levels of the end-to-end Process Blueprint.

Figure 4-18 provides an example of Level 1 SLO metrics. This figure shows that each SLO is associated with exactly one out of five performance attributes (Product, Process, Operations of the network, and

Partners). Lower level calculations (Level 2 metrics) are generally associated with a narrower subset of processes (at level 2). Then level 3 metrics may be decomposed into performance metrics, such as source cycle time that can be logically associated to choreographed, end-to-end Processes. Level 4 metrics define the performance of local, partner processes, such as SourceCycle time that defined the cycle time of sourcing processes of one of the partners in the DMN.

The above meta-model maps the QA blueprint requirements (see section 2.1.4) to the four SCOR levels. For example, the requirement security is logically mapped to Level-III performance metrics, being an intrinsic part of the Level-I reliability SLO.

5 Living Lab Case Studies on the Basis of Blueprints

In addition to the examples already provided for blueprints in the previous section from sectors such as automotive, aerospace and construction industries, we present in this section more detailed examples based on case studies conducted in the aerospace and automotive sectors. We chose these two sectors because of their complexity and richness due to factors such as: complex inter-dependent parts and diverse materials, multiple part types made in the same facility/line, numerous manufacturing steps, batch processing, complex equipment which leads to high levels of preventive maintenance and downtime, multiple levels of subassemblies, just to name a few. They also involve diverse systems that require integration and use specific standards. These provide fertile ground for a process modelling approach centred on automated workflows that support digital processes, involving supplier tier diversity, complex data exchanges, including routing information, BOMs, etc., that can adopt to new production approaches and process improvements.

5.1 Application of the Blueprint Model in the Aerospace Sector

EADS has developed a number of Aeronautic living lab-based business scenarios, which will be utilised throughout the duration of this project. These business scenarios are all related to collaborative development of a manufactured product, within networked organisations. The following business case will be considered throughout this section and will be used as a basis to derive examples of the DMN Lifecycle and blueprints.

- *Digital Business eco-system with a set of common standards for PLM scenario*: the main actor is the EADS Group itself, which aims to harmonise PLM use within the EADS Group. This means that product data interchange and sharing between the development, production, support and retirement systems for any EADS product should be ensured by a set of EADS policies based on PLM solutions and e-Business PLM standards This will ensure end-to end-process flows between all these systems and all along the phase of the Product lifecycle. The domain of interest here is a dynamic network of interconnected applications that are distributed among external partners, including the supply chain but also suppliers and clients. A special focus is given to the manufacturing system for the development of the manufactured product, with interconnection with the other enabling systems (concept, production, support, retirement).
- *Product data exchange*: main actor is the Aerospace and Defence Strategic Standardisation Group, which aims to provide a set of consistent e-Business PLM standards shared by the European and Defence Aeronautic and space digital business ecosystem. This group needs to be able make use of well-established standards to ensure continuous interoperability between the interconnected PLM solutions. The domain of interest is the dynamic network of PLM applications of the considered digital business ecosystem that should be interconnected dynamically for an effective collaboration requiring interchange of digital models of manufactured products.

The business case will be defined according to the systems engineering practises of ISO 15288, which is briefly described below.

5.1.1 ISO 15288 and the Aeronautic Business Case

Today, many products and services actually constitute multi-part systems with hardware, software and human interfaces, planned from a cradle-to-grave perspective and produced through processes - with diverse technical and managerial inputs - that may cut across both the internal and external boundaries of organisations. This trend is evident by the continuous increase of the percentage of sub-contracted activities and systematic usage of approaches such as Product Lifecycle Management or System Engineering (as defined by ISO 15288), which are widely used in Aerospace and Defence community in general, within EADS in particular.

ISO/IEC 15288 (Systems Engineering - System Life Cycle Processes) offers a portfolio of generic processes for the optimal management of all stages in the life of any product or service, in any sector [25]. It establishes a common framework for describing the life cycle of systems created by humans and defines a set of processes and associated terminology.

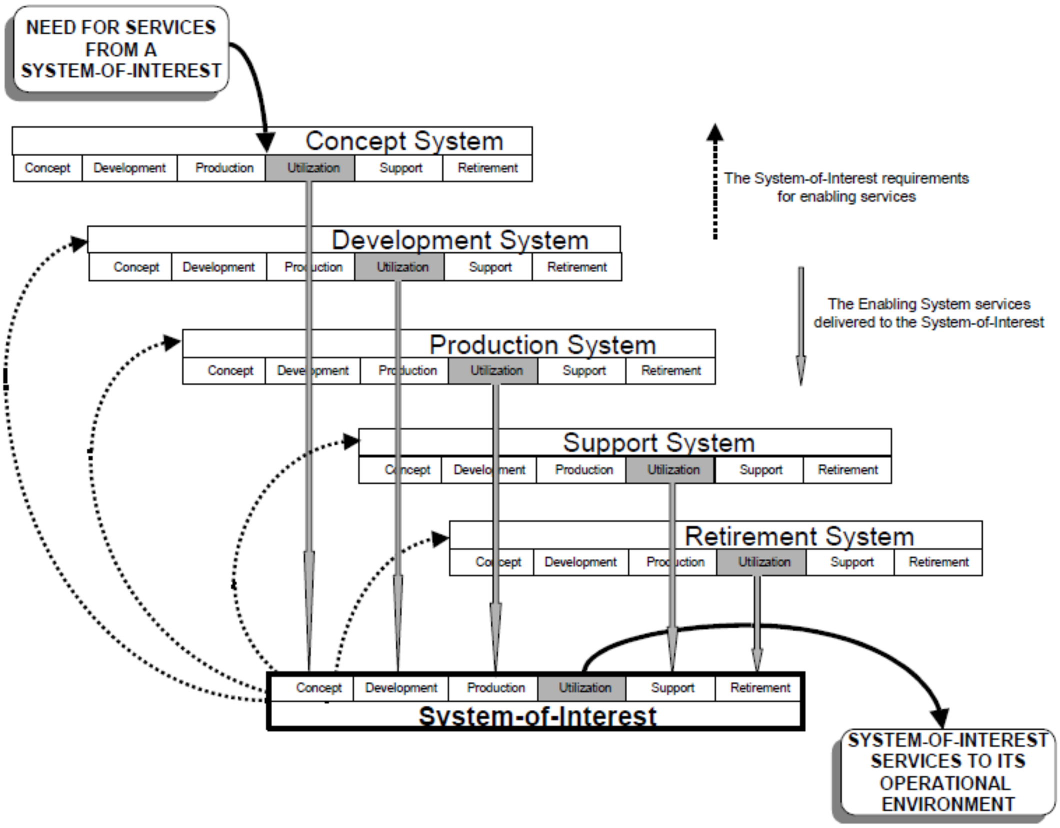

Figure 5-1: System interaction with Typical Enabling Systems (from ISO 15288)

ISO/IEC 15288 provides processes applicable to all stages in a product life cycle, from conception and development to production, utilisation, support and retirement. The standard provides guidance to the development of these processes by defining for each one the purpose it fulfils, the outcomes to be achieved and the activities that need to be performed. The detailed content of the processes will be filled in by the user according to the specific product and to the organisational context and requirements. The principles and practices found in ISO/IEC 15288 are well known in the aerospace and defence communities, they are also being applied in industries associated with transportation and energy.

In aerospace applications, ISO 15288 also depicts an essential set of characteristic lifecycle stages that exists in the complete life cycle of any system: concept, design, production, utilisation, support and retirement [25]. For each stage of the system of interest (e.g. the aircraft), some enabling systems are to be considered which have themselves their own lifecycle. It is in particular the case for Concept System (e.g. Marketing department and associated resources), Design System (e.g. Design office and associated resources), Production system (e.g. factory and associated capabilities), support system and retirement system (see Figure 5-1).

ISO 15288 contains 25 processes that form four process groups: agreement processes, enterprise processes, project processes and technical processes [25]. Each process is described by a name used for identification, a purpose which provides global objective of the process at a high level, a list of outcomes indicating expected results in case of successful execution of the process and a list of activities that are used for the structural decomposition of the process.

The EADS business case in this section is mainly related to the development phase of the Aircraft (domain of interest) and to the development enabling system and associated PLM solutions. The ISO 15288 processes of interest are those of the technical area, in particular stakeholders' needs definition process, requirement analysis process, architectural design process, implementation process, integration process and verification process. The case also deals with information flow between the different enabling systems supporting the different phases of the aircraft, for a predefined end to end process: the change management process. A strong connection exists with the agreement processes, acquisition and supply.

In addition, Product development is today performed making extensive usage of computers in order to aid the different functions of the enterprise, the industrial programs (e.g. Airbus'A380) and the different disciplines involved in this development. So all the enabling systems are encompassing applications and have to deal with interchange and sharing of digital artefacts (product models, factory models, etc.) between the applications of the network enabling systems. Accordingly, the business case also address the dynamic organisation of the design systems of the collaborating partners, which are distributed in their design offices: the change management process coupled with configuration management, and the Technical Data Package (TDP) interchange process. Such capabilities will be supported by the collaborative platform (cPlatform) developed for the Aerospace Virtual Lab.

The business case is used to provide examples for usage of blueprints related to choreography, orchestration, local process and process-segments.

5.1.2 Partner and Product blueprints

Figure 5-2 illustrates simplified version of the EADS partner blueprint profile (according to the definition in section 4.3.2), which is used in the business case described earlier in this section. For reasons of simplicity the EADS profile states that EADS is a flying systems integrator, implementing aviation system-engineering processes.

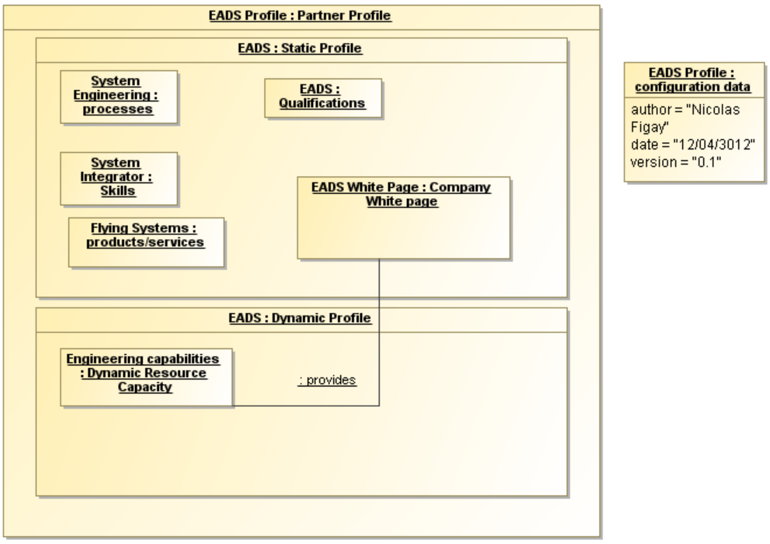

Figure 5-2: EADS Partner Blueprint Profile

The processes will be related to the system engineering processes with in particular those which are cross-organisational for cross enterprise collaboration, and which are addressed by the PLM standards proposed by the Aerospace & Defence Strategic Standardisation Group (ASD SSG) which has set standards and associated harmonised European policies for operational use in the Aerospace & Defence sector.

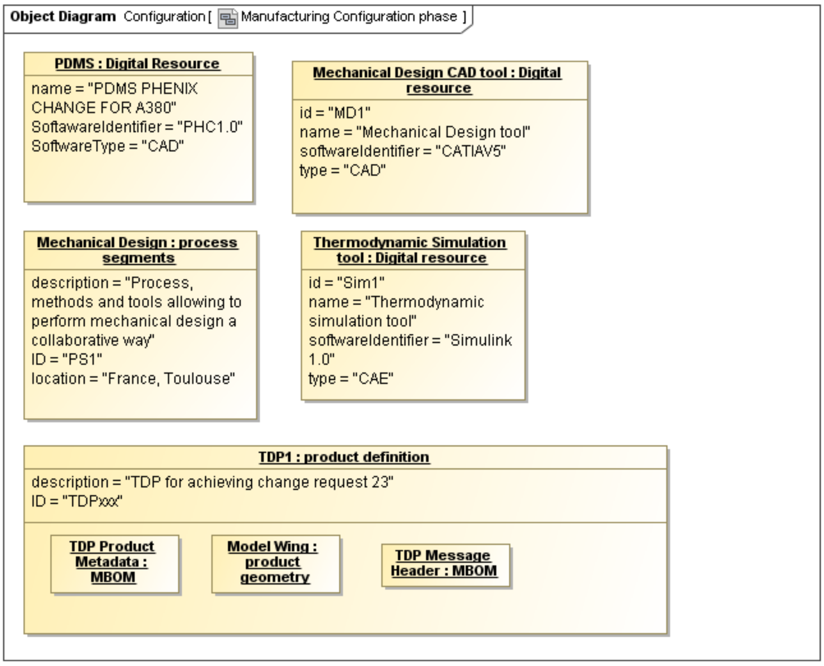

Figure 5-3: EADS Product blueprint

The product blueprint in Figure 5-3 identifies aerospace applications and processes that are available as capabilities. It provides entries for a set of product data provided by change management and Technical Data Package processes. In that respect it shows how a standard product blueprint can be extended to include aerospace sector attributes.

5.1.2.1 *Simplified end-to-end Blueprint*

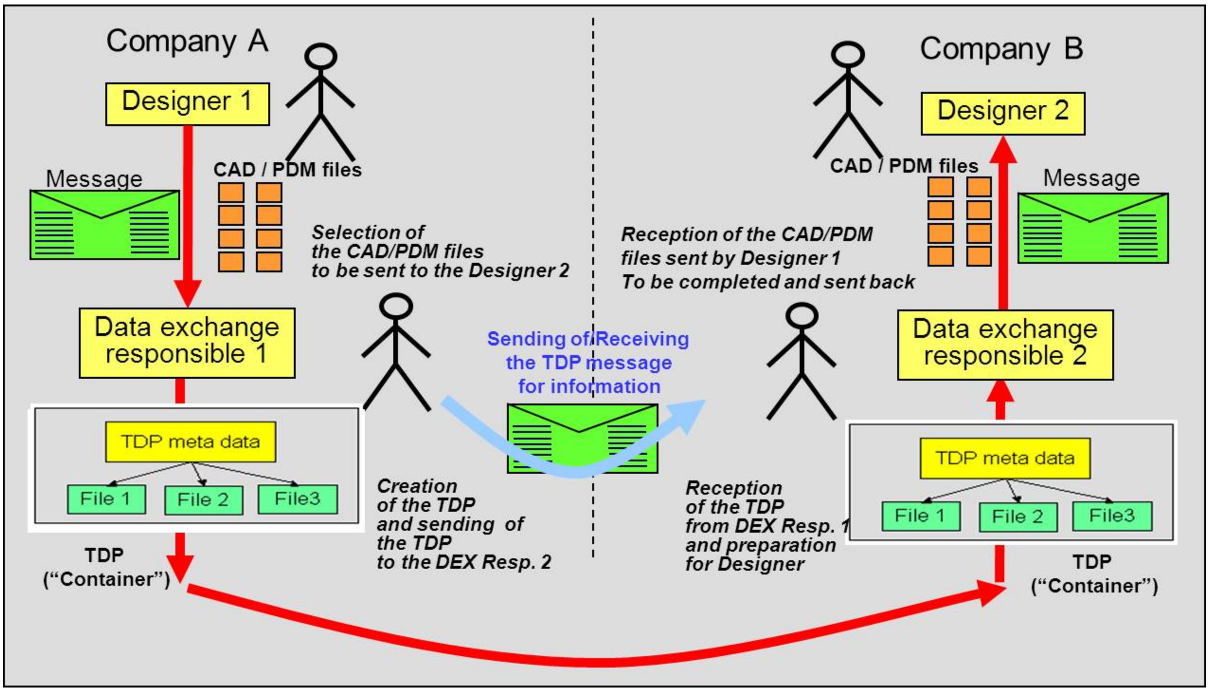

Figure 5-4: Activities in TDP process

The end-to-end process blueprint in Figure 5-4 used in order to capture the set of processes defined by ISO 15288. The example concentrates on the Technical Data Package (TDP) process and shows how Product Data Management (PDM) generated data that can be exchanged between two companies A and B to achieve an effective collaboration when designing digital models of manufactured products. In Figure 5-4 one firm acts as an Original Equipment Manufacturer, e.g., EADS (called Company A in Figure 5-4), which designs and develops a certain product (e.g. an aircraft) and externalises (outsources) a certain number of aircraft development activities to an external supplier partner (e.g. the activities related to the manufacturing of the engine) – called Company B. The data exchanges happen according to the description of the Technical Data Package process in section 4.3.3.4.

Figure 5-5 describes the workflow and information exchanges of the TDP process. In this drawing, we can see the digital resources used, two generic profiles of actor (role in the generic process), some engineering activities (TDP content preparation and usage) and some technical activities related to the secured transportation of files through a hub. We can also see the engineering artefacts: product structure, product models and associated documents.

The BPMN notation is then used to describe the choreography and orchestration for the TDP process. This is done in accordance with the end-to-end blueprint structure as described in section 4.3.4 and what is mentioned in Figure 5-5.

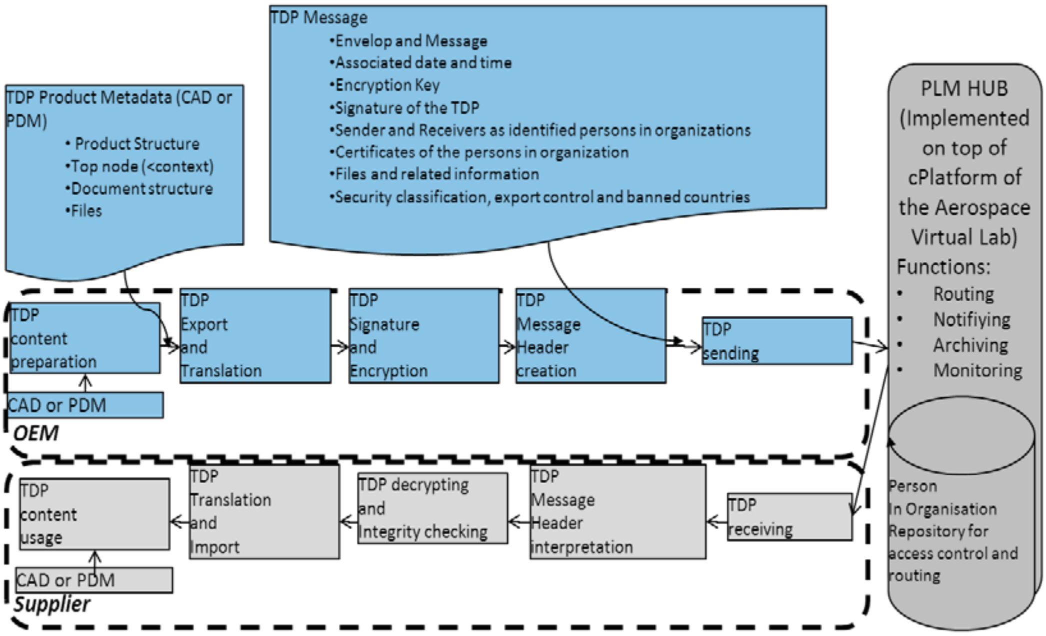

Figure 5-5: TDP end-to-end process description

Figure 5-6 describes the details of the choreography process for the TDP example. Recall that this process corresponds to SCOR Level 3.

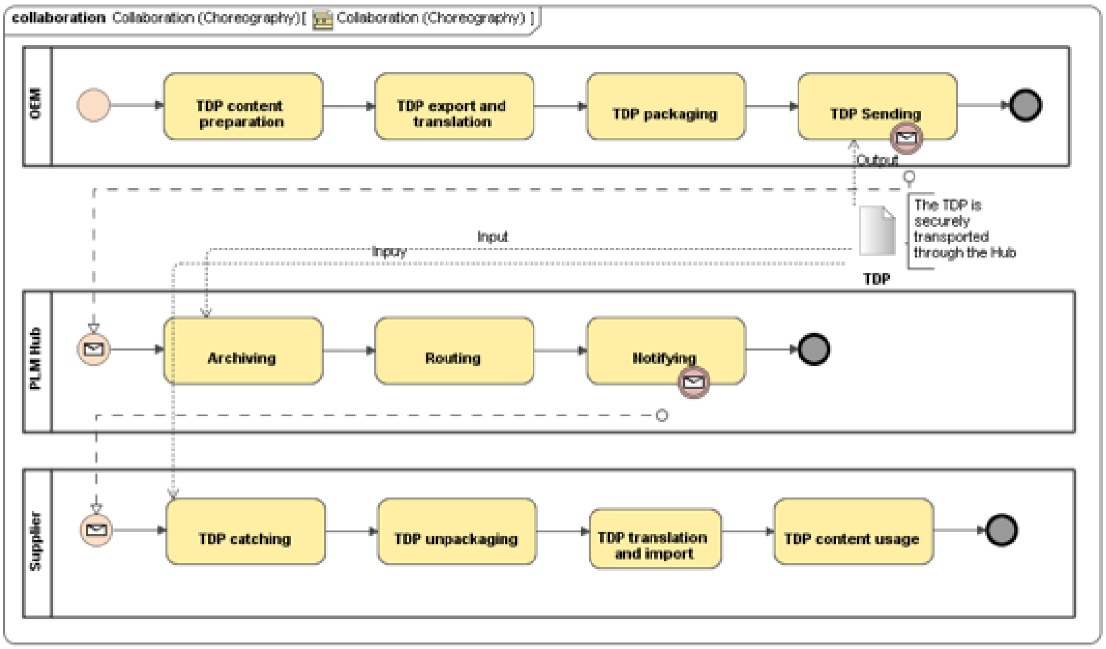

Figure 5-6: TDP process choreography – collaboration aspects

The next step is to describe the orchestration for each pool of the choreography. This is shown in Figure 5-7. Here, we do not detail activities of the choreography but the distribution of activities inside a specific pool at SCOR Level-4. This is due to the fact that it is desirable to make visible activities performed by some organisational divisions (or sub-contractors). Decomposition of the activities will be specific to a partner, so this undertaking can be accomplished at (SCOR) Levels 5 or 6 – which are not shown in this section. At this level, the partner blueprint could be updated with more details about the organisations involved in the functional decomposition. An important requirement is for the partner blueprint to be able to capture the organisational divisions involved in a process orchestration, in case that these were not identified earlier.

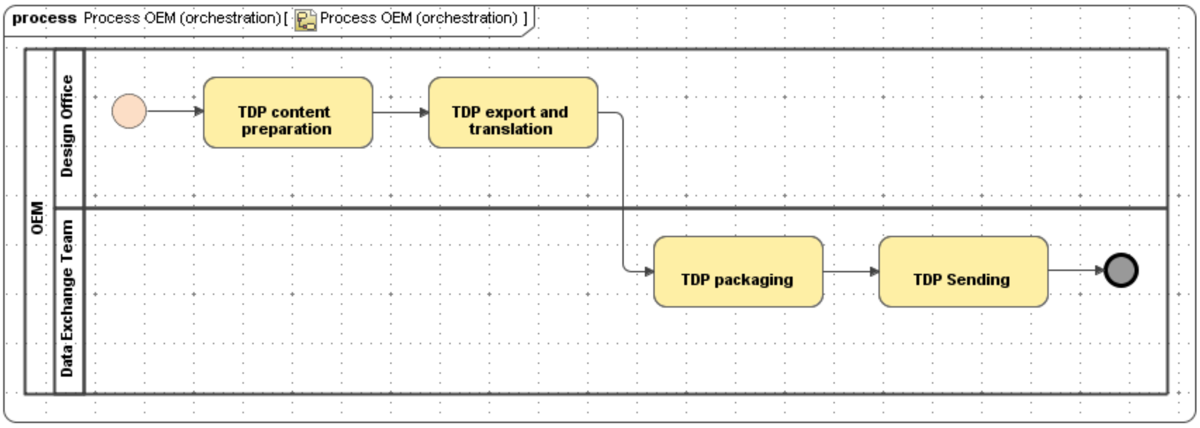

Figure 5-7: Orchestration of the OEM process

5.2 Application of the Blueprint Model in the Automotive Sector

REPLY has selected a use case scenario for the Living Lab that revolves around a car door manufactured upon a vehicle order of a car or a spare part order inside a manufacturing plant with components supplied by contracted suppliers (with required quantities, quality, due dates etc.). This use case scenario is realistic, yet fictive, and has been inspired by quality assurance issues that emerge during assembly of car doors at FIAT.

5.2.1 Production Orders for Car Manufacturing

The central factor in controlling and recording the car manufacturing process is the production order. Generally speaking, production planning commences with an incoming customer-driven vehicle order, possibly derived from planned demand, leading to part orders for car parts such as front- and rear-doors. In particular, a production order is a request to the manufacturing sites to produce a specific type of car at a specific time and in a specific quantity. It specifies the labour, machine and material resources to be used for car manufacturing. A range of data is required for the car production order, including, routing information, the Bill-of-Material and resources needed.

The production order is fed into the DMN production planning system that pools information about stock levels for parts needed during the production run. This is enabled by application interfaces between the production planning and Warehouse management application (DES). Once a rough plan is generated, "the master plan", a detailed plan is generated making use of the materials management/capacity planning application. The detailed plan schedules the work list that includes a production sequence that is feasible given available resource capacity. This plan is then issued to the Shop Floor (MES) application, to instruct people and configure product lines on the shop floor. In case parts are needed for a particular batch production at the product line, parts can be ordered.

The production process may source parts from various alternative part suppliers (labelled Supplier 1 and Supplier 2 in Figure 5-8) in order to ensure operational continuity, which is increasingly important to address potential production disruptions due to unexpected events, such as a supplier that has problems to deliver, e.g., due to a financial problems or a disaster.

5.2.2 Car Door Manufacturing Process

The living lab use case scenario revolves around the assembly of car doors. Car doors are highly complex products, comprising mechanical, electrical, plastic and metal components. Many of the door's attributes conflict: for example, improved noise reduction and personal safety will make it in general more difficult to close the door.

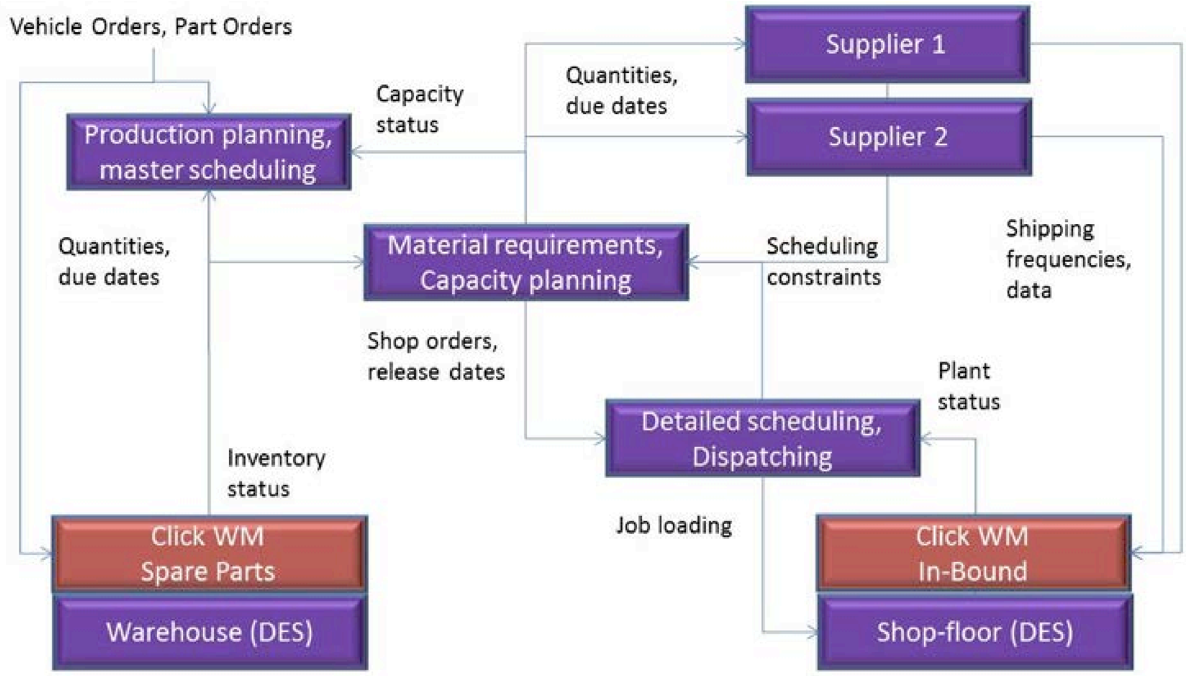

Figure 5-8: Car door manufacturing process

The discrete, end-to-end-process of car door manufacturing takes place in a single plant and is composed by five manufacturing processes as depicted in Figure 5-8).

5.2.2.1 End-to-end Manufacturing Process for Car Doors

The end-to-end process for manufacturing doors shown in Figure 5-9 is basically structured as follows

1. Firstly, bar metal shells made from sheet metal are ordered from external first-tier providers, and formed to its shape in during stamping in the factory.
2. Then the inside part of the shape is produced in a similar way the external part is made, except that the sheet has some pre-cut holes for wiring and attaching panel. These two parts the shell and inner shell are subsequently folded and welded together. Other metal components can be assembled/ welded, as well such as holding fixtures.
3. Next, the whole metal assembly is sent on painted and then issued for assembly during which interior wiring/assembly is done to the painted door, and the panel assembly is added to the door.
4. Lastly, the car door is polished and packaged.

Note that the above process relies on first- and second tier suppliers that deliver door parts such as the pre-cut sheets, and take care of manufacturing steps such as painting.

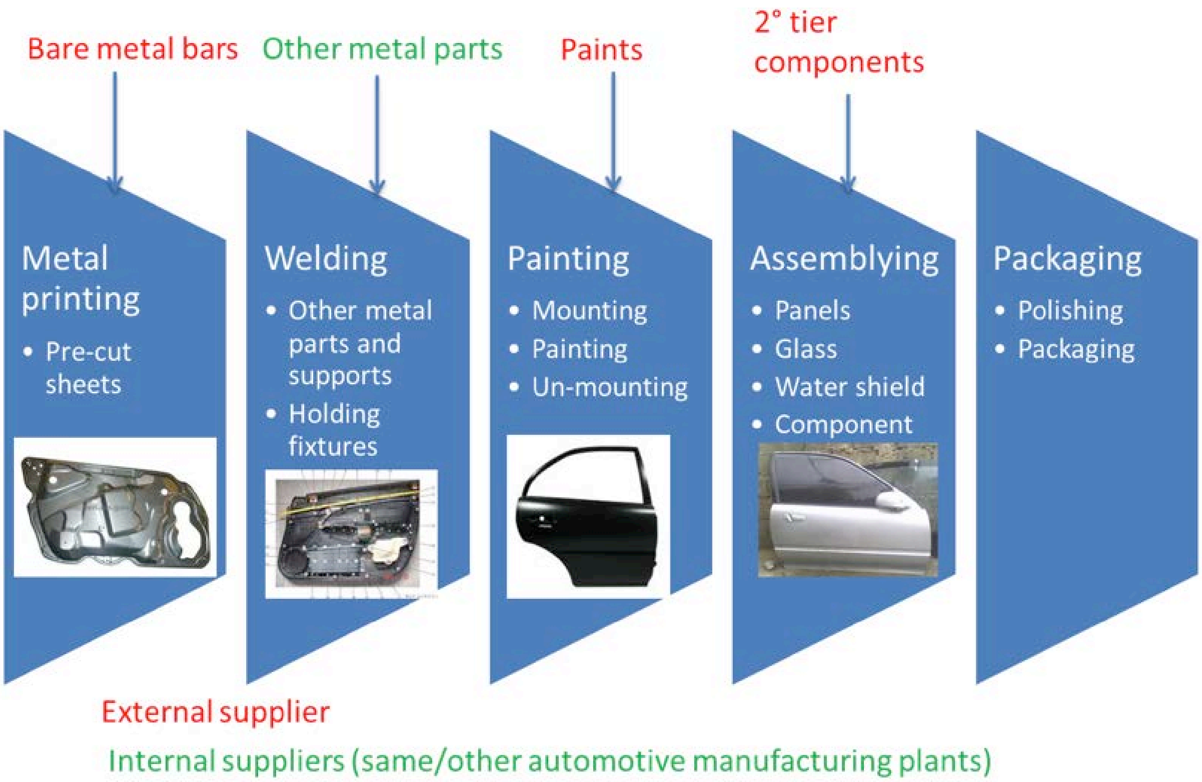

Figure 5-9: End-to-end process for manufacturing doors

Quality assurance plays a pivotal role in car manufacturing in general, and the car door scenario more in particular. In the manufacturing network a failure in the practice by one of the partners may render quality shortfall of the car, where quality assurance of car parts being manufactured and assembled must satisfy quality norms to ascertain that the car (door) at the end of the assembly line will meet the expected quality by the customer. Failure to meet quality norms by one part of the car door, may in fact jeopardise the overall quality of the car. In concert with the other IMAGINE blueprints, the QA Blueprint will help to store and manage data with regard to the car door (and its constituents) as well as the car (door) manufacturing process.

5.2.3 The Quality Assurance Blueprint Exemplified

In this section, we will describe how the Quality Assurance Blueprint can be exploited to capture the QA parameters associated to a window motor that constitutes a critical subcomponent supplied by a third party and assembled during the Assembling sub-process. In particular, this section will instantiate the formal (meta-)model of the QA blueprint that was introduced in section 4.3.5 using the car door manufacturing scenario. The result of this exercise is captured in Figure 5-10.

The overall Service Level Objective for car door manufacturing process is the “Delivery time” of the component (cf. the “Delivery time” label in Figure 5-10). This top-level SLO can be further decomposed in level 2 to 5 metrics. In particular, the SLO “Delivery time” can be mapped to into level 2 metric:

Lead Time to Deliver, which refers to the time between the creation of a production order and actual delivery. This level 2 metric can be further refined into the Level 3 metrics “lead time from order to delivery over a pre-defined schedule”. The pre-defined schedule is always defined in the contracting phase with the third-party supplier taking into account the needs of Just In Time (JIT) production. The third-party supplier delivers its components over a strict delivery calendar, so the next order is fulfilled by inserting the component into a pre-defined delivery slot. The level 4 metric actually quantifies the level-3 metric given in accordance with its measuring scale (<unit>=”days”, <value>=”2”).

Another example of a SLO is the cost to produce a component (e.g., car glass); this metric is merely used for budgetary analysis (i.e. to calculate the value of a defective lot). The Partners modelling element in Figure 5-10 is instantiated with the <name> of the company, a <supplier ID> and other information described in the Partner blueprint. This element constitutes in fact the linkage to the Partner Blueprint.

The information that is captured by the Partner Blueprint and which is in this way associated to the QA blueprint can be summarised as follows:

1. Certification: the type, validity, broadness and applicability of certifications obtained by independent certification bodies. The example instantiates <type>=”ISO9001” with <validity>=”5 years since 04/04/2009”, thus enabling to verify that the supplier retains a valid ISO9001 certificate with a reasonably recent audit performed by the independent body further defined in <certification_body>=”DNV” and therefore it can be a valid supplier.
2. Reputation: this value, chosen in a range from 1-Bad to 5-World Class (<range>=”1-5”= can be a ranking based on historical data about the delivery time (key factor) and the trust in maintain the baseline performance levels by the third party supplier.
3. Organisation: this element describes the supplier organisation in reference to its capability to deliver. What is important here is to know the size and complexity of the supplier’s organisation. A sample value can be “Offshore 2nd tier manufacturer”
4. Tooling, IT Systems and Logistics: this element describes the relevant IT, machine and logistic capabilities of the supplier, such as:
    a. Tooling: <automatic wiring equipment>
    b. IT systems: <MRP>=”not present”, <ERP>=”SAP R/3 v. 5.6>, <Wharehouse Management System>=”REPLY Click WM rel. 4.0”, <EDI interfaces>=”EDIFACT”, etc.
    c. Logistics: <Shipment_element>=”UNI EURO Palletised wooden boxes”

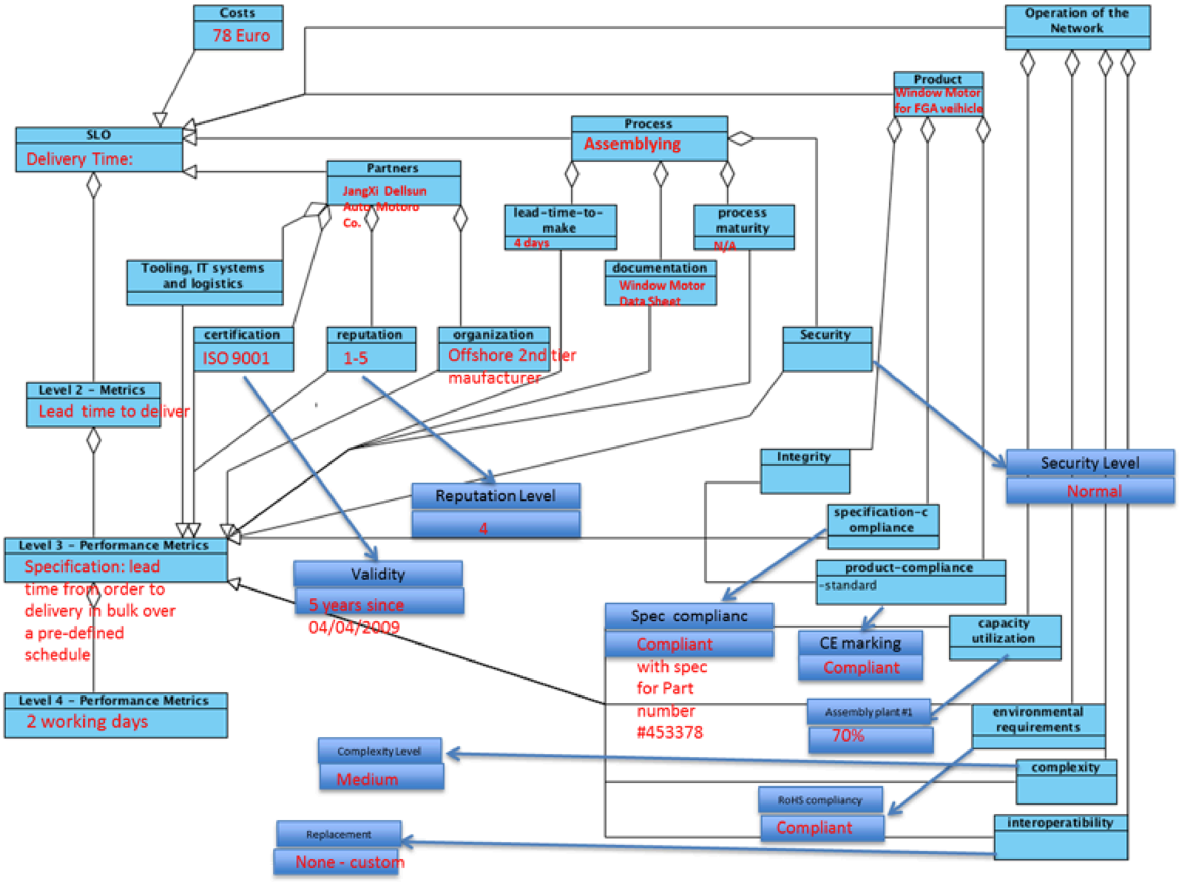

Figure 5-10: Schematic of QA parameters associated to a window motor

The Product element links the QA Blueprint to Bill-of-Material item of the Product blueprint. We assume that this information, e.g., the BOM of a Window Motor for an FGA vehicle is provided by the external, first-tier supplier. The Capacity utilisation, when available from the third party supplier, provides useful information when a third-party supplier is requested to increase its production on behalf of a failing supplier. For example, this modelling element can be expressed as a percentage of the total supplier capacity, <capacity>="70%". Again, this information is linked to the Capacity element in the Product blueprint.

Several elements of the QA Blueprint assist in assuring quality. In particular, the relevant parameters to be instantiated for quality acceptance are related to the compliance of the product with contracted characteristics (expressed in <product compliance>="standard" for example for a common, off-the-shelf electric servomotor), with <standard>="Part Number Specs #453378").

Finally, other relevant compliances can express the alignment with national or European regulations (<CE marking>="Required") or environmental compliances (e.g., the regulation Reduction of Hazardous Substances – RoHS now mandatory for all electric and electronic equipment.

6 Towards adopting a DMN approach: Benefits and Risks

This section aims to identify the benefits for enterprises' participation in efficiently managed and monitored Dynamic Manufacturing Networks and to provide business incentives for using the proposed (by the IMAGINE project) methodology for DMN management and monitoring. As it turns out (and has been showcased in the previous sections) the operation of an enterprise in a DMN is quite different to that of an enterprise belonging in a traditional supply chain network. Although the major departments and their operations remain the same, having the same objectives, the inclusion in a DMN calls for real-time, dynamic and more reliable operations. This is especially evident in those departments where the flow of messages goes out of the boundaries of the specific enterprise and communication with other partners is conducted. This is natural, as one of the major characteristics of DMNs is the active collaboration and communication between the different network nodes, and as such, operations that include communication between enterprises are heavily affected. This new modus operandi, which calls for modifications in the various internal departments and operations of an enterprise (which is also reflected on the IT infrastructure and on the day-to-day activities), is expected to offer a number of important benefits to enterprises that decide to participate in a DMN, improving in such a way not only their manufacturing capacity and operational procedures, but also offering them the possibility to enlarge their market share and improve their viability and profits.

At the same time, as the notion of a DMN is based on information sharing and collaboration, which in some cases contradicts with some fundamental ideas of enterprise culture such as confidentiality, provision of just need-to-know information, etc., potential risks, such as security and trust in information sharing in DMNs should be identified and ways of how they can be managed and avoided should be determined.

The methodology that has been used in order to identify the benefits and the risks surrounding the participation of an enterprise in a DMN includes:

- Identification of typical industrial & organisational operations of SMEs belonging to several sectors
- Grouping of operations by department and type (internal/external).
- Identification of the operations that get re-organised or indirectly influenced by a DMN
- Tracking down possible benefits of adopting the DMN methodology – classification by operation type and by department
- Identification of problems and risks imposed per industrial operation and department
- Identification of risk avoidance and mitigation strategies and proposed solutions.
- Consolidation of the enterprise specific benefits and risks (as documented in Annex E) on a higher, network level perspective in order to present the overall critical factors that influence the decision to participate in a DMN.

It needs to be noted that the present level of analysis with regard to risks/benefits and their management/exploitation is based on the actual developments of the IMAGINE DMN methodology and the associated IMAGINE Manufacturing Blueprint model. The further elaboration of the methodology and the blueprints through the operation of the Living Labs (WP4), alongside with the developments of the architecture of the DMN Platform (WP2) will result in more case/sector specific benefits and risks, which will be captured by the framework, designed in section 6.4 “Framework for Continuous Verification of Benefits and Risks”.

6.1 Business Environment and Drivers

Today's markets are subject to pressing situations like fluctuating demand or market saturation. Fluctuating demand refers to the big effect that a small change in end-customers’ demand can have on the supply chain and the participating enterprises. Saturation, on the other hand, describes the situation that a market is no longer generating new demand for a firm's products, due to competition, decreased need, obsolescence, or several other factors, so further growth can only be achieved through product improvements, market share gains or a rise in overall consumer demand. Given the fact that such pressing situations are making their appearance more and more in today’s B2B and B2C markets, the “push of supply” tends to be almost completely displaced by the “pull of demand”. That places customers in a position to dictate the supply, so companies have to satisfy discontinuous demands dominated by the urge for individuality and self-realisation needs. During the last years many companies face intense pressure caused by fast changes in technology, short product life cycle, and fierce global competition. This is why they have started realising that it is increasingly important for them to be flexible, well organised and to be able to change anything - from production plans to supply chain structure - as market demands dictate.

In order to face this situation, many enterprises have decided (particularly in the last decade) to flatten their structures by shifting authority downwards, giving employees increased autonomy and decision-making power [62]. Advantages of flatter organisation forms include a decreased need for supervisors and middle management, faster decision making, and the ability to process information faster because of the reduced number of layers in the enterprise. Although these changes have given a boost to the operation of several enterprise units, like HR, Marketing, Sales etc., they didn’t have an important effect on the departments and units related to production. Cost reduction strategies, like mass production, at this point are no longer meaningful, as reducing core production costs below a threshold is not possible in most of the cases.

Given the afore-mentioned facts and the constantly increasing competition due to globalisation, companies (especially EU-based) have just recently realised that apart from flattening their organisational structure, the only way to reduce production costs is to eliminate superfluous processes and begin focusing on their core, value-added business. So it has been accepted that flat organisations using joint ventures and strategic alliances can provide increased flexibility and innovation and replace traditional hierarchies and organisational schemes [60]. The idea of the Dynamic Manufacturing Networks adopts this philosophy in order to evolve and particularise in the manufacturing sector, the Virtual Organisations’ concept, which is considered by many [63] as an ideal path for several enterprises having to face issues like unprecedented customer expectations and alternatives, global competition, time compression, complexity, rapid change, and increased use of technology.

6.1.1 Business Environment

It is beyond any doubt that in the global competitive environment of the 21st century, each enterprise has to continuously improve in order to have chances to succeed. Today's manufacturing landscape is characterised by dramatic and often unanticipated changes. In this difficult and challenging environment, the manufacturing enterprise must develop and implement new and innovative strategies in order to remain competitive. As Gartner [15] puts it, taking as an example the logistics functions *"Performance-based logistics (PBL) sustainment contracts of more than five years are the new normal, as reduced budgets drive longer service life cycles for existing platforms, requiring greater supply chain and engineering collaboration."*

Manufacturing witnessed during the last decades a progression of initiatives aimed at improving various elements of the organisation and then integrating them into a well-defined system. In the seventies, many companies focused on Total Quality Management (TQM) [71]. Later, companies implemented factory automation in various "islands" on the factory floor and afterwards they started focusing on how to integrate these "islands of automation" [69]. Flexibility became a key component in the factory of the future. Flexibility was defined as the ability to respond to known or anticipated changes in product mix and quantity. Agility took this one step further as encompassing the ability to respond to unanticipated change. The next level of improvement was to extend beyond the factory, to suppliers.

Supply chain management has had a similar progression over the years. In the 1980s, improvements were focused on solving specific quality problems, generally at the first tier in the supply chain. The so-called "first tier" suppliers are typically comprised of independent suppliers making parts for integration into a final product by a large company. Shifting inventory risk from the large company to the supplier base was the primary strategy applied during this period. After identifying problems at the supplier level and interface problems between suppliers and large companies, suppliers typically improved through small increments in process control. In the early 1990s, supplier management achieved marginal improvements through myopic project-driven plans characterised by limited joint problem solving, strategic partnering, information sharing, and process ratings capabilities with an emphasis on improving inventory management. This period was characterised by cross-functional teams of primes and suppliers working to improve process capability and implement compatible systems interfaces with a limited contribution of suppliers' engineering knowledge to new product development.

Today, competitive pressures have greatly intensified to the point where supply chain initiatives must yield greater improvements than ever before. This challenge requires a holistic solution that takes into consideration all aspects of the entire supply chain from a systems view.

Typically, supply chain efforts focus on one-time design of the strategic level issues regarding the supply chain or, alternatively, the design of operational level decision support for "optimising" the complete chain. In this context, the supply chain is a critical link in the interlocking sequence of elements that must achieve breakthrough advancements including all aspects of the enterprise. Without a committed supply chain delivering "the right part at the right time and for the right price", many short-sighted companies continue to lose market share. An important component of lean and agile initiatives, supply chain improvements affect processes in factory operations, business systems, and engineering design in the interest of reducing costs, improving quality and shortening delivery cycles. As an enterprise seeks to continually improve, it must also continually widen the scope of improvement.

Nowadays more and more manufacturing enterprises realise that only by themselves, working as single enterprises in traditional supply chains, they cannot provide the maximum value to many of today's more demanding customers. So, for them, an increasingly popular solution to maximising value to the customers is the concept of "upgrading" their supply chains to Dynamic Manufacturing Networks. For a manufacturing enterprise, participating in (or forming) a DMN can be at least considered as a systematic way for building up extended co-operation with other members of its supply chain (i.e. suppliers, business customers, subcontractors and other collaborators).

The following figure presents the operational environment of collaborating in a traditional supply chain.

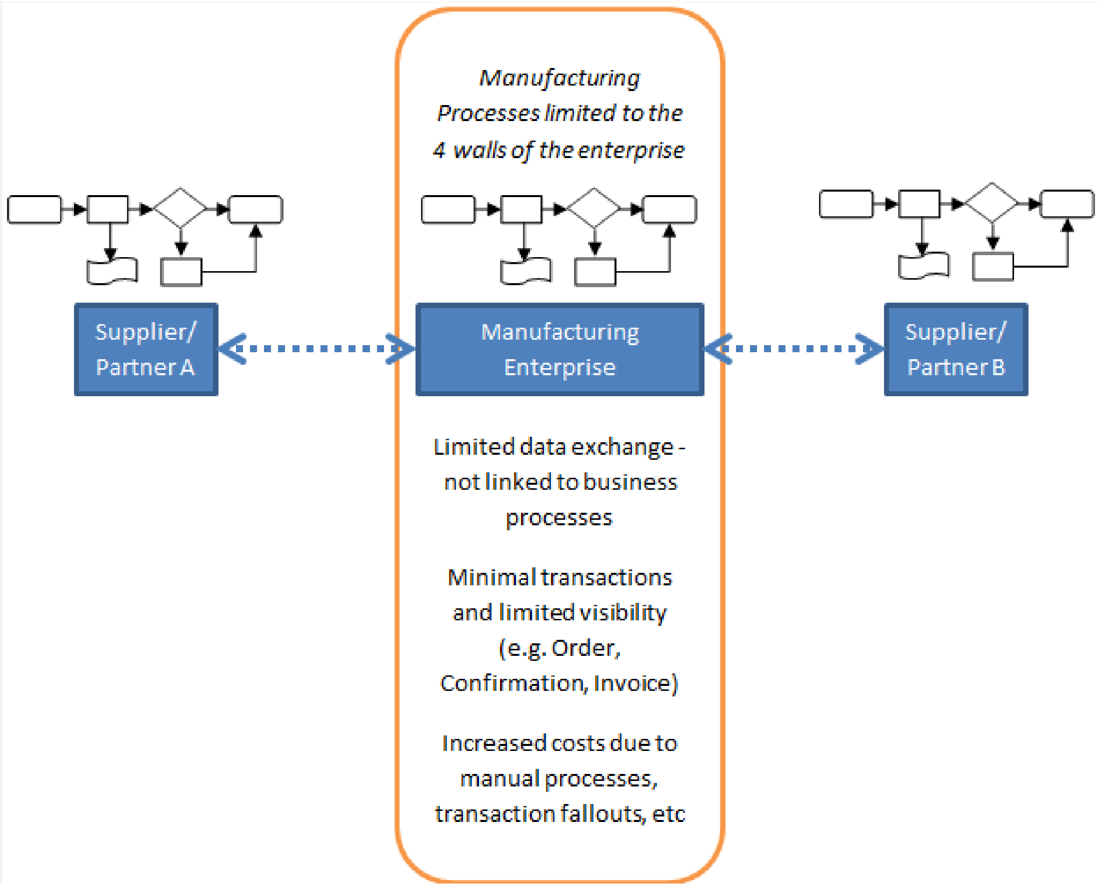

Figure 6-1: Collaboration in a typical supply chain environment

The appearance of a cost-efficient use of modern information technologies enables manufacturing enterprises to decrease transactions-costs dramatically, causing a tendency towards network structures and more specifically towards Dynamic Manufacturing Networks. A key characteristic is that enterprises participating in a DMN are more capable to adapt flexibly to a fast changing environment and to process information as single functional components of a network that manages available knowledge in DMN level. For enterprises participating in DMNs, the differentiation between internal and external processes is not easy. Most of various business functions can be managed by the network, involving interactions among the different partners. DMNs' enterprises are not operating isolated - as a contrast to ego-centric enterprises participating in traditional supply chains - but are connected in a complex context of interactions with other actors, partners, suppliers and customers. Concerning relationships between participating enterprises, the central concept of DMNs can be described as the establishment of a relationship between several independent actors in which many of the command and control functions are performed by a sophisticated IT platform, managed externally. These relationships can be either vertical (among the members of the hierarchical supply chain, like 1st tier supplier, 2nd tier and OEM) or horizontal (among enterprises of the same sector/tier).

In comparison to the traditional model described earlier, the collaborative environment of Dynamic Manufacturing Networks is presented in the next figure.

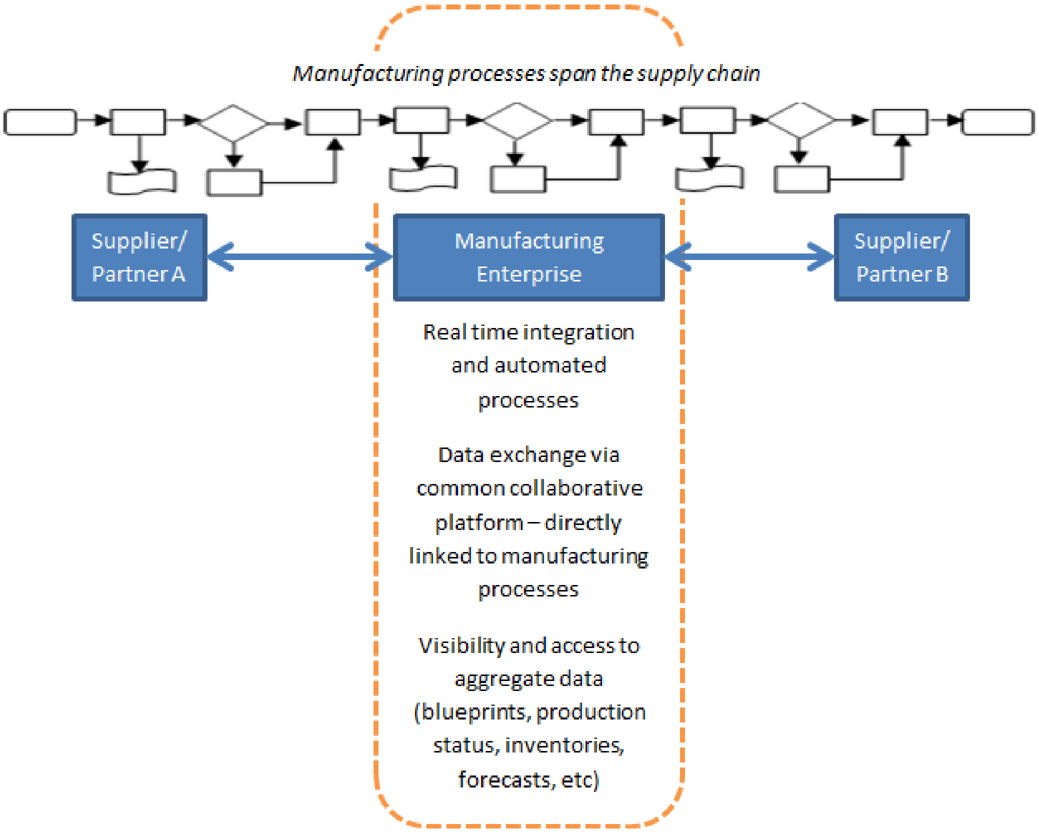

Figure 6-2: Collaboration in a DMN environment

6.1.2 Business Drivers

6.1.2.1 Key Factors

The concept of "Dynamic Manufacturing Networks" brings diverse innovations together, such as just-in-time supply, work teams, flexible manufacturing, reusable engineering, worker empowerment, organisational streamlining, computer-aided design, total quality, and mass customisation into a coherent vision for the future enterprise. Of course, forming DMNs is something that requires important changes in enterprises' organisational schemes, processes and procedures (as far as it regards the part that will be dedicated to the DMN), while at the same time a number of risks is associated to those changes. However, since the risks can be easily recognised, their avoidance or mitigation is mostly related to signing clear agreements amongst the different parties involved and establishing the right processes, always given the fact that the big change is that workflow can spread across company boundaries. This is where information technology comes, in order to support the operation of DMNs and the cooperation in strategic as well as in operational level of participating enterprises.

On the basis of the concept behind Dynamic Manufacturing Networks, the aim is to achieve market differentiation by performing better, through focusing on the core competencies and obtaining all other activities from outside, i.e. from other DMN members. Improving competitiveness and productivity, enhancing efficiency and responsiveness and decreasing overheads are results, which are, expected regardless the scheme or the scope of the DMN.

On this basis, there are some prerequisites – considered as key factors – that an enterprise should take into account before entering a DMN, regardless of the exact motives/drivers for joining the network. The following points can be considered as the most crucial:

- **Collaboration**: The entities involved are in(ter)dependent and yet tied together in a loose network with pre-defined procedures and agreements to guide any collaborative arrangement entered into.
- **Security, Agility and Trust**: While maintaining a high level of security, DMNs must be able to cope with a constantly churning pool of suppliers whose relationships vary enormously in intimacy and scope. Establishing common objectives among the partners (short-/medium-term) is a key issue.
- **Human Interaction**: DMNs are supported by technology but are still based on humans, so enterprise collaboration is based on better cooperation between groups of employees coming from the different DMN members. Trust and openness of the management and the employees, as well as the ability and willingness to cooperate are considered essential.
- **Commitment**: Commitment from each participant is required in order to reach the (short term) goals set each time. It's crucial to assure the existence of Win-Win relationships for all partners involved.
- **Knowledge Sharing**: Knowledge management becomes an extremely important issue since knowledge and competencies are shared among the partners, while at the same time intellectual property issues have to be taken into account.
- **IT Systems Maturity**: High stage of maturity of the individual IT-systems is a prerequisite. Cases of important variance concerning the IT sophistication of the network members must be handled respectively.
- **IT Backbone**: The development and adaptation of an IT platform specifically designed for DMN end-to-end management can be considered as one of the most crucial requirements in order the network to operate as intended.

6.1.2.2 Driving Forces

According to the literature [10],[11], the prospects of effectively responding to market demands, developing better products faster, improving quality and finding possibilities to lower costs can be considered as the most important driving forces for an enterprise to overcome the traditional operation and adapt a collaborative way of thinking and dealing with suppliers and partners.

However, in order to go one step further and change the whole way the enterprise operates and collaborates, as required in order to participate in a Dynamic Manufacturing Network, strong driving forces and important potential benefits must be identified and evaluated accordingly.

Efficiently managed DMNs can realise cooperation between enterprises for common undertakings and allow dynamic reconfiguration as the need arises. In the long term this is expected to bring a major breakthrough in productivity, organisation and economic growth through:

- Innovative products and services combining communication, electronic commerce and business process automation to provide effective and low-cost customer service
- Innovative workflow-enabled processes that track transactions across department, unit and enterprise boundaries
- Innovative organisations relying on workflow-based end-to-end business processes to provide the best possible service, in spite of the internal structure being adapted to match market needs
- Dynamic win-win cooperation between participating enterprises and better service for the market, based upon optimum performance of each of the assembled members and enabled through workflow-controlled business processes.

In general, typical reasons for establishing DMNs can either refer to approaching business problems or to taking advantage of business opportunities. Specific motives for an enterprise can come from within the company or from outside – for example internal cost problems versus new market developments.

In most of the cases, the drivers for setting up (or for participating in) a DMN are related on a mixture of several expected benefits (see next section for an analysis of potential benefits). In addition, usually, not all participants have the same expectations, even if potential benefits on network level may have impact on all of them. The latter is something that has to be taken into account when forming and “setting the rules” of the DMN, as well as the norms for managing and operating it efficiently. In any case the driving forces towards participation in DMNs can be summarised to the desire of any enterprise to improve market position and gain competitive advantages and, of course, to the will to bring in more profit.

6.1.3 Views from the IMAGINE Living Labs

6.1.3.1 Aerospace and Defence Industry Living Lab

Due to globalisation, competition or market pressure, a current trend is the continuous increase of the percentage of sub-contracted activities. In addition, product development is today performed making extensive usage of computers in order to aid the different functions of the enterprise, the industrial programs (e.g. Airbus’ A380) and the different disciplines involved in this development. So all the enabling systems are encompassing applications and have to deal with the interchange and sharing of digital artefacts (product models, factory models, etc.) between the applications of the network enabling systems. The Dynamic Manufacturing Network approach provides three specific advantages to the members of the Aerospace and Defence Industry Living Lab:

1. A better view of company backgrounds and their product & services

2. A better view of capabilities of each partner
3. Knowledge on their processes and their potential new products

The current aerospace and defence business environment claims for the agile adaptation to the evolving market needs in order for the enterprises involved to remain competitive and to take advantage of emerging opportunities.

The establishment of dynamic and strategic collaborations based on real-time and automated business processes allows taking full advantage of the resources, technologies and innovative knowledge of individual qualified partners.

In this sensitive context, these dynamic manufacturing network collaborations need to guarantee the adequate levels of confidentiality and security. However, sharing of knowledge and technologic capabilities may still be achieved by taking advantage of IT mechanisms enabling access to individual knowledge while preserving the required confidentiality levels. Likewise, shared resources optimisation and scalability properties can be satisfied based on well-adapted IT technologies.

6.1.3.2 Automotive Industry Living Lab

The Automotive supply chain is as complex as the vehicle itself. Made of more than twenty thousand parts, it relies on the availability of each one of them for the delivery of the final product. With the increased use of Just-In-Time (JIT) or Just-In-Sequence (JIS) to reduce the working capital, greater pressure is put on logistics and supplier responsiveness. As Tier 1 are supplying major components, and Tier 2 work on furnishing the parts that the Tier 1 suppliers require, the case of having up to 3 to 5 levels of suppliers may lead to thousands of suppliers, all of them affected by specific potential risks and involved in business continuity.

From the OEM side the focus on cost savings has led to the increased usage of platforms, components standardisation and cuts on supplier margins. Suppliers are asked to cut down on prices and increase responsiveness - while volumes are overall decreasing - and even more, to perform on their own product development, systems development and delivery, as well as increase innovation on techniques, skills and technologies to improve their own and OEM competitiveness. The supply chain is now stretched to the whole globe, with Tier 1 and Tier 2 often compelled to supply products from emerging and low-cost countries, far from the final assembly and consuming countries. Furthermore a question that lies ahead is how can automotive companies mitigate the risks in these stretched supply chains? Is there a way to predict the weak link, strengthen the chain and prepare recovery actions? Is there a way to determine the reliability of suppliers and reduce the impact of risks occurring in the supply chain, in both design and operational steps?

Using a DMN, the members of the Automotive Living Lab will be able to:

1. Define alternatives for the supply chain configuration
2. Prepare strategies for tackling supply chain interruption
3. Quantify the resilience and performance of supply chains through simulation

6.1.3.3 *Furniture Manufacturing Living Lab*

Until not long ago, common analysis from the point of view of production, focused on trying to optimise processes to add value as it is understood that these processes are the ones who really represent a cost to the company, as the process was managed but not the process flow.

In this environment many methodological approaches to managing a company and its objectives have focused on trying to optimise each process separately, although a process has been seen as a comprehensive set of operations in which excellence is not achieved by just managing processes separately, but rather by finding the optimal point where the flow between all processes is optimised, (i.e. the process flow through the whole value chain and not only the internal one).

The furniture sector Living Lab is not looking for that one process that has a high production capacity and is very efficient, but for all the processes that have the capacity or are highly efficient, as the market represented is not dealing with just buying m^2 of board edging, sectioned parts or pieces drilled, caps, bases, feet, etc., but furniture companies purchase complete orders with a final set of references.

For the analysis of potential improvements in processes that add no value, it is necessary that a company has in its full extent the fundamental premise of the current production environment.

The first assumption which must be taken into account for any performance improvement in an environment like a DMN, is that those responsible for each department understand that excellence will be reached much more quickly and efficiently if we consider optimising specific processes with the minimum possible cost in the shortest time possible for launching full production, in other words what our customer expects.

6.1.3.4 *Engineering Sector Living Lab*

Intense competition has led to increased focus on core competencies among organisations; unfortunately the market at the same time demands systems or complete solutions. Thus we find, for example, that many member SMEs in the Engineering sector Living Lab are unable to quote/bid for higher value added systems type of work because it takes them too long, or it is too difficult to configure a partnership to address the opportunity. Also companies that are providing just component level products often lose competitive advantage over a period of time because they are too far from, and receive no feedback from the end consumer. Thus for the West Midlands Collaborative Commerce Marketplace (WMCCM) Living Lab, one of our goals is to better connect end customers with competence providers. The DMN approach provides three specific advantages to the members of the WMCCM Living Lab:

1. They will be able to make new offers to their markets collectively, which are more valuable (and more profitable) than the sum of their individual offers.
2. They will be able to have better access through the network to marketing and innovation resources (e.g. through having universities / applied research partners) which will enable them to conduct collaborative new product development / enhancement with the aim of developing higher value branded products and services.
3. They will be able to share expensive resources and infrastructure with the other network members and as a result enjoy both lower costs and better quality of service.

6.1.3.5 Domain-agnostic, multi-site factory Living Lab

The growing globalisation is especially visible in the shift of production to the newer markets like Brazil, China and India. This requires a global network of production, which often is very complex to handle. Especially bigger or very high tech companies employ the means of a digital factory to handle the complexity of their products in this distributed environment and therefore have the need of a supply chain that has the ability to connect to this digital world. This required ability limits the selection of potential partners, which in return limits the possibilities to gain additional benefits through new, more innovative or simply cheaper partners. The DMN approach enables the GEMLab 2.0 laboratory to offer a specific surrounding to the supply chain, where the interoperability and interconnectivity are ensured using clear rule sets, reference models and interfaces. Thus, new partners can enter the supply chain of any partner inside the network and hopefully create new business opportunities with changing partners.

Another aspect is the possibility to migrate into new markets. The digital models of digital factories are currently mostly employed in the automotive and several high tech sectors. Enabling other supply chain members to make use of the generated experience, might speed up the migration of the digital factory approach into new industry sectors, where new benefits may be created. Such a possibility to enter the digital factory world without having to establish tools along the whole life cycle of a factory may especially convince SMEs to start their involvement in relevant projects.

6.2 Analysing DMNs Benefits and Business Incentives

6.2.1 Introduction

The establishment of Dynamic Manufacturing Networks can be thought as an advanced reaction of collaborating enterprises to a constantly changing business environment and its main characteristics: unprecedented customer expectations and alternatives, global competition, time compression, complexity, rapid change and increased use of technology. All these lead to the need for almost all enterprises to enhance their core competences to match the evolution of today's manufacturing environment.

Every DMN, independently of its size and formation has the same closely defined mission which is to enhance the entire value creation process of products and services and consequently to create extra profit for all DMN members. But, although the mission is common, the ways to achieve the expected targets can vary a lot, depending on the special characteristics of the business sector and of the DMN model applied in each case. Additional value can be created through the enhancement of any (main or secondary) process performed, either by reducing production cost or time, by improving the quality of the final product, or by acquiring access to new markets.

A DMN can be depicted as the interaction network of a variety of enterprises that are linked through both communications as well as transaction channels. Of course, the existence of a supporting IT platform, interconnecting the participants and managing the roles and responsibilities of each one, is the key for increasing the potential involvement of DMN members in the value creation process and, at the end, for establishing reliable and profitable relationships between collaborating partners.

6.2.2 Collaboration incentives

Before analysing benefits specifically derived from the concept of Dynamic Manufacturing Networks, the incentives towards establishing any type of collaboration among enterprises have to be studied. In this context, the most widely accepted motives associated with the collaboration among manufacturing enterprises are linked to the following enterprises' objectives [34],[37],[48]:

- To increase their market share.
- To increase asset utilisation.
- To enhance customer service – reduction in lead times, customer complaints, etc.
- To share and reduce the cost of product development.
- To reduce time in product development.
- To decrease risk of failure of product development.
- To increase quality of product.
- To enhance skill and knowledge.
- To have technological gain as participating firm.
- To achieve economies of scale in production.
- To reduce inventory - in the face of increasing technological complexity and rapid rate product development and obsolescence.
- To gain rapid access to markets.

In today's rapid changing competitive environment, the aforementioned objectives must be examined in conjunction to the key fact - outcome of recent business reports [16] - that large industrial companies have exhausted most of the efficiencies available within their existing supply networks, so further gains require structural changes that streamline the flow of supply and eliminate product and portfolio complexity that don't provide or protect sufficient value.

Although the aforementioned incentives are recognised, in theory, in any collaboration model presented, the truth is that achieving the expected benefits is not something easy and cannot be supported by all types of enterprise networks. This is where the idea of DMNs arrives, as defined in IMAGINE project. Both the concept and the applicability of the DMN model (supported by an advanced network management methodology and platform as proposed in our project) are the keys for materialising the targeted benefits. In this context, a detailed analysis of the most important business benefits and incentives of participating in a DMN is being presented in the next paragraphs. The analysis puts the collaboration incentives given above to their real dimensions and is in accordance to the widely accepted opinion that the motivation for each individual enterprise derives not from the fact that they want to collaborate but from the fact that there are real economic advantages to be gained through collaboration via participating in a Dynamic Manufacturing Network.

6.2.3 Benefits at DMN Level

In order to identify the benefits of Dynamic Manufacturing Networks for the participating enterprises and for the whole supply chain, a bottom-up approach has been followed. The initial step of this approach has been the identification of every effect that the participation of a manufacturing enterprise in a DMN may have on the processes and operations performed per department. Although it is recognised that a DMN is mostly focused on product development and product manufacturing processes, however several other operations running in a typical industry are affected by its participation in such a network that replaces the "currently typical" supply chain collaboration model. After analysing the DMN effects on every department of an enterprise and identifying the differences between the current and the future (DMN) model, as presented in detail in Annex E, the next steps were to pinpoint the crucial changes recognised per department and to accumulate all the potential benefits by examining the findings from a network perspective. The results of the analysis performed, using this bottom-up approach, are presented in the next paragraphs.

It has to be noticed that all the benefits described below refer at network level. However, they are based on the identified effects, which the participation in a DMN has:

i. on the operations performed at enterprise level and on each department of a participating enterprise,
ii. on the processes linked to enterprises' collaboration in the framework of a supply chain.

In order to present the several identified benefits at DMN level in the most understandable way, they were allocated in three categories:

- Benefits related to time savings
- Benefits related to cost reduction
- Benefits concerning enhancement of operations (performed at network and enterprise level)

The last category includes these kinds of benefits that are linked to improvements in the way that the network operates but do not refer directly to time or cost savings. However most of the benefits of this category can be, indirectly, linked either to time/cost minimisation or to maximisation of the potential profitability of the whole network. This is why the allocation of the benefits in these categories shall be considered as indicative.

6.2.3.1 Benefits related to time savings

Thanks to DMNs, several operations, performed in, or among, the participating enterprises, can be accomplished in less time. In the analysis, presented in Annex E, referring to the enhanced functions and role of each department of a manufacturing enterprise in a DMN environment and the derived benefits, there are several references to direct savings of time. It needs to be noted, that time savings can be translated eventually in cost reduction, therefore the benefits presented in this category fit also to the cost reduction category, if seen from their cost perspective.

Time savings refers to the reduction of the time needed to perform an operation, or a set of operations. In the case of DMNs, the following related benefits are being identified:

- **Time-to-market reduction** *through the collaborative, closely monitored, adaptive and automated processes foreseen in the IMAGINE methodology and Blueprint Model***.** Nowadays customers are less and less willing to wait for the satisfaction of their needs - best is when the custom made product is finished immediately after the very moment the customer makes his decision. Of course, by definition, this will hardly be ever possible, but by forming an efficiently managed DMN it becomes possible to reduce the time to market significantly, first of all by limiting decision uncertainties and then by optimising manufacturing processes. In DMNs new product lines can reach the market faster than by following conventional product development practices and collaborating with external suppliers. This strategic advantage, aimed to be achieved thanks to the IMAGINE DMN methodology which pursues to coordinate

OEMs and suppliers in an efficient way throughout the whole product and manufacturing lifecycle and thanks to the introduction of the IMAGINE Manufacturing Blueprint model that facilitates the uninterrupted and automated flow of the required information, is considered as an important motive for several manufacturing fields, as time is even more important than cost in terms of gaining competitive advantage.

- **Optimised design of end products and individual components,** including both conceptual and detailed design, through the collaborative and coordinated practices offered by the DMN product lifecycle. Time savings are achieved thanks to the IMAGINE DMN methodology, the iterative nature of the DMN lifecycle and the supportive IMAGINE platform which allows the designers of all the involved parties (OEM & suppliers) to work at the same time on the design of the product and its components and on their interactions.
- **Collaborative product development**, including, not only design specifications (as explained in the previous paragraph) but also operational specifications, technical specifications, and production guidelines, via the ICT supported IMAGINE methodology. Time savings are achieved thanks to the collaboration between the engineers of the companies of the network during all the product development phases. Collaboration is achieved through the IMAGINE DMN methodology and IMAGINE DMN platform that empower and support knowledge sharing among the companies and provides a common tool-supported place for collaboratively defining specifications and guidelines, while at the same time rights are protected by the contractual agreements signed during the formation of the DMN.
- **Network-optimised production planning and scheduling** via the coordination and network capabilities offered by the DMN methodology. Production planning, as well as production scheduling get synchronised and aligned in the DMN based on the directions of the DMN methodology and up-to-date product information is available anytime in order to streamline these processes, as carried out and monitored in the different blueprints constituting the IMAGINE Manufacturing Blueprint model, especially in the Partner BP, the end-to-end Process BP and the Quality Assurance BP. So, instead of each company having to contact all of its collaborators in order to align the production plans, production orders get synchronised towards the direction of the optimum operation of the whole network.
- **Fast selection of suppliers for each project/product and network setup**, thanks to the Partner BP and the initial steps of the DMN methodology. Selection of suppliers becomes much easier and faster thanks to the DMN. For each project or new product the DMN platform – having available the data of all partners – presents the suppliers who can provide each component and proposes the optimum set(s) of suppliers for the given circumstances.
- **Instant reconfiguration of the suppliers' network** based on closely monitored KPIs in the Quality Assurance BP and through the exploitation of the DMN pool of partners (Partner BPs) available and the associated partner selection process of the IMAGINE DMN Methodology**.** Concerning the reconfiguration of the network which, for example, should take place in case that something goes wrong with a supplier's production line, again it's up to the DMN platform to provide the best alternatives in order to reconfigure the whole production plan (either by adding new suppliers or by assigning more jobs to existing ones). Thanks to the DMN, this time-consuming process becomes much easier and fast, while in most of the cases it can give better results.

- **Automated communication and data exchange with suppliers/clients and partners** via the IMAGINE DMN IT platform and the IMAGINE Manufacturing Blueprint model**.** Productive communication and exchange of data among the DMN participants is a prerequisite for the operation of the DMN. The DMN platform, the adapters establishing direct communication and data exchange with the different information systems (ERP, WMS, etc.) of each partner and the blueprints supporting the configuration of the network ensure that information exchange takes place always accurately, without depending on personal communication between companies' staff and manual processes, thus saving valuable time, while also reducing mistakes causing production flaws and delays.
- **Increased visibility and access speed to information and network/manufacturing data** (including production progress and status, logistics-related information, availability and productivity reports, etc.), via the information available in the IMAGINE Manufacturing Blueprint model and the DMN methodology**.** All production and logistics related data are being collected by the DMN platform, which is connected to the individual IT systems of the DMN members. Thanks to the DMN, all usual reports requested can be produced rapidly minimising the need of "manually" collecting data from any DMN member. At the same time, the reports produced via the DMN platform contain real-time data, allowing taking any reconfiguration decision without losing valuable time, something that cannot be easily achieved in any other case.

6.2.3.2 Benefits related to cost reduction

Reducing any kind of costs is one of the main drivers for almost any organisational change in a manufacturing enterprise. Concerning participation in DMNs, reduction of costs is a very interesting issue since there are several types of costs affected, with the most important being: Procurement cost (the amount paid by the manufacturer to the material/component suppliers), Transaction overhead cost (associated with the execution of any transaction with suppliers, customers and collaborators), Manufacturing cost (deriving from manufacturing the product from its components – it incorporates the costs of components, materials, labour force and other charges) and Marketing expenses (since a DMN can be seen as a marketplace, B2B marketing expenses can be reduced).

In a DMN the goal is not to optimise (i.e. minimise) the individual costs of each partner - like in the traditional supply chain model; a configuration that may minimise transaction cost for a member may cause additional cost to another member - thus to the whole value chain of the product, leading to a higher retail price and creating competitive disadvantage. On the contrary, the idea in DMNs is to minimise the costs for the whole supply chain in order for a product to get to the market in a competitive price and with a respectful profit margin. So, each partner, instead of trying to minimise his own costs, agrees to operate in a way that can optimise the whole DMN operation and get benefited from the low total cost and the expected increased demand for the product.

Under this scope and similar to time savings, there are also specific cost-reduction points identified. It has to be mentioned that the following points refer only to direct reduction of costs (i.e. to processes that cost less when executed within the frame of a manufacturing network and for which it is easy to measure the savings), while cost reductions are also achieved indirectly in many ways (e.g. thanks to the more efficient management of all the operational processes which are required in order for the enterprises to be able to perform in the DMN).

In these terms, the most important direct cost savings can be identified in the following points:

- **Cost-optimised selection of suppliers** via the information stored in the IMAGINE Blueprints**.** The DMN platform can indicate for each project the sets of suppliers who can provide required components on time and at minimum cost, so that the cost of the final product gets as low as possible. This can be achieved through the combination of the data stored in the different blueprints, such as quality data stored in the Product BP, competences, availability, reputation and prices stored in the Partner BP and in the Quality Assurance BP.
- **Cutting down inventory costs**, via alignment of manufacturing processes thanks to the IMAGINE DMN methodology. Thanks to the DMN and the alignment of the productions of the suppliers for each project/ product, the required stock for components and materials can get minimised, achieving results similar to the just-in-time model. Given the fact that inventory costs are an important part of the total operational cost of manufacturing enterprises, minimising inventory costs is considered a very important direct benefit for enterprises joining a DMN.
- **Cost-optimised management of resources**, through accurate and timely information shared within the DMN network**.** A very important driving force for moving towards DMNs is the need to optimise allocation and coordination of all available resources (machines, computer networks, skilled personnel, IT, raw materials, capital equipment etc.) in order to reduce costs and acquire flexibility for satisfying the constantly changing demand. A DMN structure can provide optimal dynamic allocation of resources mostly through the Product BP to meet the demand requirements and the resources needed to satisfy that demand. This way the organisational structure starts following demand and performance requirements instead of setting limits, and as a result the enterprises can minimise relevant costs without any negative impact on their productivity.
- **Reducing marketing expenses**, as a result of directly providing all required information (quality, price, availability, etc.) within the network in a structured way. The DMN allows suppliers to focus on how to achieve better production results instead of investing on marketing for corporate clients (in B2B markets). Since their selection for each project/product, in the DMN, is based on their competences and availability, which are clearly recorded in the Partner BP and in the Quality Assurance BP, there is no need to spend large amounts of money for B2B marketing in order to increase their sales. So, for the whole DMN, marketing expenses are utilised for a more focused and specific promotion of end products, thus reducing dramatically the total marketing expenses in the network.

6.2.3.3 Benefits concerning enhancement of operations

This paragraph summarises all the DMN benefits identified that are related to enhancements to the operations performed in a DMN. These enhancements optimise the way that each individual enterprise operates and lead to significant benefits at network level. In this context, the most important benefits of participating in DMNs that cannot be linked directly to cost or time savings are the following:

- **Focus on core competences**, as the synthesis of a DMN network includes experts in each required area, refraining from assigning side-activities to enterprises not expert in these. Probably the most widely accepted benefit of DMNs is that they allow manufacturing enterprises to focus on building their dynamic core competences that can assist them to sustain competitive advantage in today's competitive environment. In fact, focusing on core competences is one of the major concepts behind the DMN notion, as the ability to dynamically create partnership based on each partner's expertise, provides also directly to all participating partners the opportunity to focus on their core objectives. Dynamic core competences can be used to reduce uncertainty and to induce path dependencies that create causal ambiguity (making imitation from other firms difficult). In so doing, they can form the basis of competitive advantages. According to Teese et al. [61] dynamic core competences (dynamic capabilities) can be seen as the firms' ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments. So, dynamic core competences reflect an organisation's ability to achieve new and innovative forms of competitive advantage given path dependencies and market positions. The participation of enterprises in a DMN can in a way "protect" them from the turbulent and often chaotic competitive environment, by assisting them to focus and invest in the development of advanced skills and capabilities, considered as core competences. Given the nature of today's business environment, which suggests that these factors must not remain static but should be continually improved, participation in DMNs forms the path towards their development, allowing participating enterprises to invest in and upgrade their competences. This is achieved thanks to the fact that in a DMN most supply-chain related processes get fully automated and (in some cases) taken over by a specific partner, so there is no need for each single enterprise to spend effort and invest on processes that are not related to their core competences, like demand forecasting, managing sales, issuing work-in-progress reports and alerts, managing orders, shipping processes, dealing with engineering design changes etc.
- **Product/Services co-creation**, via the IMAGINE DMN methodology and the collaborative aspects included in the IMAGINE Manufacturing Blueprint model. Co-creation can be defined as the cooperative provision and use of experience, intelligence and knowledge of a set of companies with the aim of value creation. The application of this idea to the development and production of consumer and industrial goods is considered a significant driver towards DMNs' formation, since collaborative development of new or improved products/services - usually considered useful but practically ineffective - can become an applied effective practice in a DMN environment. This is evident through the complete DMN lifecycle and the possibilities that are offered by the IMAGINE Manufacturing Blueprint model, which facilitates the collaboration and coordination of different parties that take part in a manufacturing process. This way, not only quality is being improved, but also time for developing a product can get minimised. In any case, it has to be noticed that the existence of an advanced collaborative IT platform supporting the DMN is a prerequisite for producing the expected extra value through co-creation.
- **Cost/risk sharing with collaborating partners**, as a result of the synergetic approach of the DMN product lifecycle and the overall DMN notion. In DMNs most costs and risks linked to the introduced products/services can be shared among all the involved partners who are

chosen during the initial steps of the DMN formation/configuration based on the DMN methodology. This brings a crucial change to the way projects are carried out, in comparison to the usual case of having just a few partners (sometimes only one – the OEM) exposed to most project costs and risks, while the rest are just taking advantage of the potential benefits.

- **Monitoring of product development and manufacturing operations**, through the IMAGINE Quality Assurance BP and the associated processes. In a DMN all operations performed are being monitored in real-time (or close to real time for parties that do not possess systems that could be entirely integrated working on a semi-automatic manner). The progress of any task, concerning manufacturing operations, can be identified at any time and all possible delays trigger related alarms. This way all performed operations can be managed efficiently, though monitoring their proper execution and finding alternative solutions in any case that a task or a whole operation is not performing as planned for any reason.
- **Reduction of design and production flaws**, via the closely monitored and coordinated manufacturing process instructed by the DMN methodology**.** Design and production flaws get reduced thanks to the better collaboration among the engineers of the involved enterprises. Even in case flaws make their appearance during production, tracking the problems and proceeding to alternative options becomes much simpler and fast thanks to the Quality Assurance BP. The early warnings system that is part of the DMN management methodology is the key for identifying and managing problems early enough, so that they don't lead to uncontrolled situations.
- **Optimal selection of suppliers and collaborators**, by combining supplier specific information and manufacturing needs as stored in the Partner, Manufacturing and Quality Assurance BP. In a DMN, selection of suppliers and other collaborators takes place in a much more sophisticated way than in any other case. The process of partner selection, supported by the related blueprints, leads to the establishment of more successful and win-win collaborations, since for each project/product, the selection of suppliers can be based on characteristics such as their core competences, their actual capability to deliver specific results within a given time, quality, etc.
- **Improved quality throughout the complete product lifecycle**, through continuous KPIs monitoring and SLA compliance procedures. In DMNs the application of improved quality assurance processes is a prerequisite for their operation, directly linked to the management of all the processes performed and get co-ordinated in the network through the establishment of SLAs and SLOs in the Partner BP and the close monitoring of KPIs through the Quality Assurance BP. On the other hand, quality of the end product is improved thanks to the standards applied not only during each component's production, but also during the development of the product. The IMAGINE Manufacturing Blueprint model offers improved visibility into supplier performance and offers the ability to uncover and remove poor quality, and increase competitive advantage and also to aligning practices between network partners. In addition, the fact that the Quality Assurance BP covers all aspects related to the quality of the final product, as well as of its individual components, assures that the whole network operates on the basis of high quality standards. In this way, best practices are captured and

standardised across the DMN, resulting in the long run to more efficient products and improved, standardised and quality assured manufacturing processes.

- **Know-how exchange, shared knowledge management and access to new technologies** via the close collaboration of enterprises. An important benefit of the notion of a DMN is that through close collaboration, there is constant exchange of knowledge, concerning both product-related matters, as well as new applied (or under testing) technological improvements. Parts of the advanced knowledge of every partner in the network are transferred to other DMN members, a fact that constitutes an important factor for developing better products, as well as for gaining access to new technologies that could improve the operation and/or the efficiency of the whole network. In this way, manufacturing assets can be leveraged and opportunities to re-use them can be identified. Moreover, sensitive confidential knowledge can still be preserved within the partner sub-networks.
- **Access to new customers/markets**, as a direct benefit of the nature of a DMN network and the variety of sectors where the DMN members are active. Any member of a DMN may gain access to new markets through the activation of other DMN members in those markets. On the basis of this idea, one more reason for enterprises to participate in a DMN is that through the network they can expand their customers' base and at the same time they can enter new markets, not possible to access individually.
- **Integrate diverse enterprise IT systems for better, holistic and efficient production**, by combining high level IT platforms (ERPs, CRMs, etc.) with shop floor systems via the IMAGINE IT platform**.** Information technology is definitely a major ingredient in "transforming" manufacturing enterprises participating in a traditional supply chain to members of a DMN. Thanks to IT infrastructure, DMN members can exchange integrate their manufacturing processes and systems with the different enterprise systems they possess and also share data and information in rates that cannot be achieved conventionally. The final aim is to utilise these data in order for partners to get coordinated towards optimising the operation and productivity of the whole network. However, using information technology alone is not a sufficient condition to form a DMN successfully. Information technology is merely an enabler for adopting the concept of DMNs and at the same time a business driver for moving toward DMNs in order to take advantage of the extra capabilities offered. This is where the IMAGINE DMN methodology kicks in in order to identify and dictate how these data should be used through the IMAGINE Manufacturing Blueprint model in order to achieve the benefits offered by the concept of a DMN.

Table 6-1: Network Level Benefits and their Relation to IMAGINE DMN Methodology

Benefits at Network Level	Offered by IMAGINE as
Time-to-market reduction	The IMAGINE DMN Methodology coordinates the whole manufacturing process The IMAGINE Manufacturing Blueprint model facilitates the uninterrupted exchange of information
Optimised design of end products and individual components	The IMAGINE DMN Methodology and the iterative nature of the DMN lifecycle allow optimised design in less time The IMAGINE platform allows coordinated and collaborative working of involved parties reducing delays and speeding up design cycles.
Collaborative product development	The IMAGINE DMN methodology supports knowledge sharing The IMAGINE DMN platform constitutes a common platform for collaboratively defining specifications and guidelines.
Network-optimised production planning and scheduling	The DMN Methodology defines the usage of up-to-date product information is available anytime in order to streamline manufacturing processes, The IMAGINE Manufacturing Blueprint model, and especially the Partner BP, the end-to-end Process BP and the Quality Assurance BP provide the related information for optimising production
Fast selection of suppliers for each project/product and network setup	The Partner BP includes all required information for deciding on the selection of partners
Instant reconfiguration of the suppliers' network	KPIs of the Quality Assurance BP signal the need for network reconfiguration. The IMAGINE DMN Methodology assisted by the Partner BPs carry out the selection of new network members
Automated communication and data exchange with suppliers/clients and partners	The IMAGINE DMN Platform is the communication centre for the whole DMN The IMAGINE Manufacturing Blueprint model ensures interoperability amongst the involved IT systems of the DMN members
Increased visibility and access speed to information and network/manufacturing data	Visibility and access to information is ensured by the IMAGINE Manufacturing Blueprint model and the DMN methodology. The end-to-end Process BP supports the provisioning of related data.
Cost-optimised selection of suppliers	Utilising the information of the Product BP, the Partner BP and the Quality Assurance BP can lead to more efficient selection of suppliers.
Cutting down inventory costs	The IMAGINE DMN methodology aligns demand with production and helps the whole DMN chain to reduce the level of inventory stored.
Cost-optimised management of resources	The Product BP reveals the need of resources required, resulting in better resource management for the enterprises.
Reducing marketing expenses	All partner related information is part of the Partner BP and the Quality Assurance BP reducing the need for B2B marketing.
Focus on core competences	Focusing on core competences is one of the major concepts behind the DMN notion.
Product/Services co-creation	Co-creation is the result of the iterative DMN lifecycle and the possibilities that are offered by the IMAGINE Manufacturing Blueprint model.
Cost/risk sharing with collaborating partners	One of the main concepts of the DMN notion and the DMN methodology is to build dynamic alliances for sharing risks and costs and minimising exposure to threats
Monitoring of product development and manufacturing operations	The IMAGINE Quality Assurance BP is in position to offer constant monitoring of these processes.
Reduction of design and production	Achieved through the DMN Methodology and assisted by the Quality

flaws	Assurance BP for early detection and correction.
Optimal selection of suppliers and collaborators	Achieved through the instantiations of the Partner, Product and Quality Assurance BPs.
Improved quality throughout the complete product lifecycle	The IMAGINE Manufacturing Blueprint model and especially the Quality Assurance BP offer improved visibility into supplier performance and hence improves quality through SLAs, monitoring and management.
Know-how exchange, shared knowledge management and access to new technologies	Close collaboration being a central concept of the DMN notion promotes constant exchange of knowledge and innovation
Access to new customers/markets	The character of a DMN, consisting of various partners has the potential to reach new markets and customers through portfolio sharing and responding to new opportunities.
Integrate diverse enterprise IT systems for better, holistic and efficient production	The IMAGINE IT platform is able to combine high level IT platforms (ERPs, CRMs, etc.) with shop floor systems. The IMAGINE DMN methodology and the IMAGINE Manufacturing Blueprint model ensure interoperation and mandate the flow and use of information.

The following table summarises the interconnections between the network level benefits, presented above, and the blueprints as defined in the present deliverable. It has to be mentioned that some of the identified benefits are related to the whole IMAGINE DMN methodology and to the DMN notion, so they are not linked to specific blueprints.

Table 6-2: Cumulative Benefits Matrix

Benefits	**Addressed in**				
	Framework Level	**Partner Blueprint**	**Product Blueprint**	**End-to-end Process Blueprint**	**Quality Assurance Blueprint**
Time-to-market reduction	X				
Optimised design of end products and individual components	X				
Collaborative product development	X				
Network-optimised production planning and scheduling	X	X		X	X
Fast selection of suppliers for each project/product and network setup		X			
Instant reconfiguration of the suppliers' network	X	X			X
Automated communication and data exchange with suppliers/clients and partners	X				
Increased visibility and access speed to information and network/manufacturing data	X			X	
Cost-optimised selection of suppliers		X	X		X

Cutting down inventory costs	X				
Cost-optimised management of resources			X		
Reducing marketing expenses		X			X
Focus on core competences	X				
Product/Services co-creation	X				
Cost/risk sharing with collaborating partners	X				
Monitoring of product development and manufacturing operations					X
Reduction of design and production flaws	X				X
Optimal selection of suppliers and collaborators		X	X		X
Improved quality throughout the complete product lifecycle	X				X
Know-how exchange, shared knowledge management and access to new technologies	X				
Access to new customers/markets	X				
Integrate diverse enterprise IT systems for better, holistic and efficient production	X				

6.2.4 Business incentives in numbers

Joining a DMN is an important decision for any enterprise, since it is related to many changes not only to the way that the enterprise collaborates with the external environment, but also to the way that almost all the internal processes are being performed. This is why such a decision shall always be based on real estimations of the expected results, taking advantage of the good practices of previous cases. In any case, as explained earlier, the main drivers for joining (or forming) a DMN are the reduction of costs and the improvement of profitability.

Concerning cost savings, according to studies [4],[5],[64] in a typical manufacturing sector like automotive, amazingly only 30% of the cost of the final product has to do with "value activities". The other 70% are the costs and overheads of running a major manufacturer in its current form. The scope for cost savings through collaborating in a DMN is therefore huge.

Previous experience on networked manufacturing as presented in several studies shows that if manufacturing networks run properly they can generate up to 30% additional profit per member after the initial settling in period [32],[64]. This has to do with estimated reduction of up to 25% concerning total manufacturing and operational costs, as well as a maximum of 20% reduction concerning costs incurred due to poor quality issues. Additionally, improved profitability is also linked with the expected increase of productivity in a well-established DMN that can reach up to 30%, according to cases examined in past studies [6]. Another important fact is that not only profits get higher but also at the same time the financial exposure of partners can get decreased up to 25%. Concerning the overall reduction of required investments by the partners of a DMN, whether these regard IT infrastructure, knowledge or machinery, it is estimated at a maximum of 20% [65].

Furthermore, very good results are expected, by joining a DMN, on the product development operations. Previous applications of collaborative product development processes like those in DMNs have proved up to 30% lead-time reduction and up to 50% cost reduction are realistic objectives which can be achieved [29].

Finally, a carefully established and well-managed DMN can lead to very efficient operation of all its members. This is proved not only by the financial results, previously presented, but also by the improvements on the values of several metrics related to the operation of each individual enterprise and of the whole supply chain. According to the literature on virtual enterprises and manufacturing networks the following achievements can be expected: reduction of time required for co-operation contractual formalisation up to 50%[52], reduction of time-to-market up to 25% up to 50% [49],[52], reduction of lead time up to 20% [30],[52], improved efficiency of co-operation processes (manufacturing network design, re-configuration, re-engineering as opposed to the previous time which also included the various delays) up to 30% [52], Reduction of product cycle times up to 50% [32], reduction of life cycle costs up to 30% [49] and reduction of maintenance costs up to 30% [32].

It has to be noticed that the figures presented in this paragraph are mostly based on specific examples/cases analysed in the literature and cannot be considered as reference values for all cases. However, they provide a direction as far as it concerns the objectives that should be set and expected when establishing a Dynamic Manufacturing Network.

In conclusion, it is a real fact that the DMN approach, when supported by an efficiently managed platform, can introduce important benefits and advantages from the overall business parameters' point of view. At the same time the approach does not introduce significant gaps or major impacts on companies' current ways of working – on the contrary, the internal processes (not linked to cooperation activities) get more efficient, thanks to the improved management methods applied and to the increased productivity achieved throughout the whole enterprise.

The following table summarises the most important directly measurable benefits of DMNs, as found in literature and presented above, together with relevant estimations concerning the expected benefits in the sectors that the project's Living Labs belong to. Obviously not the same results should be expected in every DMN, since not all supply chains are of the same type/model or of the same level concerning existing collaboration practices. The figures presented below are based on estimations by the LL during the initial steps of the project, so they cannot and should not as reference values or objectives but rather as anticipated results based on the proposed methodology. As it also mentioned above, these figures will be closely monitored on a Living Lab basis with the use of the "Framework for Continuous Verification of Benefits and Risks" (see section 6.4) in order to derive to specific and more accurate numbers for each sector of the ones represented in the IMAGINE project.

Table 6-3: Expected Benefits following a DMN formation

Metric	Improvement Direction	Aerospace & Defence Industry LL (up to)	Automotive Industry LL (up to)	Furniture Manufacturing LL (up to)	Engineering Sector LL (up to)	Industry Agnostic Single Site Factory LL (up to)
Total Profitability	⇑	35%	5-10%	20%	15%	10-15%
Total operational & manufacturing cost	⇓	30%	5-10%	15%	12%	10%
Cost due to quality issues	⇓	40%	20%	20%	10%	20%
Total productivity	⇑	30%	30%	20%	15%	30%
Financial exposure of partners	⇓	20%	5-10%	15%	10%	10%
Required investments by partners	⇓	30%	15%-20%	15%	10%	25%
Product development lead time	⇓	40%	5-10%	20%	15%	Not relevant
Product development cost	⇓	50%	5-10%	10%	10%	Not relevant
Time for contractual formalisation	⇓	40%	50%	30%	25%	30%
Manufacturing lead time	⇓	40%	10%-30%	15%	20%	20-30%
Co-operation processes efficiency	⇑	40%	5-10%	15%	15%	5-10%
Product cycle times	⇓	50%	0-25%	15%	15%	Not relevant
Life cycle costs	⇓	40%	10%-20%	20%	10%	10%
Maintenance costs	⇓	30%	0-2%	15%	15%	5%
IMAGINE KPIs						
Time for manufacturing network design, re-configuration, re-engineering (N-KP 1)	⇓	15%				
Time to market (N-KP 2)	⇓	20%				
Time for multi-site factory design, re-configuration, re-engineering (F-KP 1)	⇓	20%				
Time-to-production (F-KP 2)	⇓	20%-30%				
Cost for multi-site factory design, re-configuration, re-engineering (F-KP 3)	⇓	30%				
Ramp-up time (F-KP 4)	⇓	30%				
Process Capability Index Cp (F-KP 5)	⇑	>=2.0				
Resource utilisation (O-KP 1)	⇑	10%-15%				
Delivery time (O-KP 3)	⇓	15%-20%				

6.3 Risks addressed through the IMAGINE methodology

It is inarguable that the introduction of any new innovation does not come without any risk for the possible adopters. The same is true for the DMN methodology and the general idea of walking away from typical, long operating models of traditional supply chains to new models of virtual factories and dynamic manufacturing networks. Potential adopters of the DMN methodology (whether they are suppliers that are interested in joining a DMN or OEMs which are interested in setting up and managing such a network) will not only ask for the benefits they could get from such a shift, but will be as well heavily concerned on risks that they might need to encounter and how the proposed methodology can aid them to surpass them, minimising in such a way their exposure and the impact the occurrence of such risks could have on them.

According to Hallikas et al. [20], functions that generate the possibility of beneficial effects or profit often include risks. The tighter relationships may mean more dependencies between the companies, which contributes to disturbance propagation in any network. For example, in a typical supply chain the major risk that an enterprise might face has to do with the inability to deliver to the end-customer. This risk is also evident in a networked environment (such as a DMN), however other risks are there too, which have to do with information flow and data security, IPR issues, etc. So it is self-evident that the risks that come along with the decision to join such a network differ a lot from those faced by a stand-alone enterprise. Moreover, it is a fact that disturbances or unexpected events have different consequences to different members of the network. Therefore risks should be considered at both a network and at an enterprise level. For this reason, risks that are related to establishing or participating in a DMN and ways to minimise them have been studied through a bottom-up approach, focusing at the risks that may affect the different departments of an enterprise (see Annex E) and then elevating them to the DMN level.

The risk analysis performed is based on the concept of DMNs as defined in IMAGINE project and on the current progress status of the methodology, as presented in the present deliverable. This first level of analysis examines the potential risks from a conceptual perspective. During the next phases of the project that the architecture will be fully defined and on the basis of the use cases, a second and probably a third level of risk analysis will take place. The relevant objective is to have, at the end of the project, after the application of the outcomes in the Living Labs, all the potential/involved risks identified and analysed in depth, together with applicable avoidance or mitigation plans, as part of the reaction protocol (a draft of which is presented later in this deliverable).

Based on the first level analysis performed, the main risks which are shared amongst DMN members and can be considered as network level (or, else, horizontal) risks are the following:

- **Information security and trust**: The risk of facing information leaks with regard to important enterprise data concerning capabilities, availability, capacity, manufacturing procedures, quality procedures, etc. can prove to be very harmful for an enterprise, especially if such information falls in the hand of competitors. Such a risk can affect both the 1-tier (or subsequent tier) supplier working in a DMN, as information can be conveyed to competitor suppliers of the same tier (or below), but also the OEMs, as information can be channelled through a supplier to a competitor OEM who is not part of the DMN but has been collaborating with the same supplier. In order to eliminate the possibility of occurrence of this risk, the DMN methodology and the IMAGINE Manufacturing Blueprint model follow a mechanism of having different views regarding the blueprints to be used, so that only the necessary information is exposed to the partners that need to know it. Moreover, contracts that should be signed upon the establishment of a DMN should also foresee the existence of special clauses regarding information confidentiality. Moreover, efficient security mechanisms (such as HTTPS, SSL, etc.) for securing the data that will be transferred through the IMAGINE DMN platform and authentication mechanisms for the different DMN partners will be used.

- **Poor configuration of the network's synthesis**. Assuming that the proper configuration of the manufacturing network during the Manufacturing Network Analysis and Configuration phase, being the first phase of the DMN lifecycle, is quite crucial for the subsequent design and operation of the DMN, and therefore for the success of common manufacturing projects, it has to rely on explicit and accurate information, based on which focused partner searches, negotiations and initial strategy planning actions can be carried out. As a consequence, the provision of non-valid, deficient or even out-dated information makes up a risk which may result in poor configuration of the network, affecting also its subsequent operation and calling for several corrective actions and modifications in the DMN design and synthesis, which could be avoided in the first place. Within the context of the IMAGINE Methodology and DMN Blueprint Model, this risk is addressed through the Partner BP, which not only includes static information on the enterprises' skills, capabilities and track record, but captures also dynamic data, pulled real-time, that reflect the actual capacity of each DMN member to meet the required manufacturing and delivery times, minimising thus the concern for carrying out negotiations among DMN partners and thereby designing the DMN based on non-valid information.
- **Poor design/coordination/management (governance) of the manufacturing process**. A Dynamic Manufacturing Network is a complex and evolving structure which encompasses multiple actors, functions and processes, and flows of information, and as such it requires proper design and suitable coordination mechanisms, that enable to tie together all the aforementioned elements and offer visibility across the whole network. Poor design of the DMN may prove to be a fatal risk not only for the correct operation of the network but also for its survival. In the context of the IMAGINE Methodology, all these elements are brought together under the umbrella of the End-to-end Process BP, which is initially set up during the Network Design phase and constantly monitored in order to fine tune the network's performance.
- **DMN dissolution when key partner drops out of the network**. Although the DMN notion promotes the agile and flexible configuration and re-configuration of the DMN structure in case of unexpected events and critical situations, caused e.g. due to the inability of specific DMN suppliers to meet manufacturing and delivery times; yet addressed through their relinquishment and dynamic replacement through the pool of DMN members, risky situations arising as a result of the withdrawal of DMN partners may not always be that simple to resolve. In fact, the withdrawal from the network of a key supplier/manufacturer could jeopardise not only the success of a common manufacturing project but could even end up in the network's dissolution. Such a risk should be foreseen in the contracts, signed upon the establishment of the DMN and legally binding the DMN members not to be able to drop out of the network under specific circumstances.
- **Transition issues related to resistance to changes in the followed procedures and the IT systems supporting the operations of the participating enterprises.** The transition from an isolated to a collaborative manufacturing model is not easy and may face several problems since there is always strong "resistance to changes" in every big or medium sized organisation. In order to manage the serious amendments to the collaboration model, to the processes and especially to the culture of the organisation, it is important to make the

transition as smooth are possible. Probably the most usual problem has to do with the fact that in order to be able to collaborate within the network, both the followed procedures as well as the information systems which support the operation of several departments have to be modified severely or even to get replaced. This makes the operation of the enterprises very unstable and unreliable during the transition period something that may lead to bad results for the operation of the network. Handling this risk is a serious concern during the design and development of the IMAGINE DMN methodology and of the IMAGINE IT Platform. This is why they are being developed towards the direction of providing a common environment for collaboration which does not require significant changes to be made to the systems and the procedures that define the operation of the several departments. So, instead of enforcing all the enterprises to completely change the way they operate as well as their IT systems, the IMAGINE approach introduces the IMAGINE Manufacturing Blueprint model, together with a set of adapters for interconnecting the IT systems of all DMN members to the IMAGINE platform. This way every enterprise keeps operating using its own IT systems and running its own procedures per department and at the same time the IMAGINE platform interconnects all the systems to the network management (and indirectly to each other), while the exchanged information is handled efficiently thanks to the proposed IMAGINE Manufacturing Blueprint model. Following this innovative approach, the required alteration of the operation of every DMN member and even of the employees' culture get much smoother, since they don't have to face significant changes in their internal operation and in the systems they use, but only in the part that has to do with the direct collaboration with the partners.

- **Need for continuous IT investments**. As the DMN relies heavily on IT infrastructure and on connected systems, organisations willing to adopt the DMN idea might be reluctant to do so because of the increasing need to modernise their IT infrastructure in order not only to become members of the network, but also to continue to be part of it as time goes by. The IMAGINE Manufacturing Blueprint model comes as an answer to this concern, as the purpose of the blueprints which are proposed by the DMN methodology, is no other than to interconnect incompatible systems of enterprises towards building a network that can operate in an automated manner thanks to the interoperability achieved amongst the basic enterprise systems used by its members. This fact points out that apart from the initial investments that have to be made for becoming a member of a DMN network (building the necessary IT connectors, etc.), no other investment on IT infrastructure is necessary, as interconnection and flow of information is achieved by the IMAGINE Manufacturing Blueprint model and the IMAGINE IT Platform. This way, legacy systems don't need to be replaced in order for the individual enterprise to become a member of a DMN, having as a prerequisite only the development of the appropriate connectors and perhaps minor modifications throughout the network's operation.
- **Competitive threats after the exiting of a partner or the terminating of a DMN**. In case a member exits the DMN or a DMN is dissolved, there is a risk that important R&D knowledge and manufacturing methods, if shared within the DMN, will be utilised by former DMN members in order to increase their competitive advantage over former collaborators. This risk can be mitigated by all DMN members signing legal agreements and contracts upon

the establishment (or their entry to) the DMN, in order to explicitly define the use and exploitation of intellectual property, foreground and background knowledge of partners and knowledge generated during the operation of the DMN. Moreover, apart from the knowledge to be shared in the DMN, the multiple view levels of the IMAGINE Manufacturing Blueprint model will guarantee that there is no transfer of private knowledge to other DMN partners. Activities can, this way, eliminate the cases that coordination issues make their appearance.

- **Loss of Partners' Reputation due to ineffective network operation**. Companies entering the network (or that operate the network) will be concerned on the general reputation of the former, in case a partner fails to deliver as planned, as such a situation can affect the overall operation of the whole structure. However, the main idea behind the IMAGINE DMN methodology and the DMN lifecycle in general succeeds in minimising this risk, as one of the main targets of a DMN is to be able to pro-actively avoid such situations during the network set up, and in the case of occurrence to detect the problem at a very early stage and to drastically make all the necessary actions to minimise its impact and carry on with the operation as planned. The Partner BP will be used in order to make it possible for DMN managers to select the most appropriate partners, while the Quality Assurance BP plays also a very important role in this case, as it helps to detect any deviation from the production plan (in every possible term, whether it regards the scheduling, the quality, etc.) and will trigger the activities for reconfiguring the network and continuing the manufacturing process with minimal or zero damage to the whole network operation. This way, the reputation of the network will not be affected, while the early detection mechanism and the ability of reconfiguration will have a positive effect on the whole reputation, when compared with other traditional supply chains.
- **Lack of coordination of network activities.** In order for any collaboration among enterprises to work as supposed, coordination of all activities performed is a very crucial parameter. The DMN management methodology and the supportive IT platform aim to coordinate the core network activities; however, for several reasons linked to the independency of the partners, several secondary (but also network-related) activities performed by each enterprise are not centrally managed. So, there behoves a risk those activities to present inconsistencies, lack of coordination and cause problems in the execution of the planned network operations. Products/components' transportation, warehousing, invoicing are indicative examples of activities that are managed by each enterprise individually; however they are closely related to the flawless operation of the network. There are three ways identified in order to handle this risk. The first has to do with the SLAs that accompany the participation in the network. These SLAs shall refer to the whole service provided by each DMN member, including the crucial secondary activities like those linked to logistics, invoicing etc. Another way to handle this risk, although not always applicable, has to do with the establishment of further collaboration among the DMN partners in order to use shared/common providers of external services (e.g. 3rd party logistics providers) or to offer/share part of their own resources to the network on the basis of relevant cooperation agreements among partners. The third and most important way for mitigating the risk is related to the data exchanged on the basis of the IMAGINE Manufacturing Blueprint model introduced in the present deliverable. The information included in the blueprints defines all

the details needed in order for the participating enterprises to be able to coordinate and ground the scheduling of their secondary activities on those that are centrally managed.

Table 6-4: Network Level Risks and how they are handled by IMAGINE

Risk at Network Level	Mitigated by IMAGINE through
Information security and trust	• The IMAGINE DMN methodology and the IMAGINE Manufacturing Blueprint model follows a mechanism of having different views regarding the blueprints. • Contracts that should be signed upon the establishment of a DMN. • Security Protocols (HTTPS, SSL, etc.) and Authentication mechanisms in the IMAGINE platform.
Poor configuration of the network's synthesis	• The Partner BP captures both static and dynamic, real-time information that reflects the actual capacity of the enterprise to respond to DMN requirements and facilitates the configuration and subsequent design of the network.
Poor design/coordination/management (governance) of the manufacturing process	• The end-to-end Process BP ties together the many discrete processes which inherently cross functions, departments and actors within the manufacturing network.
DMN dissolution when key partner drops out of the network	• Establishment of contracts, legally binding the DMN members not to be able to drop out of the network under specific circumstances.
Transition issues related to resistance to changes in the followed procedures and the IT systems supporting the operations of the participating enterprises	• The IMAGINE DMN Methodology ensures that the minimum number of changes will have to be applied internally in an enterprise in order to be able to operate within the network, as far as it concerns the operations that are not directly related to the collaboration in the supply chain. • The IMAGINE Platform and the adapters to the existing IT systems ensure that no significant changes are required concerning the systems currently in use, thus the transition to the new model will be smooth even as far as it concerns IT.
Need for continuous IT investments	• The IMAGINE Manufacturing Blueprint model and the IMAGINE Platform ensure interoperability with legacy/existing systems.
Competitive threats after the exiting/terminating a DMN	• Legal agreements and contract upon the establishment (or their entry to) the DMN to define the use and exploitation of knowledge. • The IMAGINE Manufacturing Blueprint model's different view levels will guarantee no transfer of private knowledge.
Loss of Partners' Reputation	• The IMAGINE DMN methodology and the DMN lifecycle improve quality (and reputation) through monitoring and management of network. • The Partner BP to be used for proper partner selection. • The Quality Assurance BP to be used for detecting deviations from the production plan.
Lack of coordination of network activities	• SLAs referring to the whole service provided by each DMN member, including the crucial secondary activities. • Establishment of further collaboration among the DMN partners in order

	to use shared/common providers of external services, or to offer/share part of their own resources to the network on the basis of relevant cooperation agreements among partners. • IMAGINE Manufacturing Blueprint model defining all the details needed in order for the participating enterprises to be able to coordinate and ground the scheduling of their secondary activities on those that are centrally managed.

The following table summarises the interconnections between the network level risks, presented above, and the blueprints as defined in the present deliverable. It has to be mentioned that some of the identified risk are addressed by the IMAGINE DMN methodology as a whole, so they are not linked to specific blueprints.

Table 6-5: Cumulative Risk Matrix

Risks	Addressed in				
	Framework Level	Partner Blueprint	Product Blueprint	End-to-end Process Blueprint	Quality Assurance Blueprint
Information security and trust	X				
Poor configuration of the network's synthesis		X			
Poor design/coordination/management (governance) of the manufacturing process				X	
DMN dissolution when key partner drops out of the network	X				
Transition issues related to resistance to changes in the followed procedures and the IT systems supporting the operations of the participating enterprises	X				
Need for continuous IT investments	X				
Competitive threats after the exiting/terminating a DMN	X				
Loss of Partners' Reputation	X	X			X
Lack of coordination of network activities	X				

It has to be noted that the increased cooperation within a manufacturing network causes transfer of risks between the companies, but at the end risks are totally dependent on the circumstances of each network and network member, so the way to document and analyse them cannot be generic and should be case specific. The "reaction protocol" presented in the following section aims to tackle this need, as it provides to the different Living Labs and their members a reference regarding some generic and already identified risks and will be used in order to verify the existence of those, the way they have been mitigated and also to record new risks and threats identified during the operation of the network.

6.4 Framework for Continuous Verification of Benefits and Risks (Reaction Protocol)

The analysis of the aforementioned benefits and risks, alongside with the mitigation plans which will be integrated in the DMN management methodology and in the technological infrastructure that will realise the IMAGINE concept, is the initial step for identifying key factors that could be utilised in order to attract organisations and enterprises into embracing the vision of DMNs. In this context, enterprises depending on their nature (OEMs, Suppliers, Collaborative Enterprises) will be presented with motives and real life facts which will encourage them to either develop a DMN and be the DMN managers, join an already established and operational DMN or deciding on forming (alongside with other collaborators) a DMN which will be at the initial step jointly managed. Such transitions are presented in the following figure.

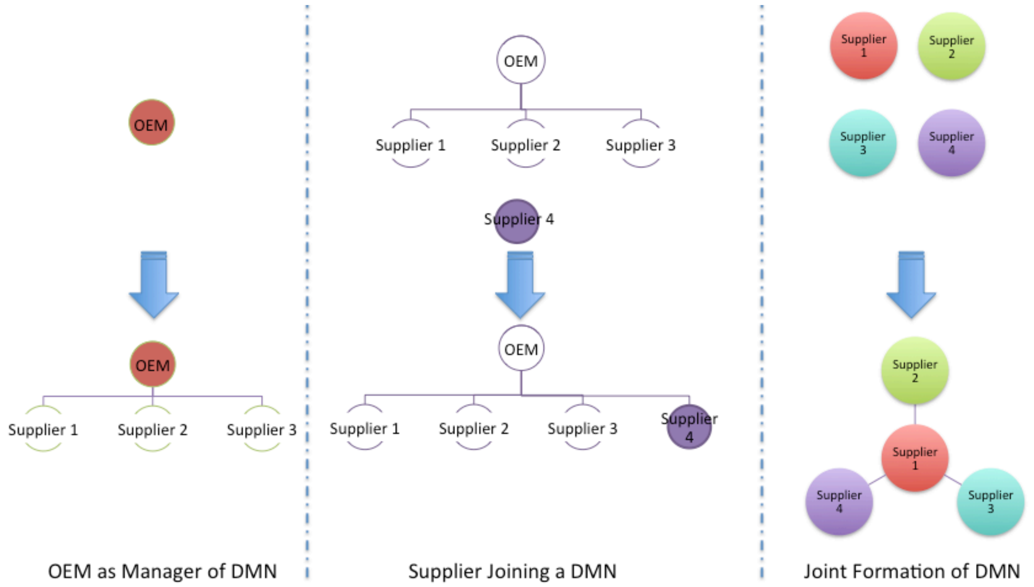

Figure 6-3: Developing, Joining or Jointly Establishing DMNs

However, as described above, the realisation of any such case depends heavily on the ability to tackle the emerging needs and concerns of enterprises and ultimately the questions regarding the Return on Investment (ROI) [72] when considering adopting the IMAGINE methodology. Therefore, it is essential to provide realistic answers and hard facts, in order to persuade more and more enterprises to invest in the IMAGINE methodology and become parties (or leading parties) of DMNs.

The procedure that will drive the initial steps of approaching an enterprise and persuading its managers to enter and become part (or manager) of a DMN is called “reaction protocol”. This procedural activity which takes place between the DMN members/managers and the potential adoprtes of the methodology (therefore the adjective “reaction”) aims to present in a structured and measurable way the advantages of adopting the IMAGINE DMN methodology and also present the associated risks and the avoidance/ mitigation actions. In more detail, the reaction protocol is based on the following steps:

I. Identification of the type of enterprise (OEM or Supplier) and Business Sector. The benefits and the risks rely heavily on the sector where each enterprise belongs and the indicative risks may change depending on this factor.

II. Presentation of a structured list of departments/functions towards identifying the ones that are valid for the case under investigation.

III. Presentation of the quantitative and qualitative benefits per department, based on previous cases and literature.

IV. Presentation of potential risks and appropriate avoidance/ mitigation plans

V. Initial Assessment of the enterprise's operation before inclusion in a DMN
   a. Regarding the factors that might be improved through the DMN (Annex E.5–Table A.15)
   b. Regarding risks that are associated with the type/nature/size of the enterprise (Annex E.5–Table A.16)

VI. Re-assessment of enterprise's operation on a timely basis (constant intervals measuring also the DMN size) after inclusion in a DMN
   a. Regarding the predefined factors where there are evident benefits
   b. Regarding other factors where there are evident benefits
   c. Regarding the occurrence of the identified risks and their avoidance/ mitigation
   d. Regarding the occurrence of other, not previously identified risks and their avoidance/ mitigation
   e. Measuring the total investments put (in terms of enhancing the different departments' interoperability) and relating them to the achieved performance improvements for measuring the net investment needed for shifting to a DMN (Annex E.5–Table A.17)

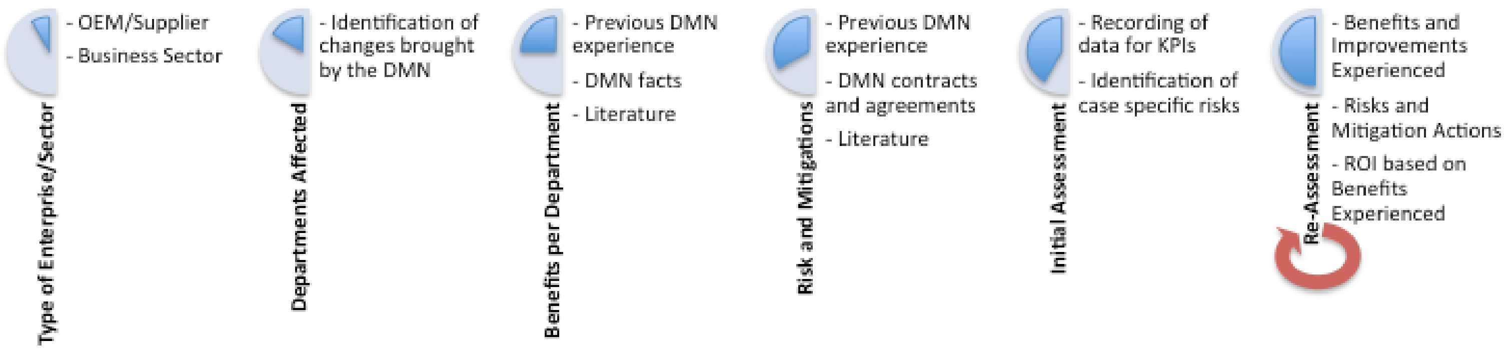

Figure 6-4: Illustration of Framework for Continuous Verification of Benefits and Risks

This iterative process, which according to IMAGINE DoW [22] "will be further developed in the Living Labs (WP4) and the Stakeholders Involvement and Engagement (WP6)", aims through observation in real conditions to specify in more detail the benefits that the IMAGINE DMN methodology (and the IMAGINE platform) will bring to enterprises participating or forming DMNs, while at the same time risks and avoidance/mitigation strategies will be recorded and verified in order to further optimise the current methodology.

Using this methodology, one will be able to construct a more detailed and accurate picture regarding the benefits and the risks faced for each type of enterprise, based on the sector it belongs and on the nature/size of the DMN. The templates to be used for this process can be found in Annex E.

7 Future Work

Product and manufacturing process models need better interfaces to improve interoperability, improve product quality, and enhance the ability of plants to adapt or transition to new products. IMAGINE will develop a platform based on service-oriented technologies to support the DMN Lifecycle described in this deliverable. This will happen in WP-2 (Technology Foundation and Architecture Specification). The platform will encompass a suite of validated, open-source software and standardised service-enabled modules that integrate product and manufacturing process models as supported by the IMAGINE blueprints. The platform will have a suite of generic (industry sector agnostic) modules that can be extended and can be applied and customised for individual industry sectors. The detailed design and implementation of the components and interfaces of the IMAGINE Platform will take place in WP-3. The IMAGINE Platform developed in WP3 will be customised in WP4 for each Living Lab to include selected scenarios for setting up a DMN for the aerospace, automotive and furniture construction sectors. The SOA-based enterprise and manufacturing bus will be customised to the specific scenarios requirements for end-to-end DMN lifecycle management. This will also include the production systems of the participating enterprises and specialised tools and will be the subject of WP-4 (Living Lab Demonstrations). In this section we briefly describe the IMAGINE platform for completeness.

The IMAGINE platform aims to integrate small/medium suppliers with Original Equipment Manufacturers. The platform will support all aspects of manufacturing from plant operations to the supply chain, and enable virtual tracking of processes, and manufacturing resources (including equipment and people) throughout the entire DMN Lifecycle. The end result would be a flexible, agile, and innovative manufacturing environment in which performance and efficiency are adjusted and business and manufacturing operations work efficiently in tandem. This would enable the rapid, seamless integration of manufacturing processes and effective transfer data between manufacturing enterprises. Achieving this integration requires a common architecture that can be applied across diverse supply chains and sectors. The benefits would be flexible and less costly supply chain integration, lower barriers to entry for SMEs in new industries.

To achieve functional objectives the IMAGINE platform will rely on Service-Oriented Architectures (SOA) and advanced service technologies for integrating product and process models and realising the functionality of manufacturing networks. The manufacturing operations specific requirements for SOA within distributed pull supply chains are called Manufacturing 2.0 (MFG 2.0). MFG 2.0 is an information environment that supports multiple manufacturing operating modes (process, discrete, lean, etc.) and global operations based largely on an SOA approach combined with a user-centric interface along with the introduction of new Web 2.0 technologies. Several authors such as [35] and [74] suggest the usage of Service Oriented Architectures for manufacturing due to the synergies, which can be achieved since manufacturing service concepts focus on resource sharing and SOA provides distributed architecture concepts which enable interoperability, easily integration, simplicity, extensibility and properties of secure access.

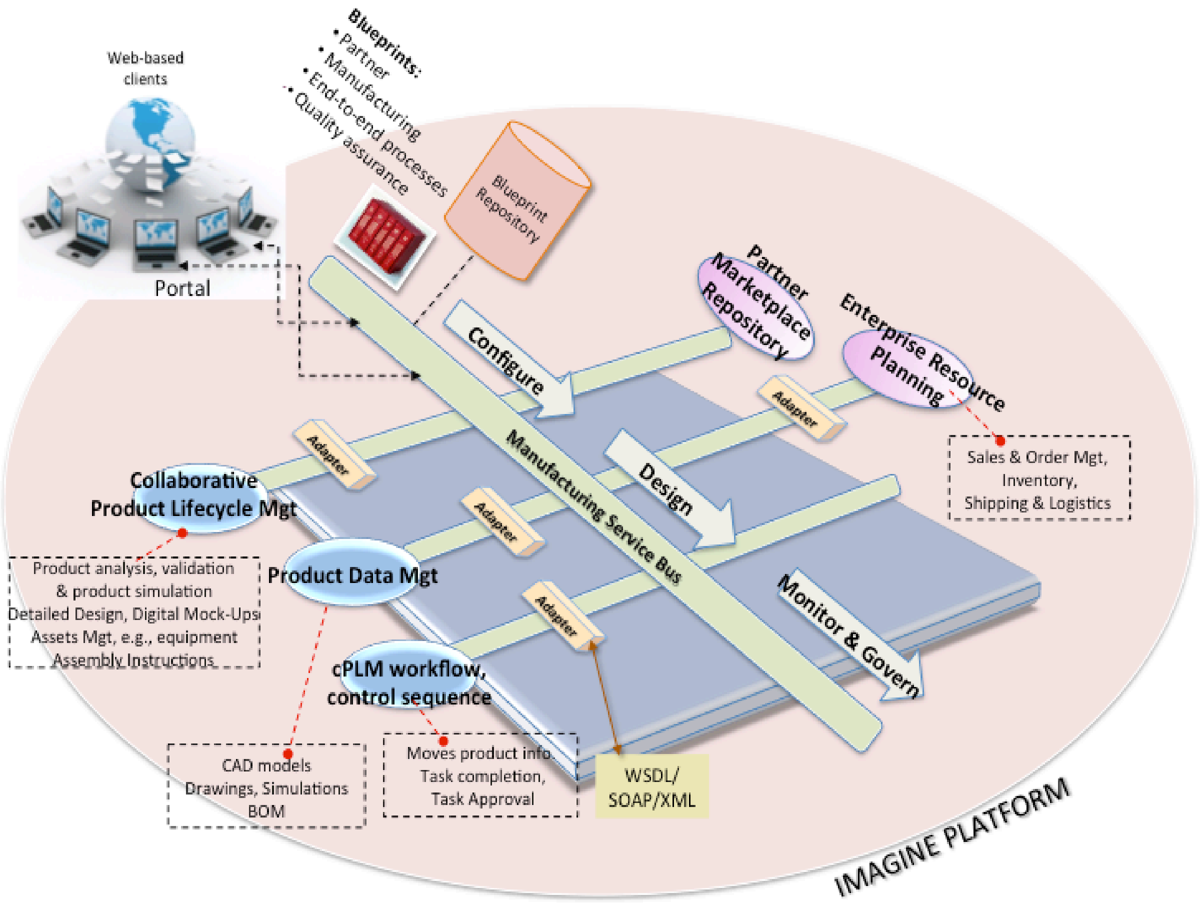

Figure 7-1: Initial architecture of the he IMAGINE Framework

Figure 7-1 illustrates the use of a Manufacturing Service Bus (MSB), which constitutes the backbone of the IMAGINE platform, to support Collaborative PLM and ERP capabilities. The MSB can be scaled down to a plant or an area of a plant or across multiple production facilities depending on the transaction/data load and response requirements of the operation workflows being supported by plant applications. In this figure adapter modules are responsible for service-enabling component business or manufacturing systems (nodes) in the MSB, e.g., ERP, cPLM, product data. The component adapters in this figure facilitate point integration of component systems by adapting legacy systems and applications and other back-office enterprise information systems), and PLM, to the MSB so that they can express data and messages in the standard internal format expected by the MSB. Workflow execution in this type of architecture occurs among component system adapters within the MSB. In Figure 7-1 there are multiple manufacturing repositories that help store, retrieve and collate production data, depending on the size and complexity of the manufacturing operations.

The form and role of the MSB extensions to its generic service modules will be very much dependent on the vertical industry, product set, production type and complexity. For instance, the MSB will be quite different for automotive, aerospace, and furniture applications. This will be reflected not only in specialised MSB modules but also in the content of the blueprints stored in the MSB repositories.

In the following deliverable (WP-2 D2.2.3) we shall provide an architectural approach and specify the software module in the IMAGINE platform that enable support of the DMN Lifecycle and blueprint model elaborated in the present deliverable. In our architectural approach we shall consider architectural support for issues which are central to the DMN Lifecycle and blueprints. These include the following:

- Improve visibility by providing a detail view of end-to-end operations and quality performance as well as corporate level roll-ups for supply, demand and asset balancing, and comparative analysis.
- Streamline processes and eliminating work steps by making use of a simple cause-and-effect relationship with fewer steps, faster response times, reduced throughput times, and higher profitability.
- Achieve inter-enterprise collaboration on products and manufacturing processes in the DMN.
- Support the creation of composite manufacturing applications, especially those with workflow triggers and alerting.
- Reduce friction: Make the entire manufacturing process happen faster and at lower cost by incorporating easy-to-use, role-based interfaces and making information available across organisations enable the people using them to make better decisions.
- Support the incorporation of legacy resources into the IMAGINE platform.
- Support the creation of production schedules out of customer requests.
- Bringing manufacturing-class metrics into play.
- Commissioning of services by deploying services into the MSB and configuring them for use and securing them against misuse.

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Annex B: List of Acronyms

BPM: Business Process Management

cPLM: collaborative Product Lifecycle Management

DMN: Dynamic Manufacturing Network

ERP: Enterprise Resource Planning

ESB: Enterprise Service Bus

ICT: Information & Communication Technology

MES: Manufacturing Execution System

MRP: Material Resource Planning

PLM: product lifecycle management

QoS: Quality of Service

SCM: Supply Chain Management

Annex C: SCOR

SCOR assigns three standard process levels within each major supply-chain application to identify specific attributes of the five main processes described in the previous section. Figure A-1 shows the three core SCOR levels as well as two additional that may include company-specific process extensions.

Level 1 is the highest level. This level describes supply chain processes at the most general level. It consists of the five key supply chain process types Plan, Source, Make, Deliver, and Return and assumes that all supply chains are composed out of these four basic processes. In addition, performance targets are established.

Level 2 provides more definition of the five core process categories and defines the configuration level through which a company's operations strategy is implemented. Actually, Level 2 provides for variations in the Level 1 processes. A company's supply chain can be "configured-to-order" at Level 2 from the core "process categories." Companies implement their operations strategy through the configuration they choose for their supply chain. These are not in fact sub-processes, but variations in the way the processes can be implemented.

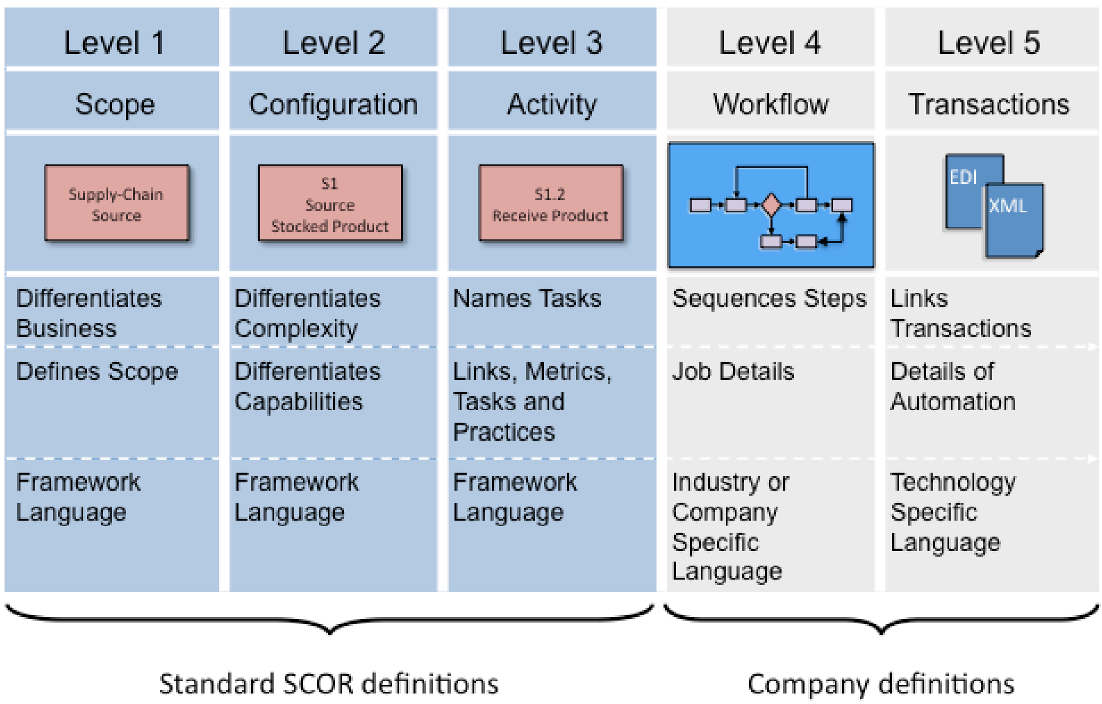

Figure A - 1: Standard SCOR

At Level 3, the processes are decomposed process element definitions, inputs, outputs, process performance metrics, and best practices are defined to "fine tune" a company's operations strategy. Level 3 defines a company's ability to compete successfully in its chosen markets, and consists of:

- Process element definitions.
- Process element information inputs and outputs.

- Process performance metrics attributes and definitions.
- Best practices definitions.

The SCOR-model identifies an additional Level 4 for processes, which is not in its scope, as the definition of strategic, company specific supply-chain processes and practices to achieve competitive advantage and to adapt to changing business conditions. Companies implement supply-chain management practices that are unique to their organisations at this level. Level 4 and lower defines specific practices to achieve competitive advantage and to adapt to changing business conditions.

Figure A-1 illustrates an extension of the standard SCOR definition that includes additional levels 4 and 5 with company (or vertical industry) specific components. As shown in this figure Level-4 introduces company (or vertical industry) specific workflow constructs while Level-5 uses transactional constructs expressed in XML or EDI.

Figure A-2 illustrates an example of a supply-chain that follows the SCOR model and comprises five levels of processes. In this example, when implementing a process, an application developer first focuses on a delivery a delivery process (Level 1 process) and then may decide which of three (Level 2) variations of delivery process it is.

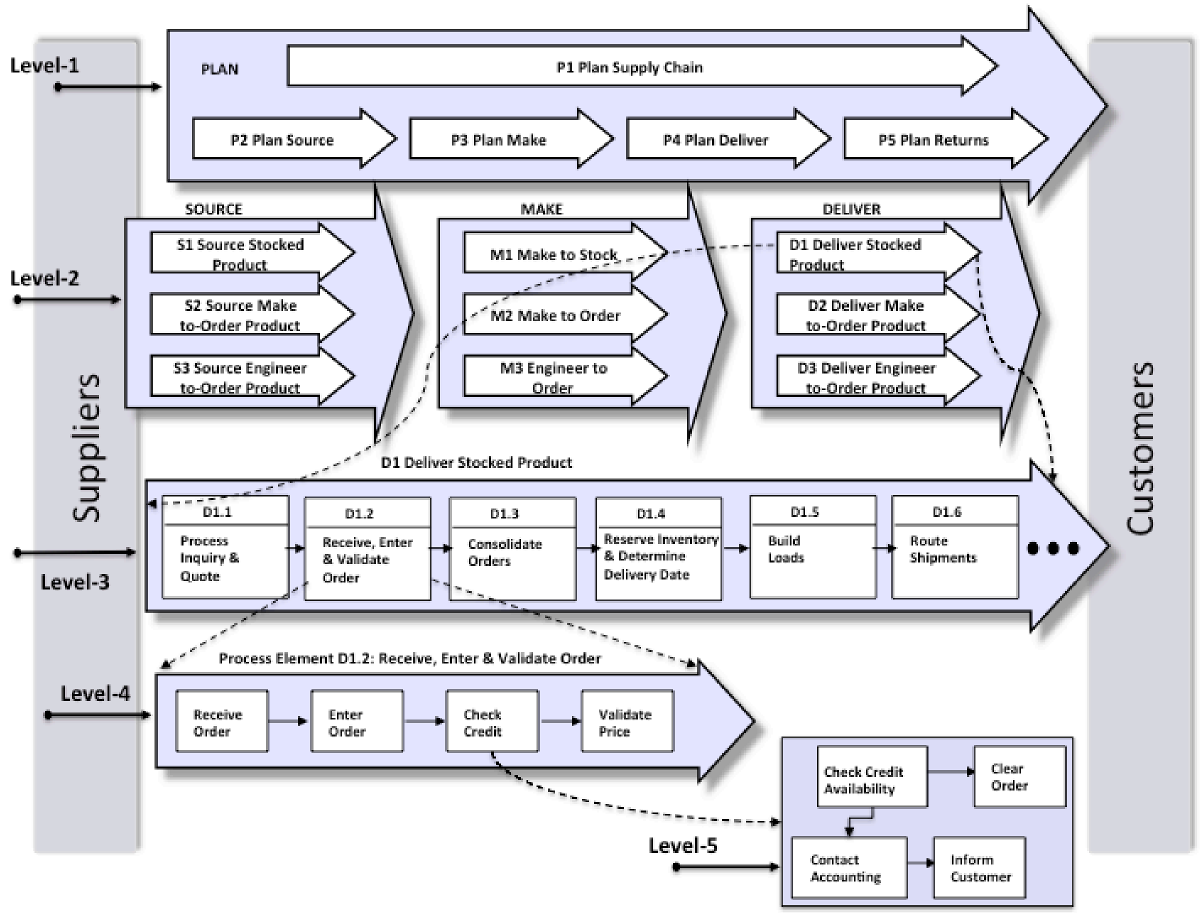

Figure A - 2: Implementation of a Supply-Chain using SCOR processes at five levels

In the case of Level 1 Deliver process, the Level 2 variations are D1: Deliver Stocked Product, D2: Deliver Made-to-Order Product, or D3: Deliver Engineered-to-Order Product. Figure A-2 shows all of the five basic SCOR Level 1 processes with current Level 2 variations for each Level 1 process. Each

Level 2 process is further decomposed into a set of sub-processes or activities at Level 3 that define the basic sequence of steps involved in implementing the process.

Figure A-2 shows that in this example the application developer is decomposing the Level 2 D1: Deliver Stocked Product process into a number of predefined SCOR sub-process such as D1.1, D1.2, D1.3, D1.4, and so on. The example further indicates that the application developer focuses on process D.1.2: Receive, Enter & Validate Order. This process will be implemented now using company specific practices and as such is not part of the SCOR model. The figure illustrates a possible implementation of process D.1.2 at Levels 4 and 5. As illustrated by this example, the first three levels of the SCOR framework serve as the foundation for the development of Level 4 processes.

C.1 SCOR Metrics

SCOR enables companies to analyse and improve their supply chain operations by helping them to communicate supply chain information across the enterprise and measure performance objectively. SCOR also assists enterprises with identifying supply chain performance gaps and improvement objectives and influences the development of future supply chain management software. It provides standard definitions of measures and procedure for calculating the metrics.

The SCOR metrics are used in conjunction with performance attributes. SCOR metrics are used in conjunction with the performance attributes of reliability, responsiveness, agility, cost, and assets. These performance attributes are characteristics of the supply chain that permit it to be analysed and evaluated against other supply chains with competing strategies. Like processes, SCOR metrics are classified into a number of levels but these do not necessarily correspond to the process levels.

The Level 1 strategic metrics are the calculations by which an implementing organisation can measure how successful they are in achieving their desired positioning within the competitive market space. Many metrics in the SCOR model are hierarchical – just as the process elements are hierarchical. Level 1 metrics are created from lower level calculations and are primary, high level measures that may cross multiple SCOR processes. Lower level calculations (Level 2 and 3 metrics) are generally associated with a narrower subset of processes.

Level 1 Metrics	Performance Attributes				
	Customer-Facing			Internal-Facing	
	Reliability	Responsiveness	Flexibility	Costs	Assets
Perfect Order Fulfillment	X				
Order Fulfillment Cycle Time		X			
Upside Supply Chain Flexibility			X		
Upside Supply Chain Adaptability			X		
Downside Supply Chain Adaptability			X		
Supply Chain Management Cost				X	
Cost of Goods Sold				X	
Cash-To-Cash Cycle Time					X
Return on Supply Chain Fixed Assets					X
Return on Working Capital					X

Figure A - 3: SCOR Level 1 Metrics (source [59])

Figure A-3 is an example of Level 1 metrics. This figure shows that each metric is associated with exactly one out of five performance attributes (Reliability, Responsiveness, Flexibility Costs, and Assets). The ten Level 1 metrics mentioned in Figure A-3 are high-level business measures that are of interest to the supply chain managers. It should be noted that a given metric can have multiple associations with processes on various levels depending on whether the metric calculation requires data carried by the process. Calculation of a metric may be dependent not only on the process data items but on the calculation of more detailed, lower level metrics as well.

Lower level calculations (Level 2 metrics) are generally associated with a narrower subset of processes. For example, "Delivery Performance" is calculated as the total number of products delivered on time and in full based on a commit date. Additionally, even lower level metrics (diagnostics) are used to diagnose variations in performance against plan. For example, an organisation may wish to examine the correlation between the request date and commit date. For example, consider the Level 2 metric "Delivery Performance" depends on finer grained metrics "Delivery Performance to Customer Commit Date" and "Delivery Performance to Customer Request Date"). The SCOR model does not prescribe a method for rolling up the metrics. Level 2 and 3 metrics associated with Level 1 metrics can be found in the SCOR 10.0 Metrics Hierarchy in the Metrics Chapter [59].

Annex D: BPMN-2

BPMN specifies a single business process diagram, called the Business Process Diagram (BPD), which is a diagram designed for use by the people who design and manage business processes. BPD provides a summary of the BPMN graphical elements and their relationships. This diagram is easy to use and understand, offers the expressiveness to model complex business processes, and can be naturally mapped to business execution languages.

A business process diagram is defined as a series of events and activities connected by sequence flow, where the direction of the sequence flow arrowheads determines the order of the sequence. The purpose of this section is not to serve as an exhaustive description of BPMN. We shall rather examine the essential BPD constructs that readers need to understand in order to create BPMN processes. We shall therefore examine a series of graphical constructs that include events, activities, sequence and message flows, gateways and associations, which comprise a BPD. For a more detailed description of the BPMN language we refer readers to [45], which focuses on the BPMN 2.0 notation and symbols.

Events: A basic BPMN process has a start event, one or more activities, and an end event. An event is the first basic element of BPMN. As usual an event signifies the occurrence of an important incident that happens during the course of a business process. Events affect the flow of the process and usually have a cause (trigger) or an impact (result). An event in BPMN is represented by a circle with open centres to allow internal markers to differentiate different triggers or results. There are three types of events, based on when they affect the flow: start, intermediate, and end events. There are also two kinds of intermediate message events - one kind responsible for reception of messages ("catching") and one kind responsible for sending messages ("throwing"). Start events can only react to ("catch") a trigger while end events can only create ("throw") a result. Intermediate events can catch or throw triggers.

Activities: An activity is the second basic element of BPMN. An activity is a generic term for work that a business process performs and is represented by a rounded-corner rectangle. An activity can be atomic or non-atomic (compound). An atomic activity, also known as task performs a single action. A compound activity, also known as process, has its own set of atomic or compound activities, as well as events, gateways, and all other BPMN constructs. Processes can be nested and thus spawn children which are referred to as sub-processes. Finally, tasks are the lowest-level processes, which cannot be further decomposed. A compensated activity is one that has special compensation logic attached to it to revert (undo) its effects. Processes are contained within a Pool construct.

Gateways: A gateway is the third basic element used to determine traditional flow decisions, as well as the forking, merging, and joining of paths and is represented by the familiar diamond shape.

Flow objects in BPMN (events, activities, and gateways) are connected together in a diagram to create the basic skeletal structure of a business process. There are three types of connecting objects that provide this function: sequence flows, message flows and associations.

Sequence flow: A sequence flow is used to indicate the sequence in which activities will be performed in a business process and is represented by a solid line with a solid arrowhead connecting source and target activities, events or gateways.

Message flow: A message flow is used to show the flow of messages between two separate process participants (business entities or business roles) that send and receive them and is represented by a dashed line with an open arrowhead. In BPMN, two separate pools in a BPD will represent the two participants.

Associations: An association is used to associate data, text, and other artefacts with flow objects and is represented by a dotted line with a line arrowhead. Associations are used to show the inputs and outputs of activities. A directional association is often used with data objects to show that a data object is either an input to or an output from an activity.

D.1 Notation

The main conventions in BPMN diagrams are the following:

- Small rounded boxes are called activities.
- Circles containing an envelope symbol are inbound events. Events are asynchronous service operations that a process provides to its clients. A message arrives from a participant and triggers the event. When used to "catch" the message, then the event marker will be unfilled (white). Message intermediate events can be used for sending messages to a participant. When used to "throw" the message, the event marker will be filled (dark).
- Deferred choice, also known as an event pick, uses a diamond containing an inscribed star (known as an event-based gateway) with arrows leading to a set of intermediate events.
- Workflow constructs such as split and join patterns, are represented in BPMN by means of gateways, which represent common programming control structures as if-then, switch, all and parallel execution.
- The diamond containing an X symbol is an exclusive data gateway, which operates like an XOR split.
- The diamond containing a + symbol is a parallel gateways that provides a mechanism to synchronise parallel flow and to create parallel flow.

D.1.1 BPMN examples of use

In what follows, we shall illustrate various additional BPMN constructs that can help model manufacturing-based applications using a number of examples on the basis of a case study – borrowed from the domain of automotive.

Figure A-4 illustrates the processing of a check-inventory activity. This example is based on a data-based exclusive OR gateway, which uses an if-then-else, and switch constructs with mutually exclusive properties as a control structure. In the split mode the exclusive OR gateway evaluates a separate condition for each of its outgoing paths and lets through the first one whose condition evaluates to true. All other paths are discarded. In the join mode the exclusive OR gateway lets through the first incoming path and ignores all others.

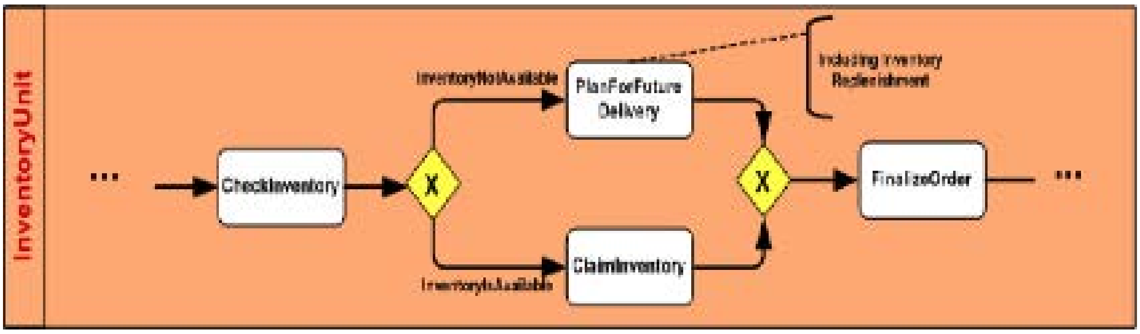

Figure A - 4: BPMN example of a data-based exclusive OR-gateway

Figure A - 4 illustrates that a "Finalise-Order" activity can be reached when either of the activities "Plan-for-Future-Delivery" or "Claim-Inventory" completes successfully.

The example in Figure A - 5 shows the process of order confirmation based on the concept of a deferred choice (event pick) gateway. This pattern represents a type of exclusive decision, where the intent is to wait for one of the process events to occur, execute its activities, and ignore all other remaining events.

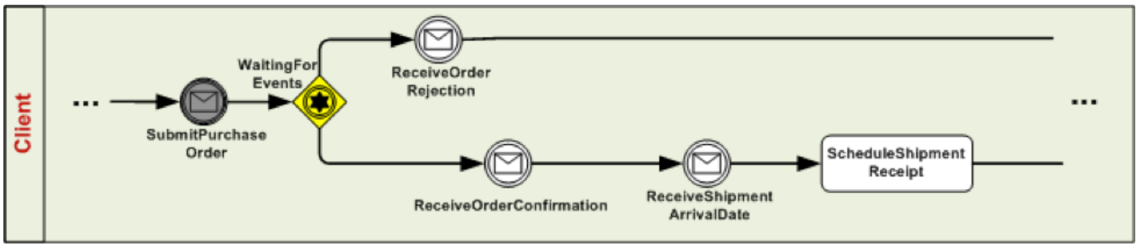

Figure A - 5: BPMN example of an event-based exclusive OR gateway

In this example the gateway lets through the branch having the first triggered event, e.g., "receive-order-confirmation" and continues with the following event "Receive-Shipment-Arrival-Date". In this example the "Receive-Order-Rejection" event is ignored.

The example Figure A - 6 shows the process of reserving inventory, scheduling release dates and order confirmation based on the concept of the parallel split pattern

The BPMN diagram in Figure A - 6 uses a gateway element to model split and join patterns, which represent common programming control structures such as if-then, switch, and all. In the split mode, it lets through each outgoing path. In the join mode, it blocks until each incoming path completes. This means that in this example "Reserve-Inventory" and "Confirm-Order" are executed in parallel and only once both are complete the order is consolidated.

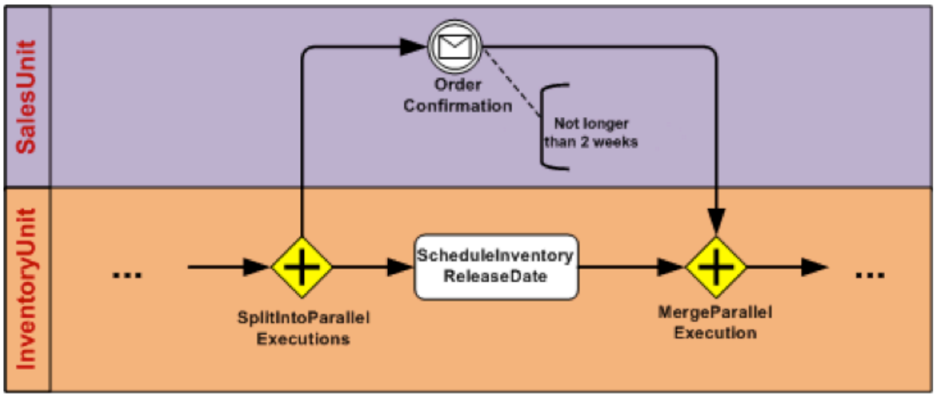

Figure A - 6: BPMN example of a parallel gateway

Flow objects and connectors can be used to specify BPMN process models at a high-level of detail for documentation and communication purposes as shown in Figure A - 6. Swim lanes are used as a mechanism to master complexity and organise activities into separate visual categories in order to illustrate different functional capabilities or responsibilities.

Annex E: Benefits and Risks at Enterprise Level

As mentioned in the previous section, the methodology that has been used in order to identify the benefits and the risks surrounding the participation of an enterprise in a DMN includes:

- Identification of typical industrial & organisational operations of SMEs belonging to several sectors
- Grouping of operations by department and type (internal/external)
- Identification of the operations that get re-organised and those indirectly influenced when joining a DMN
- Tracking down possible benefits of adopting the DMN methodology – classification by operation type and by department
- Identification of problems and risks imposed per industrial operation and department
- Identification of risk avoidance and mitigation strategies and proposed solutions.

The main body of work of the above-mentioned steps is presented in Annexes B and C and these sections provide a consolidated view of the benefits that enterprises might enjoy and the risks factors they are concerned of, when thinking of participating in a DMN.

It has to be noted, that the aforementioned steps will be also executed separately for each living lab in order to focus on any benefits and risks specifically identified in each sector and to monitor them closely in the time frame of the IMAGINE project. The related objective is to provide accurate measurable outcomes per case and to identify actual and applicable risk mitigation/avoidance practices.

Symbol	Illustration
	Company Department/ Operation
	Extroverted Operations
	Interdepartmental Operations
X	Interfacing Operations
	Identified Benefit
	Identified Risk

Figure A - 7: Symbols used in the tables

This section presents the different departments of a typical SME and tries to identify how an enterprise will be affected if it adopts a DMN approach. For this purpose, the current modus operandi of a typical SME in a traditional supply chain environment is described, and the envisaged changes when entering a DMN are presented, which are then translated to benefits and risks. For each department, the operations identified along with their interrelationships with functions pertaining to other company departments are illustrated in an organisation chart and further summarised in a table, where operations directly affected by the DMN are also marked. In the same table, the different operations are further quantitatively correlated with potential risks and benefits for the main DMN actors, e.g. OEMs and suppliers. The symbols employed in both cases are utilised as shown in Figure A-7.

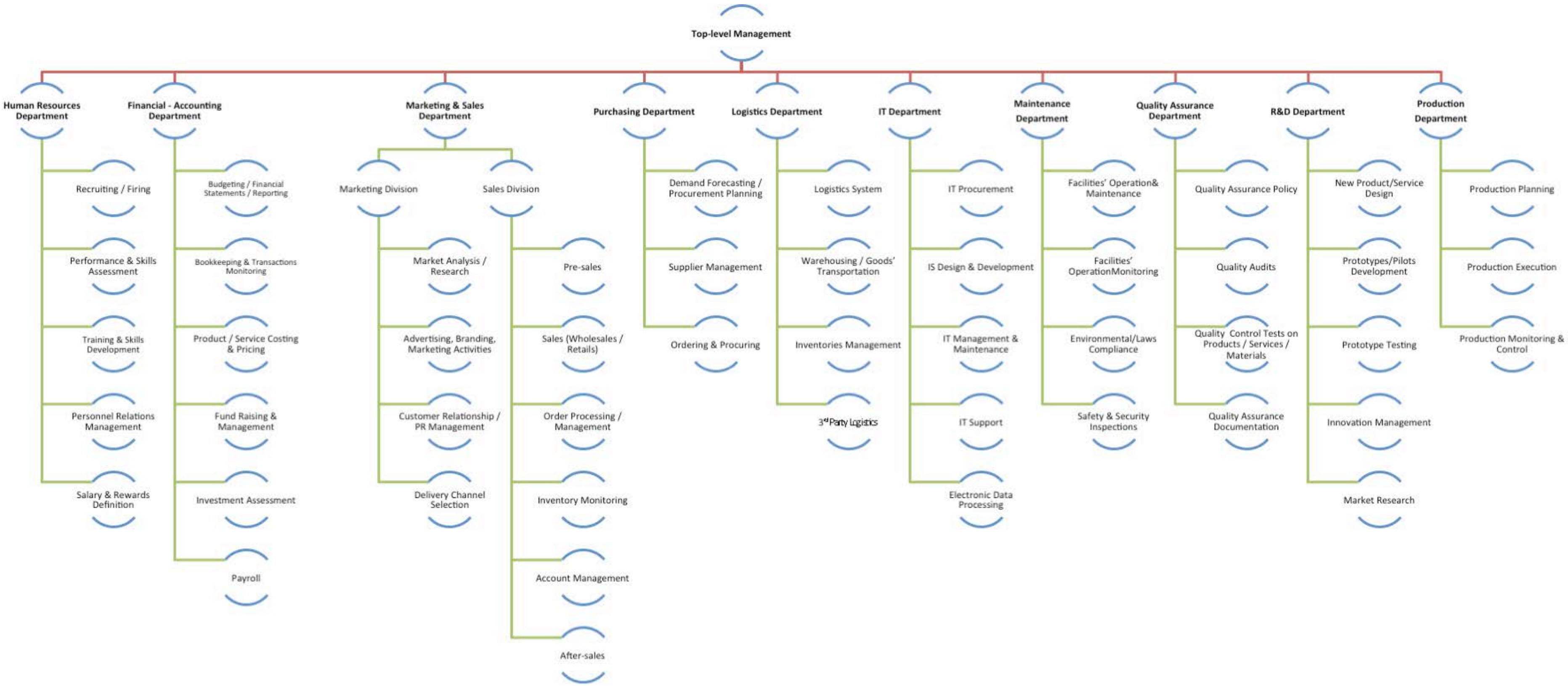

Figure A - 8: Major Departments and Functions within an enterprise

E.1 From current modus operandi to Dynamic Manufacturing Networks

E.1.1 Production Department

E.1.1.1 Role of the department in the traditional supply chain model

The main role of production is to turn inputs (raw materials or individual components) into outputs (finished goods/products or services). When a business completes this process it is able to achieve customer satisfaction by producing products that are ready to be used and fit for a specific purpose. The Production Department, in collaboration with the Quality Assurance Department, is also responsible for ensuring that quality is achieved in each item produced. Consequently, it can be defined that the main function of a Production Department is to produce products based on receiver specifications, on time, to the required quality levels and at a defined product cost.

Obviously, the production department is the core department of the whole manufacturing enterprise and its smooth operation is a very crucial matter. This doesn't have to do with the "value" that gets produced via the department's operations only, but also with the fact that the required inputs and the (expected) outputs of the department drive the operations of the other departments in the enterprise, as well as of the supply chain. Concerning the latter, the needs of the department in raw materials or components define the operations of the Purchasing Department, which assumes responsibility for procuring the required goods from suppliers, while the achieved or expected real production is strongly related to the rest of the Logistics functions (warehousing, distribution, delivery), as well as to Marketing and Sales operations. On the other hand, and as far as the department's interrelationships with external entities are concerned, in the traditional supply chain model the Production Department of an enterprise is not directly dealing with other supply chain members since this is done via the R&D Department (supposing that product design takes place there), the Procurement/Purchasing Department (concerning materials purchasing) and the Logistics Department (concerning handling of produced goods). Even the requirements of the type "what has to be produced when" come from the Sales Department directly. Of course, in any case, the ability/capability of the production department to produce something, in given time and cost, plays a significant role concerning the position and operation of the company in the supply chain. In the traditional supply chain model case, the Production Department accepts orders from the Sales Department and after confirming time and cost, it posts relevant requirements for raw materials and components to the company's warehouse and if needed to the Purchasing Department in order to get the needed materials. Finally, concerning production scheduling, rescheduling and control, these responsibilities belong to the Production Department which just informs the other departments of the enterprise and - indirectly only - the supply chain collaborators about the production progress and any delays or flaws, when these occur.

In summary, the operations of the Production Department include:

- Production Planning, based on the production requests received by the Sales Department, and taking as input the final product design and specification, as provided by the R&D Department. This function involves both the scheduling of production operations with respect to the requested quantities and delivery dates, as well as the conduction of a number of preparatory activities, such as resources allocation, infrastructure capacity management, machinery preparation and layout planning, inventory control and goods'/materials' internal transportation to the production lines where needed, required for the actual execution of the manufacturing activities.

- Production execution, embodying the main role of the department in question, which as already discussed, lies in turning inputs, e.g. raw materials and individual components into outputs (finished goods/products), and therefore encompasses manufacturing and, if applicable, packaging activities, while ensuring quality requirements as mandated by the enterprise's quality assurance policy.
- Production monitoring and control, relying on observation of the operation of all production lines and taking corrective measures in collaboration with the Maintenance Department, and rescheduling the production if needed.

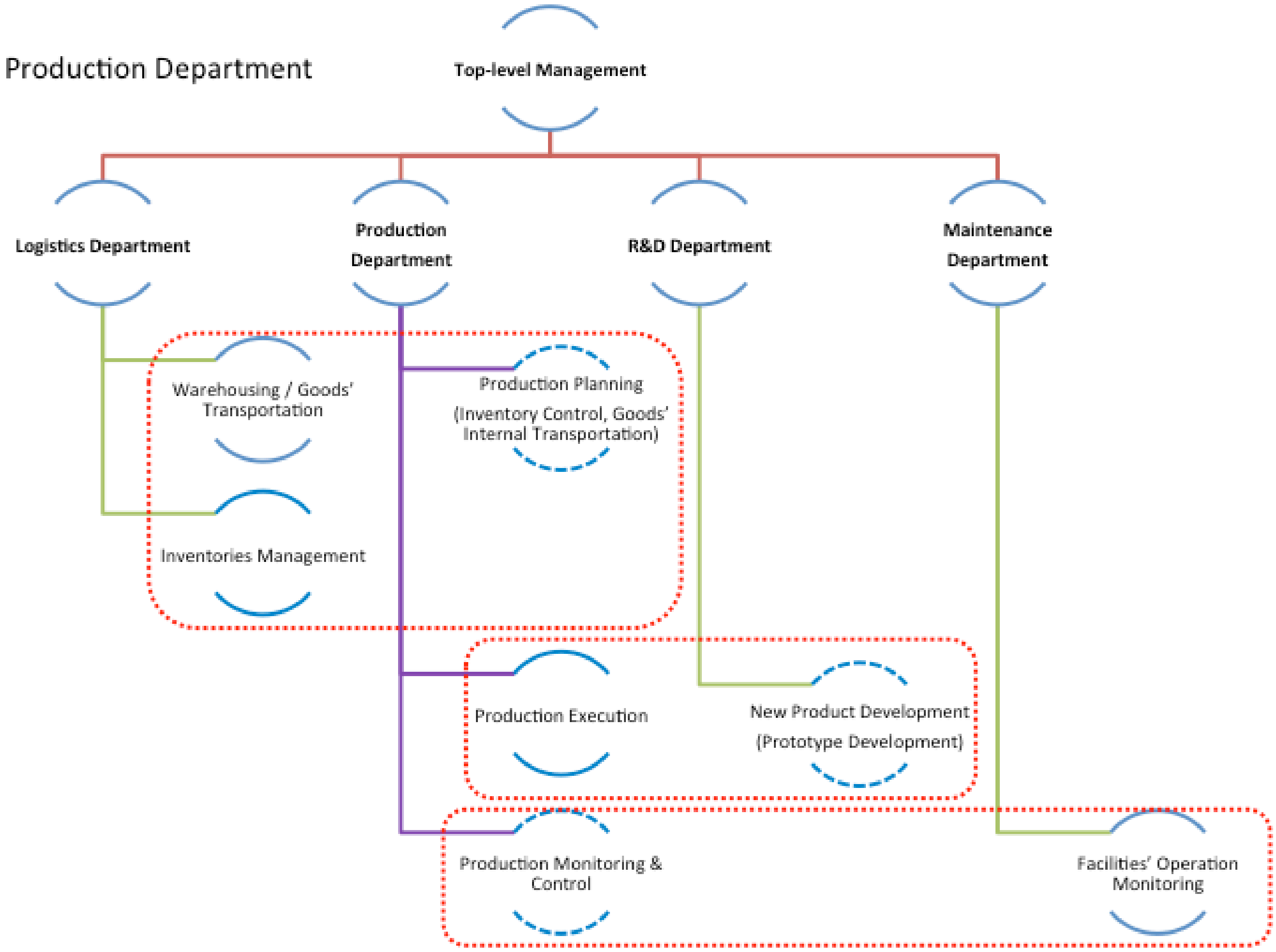

Figure A - 9: Production Department and relation to other departments

E.1.1.2 Enhanced functions and role of the department in a DMN environment

While the core functions and operations, performed by the Production Department are almost the same in case an enterprise becomes part of a Dynamic Manufacturing Network, the participation in the network can change completely the way that the department performs. This is based on two facts, concerning production planning/scheduling and production control respectively:

Table A -1: Consolidated view of the Production Department's Benefits and Risks

Supply Chain / DMN actors		Production Department: Production Planning	Production Department: Production Execution	Production Department: Production Monitoring and Control
Relations to other departments /operations within the same enterprise	Logistics Dept. > Goods' Transportation	X		
	Logistics Dept. > Inventories Management	X		
	R&D Dept. > New Product Development (Prototype Development)		X	
	Maintenance Dept.> Facilities' Operation Monitoring			X
Direct Changes enduced by a DMN		X		X
Benefits	for OEMs	⊕⊕	⊕⊕	⊕⊕
	for Suppliers	⊕⊕	⊕	⊕⊕
Risks	for OEMs	⚠⚠	⚠⚠	⚠⚠
	for Suppliers	⚠	⚠⚠	

- Production planning in a DMN environment is not just an internal matter of the enterprise. Since the enterprise has to fulfil specific production requirements coming from the network, the production is planned on the basis of these requirements. Even if not all production orders derive from the DMN partners, the enterprise's production capacity is more or less known to the network administration, so it poses a set of barriers concerning production planning and consequently production scheduling.
- In a DMN environment production control is probably one of the most important enhanced operations. The reason behind this, is that production monitoring and control gets possible throughout the whole network, so the relevant basic operation of the Production Department changes scope: instead of just controlling enterprise's production by itself, the department also provides the DMN platform with the required data in order for the DMN manager to be able to achieve central monitoring and control of all production lines in the DMN A basic concept of any DMN is that production is constantly being controlled and co-ordinated centrally. Exact progress indicators concerning production orders are being monitored by the administration of the network. So, although the production department of each participating enterprise is still controlling enterprise's production as far as it concerns technical issues, in the DMN case what is of great importance is the co-ordination among all production lines in the whole network.
- Any delay or flaw which could cause problems in the delivery of an order becomes known to the DMN administration immediately (even as a delay projection), so the production orders coming from the network can change whenever a reconfiguration of the network is being decided – new orders may arrive which have to be scheduled and existing orders may change, leading to rescheduling of the production as well.

The changes that are evident in the production department are basically based on the novelties that the different blueprints bring, alongside with the general idea behind the DMN management methodology which calls for an automated and coordinated production. More precisely, the <u>Manufacturing, the end-to-end Process and the Quality Assurance BP</u> heavily affect the production department, as they carry all the required information for setting up, executing and monitoring the production process of any enterprise that is part of an operating DMN.

E.1.2 Logistics Department

E.2.1.1 Role of the department in the traditional supply chain model

The Logistics Department is one of the core departments of any company. It is indicative that there is no well-established enterprise that does not pay particular attention to this department. There is hardly any manufacturing (or even marketing) activity (internal or external) that can be achieved without the support of an effective Logistics Department. The key role of a logistics department is to ensure optimal geographical positioning of unfinished goods, while it also concerns the finished inventories of the organisation being at the required place at the lowest possible cost, while keeping up with all required specifications.

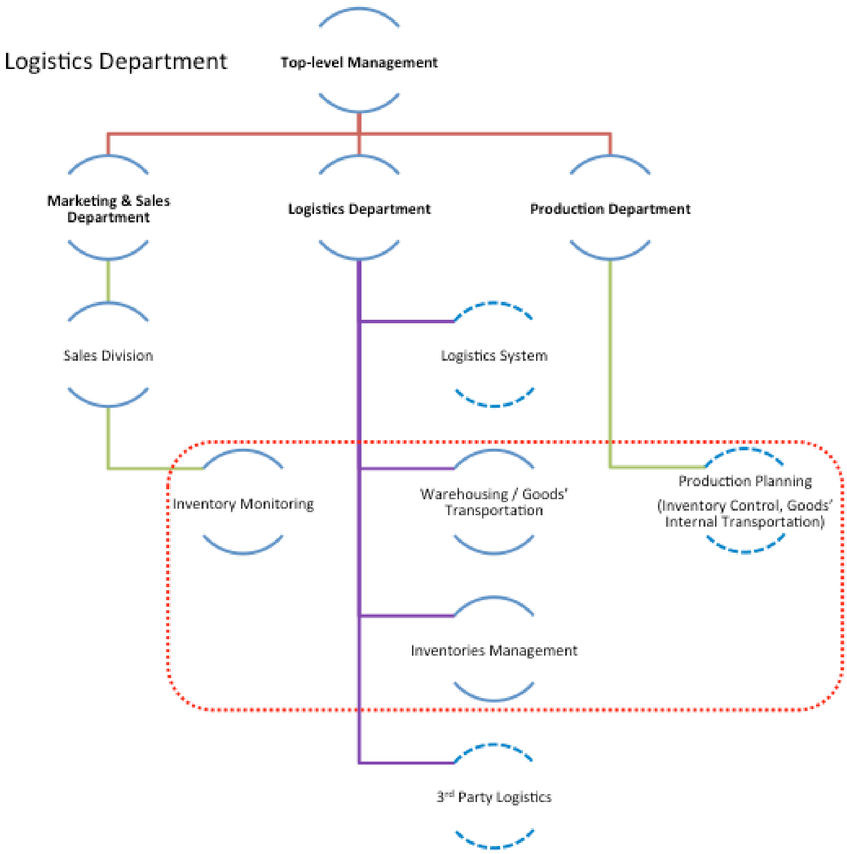

Figure A - 10: Logistics Department and relation to other departments

The objectives of such a department usually include:

- The development and application of plans, policies and procedures to implement a logistics system in line with the enterprise's business and operational goals.
- The storage, as well as the safe and timely transportation of goods, e.g. raw materials, semi-finished products, components and finished products to the specific locations where needed

- The monitoring and management of inventory levels of the aforementioned categories of goods, so as to both be able to react to unexpected needs as well as to minimise warehousing costs.
- The coordination with third party logistics, i.e. warehouses, transportation carriers etc. in case the enterprise relies on external logistics services as well.

Logistics is a department that inevitably deals with a large amount of data, coming from and being addressed to many different entities, internal and external, in order to perform all the aforementioned functions and tasks. The data exchange function includes means such as phone calls, exchange of e-mails, faxes, hard copy templates etc.

E.1.2.2 Enhanced functions and role of the department in a DMN environment

As stated above, the Logistics Department deals with many different entities inside and outside its company and in every possible tier. Thus, it is one of the departments that are directly affected by an introduction of a DMN. The DMN platform and methodology affects all sub-processes and sub-tasks that take place as part of the Logistics Department's work. Plans, policies and procedures are set as core enterprise principles, but become also principles of the network as a whole, making compliance control with them much easier. Business goals of the organisation are clearer and synchronised with the Logistics Department, which are supported by the presence of SLAs and the SLOs in the Partner BP, while real-time monitoring of the whole network via the KPIs incorporated in the Quality Assurance BP provides the ability of ensuring the smooth operation of each order (end-user, internal or external). Last but not least, coordination with suppliers, service providers and transport carriers becomes structured due to the fact that real-time information is available to each one of the aforementioned entities, thanks to the IMAGINE Blueprint model and the general DMN methodology.

Table A -2: Consolidated view of the Logistics Department's Benefits and Risks

Supply Chain / DMN actors		Logistics Department			
		Logistics System Development	Warehousing / Goods' Transportation	Inventories Management	3rd Party Logistics
Relations to other departments / operations within the same enterprise	Marketing & Sales Dept. > Inventory Monitoring			X	
	Production Dept.> Production Planning (Inventory Control, Goods' Internal Transportation)		X	X	
Direct Changes enduced by a DMN		X			X
Benefits	for OEMs	⊕⊕	⊕	⊕⊕	⊕
	for Suppliers	⊕⊕	⊕⊕	⊕	⊕
Risks	for OEMs	⚠	⚠⚠	⚠⚠	⚠⚠
	for Suppliers	⚠	⚠	⚠	⚠

E.1.3 Procurement/Purchasing Department

E.1.3.1 Role of the department in the traditional supply chain model

The Procurement/ Purchasing Department is one of the most well-established and recognisable departments of any business. This department is mainly responsible for every action related to ordering materials and dealing with all possible vendors. The objectives of such a department move beyond the belief that its primary role is to obtain goods and services in response to internal needs. The primary objectives of a Purchasing Department can be:

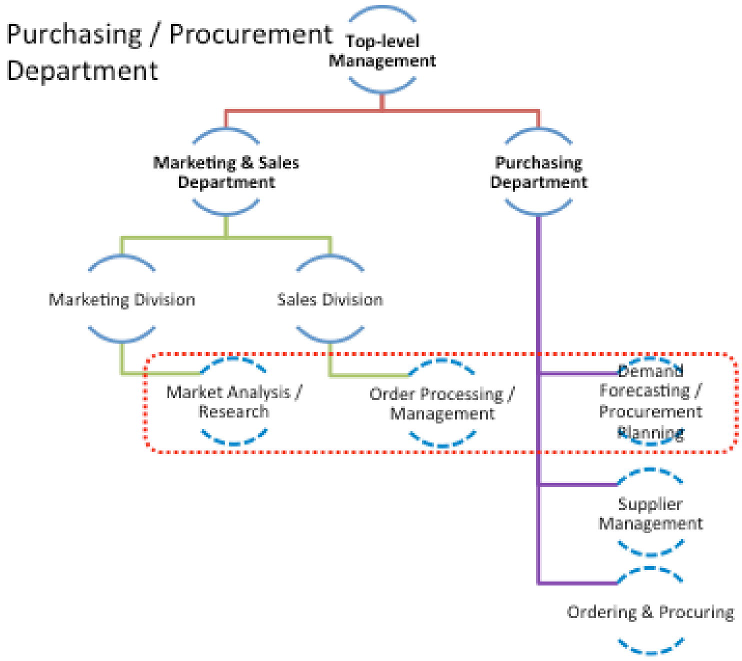

Figure A - 11: Purchasing Department and relation to other departments

- Forecasting the demand on materials based on the production schedule and on the overall forecasting regarding the demand for the products / services offered in order to plan the procurement of the required resources.
- Supplier management, which involves contacting potential suppliers, identifying opportunities, receiving and evaluating supplier offers, and negotiating prices in order to ultimately select the optimal and most advantageous offer.
- Ordering and procuring, lying in issuing orders, purchasing, and controlling orders' status so as to ensure timely receipt of the resources required in the production process

In order to perform the aforementioned functions, the department exchanges several types of data (requirements, specifications, quality standards) with the suppliers and the clients of the company in the supply chain. The data exchange function includes procedures such as (hard copy or electronic) communication with multiple entities of the same tier (in order to ensure multiple sourcing for example), comparing and negotiating prices, evaluating of vendors, tracking the status of several orders, initial checking of invoices etc.

E.1.3.2 Enhanced functions and role of the department in a DMN environment

It can be taken for granted that the Procurement (Purchasing) Department is one of the departments that are directly affected by the DMN environment. Regardless if the functions and operations performed by the aforementioned department stay the same, or change (e.g. are merged with others or even repealed) the collaborative notion of the DMN changes the way that the work is carried out.

The selection of suppliers becomes easier and clearer as every member participating in the DMN provides clear and reliable information regarding his capabilities, which is a task that utilises the capabilities offered by the Partner BP. Order characteristics (e.g. prices) are also available and can automatically be compared, reducing in such a way long lasting negotiations for ensuring the proper price, quality and quantity. Moreover, tracking of orders is no longer a pain-point, as the DMN platform, with the use of the end-to-end Process BP and the Quality Assurance BP provides real-time information on the order progress and grants the ability to act fast in case of an unexpected event. In addition, specific operational requirements are clearly documented in the DMN platform through the Manufacturing and end-to-end Process BP, making their fulfilment a much more efficient procedure.

Table A -3: Consolidated view of the Purchasing Department's Benefits and Risks

Supply Chain / DMN actors		Purchasing / Procurement Department		
		Demand Forecasting / Procurement Planning	Supplier Management	Ordering & Procuring
Relations to other departments / operations within the same enterprise	Marketing & Sales Dept. > Market Analysis / Research	X		
	Marketing & Sales Dept. > Order Processing / Management	X		
Direct Changes enduced by a DMN		X	X	X
Benefits	for OEMs	+ +	+ +	+ +
	for Suppliers	+ +	+	+
Risks	for OEMs	⚠ ⚠	⚠ ⚠	⚠
	for Suppliers	⚠	⚠	⚠

E.1.4 Sales - Marketing Department

E.1.4.1 Role of the department in the traditional supply chain model

Sales and marketing, although meaning different things and having major differences in their operations, have ultimately the same goal, which is to attract and sign customer accounts for an organisation. Marketing improves the selling environment and plays a very important role in sales. If the Marketing Department generates a list of potential customers, that can benefit sales. A Marketing Department in an organisation has the goal of increasing the number of interactions between potential customers and the organisation. Achieving this goal may involve the sales team using promotional techniques such as advertising, sales promotion, publicity, and public relations, creating new sales channels, or creating new products (new product development), among other things.

In this context, "Sales" includes mainly the activities directly related to a client's purchase of products or services, which can be further analysed in three major sub-activities "Pre-sales", "Sales" and "After-sales", while "Marketing" includes activities directly related to increasing a potential customer's awareness of the product/service on display.

The main responsibilities of the Sales & Marketing Department include:

- Marketing:
  - The conduction of a series of preparatory activities, enabling the enterprise to define its position in the market and assess the degree of acceptance that its

products/services will meet by potential customers, and thereby estimate the volume of demand and sales of its products in order to plan accordingly its production, as well as to come up with ideas and customer feedback for the development of new or the refinement of existing products. These activities include market analysis, competition analysis, definition of market segments, marketing and customer satisfaction surveys, trial launch of new products, analysis of historical data on demand and sales (e.g. sales per product, territory, customer type etc.) etc.

  - The conduction of advertising, branding and marketing activities so as to promote the company's products / services and attract new customers.
  - Customer relationship management and customer profiling as well as PR management, for representing the company towards its customers and collaborators, suppliers and the general public.
  - The selection of delivery channels to the market (through retailers, big dealers, direct sales, etc.) and evaluation of their efficiency.

- Sales:
  - The estimation of customer needs and reflection of these needs in product lines as well as in specific solution proposals prepared for potential customers (presales).
  - Actual sales activities, including the settlement of agreements with customers, wholesales, retails, etc.
  - The management and processing of customers' orders, which involves collecting and aggregating orders from customers, checking inventory levels of ready-made products, estimating delivery times and quantities, tracking the status of placed orders, i.e. monitoring production progress and identifying delays/bottlenecks, so as to ensure timely delivery, as well as completing orders through the shipment of final products to customers.
  - Monitoring of manufactured products inventory, aiming at keeping the amount of ready-made products to a minimum for reducing inventory costs but at the same time trying to be able to satisfy the customers' demands through keeping a minimum reserve inventory. This task is directly related with the planning and the control of the production/manufacturing process and of logistics planning.
  - The management of the enterprise's clientele (account management) and the designation of the pricing policy to be followed depending on the case, including the provision of special offerings, discounts etc.
  - After-sales activities, including the provision of product support and customer service activities, such as offering consulting and training services, handling complaints and repairing products

This department is a very essential and horizontal department that is of outmost importance in any organisation as it is responsible for the interaction with the customers of an enterprise, who at the very end are necessary for the survival of it.

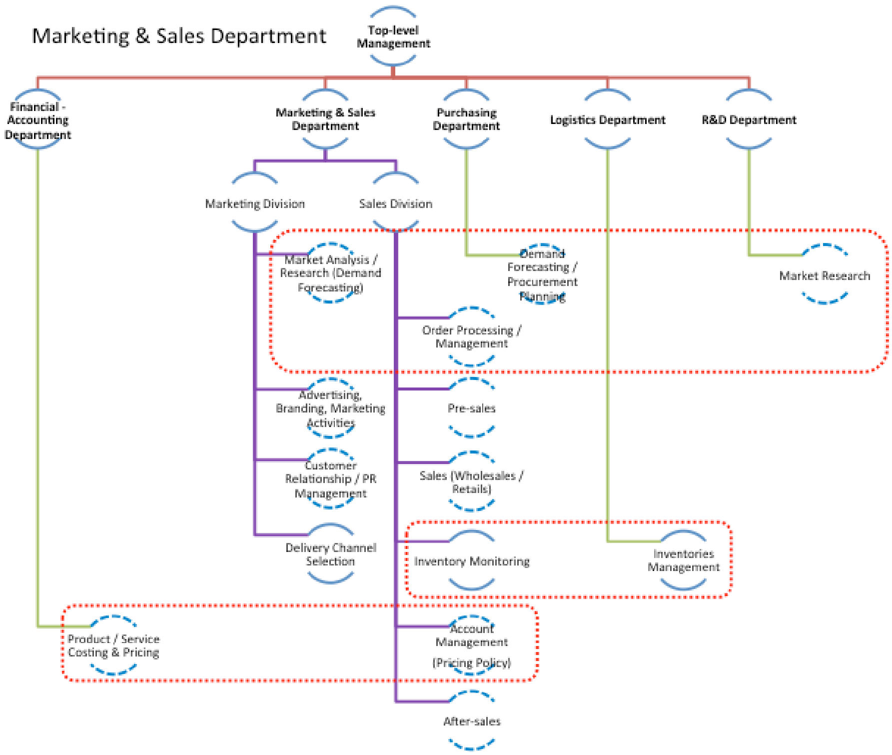

Figure A - 12: Marketing & Sales Department and relation to other departments

E.1.4.2 Enhanced functions and role of the department in a DMN environment

Joining a DMN is expected to affect some of the Marketing and Sales Department functions, as through the inclusion in such a network an organisation will be able to enlarge its customer base. Functions that will be affected include:

- The estimation of demand and sales volume, based on the extended customer base offered to enterprises that participate in a DMN.

Table A -4: Consolidated view of the Sales & Marketing Department's Benefits and Risks

Supply Chain / DMN actors		Sales – Marketing Department									
		Marketing Division				Sales Division					
		Market Analysis / Research	Advertising, Branding, Marketing Activities	Customer Relationship / PR Management	Delivery Channel Selection	Pre-sales	Sales (Wholesales / Retails)	Order Processing / Management	Inventory Monitoring	Account Management (Pricing Policy)	After-sales
Relations to other departments / operations within the same enterprise	R&D Dept. > Market Research	x									
	Purchasing Dept. > Demand Forecasting / Procurement Planning	x						x			
	Logistics Dept. > Inventories Management								x		
	Financial - Accounting Dept.> Product / Service Costing & Pricing										
Direct Changes enduced by a DMN		x	x	x				x		x	
Benefits	for OEMs	+	+	+	+	+	+	++	++	+	+
	for Suppliers	+	++	++	++		+	++	+	+	+
Risks	for OEMs	⚠	⚠	⚠	⚠	⚠	⚠⚠	⚠⚠	⚠⚠	⚠	⚠
	for Suppliers	⚠	⚠	⚠	⚠		⚠	⚠	⚠	⚠	-

- The management of the manufactured products, as the DMN nature calls for enterprises ready to respond to emerging business opportunities.

- The management of the customers' orders, as these will be processed through electronic channels, utilising the IMAGINE DMN methodology and the Manufacturing, end-to-end Process and the Quality Assurance BP.

E.1.5 Quality Assurance Department

E.1.5.1 Role of the department in the traditional supply chain model

Quality assurance is a complex process, focused on reviewing the quality of all factors (e.g. processes, resources, competencies etc.) involved in the manufacturing process. Many enterprises have a Quality Assurance Department, whose main goal is to provide, develop and maintain a system of quality assurance management, in order to minimise unintentional errors and occurrence of defective goods and to prevent claims from customers. To achieve this goal, the Quality Assurance Department assumes responsibility for the following competencies:

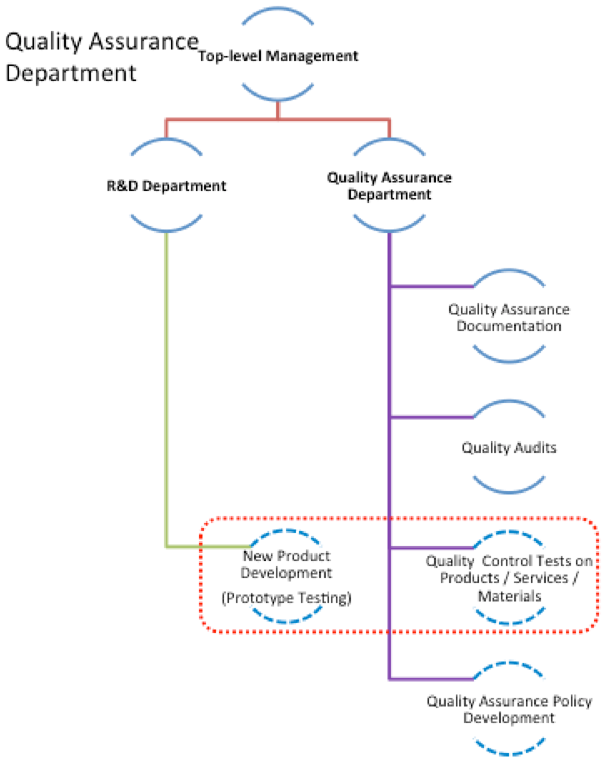

Figure A - 13: Quality Assurance Department and relation to other departments

- The development of a quality assurance policy, consisting in the designation, application and maintenance of quality assurance standards, measures and procedures, so as to guarantee satisfactory quality of products and services.
- The conduction of internal and external audits of the quality management system, in order to ensure compliance with the quality assurance policy in company divisions and produced goods and services.
- The conduction of quality control tests on raw materials, semi-finished products, components, and final products, utilised or fabricated by the manufacturing company.
- The development of the required documentation for formalising tasks and processes, keeping statistics and exploiting lessons learnt to improve quality management.

The conduction of quality control tests in particular, is a process that concerns all the aforementioned categories of products and typically takes place:

- upon the delivery of materials and components procured by external suppliers, so as to verify their quality and suitability to be utilised in the manufacturing process;
- both betwixt distinct phases of the manufacturing process and after the fabrication of the end product, in order to detect – usually through a sampling method – the defects in intermediate and finished products;

- as a next step, following the development of a new prototype by the R&D department, in the context of evaluating its properties and providing input for further product quality refinements.

The Quality Assurance Department has clearly strong links with the Manufacturing, and the Research & Development Departments, thus it may exist either as an individual department or a sub-division of the former departments, while it may even incorporated under the Human Resources Department, when, besides processes and resources, emphasis is also put on competencies and cultural aspects, such as skills, qualifications, organisational culture, motivation, team spirit etc. It further has some links with the manufacturing company's external associates to the degree at which quality standards and specifications are provided to the enterprises' suppliers as requirements which must be met by the products or services ordered and purchased.

E.1.5.2 Enhanced functions and role of the department in a DMN environment

The participation of a manufacturing company in a DMN does not directly affect the operation of the Quality Assurance Department; however it enhances the level of automation and reliability of the bidirectional information flows that take place both within and beyond the boundaries of the manufacturing company and in which the department in question is involved. The utilisation of the collaborative DMN platform, in which all data with regard to common production projects and delivery deadlines are kept as part of the Quality Assurance BP, ensures more specifically the scheduling of audits and corrective or preventive actions of quality management at the right time and in accordance with the needs of collaborative manufacturing projects, always in line with the DMN methodology and the DMN lifecycle model. On another level, participation in a DMN obliges companies to comply with a minimum of quality requirements, but facilitates at the same time the selection of collaborators, e.g. suppliers, partners etc. with affined quality assurance policies, resulting therefore in more effective and successful co-operations.

Table A -5: Consolidated view of the Quality Assurance Department's Benefits and Risks

Supply Chain / DMN actors		Quality Assurance Department			
		Quality Assurance Policy Development	Quality Audits	Quality Control Tests on Products/ Services/ Materials	Quality Assurance Documentation
Relations to other departments /operations within the same enterprise	R&D Dept. > New product Development (Prototype Testing)			x	
Direct Changes enduced by a DMN		x	x		
Benefits	for OEMs	⊕⊕	⊕	⊕⊕	⊕⊕
	for Suppliers	⊕⊕	⊕	⊕⊕	⊕⊕
Risks	for OEMs	⚠	⚠	⚠⚠	⚠
	for Suppliers	⚠	⚠	⚠	⚠

E.1.6 Research & Development Department

E.1.6.1 Role of the department in the traditional supply chain model

The Research & Development department of a manufacturing enterprise holds a very important role concerning the whole operation of the enterprise and its position in the supply chain. Probably the most crucial operation performed by the department is the design and development of new products.

The main functions of the R&D department include:

- The development of new products, including all relevant operations from the design of the new product and the definition of the required specifications, to the development of the product prototype and the testing and quality control of the latter, so as to evaluate its properties and to proceed to further refinements.

- The enhancement and expansion of existing products in order to respond to changing market needs.
- The conduction of market research in collaboration with the Marketing and Sales Department, as well as the corresponding feasibility analysis in order to respectively collect ideas for the design of new products and to guide their development taking into account quality requirements, available resources and capacity limitations.
- The management of innovation, patents and copyrights.

In order to perform the aforementioned functions, the department exchanges several types of data (requirements, specifications, quality standards) with the suppliers and the clients of the company in the supply chain. The data are exchanged asynchronously using conventional ways (email, fax, hard copies). Especially concerning product development, which is a function requiring strong collaboration between the company and other members of the supply chain, there are several iterations of exchanging blueprints and designs with collaborators until the new product gets its final characteristics and sometimes working meetings with the R&D departments of collaborating companies.

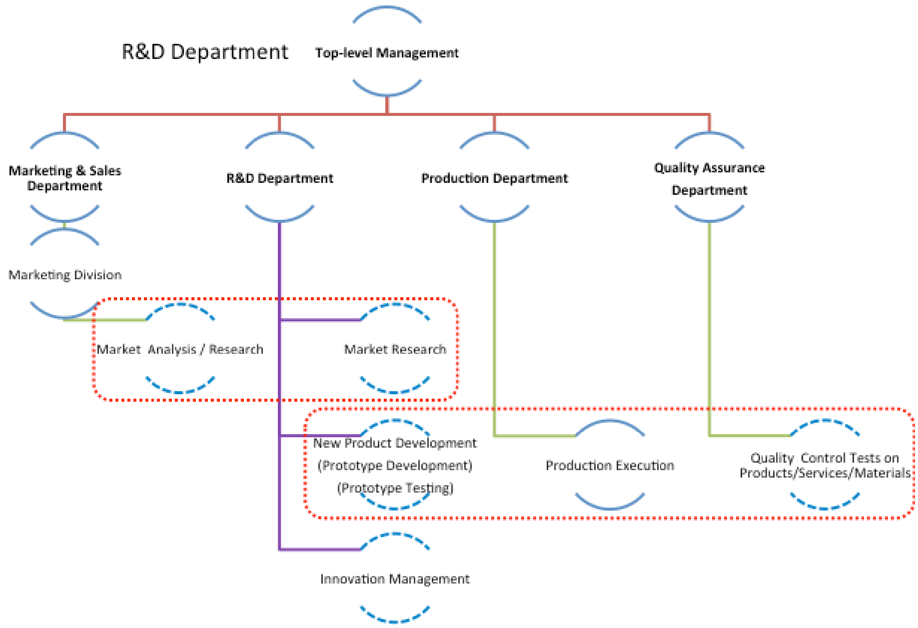

Figure A - 14: R&D Department and relation to other departments

E.1.6.2 Enhanced functions and role of the department in a DMN environment

While the functions and the operations, performed by the R&D Department of a company participating in an efficiently managed and operating DMN are exactly the same, the introduction of the DMN collaborative platform changes the way that those functions are being performed. Primarily the development of a new product takes place through constant (and almost real-time) collaboration between the R&D Department of the company and the corresponding departments of both the potential suppliers of materials/components for the new product and the client who ordered the product. This is achieved through the whole process supported by the DMN BP model, as any design of a product/service can follow the DMN lifecycle as if it was a final product. The fact that the design and development operations take place in liaison between departments of different companies also changes the way in which the knowledge of the R&D department is being organised and shared. Innovation, patent and copyright management becomes very important since the company needs the proper warranties, in order to be able to collaborate without concerns about the innovative or copyrighted information getting shared or misused.

Table A -6: Consolidated view of the R&D Department's Benefits and Risks

Supply Chain / DMN actors		R&D Department		
		Market Research	New Product Development	Innovation Management
Relations to other departments /operations within the same enterprise	Marketing & Sales Dept. > Market Analysis / Research	x		
	Production Dept. > Production Execution		x	
	Quality Assurance Dept. > Quality Control Tests on Products/Services/Materials		x	
Direct Changes enduced by a DMN			x	x
Benefits	for OEMs	+	+ +	+ +
	for Suppliers	+	+	+ +
Risks	for OEMs	⚠	⚠ ⚠	⚠ ⚠
	for Suppliers	⚠	⚠	⚠ ⚠

E.1.7 Information Technology (IT) Department

E.1.7.1 Role of the department in the traditional supply chain model

In the typical case, there are a few functions performed by the IT department of a manufacturing company that are supportive to the operation of the rest of the company's departments. Those functions are as follows:

- The procurement of IT, i.e. software (e.g. ERP, CRM, MRP, PLM, MES and other business IT systems) and hardware systems (e.g. servers, work stations, network infrastructure, etc.) from external IT vendors.
- The design and development of information systems, customised to the enterprise's needs.
- The above mentioned systems' management, including their installation, setup and configuration, customisation, interconnection with the rest of the company's IT systems, maintenance and upgrading, depending in the case of procured IT systems on the external vendors.

- The provision of IT support to the rest of the company's departments, including the provision of technical advice and the resolution of the relevant problems.
- The concern for computerising and enabling electronic processing of the data volumes which are made available inside the enterprise.

The IT Department plays a valuable role in making all other company departments productive and successful in their endeavours; therefore its operation can be characterised as horizontal to the operation of the manufacturing company as a whole, while it displays a few interfaces with external associates of the company. The implementation of the aforementioned functions, and particularly the procurement or design and development of specific purpose software systems, and consequently the provision of IT support require primarily thorough knowledge of the enterprise's operation and needs, and close collaboration with the rest of the enterprise's departments. On the other hand, the procurement of IT equipment imposes the exchange of information (e.g. requirements, specifications, interoperability standards) with IT suppliers, while it is usually a non-isolated process, as it creates thereafter dependability from the latter on the provision of IT support.

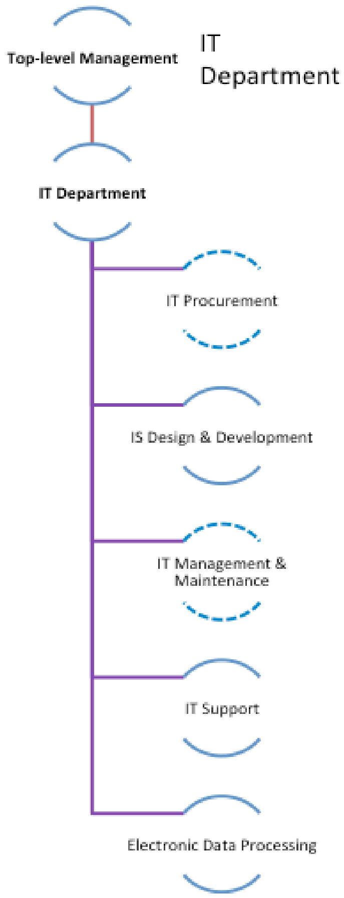

Figure A - 15: IT Department and relation to other

E.1.7.2 Enhanced functions and role of the department in a DMN environment

While the functions and operations, performed by the IT department of a company participating in an efficiently managed and operating DMN are altogether the same, the introduction of the DMN IT platform reinforces significantly the role of the IT department, which now assumes responsibility for ensuring interconnection, and thereby interoperability, not only among the manufacturing company's own IT systems, but also among the company's IT systems and the DMN IT platform.

Table A -7: Consolidated view of the IT Department's Benefits and Risks

Supply Chain / DMN actors		IT Department: IT Procurement	IT Department: IS Design and Development	IT Department: IT Management and Maintenance	IT Department: IT Support	IT Department: Electronic Data Processing
Relations to other departments /operations within the same enterprise						
Direct Changes enduced by a DMN		X	X			X
Benefits	for OEMs	+	++	+	+	++
	for Suppliers	+	++	+	++	++
Risks	for OEMs	⚠	⚠⚠	⚠	⚠	⚠⚠
	for Suppliers	⚠	⚠⚠	⚠	⚠	⚠

The need to achieve interoperability among in-house systems and the DMN platform influences primarily the operations with regard to the procurement, design and development and maintenance of information systems as well as with regard to the computerisation of data, as it imposes respectively the use of common standards, and data formats which can be universally processed within the DMN. However, the IMAGINE concept and the underlying platform makes it possible to interconnect most of the underlying systems to the complete DMN platform through utilising the IMAGINE Blueprint model, which main task is to carry information and coordinate the different processes that should be operated.

On the other hand and besides the challenge of achieving interoperability, participation of a company in a DMN creates as well the need for handling information cautiously, so that only the information that is necessary for the operation of the DMN is shared among DMN partners, and any critical or strategic importance data remain undisclosed.

E.1.8 Human Resources Department

E.1.8.1 Role of the department in the traditional supply chain model

Based on the fact that each enterprise or organisation is employing a number of people for carrying out the different tasks, a very vital department within each organisation is the Human Resources (HR) Department. Of course, the physical existence of such a department depends on the size of an enterprise, however, human resource management tasks are performed in any organisation, even if there is not a self-standing and self-operating department. For example, in the case of small companies, HR's duties are in most cases performed by trained professionals or even by non-HR personnel that run the company, while in larger enterprises, an entire functional group is dedicated to the discipline, with staff specialising in various HR tasks.

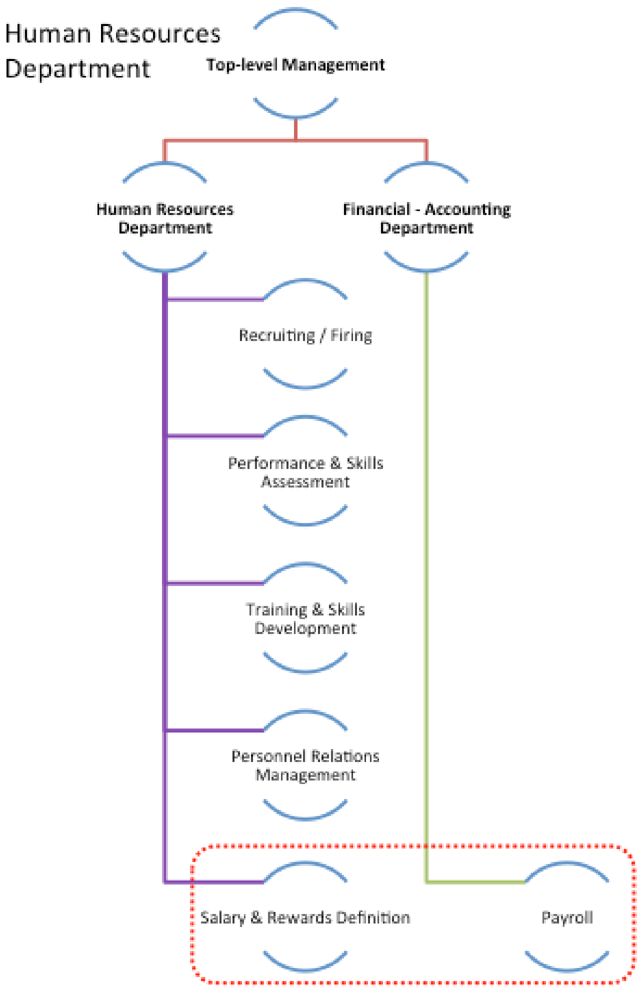

Figure A - 16: HR Department and relation to other departments

Each HR Department is responsible for the attraction, selection, training, assessment, and rewarding of employees, while also overseeing organisational leadership and culture, and ensuring compliance with employment and labour laws. Based on these tasks, the overall aim of an HR department is to forecast and plan the necessary human resource capacity of an organisation, in order for an enterprise to be able to possess at any given time the necessary amount of employees, with the required skills for carrying out their tasks, towards improving its productivity and maximising its resource utilisation. In more detail, the main tasks that are carried out by the HR Department are the following:

- Employment/Lay off Process. This process deals with the recruitment of people for covering the needs of an organisation and the activities regarding the discharge of people which are no longer needed by the enterprise and as such it includes more specifically:
    - Definition of the job description, the position's responsibilities and the necessary skills of applicants
    - Seeking applicants from within the organisation or from outside
    - Interview and evaluation of applicants
    - Employee Orientation and Induction Programmes Executions
    - Lay off process
- Employee Performance and Skills Assessment. This operation is carried out based on a set of criteria which are both qualitative (like educational background, communication skills, team spirit, etc.) and quantitative (like measuring the time for completing tasks, their productivity, etc.) A record for each employee is also kept with data regarding his skills, his evaluation and other relevant information.
- Training and Skills Development Programmes. The HR Department, in cooperation with the other departments of an enterprise aims to constantly develop the skills of the employees in order for them to get familiar with new requirements, new positions and new processes and to continuously improve their productivity and quality of work. At the same time, training targets at the career development of the employees in order for an organisation to cover its needs from its own pool of resources.
- Salary and Rewards definition. The HR Department is in many cases responsible for the definition of the salaries and the reward schemes of the employees (including stock options, fringe benefits, pension programmes, etc.).
- Monitoring of business relationships and working conditions. These activities aim to monitor and manage the relationships between the different employees of an enterprise and between the employees and the management (contacts with unions and representatives of the workforce) and to constantly monitor and secure the appropriate working conditions, as set by the corporate management strategy and also by the standing labour legislation.

The operation of the HR Department provides support to all other departments within an organisation and maintains with them close links in order to evaluate the needs of such departments and the performance of the employees. However, it is not directly linked with departments of other external entities/organisations as its main role concentrates on the internal management of human resources, which of course can be used to satisfy the needs of other departments (e.g. people with special skills for designing new products, workers for manufacturing, etc.).

In this context, the operations of the HR Department, although not isolated from the operations of the other departments, are in most cases planned and executed on a higher strategic level, based on concrete and well defined procedures and action lines. This fact characterises the operations of the HR Department as not core-business activities and in many cases the linkage between the other departments and the HR Department (which is not direct) is responsible for the time (and in many cases the quality) lag experience when the HR is called to satisfy the needs of the other departments.

E.1.8.2 Enhanced functions and role of the department in a DMN environment

The introduction of DMN characteristics within an organisation, as a direct consequence of the inclusion of such an organisation in a DMN, is not having a great impact on the operations and functions of the HR Department. The reason behind this limited impact can be justified by the supportive role of the HR Department to the whole organisation and by the lack of core-business processes within this department.

Of course, the different processes may experience a slight difference, as stepping into a DMN creates a more demanding internal operational environment. Hiring, evaluation of performance and skills and training are strongly connected to dynamic collaboration needs. However the various processes remain the same as there is not a direct relationship with the HR Department and the supply chain which is the main target of a DMN.

Table A - 8: Consolidated view of the HR Department's Benefits and Risks

Supply Chain / DMN actors		Human Resources Department: Recruiting / Firing	Performance & Skills Assessment	Training & Skills Development	Personnel Relations Management	Salary & Rewards Definition
Relations to other departments /operations within the same enterprise	Financial – Accounting Dept.> Payroll					X
Direct Changes enduced by a DMN						
Benefits	for OEMs	+	++	+	+	
	for Suppliers	++	++	++	+	
Risks	for OEMs	⚠	⚠	⚠	⚠	⚠
	for Suppliers	⚠⚠	⚠	⚠	⚠	⚠

E.1.9 Financial - Accounting Department

E.1.9.1 Role of the department in the traditional supply chain model

The Financial - Accounting Department of an enterprise takes the responsibility for organising the financial and accounting affairs including the preparation and presentation of appropriate accounts, and the provision of financial information for managers.

The main responsibilities of the Financial Department include:

- Planning, designing and monitoring of budget plans for every business activity foreseen, while also producing financial statements and reporting to the top-level management when needed. This function involves the distribution of the money resources to the different activities and needs of the organisation (e.g. paying taxes, loans, gas, electricity, water, salaries etc.) in order to ensure its smooth operation, as well as the creation of balance sheets and profit and loss accounts. (Financial statements are produced at given time intervals, for example at the end of each financial year. Trial balances are extracted from the ledger entries to create a Balance Sheet showing the assets and liabilities of a business at the year's end. In addition, records of purchases and sales are totalled up to create a Profit and Loss (P&L) account.). It further involves the provision of financial data and indexes to the company's top-level management, to enable the former reach better and more accurate decisions.

- Book keeping and transactions monitoring. This operation involves the management of money flows from all day-to-day business activities, and therefore record keeping of the purchases and sales made by a business as well as of capital spending.
- Products/Services cost analysis and price tagging. The Financial Department is also responsible for defining the price of each product/service that is being delivered by the organisation. This task takes into consideration not only the production and the overall costs of running the enterprise, but considers also the current situation in the market, the actions of competitors, the philosophy of the organisation itself, and other factors that are all affecting the final price.

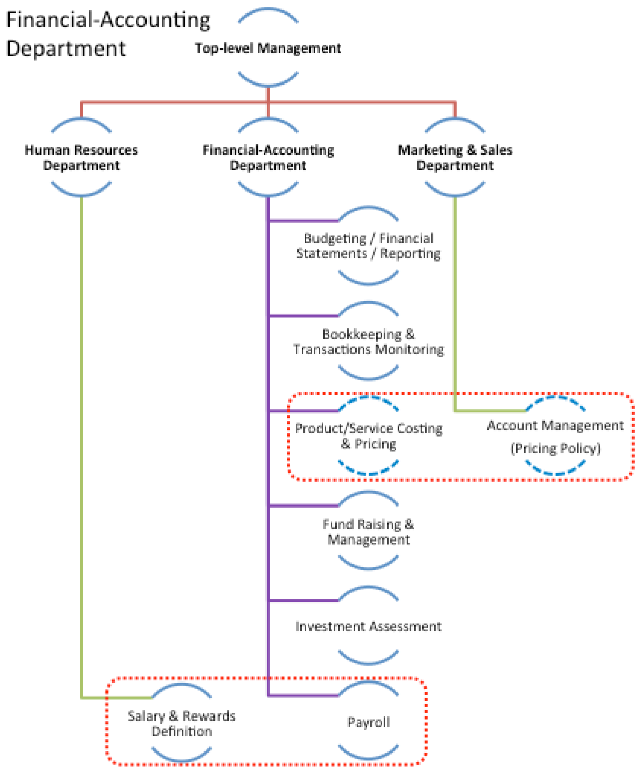

Figure A - 17: Financial-Accounting Department and relation to other departments

- Fund raising and financial management. The Financial Department is also responsible for the technical details of how a business raises finances e.g. through loans, investors etc., and the repayment of interest on those finances. In addition it supervises the payment of dividends to shareholders.
- Credit Collection. This is one of the most important tasks of the financial department, which deals with the collection of credit from the different clients.
- Investment Assessment. Any investment that is considered by an organisation has to be firstly evaluated by the Financial Department in order for its potential and its anticipated impact to be estimated.
- Calculating the payroll (wages and salaries) of employees in close collaboration with the HR Department.

The Financial Department is another horizontal department within an organisation which is not directly related to production, though it is quite essential as it provides the clearance to the production units to operate based on the financial resources available, and at the same time is responsible for attracting customers by setting the prices of the delivered products/services.

E.1.9.2 Enhanced functions and role of the department in a DMN environment

The horizontal character of the Financial Department makes it difficult to experience drastic changes in case an organisation decides to participate to a DMN. The main functions that are expected to witness a change are the ones that have to do with the planning and monitoring of budget and money flows and of course the ones that have to do with the monitoring of the production costs and those of setting the prices. The reason for these changes is the dynamic character of a DMN that calls for real time responsiveness of organisations in order to ensure the smooth and unobstructed operation of the whole production network. In this context, organisations need to monitor closely their money flows regarding production in order to be able to identify whether they are capable of carrying out the requested tasks and instantly respond on price quotes, based on their capacity, their costs and their business strategy.

Table A -9: Consolidated view of the Financial-Accounting Department's Benefits and Risks

Supply Chain / DMN actors		Financial – Accounting Department: Budgeting / Financial Statements / Reporting	Bookkeeping and Transactions Monitoring	Product/Service Costing & Pricing	Fund Raising and Management	Investment Assessment	Payroll
Relations to other departments / operations within the same enterprise	Human Resources Dept. > Salary and Rewards Definition						x
	Marketing & Sales Dept. > Account Management (Pricing Policy)			x			
Direct Changes enduced by a DMN		x	x	x	x		
Benefits	for OEMs	⊕⊕	⊕	⊕⊕	⊕	⊕	⊕
	for Suppliers	⊕⊕	⊕	⊕	⊕	⊕	⊕
Risks	for OEMs	⚠	⚠	⚠⚠	⚠	⚠	⚠
	for Suppliers	⚠	⚠	⚠	⚠	⚠	⚠

E.1.10 Maintenance Department

E.1.10.1 Role of the department in the traditional supply chain model

The Maintenance Department may be either an individual department within a manufacturing company or a sub-division under the Production Department, as the two units share responsibility for optimising facility performance. The goals and, therefore, the mission of the Maintenance Department typically include:

- Operating the company's facilities (real property, production equipment, utility services etc.) and scheduling and implementing all activities with regard to their maintenance, in order to extend their life, maximise their potential use and productivity and improve and maintain their aesthetics, while also applying predictive maintenance techniques and thereby conducting the necessary tests,

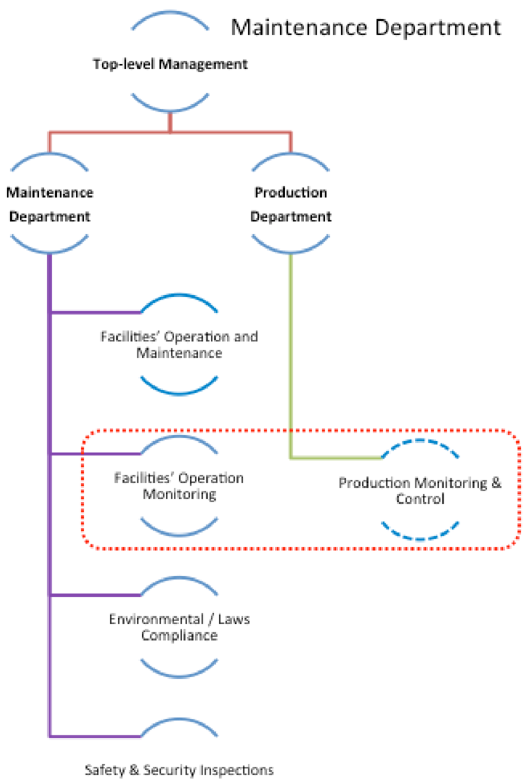

Figure A - 18: Maintenance Department and relation to other departments

inspections and investigations, to reduce equipment failure and maintenance workload

- Monitoring the operation of the company's facilities and maintaining operating logs and records.
- Ensuring environmental compliance and implementing programs to conserve energy.
- Ensuring compliance with applicable state and local laws, regulations, statutes, codes and standards.
- Ensuring the safety and security of people and buildings/facilities.

Efficient and effective operation of the Maintenance Department requires well-defined processes and adequate information to plan and manage daily maintenance operations, including a good work-order system that enables the Maintenance Department to respond quickly to repair requests, a preventive maintenance system that ensures that maintenance operations are regularly performed to minimise equipment down-time, and a mechanism to monitor maintenance service levels and obtain periodic feedback about functions that need improvement. Therefore it displays liaisons and information exchange, e.g. with regard to production schedules, maintenance budgets, repair requests, specifications of spare parts etc., with several other departments within the manufacturing company. It further presents interfaces with external entities as far as contracting external collaborators for the procurement of production equipment or for carrying out maintenance works is concerned.

E.1.10.2 Enhanced functions and role of the department in a DMN environment

Table A - 10: Consolidated view of the Maintenance Department's Benefits and Risks

Supply Chain / DMN actors		Maintenance Department: Facilities' Operation and Maintenance	Maintenance Department: Facilities' Operation Monitoring	Maintenance Department: Environmental / Laws Compliance	Maintenance Department: Safety & Security Inspections
Relations to other departments /operations within the same enterprise					
Direct Changes enduced by a DMN		x			
Benefits	for OEMs	+	++		+
	for Suppliers	+	++		+
Risks	for OEMs	⚠	⚠	⚠	⚠
	for Suppliers	⚠	⚠	⚠	⚠

The participation of a manufacturing company in a DMN does not directly affect the operation of the Maintenance Department; however it enhances the level of automation and transparency of the bidirectional information flows that take place within and beyond the boundaries of the manufacturing company and in which the Maintenance Department is involved. The utilisation of the DMN platform, in which all data with regard to common production projects and delivery deadlines are kept, ensures more specifically the scheduling of maintenance operations in accordance with production needs, i.e. taking into account the production schedules and exploiting the time intervals when the relevant production equipment is inactive. It further allows the direct briefing of both the rest of the company's departments as well as the DMN collaborators on problems, e.g. breakdowns, equipment failures etc., occurring during the manufacturing process, by sending out relevant notifications and alarms.

E.2 Benefits per Enterprise Department

Table A - 11: Benefits per Enterprise Department and Links to IMAGINE Methodology and Blueprint Model

Identified Benefit	Links to IMAGINE Methodology
Production Department	
Rapid rescheduling/ reconfiguration of production plans for covering unexpected needs or for replacing in collaboration with the Purchasing/ Procurement Department suppliers not able to deliver.	Variations in the production related KPIs are noticed thanks to the ***Quality Assurance BP*** and production can be altered by utilising the ***Manufacturing BP***, and the ***Partner BP***
Better and more efficient management of human and other production resources.	This benefit emanates as a result of the global visibility, ensured mainly through the ***Manufacturing*** and the ***end-to-end Process BPs***.
Efficient management of risks, problems and production flaws, including early warnings in order to respond to any abnormality.	This benefit can be achieved through constant monitoring of production with the help of the production performance and integrity KPIs stored in the ***Quality Assurance BP***.
Receiving accurate and detailed production requirements earlier, without many communication iterations, leading to more accurate planning of the production, lower costs and more efficient handling of materials.	The production planning process can be facilitated through the general idea of automation and smooth information flow surrounding the ***DMN methodology***, and through the introduction of the necessary infrastructure of the ***Manufacturing*** and the ***end-to-end Process BPs***.
Logistics Department	
Complete, accurate and timely information regarding the goods' status: that benefit could lead to more effective, efficient management of end products. Status and positioning of goods are monitored in real time, ensuring that they are produced, transported, stored and delivered in time.	This benefit emanates from the core philosophy of the ***IMAGINE Methodology***, promoting global visibility into logistics operations as well, and reflected mainly in the ***end-to-end Process*** and ***Quality Assurance BPs***, as well as in the ***Partner BP***, which comprises information about inventory capacities.
Optimal and dynamic selection and coordination of suppliers, service providers and transport carriers: that benefit could lead to an uninterrupted and clear coordination of those stakeholders, minimising the possibility of delayed orders.	This benefit is ensured through availability of accurate information regarding logistical capabilities and requirements in the ***Partner*** and in the ***Quality Assurance BPs*** respectively.
Efficient and effective customer support: real time information regarding any order or customer request, in conjunction with the ability to directly contact the proper network member for each customer request.	Real time information and customer support is once again achieved by ensuring global visibility across the whole DMN with the help of the ***end-to-end Process BP***.
Clear and well-established plans and policies regarding logistics: when a member of a DMN, the Logistics Department has concrete and clear plans regarding its operation and has to follow certain policies, free from uncertainty.	The existence of logistics plans and policies is reflected in the ***Partner BP*** through the SLAs and the SLOs that will be set for every transaction, while they can be continuously monitored through the metrics available in the ***Quality Assurance BP*** that defines important quality aspects for all partners and processes within the DMN.
Optimisation and automation of the logistics procedures, leading to time and cost savings as well as to the reduction of the personnel that is required to monitor the procedures in question, and that can be therefore employed in other operations of the enterprise.	This benefit has its basis in both the optimal partner selection, supported by the ***Partner BP***, as well as in the process alignment to network needs and the process interoperability enabled by the ***end-to-end Process BP*** and the ***Quality Assurance BP***.
Procurement/ Purchasing Department	
Complete, accurate and timely information regarding the order status. This benefit could lead to more effective, efficient and less stressful management of external (and internal) orders and, eventually, to time savings.	As in the Logistics Department, this benefit emanates from the core philosophy of the ***IMAGINE methodology***, promoting global visibility into operations that are critical for the production and is reflected mainly in the ***end-to-end Process BP*** and in the ***Quality Assurance BP***.

Optimal and dynamic selection of suppliers/vendors. This could lead to an unbiased, concrete and informed selection of vendors, ideally free from any risk. Optimum coordination of all vendors could possibly also be achieved, minimising the possibility of a delayed order.	Optimal selection and coordination of suppliers/vendors are both ensured in terms of the information provided through the ***Partner*** and ***end-to-end Process BPs*** respectively as well as in terms of the reputation factor assigned to each DMN member in the ***Quality Assurance BP***.
Direct treatment of any unexpected even. Real time information regarding any order, in conjunction with the ability of real-time reconfiguration of the selection of vendors gives the ability to directly and effectively treat any unexpected event.	This is achieved by continuously monitoring delivery times with the help of the ***end-to-end Process*** and ***Quality Assurance BPs***.
Avoiding situations of raw material shortcomings: as mentioned above, real time information regarding any order (internal or external) can minimise for the company the possibility of stock-outs.	Understanding the requirements of collaborative manufacturing projects thanks to the information comprised in the Manufacturing and the ***end-to-end Process BP***s, and scheduling production accordingly enables to minimise stock-outs, while the general automation process and the philosophy of the DMN guarantees the close to real time execution of manufacturing orders in order to be able to respond instantly to demand. Moreover, the selection of appropriate partners, thanks to the dynamic information regarding product inventories, as included in the ***Partner BP*** also helps an enterprise to be able to efficiently use and activate its suppliers in order to avoid stock-out situations.
Optimisation of the whole procurement process, as a result of the automation of the supplier evaluation and selection tasks and the minimisation of errors in issuing orders, leading to significant time and cost savings.	This benefit has its basis in both the optimal supplier selection, supported by the ***Partner BP***, as well as in the alignment of the procurement process to the DMN needs, enabled by the ***end-to-end Process BP***. In general, it is the automation and the sub consequent speed of transactions offered by the DMN platform that contributes into achieving this benefit (as all suppliers, their offered products/services alongside with critical information such as inventory levels, etc. are available electronically).
Sales-Marketing Department	
A wider customer base to reach out through the use of contacts of other partners in the DMN, which is made possible by the very nature of the DMN which can be seen as a vertical marketplace where enterprises can join for offering their products/services to OEMs.	This benefit is inherent to the establishment of a Dynamic Manufacturing Network; yet it is further enhanced through the exchange of information, supported by the IMAGINE Methodology and DMN Blueprint Model.
A more stable and sustainable environment for promoting and selling products and services, as becoming part of a DMN improves the potential for long term collaboration with other enterprises, resulting in increased sales volumes.	The potential for establishing long-term collaborations is supported by the ***Partner BP***, which aims among others at generating trust among DMN partners.
Reduced costs for marketing approaches, as the inclusion in a DMN reduces the need to conduct marketing activities for getting the attention of DMN partners.	Under the prism of the IMAGINE framework, marketing activities are “replaced” by providing accurate profile information in the ***Partner BP*** and ensuring compliance with quality aspects as reflected in the ***Quality Assurance BP***.
More accurate demand and sales volume estimation based on the information that will be shared in the DMN.	Proper understanding of the requirements of collaborative manufacturing projects, supported through the ***IMAGINE Blueprint Model***, in combination with historical data can lead to his benefit.
More direct, real time and efficient monitoring and management of inventories and reserve levels of ready-made products, in order to rapidly respond to any emerging business opportunity.	Inventories and reserve levels of ready-made products are monitored with the help of the ***Quality Assurance BP***.

More flexible and detailed management of customer orders, through the constant monitoring of production and manufacturing processes, based on real time data shared between the different in house systems and also based on the data coming from the different suppliers as parts of the DMN.	This benefit comes as a result of the global visibility across DMN processes, the process interoperability promoted by the ***end-to-end Process BP*** and the monitoring capabilities that are supported by the elements of the ***Quality Assurance BP***.
Enhanced Credibility towards end customers. Thanks to the DMN, real-time information can be given to the end-customer regarding his order, and the credibility of the enterprises participating in the DMN is enhanced. This information derives from the aggregated data regarding all stages of the production.	Proper understanding of the requirements of common manufacturing projects as described in the ***IMAGINE Blueprint Model***, enhances the DMN credibility in total.
Quality Assurance Department	
Alignment and scheduling of activities and tasks for internal audit and compliance adherence in accordance with manufacturing schedules, resulting thereby in improved operational performance and agility at both enterprise and network level.	This benefit is attained as a result of the global visibility of the production and of the rest of the network processes, supported by the ***Manufacturing*** and the ***end-to-end Process BPs***.
Real-time monitoring of tasks and network performance with regard to quality assurance, enabling integrated management of quality control at network level.	This requirement is achieved by monitoring the metrics comprised in the ***Quality Assurance BP***.
Greater customer satisfaction and enhanced reputation and credibility, as a result of the company's commitment to comply with the DMN quality assurance policy, designating a widely accepted threshold for quality requirements.	Quality standards and requirements are agreed upon and presented in the SLAs and SLOs of the ***Partner BP*** and in the ***Manufacturing*** and the ***Quality Assurance BP***.
Optimal selection of collaborators, i.e. selection of partners with affined quality assurance policies, enabling to minimise claims from end-customers and leading thereby to more effective and successful co-operations	This task is facilitated with the help of the partner profiles and partner quality attributes provided respectively in the ***Partner*** and ***Quality Assurance BPs***.
Research and Development (R&D) Department	
Researchers from all collaborating parties can be considered as members of a shared "virtual R&D Department" working towards a common goal that bases its operation on common workspaces, interoperable IT systems, end-to-end interoperable processes and global quality parameters. This way the researchers develop a shared technical language, which enables them to bridge the gap between user and technological contexts. In addition, or as a result of this, several other benefits can be identified, including the following: Exposure to new ideas stimulating innovation; Development cost reduction and service improvement; Acceleration of product development processes;etc.	This benefit has its basis on the features and specification of all different blueprints of the ***IMAGINE Blueprint Model***. Collaboration among the different partners is achieved through the ***Partner BP***, requirements of common projects are imprinted in the ***Manufacturing BP***, interoperability of systems and processes is ensured by the ***end-to-end Process BP***, while global quality parameters are determined in the ***Quality Assurance BP***.
Information Technology (IT) Department	
Utilisation and exploitation of the DMN software platform and the know-how that is associated with it, generating innovation benefits and enabling the manufacturing company and its IT Department to reduce the required investment in IT, while also enabling remote access to the required information and eliminating therefore the need for physical proximity in order to conduct joint collaboration activities, and offering the possibility to develop partnerships and business relationships in markets beyond the boundaries of the local environment.	Using the ***IMAGINE platform*** and the ***IMAGINE Blueprint Model***, various enterprise systems can get interconnected, reducing in such a way the needs to invest huge amounts of funds for building different connectors with the various IT systems of collaborators. The proposed methodology allows in such a way an enterprise to use its existing IT systems through the utilisation of generic connectors, minimising in such a way the required investment and maximising the connection opportunities through the utilisation of the network wide accepted blueprints.
Redesign, standardisation and integration/alignment of business processes, resulting in improved operational performance and coordination along the supply chain, higher competitiveness and agility at both enterprise and network level, and thereby time and cost savings.	Integration and alignment of business processes is supported by the ***end-to-end Process BP*** and by the SLAs and SLOs of the ***Partner BP***.

Real-time monitoring and online provision of information, enabling to predict and prevent problems, and leading to improved agility in handling unexpected or unplanned events, e.g. increases in customer demand, depletion of production resources, problems in the manufacturing process, delays in the delivery of shipments etc.	Real-time monitoring and online provision of information is achieved with the help of the metrics comprised in the ***Quality Assurance BP***.
More effective and cost-efficient communication with partner companies and ability to carry out certain tasks exclusively online, resulting in significant time and cost savings.	This benefit is achieved due to the integration of individual IT systems via the ***IMAGINE platform***, as well as thanks to the adoption and use of the ***DMN Blueprint Model*** as a common reference framework.
Human Resources (HR) Department	
Accurate calculation and effective management of required human resources. The inclusion of an organisation in a DMN means that such an organisation has to implement a more agile, flexible and efficient system for managing its human resources. As a result, the benefits for the HR department will have to do with increasing their accuracy in forecasting the necessary resources required at any given time, based on historic data retrieved from the DMN and also on having a real-time estimation of the resources needed for carrying out the necessary production orders.	The requirements on the human resources are to be imprinted in the ***Manufacturing*** and ***end-to-end Process BPs***, while effective management of the former is to be facilitated also through the ***Quality Assurance BP***, which aims among others at serving as a source of analytics for optimising various aspects of the DMN operation.
Improved, continuous and real-time evaluation of employees' productivity. The operation of a DMN is closely related with control and monitoring mechanisms that are able to coordinate and optimise the throughput and the quality of the overall network. In order to implement such control mechanisms, the effort and the quality in every single node of the network has to be carefully measured and evaluated. As a result, the HR Department will be in a position to have access to various evaluation data regarding the workforce occupied for an operation, which in turn will contribute to a more detailed and objective evaluation report for each individual human resource engaged in the operation of the organisation.	This particular benefit for the HR Department is also indirectly supported by tracking the production status and productivity information through the ***end-to-end Process*** and ***Quality Assurance BPs***.
Assessment of skills needed and required training programmes for improving the competitiveness of the organisation. As part of a DMN, each organisation will be able to be informed about the quality required for the production of specific products; as such information will be stored in the different blueprints. The quality in many cases is related with the skills of the workforce and in such a way, the HR Department will be able to know first-hand which skills need to be developed and will organise training programmes that will be in a position to satisfy these needs, making the organisation more competitive and more competent in the various activities that define its core business expertise.	The HR Department and therefore the enterprise will be in place to advance its human resources in the abovementioned ways by evaluating and comprehending the personnel requirements, comprised in previous ***Manufacturing BPs*** as well as by exploiting specific quality parameters regarding the human resources, provided in previous ***Quality Assurance BPs.*** Moreover, the enterprise can also utilise its ***Partner BP*** to identify the current level of skills and schedule any improvements.
Financial – Accounting Department	
Enhanced reputation and credibility of the enterprise as part of the Dynamic Manufacturing Network, raising the possibilities for attracting funds from external investors.	This benefit derives from the exploitation of the ***IMAGINE Methodology*** in total.
Optimisation of the product/service costing and pricing process at both enterprise and network level, increasing the competitiveness of the goods and services produced.	This is one of the multiple DMN aspects that the ***Quality Assurance BP*** can help improve as a source of analytics.
Maintenance Department	

Alignment and scheduling of own maintenance activities in accordance not only with the enterprise's production plans, but also with the manufacturing needs and production schedules of the whole network. This results in improved operational performance and agility at both enterprise and network level.	This benefit attained thanks to the global visibility of the production and of the rest of the network processes, supported by the ***Manufacturing*** and the ***end-to-end Process BPs***.
Real-time information on customer demand and production requirements, leading to optimal planning with regard to the procurement of spare parts, components and backup service utilities and therefore cost savings.	This is ensured through the requirements on equipment resources exposed in the ***Manufacturing BP***.
Greater customer satisfaction and enhanced reputation and credibility, as a result of the company's commitment to comply with the DMN policy and quality standards, adopt transparent procedures and notify DMN partners in case of equipment failure.	Quality standards are set in the ***Quality Assurance BP***.

E.3 Dealing with Risks

E3.1 Risk Management Methodology

It can be taken as granted that functions aiming at generating added value and/or profit often include different types of risks, a fact which applies to business activities too. It can be also presumed that unexpected events and misfortunes can have much different consequences to different companies over the DMN, as risks are related to their objectives.

Possible losses and uncertainty about their occurrence and amount constitute two essential components of risks [20]. Risks generally derive from uncertainty [9]. Excluding the internal risks that all operations come with, the main sources of uncertainty are customer demand and customer deliveries (by customer we mean either the end buyer of the final product, or the intermediate client inside a DMN). Budgets (costs), time, quality, as well as data/information security might raise uncertainties and risks [20].

As described in previous chapters, the transformation of a traditional supply chain method of operation to a more modern and dynamic, such as a DMN, does not come only with benefits for the participating members. As with any other radical change, there is a number of risks that need to be identified and tackled through a set of avoidance and/or mitigation activities, which will guarantee that the members of a DMN will be able to enjoy the benefits presented, without being put in any kind of danger. For this purpose, a risk analysis and assessment methodology is required, which will proactively help DMN members to avoid risks and will persuade them to fearlessly be part of such a networked manufacturing environment

The risk analysis and assessment methodology that will be employed for this purpose consists of 6 discrete steps [3],[21],[33]:

I. Step 1: List all aspects of identified event activities.
II. Step 2: Identify (thinking broadly) the risks associated with each activity.
III. Step 3: Use the matrix in Table A -12 in order to determine the level of risk associated with each activity before applying any risk management strategies:
IV. Step 4: Brainstorm methods to manage risks. Find strategies which can be applied to reduce the severity of the risk and the probability that something will go wrong
V. Step 5: Use the matrix of Table A -13 to re-assess the activities, after applying risk management strategies
VI. Step 6: Determine if an acceptable level of risk has been reached by applying risk management strategies. Consider modifying or eliminating activities that have unreasonable risk associated with them. Also consider how the activity relates to the mission & purpose of each organisation

Table A -12: Risk Probability and Impact Severity Matrix

PROBABILITY THAT SOMETHING WILL GO WRONG

SEVERITY OF RISK

Category	**FREQUENT** Expected to occur frequently	**LIKELY** Quite likely to occur	**OCCASIONAL** May occur	**SELDOM** Not likely to occur but possible	**UNLIKELY** Unlikely to occur
CATASTROPHIC May have catastrophic consequences for the enterprise	E	E	H	H	M
CRITICAL May cause severe financial loss, severe loss of reputation etc.	E	H	H	M	L
MARGINAL May cause financial loss, loss of reputation etc.	H	M	M	L	L
NEGLIGIBLE Introduces a minimal threat to the enterprise	M	L	L	L	L

The letters "E", "H", "M" and "L" represent the definition of each of the risks analysed:

Table A -13: Risk Definition Analysis

	RISK DEFINITIONS	Many situations/changes, without proper planning, may have unreasonable levels of risk. However, by applying risk mitigation strategies, risk can be reduced to an acceptable level
E	**Extremely High Risk**	Activities in this category contain unacceptable levels of risk. Organisations should consider modifying or even terminating activities in this category.
H	**High Risk**	Activities in this category contain potentially serious risks that are likely to occur. Application of proactive risk mitigation strategies is highly advised.
M	**Moderate Risk**	Activities in this category contain some level of risk that is probably unlikely to occur.
L	**Low Risk**	Activities in this category contain minimal risk that is also unlikely to occur.

E.3.2 Risk for enterprises joining/setting up a DMNs and Mitigation Strategies

The first two steps of the methodology are generic and refer to the analysis regarding the operations and departments of a candidate DMN enterprise that has been performed in the previous chapters. Therefore, only a high level reference will be made in the current section.

On the other hand, the last four steps of the methodology are focused on each specific risk that has been identified and have to be presented in detail. The risks analysis which follows derives from an extended literature review and is based both on theoretical analysis of potential risks in virtual enterprises and enterprise networks and on real-life experience coming from cases of existing manufacturing networks [21],[41],[66].

Since the literature sources examined do not refer only to DMNs but also to other types of virtual/ collaborating enterprises, the risks selected, presented and analysed below are result of brainstorming which took place, in the framework of the project, among experts coming from different industrial sectors and researchers specialised in the field of industrial management.

Step 1

The different aspects of our case's event activities are reflected to the various departments of the DMN participating enterprise and to the contained activities and functions. Therefore we can list the Human Resources Department, the Financial – Accounting Department, the Sales – Marketing Department, the Purchasing Department, the Logistics Department, the Information Technology Department, the Maintenance Department, the Quality Control Department, the Research and Development Department and, finally, the Production Department.

Steps 2, 3, 4, 5

The risks that are related to or derive from the operation and contained activities of each aforementioned DMN enterprise department have been reported in detail in the previous chapters. In the current section each of the identified risks will be reported and assessed. In addition, initial avoidance/ mitigation strategies will be identified per risk and, finally, a re-assessment of each initially reported risk will take place. This will be presented in a (per risk) matrix form:

Identifier	R1
Risk	Information leaks about capabilities, availability and capacity can be harmful if this information gets to competitors.
Applies to	Production Department
Initial Assessment	Critical and Likely → High Risk
Avoidance/ Mitigation Strategies	In order to deal with the aforementioned risk, there are two prerequisites. The first one has to do with the operation of an advanced system for managing efficiently the DMN and the production plans of the whole network and for governing the operations of all the members. The system must be able to accept information from the participating companies and their respective production departments but not to make this information available to the whole network. So the DMN partners can be able to have access to processed information but not to raw or sensitive data revealing production department "secrets" which should not be shared. The second prerequisite refers to averting any leaks and inappropriate usage of the shared information by setting up contracts/legal agreements binding all DMN members not only during their collaboration but also after the termination of the DMN relationship. The methodology makes sure that sensitive information such as quality standards, production procedures, resource availability, etc. stays is only available to the appropriate partners of

	the DMN. As an example, the information stored in the Partner BP regarding skills and capabilities will be available in a structured and safe way only to the proper DMN members (in most cases to OEM/DMN Manager and higher tier members who are in direct collaboration with an enterprise). In addition, the end-to-end Process BP, by clearly identifying and managing all manufacturing operations a priori, ensures the smooth operation of the manufacturing process, while the different view levels it contains make it impossible for sensitive information to be publicly visible across all DMN members. Last but not least, the use of the Quality Assurance BP by collecting all necessary data and metrics will assure the stability and reliability of the whole production process.
Links to IMAGINE Methodology	Partner blueprint, End-to-End Process blueprint, Quality Assurance blueprint
Final Assessment	Critical and Seldom → Moderate Risk

Identifier	R2
Risk	Communicating, negotiating and transferring knowledge, which may be required in order to proceed to the replacement of another producer can lead to delays and disturbances in the running production.
Applies to	Production Department
Initial Assessment	Marginal and Likely → Moderate Risk
Avoidance/ Mitigation Strategies	Similar to R1
Links to IMAGINE Methodology	Partner blueprint, End-to-End Process blueprint, Quality Assurance blueprint
Final Assessment	Marginal and Unlikely → Low Risk

Identifier	R3
Risk	Loss of control concerning intellectual property and “production secrets” is possible.
Applies to	Production Department
Initial Assessment	Critical and Occasional → High Risk
Avoidance/ Mitigation Strategies	Similar to R1 and R2
Links to IMAGINE Methodology	Partner blueprint, End-to-End Process blueprint, Quality Assurance blueprint
Final Assessment	Marginal and Unlikely → Low Risk

Identifier	R4
Risk	Competitive threats after the termination of the DMN relationship may appear.
Applies to	Production Department
Initial Assessment	Critical and Likely → High Risk
Avoidance/ Mitigation Strategies	Contracts/legal agreements binding all DMN members not only during their collaboration but also after the termination of the DMN relationship.
Links to IMAGINE Methodology	Partner blueprint, End-to-End Process blueprint
Final Assessment	Critical and Unlikely → Low Risk

Identifier	R5
Risk	Collapse of an order due to ineffective operation of logistics. In case that a collaborating department fails to keep up e.g. with the delivery coordination of an order and manages to conceal this fact, the whole network can be adversely affected.
Applies to	Logistics Department
Initial Assessment	Critical and Likely → High Risk
Avoidance / Mitigation Strategies	The introduction of clear and strict SLAs, as well as automated and not user-operated control mechanisms, can prevent such phenomena. The Partner BP records in a clear way the features of each DMN partner, helping the avoidance of unreliable partners, while it instructs the development of SLAs and SLOs which a partner has to respect. Based on these SLAs, each partner participating in the DMN becomes more cautious and careful regarding his collaboration with third parties (like 3PL providers, transport carriers, etc.), as any inconsistency in such collaboration, may also have consequences on his interaction with the DMN, and affect the SLAs. Last but not least, the use of the Quality Assurance BP by collecting all necessary data and metrics will assure the early treatment of any such problems that may come up.
Links to IMAGINE Methodology	Partner blueprint, Quality Assurance blueprint
Final Assessment	Critical and Unlikely → Low Risk

Identifier	R6
Risk	Disclosure and misuse of corporate practices and experiences regarding logistics. This risk refers to the possible disclosure of information that can be used (or even misused) by the logistics departments of other companies in the network.
Applies to	Logistics Department
Initial Assessment	Marginal and Likely → Moderate Risk
Avoidance / Mitigation Strategies	Clear and strict contract agreements concerning information exchange security and trust, as well as long-term relationships inside a DMN can prevent such a risk. The different levels of the end-to-end BP and the access of only enterprises of higher tiers and that directly collaborate with each dispatcher to the KPIs of the Quality Assurance BP will reassure that such information is not released within the network. The Partner BP will have a critical contribution to the mitigation of this risk, as the data regarding the logistics department will be available in a structured and safe way only to the proper DMN members.
Links to IMAGINE Methodology	Partner blueprint, Quality Assurance blueprint, End-to-End Process blueprint
Final Assessment	Marginal and Unlikely → Low Risk

Identifier	R7
Risk	Collapse of an order due to an ineffective supplier. In case a supplier fails to keep up e.g. with the time-plan of an order and manages to conceal this fact, the whole network can be adversely affected.
Applies to	Purchasing Department
Initial Assessment	Critical and Likely → High Risk
Avoidance / Mitigation Strategies	The introduction of clear and strict SLAs, as well as automated and not user-operated control mechanisms, can prevent (or even eliminate the possibility of) such phenomena. The Partner BP records in a clear way the features of each DMN partner, helping the avoidance of unreliable partners, while it also sets SLAs and SLOs for the collaboration of the different parties, bounding them to respect the various aspects of the collaboration. Moreover, the use of the Quality Assurance BP by collecting all necessary data and metrics will assure the early treatment of any problems that may come up.
Links to IMAGINE Methodology	Partner blueprint, Quality Assurance blueprint

Final Assessment	Critical and Unlikely → Moderate Risk

Identifier	R8
Risk	Ignoring potential "external" business opportunities. The top-level companies inside a DMN might lose the ability to attract special offers from suppliers, e.g. remarkably low price due to a large order from an external supplier.
Applies to	Purchasing Department
Initial Assessment	Marginal and Occasional → Moderate Risk
Avoidance / Mitigation Strategies	This risk can be addressed by the fast inclusion process through the utilisation of the Partner BP of new members in a DMN and it open character, as instructed by the IMAGINE methodology. Moreover, the utilisation of the IMAGINE DMN platform does not force enterprises to a DMN lock-in situation, therefore such opportunities can be also grasped.
Links to IMAGINE Methodology	Partner blueprint
Final Assessment	Critical and Seldom → Low Risk

Identifier	R9
Risk	Exclusion of other DMN collaborators due to a supplier clearly standing out amongst its competitors. In case of a supplier with large capacity, high credibility and low prices, there is a risk of completely excluding all other DMN members from the procedure.
Applies to	Purchasing Department
Initial Assessment	Marginal and Likely → Moderate Risk
Avoidance / Mitigation Strategies	The balanced synthesis of the DMN, through the analysis of the information provided in the Partner BP, can be a solution to this risk in order to foster competition among the DMN members. Moreover, the nature of the DMN by itself reduces the possibility of the occurrence of this risk, as the pool of collaborating parties guarantees (to a certain extent) the differentiation in prices, availability and performance, which will eventually lead to a more distributed supply chain.
Links to IMAGINE Methodology	Partner blueprint
Final Assessment	Marginal and Seldom → Low Risk

Identifier	R10
Risk	Inability to respond to demand (especially high peaks) of external sources (non DMN partners).
Applies to	Sales – Marketing Department
Initial Assessment	Marginal and Occasional → Moderate Risk
Avoidance / Mitigation Strategies	This risk can be mitigated either by treating different customers (coming out of the DMN) through different accounts, or by setting different/longer delivery times to non DMN members for accepting their orders during high demand periods.
Links to IMAGINE Methodology	-
Final Assessment	Marginal and Seldom → Low Risk

Identifier	R11
Risk	Neglecting to dedicate the necessary resources for promoting and selling products and services to non DMN members as a result of being satisfied with the benefits offered through the DMN. This way, enterprises may end up in a DMN lock-in situation, making in such a way themselves totally dependent on the DMN for growth and viability.
Applies to	Sales – Marketing Department

Initial Assessment	Marginal and Occasional → Moderate Risk
Avoidance / Mitigation Strategies	In order to avoid this risk, enterprises should not put aside their already working strategies for attracting customers and retaining close relationships with them (and also analysing the market), as those activities will be always essential not only for their own sustainability and survival, but also for expanding the customer base of the DMN.
Links to IMAGINE Methodology	-
Final Assessment	Marginal and Unlikely → Low Risk

Identifier	R12
Risk	Disclosure of corporate practices and other critical or strategic information regarding sales practices and price levels.
Applies to	Sales – Marketing Department
Initial Assessment	Critical and Likely → High Risk
Avoidance / Mitigation Strategies	For this case, strictly defined contract agreements regarding the information exchange, information security and trust should be put in place in order to guarantee the proper access to information by all DMN parties. The Partner BP will have a critical contribution to the mitigation of this risk, as appropriate it will include the necessary information deriving from the for the sales - marketing department that will be available in a structured and safe way only to the appropriate DMN members who have the authorisation to access them.
Links to IMAGINE Methodology	Partner blueprint
Final Assessment	Marginal and Seldom → Low Risk

Identifier	R13
Risk	Failure of the Quality Assurance Department to plan and carry out its operations and reciprocate to the requirements of collaborative manufacturing projects undertaken by the DMN
Applies to	Quality Assurance Department
Initial Assessment	Critical and Seldom → Moderate Risk
Avoidance / Mitigation Strategies	This risk can be mitigated through the proper design and implementation of end-to-end business processes and the exchange of adequate information regarding product qualities, production schedules and delivery dates. Apart from the Quality Assurance BP which aids the effectiveness and stability of the Quality Assurance procedure throughout the whole DMN, the inclusion of quality requirements per product/partner in the Partner and in the Manufacturing BP is also contributing to mitigate this risk.
Links to IMAGINE Methodology	Partner blueprint, Quality Assurance blueprint, Product blueprint
Final Assessment	Critical and Unlikely → Low Risk

Identifier	R14
Risk	Incorrect partner selection as far as quality assurance procedures are concerned.
Applies to	Quality Assurance Department
Initial Assessment	Marginal and Seldom → Low Risk
Avoidance / Mitigation Strategies	This fact can be confronted through the provision of accurate partner profiles with sufficient information and the formation of SLAs, SLOs and contracts with well defined terms as far as quality assurance is concerned. This process is facilitated by the structure of the Partner BP. Moreover, the Quality Assurance blueprint, aids the effectiveness and stability of the Quality Assurance procedure throughout the whole DMN, regardless the partner/ department responsible for it, and operates as an input for early detection mechanisms for identifying

	quality issues at the very first steps of their occurrence.
Links to IMAGINE Methodology	Partner blueprint, Quality Assurance blueprint
Final Assessment	Marginal and Unlikely → Low Risk

Identifier	R15
Risk	Disclosure of critical information and exposure of the company's weak points as far as quality assurance is concerned.
Applies to	Quality Assurance Department
Initial Assessment	Critical and Likely → High Risk
Avoidance / Mitigation Strategies	This risk can be prevented through the establishment of contract agreements with strict and well-defined terms regarding the information security and trust, as well as long-term relationships of trust and common interest. The Partner BP will have a critical contribution to the mitigation of this risk, as unique skills and capabilities will be available in a structured and safe way only to the appropriate DMN members.
Links to IMAGINE Methodology	Partner blueprint
Final Assessment	Critical and Seldom → Moderate Risk

Identifier	R16
Risk	Spiralling costs due to poor R&D supplier selection, as the event of suppliers unable to deliver the requested service or product may result to increase of R&D costs.
Applies to	R&D Department
Initial Assessment	Marginal and Likely → Moderate Risk
Avoidance / Mitigation Strategies	The previously mentioned issue can be successfully mitigated through the establishment of a well-designed network of suppliers, all bound with strict SLAs and SLOs (which are part of the Partner BP) that guarantee the smooth operation of the whole network.
Links to IMAGINE Methodology	Partner blueprint
Final Assessment	Marginal and Seldom → Low Risk

Identifier	R17
Risk	Loss of control as suppliers develop critical skills and loss of Intellectual Property.
Applies to	R&D Department
Initial Assessment	Critical and Likely → High Risk
Avoidance / Mitigation Strategies	In order to respond to this threat, enterprises should mostly focus on and promote their own core competences, and also put in place well-designed contracts that describe in detail the ways to exploit the acquired shared knowledge and issues regarding the foreground and background of knowledge that each member carries into the DMN. Moreover, the different view levels of the end-to-end Process and the Manufacturing BP ensure that critical information is not shared amongst members of the DMN that have not the necessary security clearance.
Links to IMAGINE Methodology	End-to-End Process blueprint, Product blueprint
Final Assessment	Critical and Seldom → Moderate Risk

Identifier	R18
Risk	Lack of cooperation from staff, as employees might be unwilling to share their thoughts and ideas to be used over a large network.

Applies to	R&D Department
Initial Assessment	Marginal and Unlikely → Low Risk
Avoidance / Mitigation Strategies	The aforementioned risk can be successfully mitigated through the introduction of the right strategic and tactical management processes. Well-designed contracts concerning management of the acquired shared knowledge are also required in order to eliminate the competitive threats, as well Intellectual Property (IP) issues. The contribution of end-to-end Process BP is critical to these risks too, as it assures the management and control of the whole network.
Links to IMAGINE Methodology	End-to-End Process blueprint
Final Assessment	Marginal and Unlikely → Low Risk

Identifier	R19
Risk	Delays and poor performance due to lack of collaborative R&D management processes.
Applies to	R&D Department
Initial Assessment	Marginal and Likely → Moderate Risk
Avoidance / Mitigation Strategies	This threat is easily mitigated by following closely the SLAs and the procedures that will be specified in a DMN, as through this network the R&D Department will be able to work in a more collaborative way with the other departments of the DMN members.
Links to IMAGINE Methodology	End-to-End Process blueprint
Final Assessment	Marginal and Unlikely → Low Risk

Identifier	R20
Risk	Competition threats after the termination of the DMN relationship, as the know-how of other DMN members might incorporate knowledge shared within the DMN.
Applies to	R&D Department
Initial Assessment	Critical and Likely → High Risk
Avoidance / Mitigation Strategies	Same to R19.
Links to IMAGINE Methodology	End-to-End Process blueprint
Final Assessment	Marginal and Seldom → Moderate Risk

Identifier	R21
Risk	Security risks, associated with malicious and unwanted attacks to confidential information either by other DMN members or external users.
Applies to	IT Department
Initial Assessment	Marginal and Likely → Moderate Risk
Avoidance / Mitigation Strategies	This risk is addressed through the design and incorporation in the DMN IT platform of adequate security policies and features, impeding unauthorised access and/or defining different access levels of the various blueprints to such information.
Links to IMAGINE Methodology	All IMAGINE blueprints
Final Assessment	Marginal and Seldom → Low Risk

Identifier	R22
Risk	Ineffective design and integration of IT systems supporting the end-to-end business processes, resulting in increase of cost and production cycles, while also degrading quality of products and services and reducing the DMN flexibility
Applied to	IT Department
Initial Assessment	Critical and Likely → High Risk
Avoidance / Mitigation Strategies	This risk can be mitigated by carrying out an adequate IT supporting system design aimed at satisfying the non-functional requirements of the DMN and based on the resources and capabilities of participants.
Links to IMAGINE Methodology	-
Final Assessment	Critical and Unlikely → Low Risk

Identifier	R23
Risk	Inability to keep up with the DMN requirements for IT equipment upgrading or renewal, which in turn generates systems' compatibility problems and imposes transition and integration costs.
Applies to	IT Department
Initial Assessment	Critical and Likely → High Risk
Avoidance / Mitigation Strategies	T This risk can be mitigated by applying common standards and ensuring interoperability among older and newer systems, as well as by utilising open source software where possible. In fact, it is the IMAGINE Blueprint model and the associated DMN methodology which addresses this need, as through the IMAGINE platform and the utilisation of the blueprints, disconnected and incompatible systems are able to communicate effectively, minimising in this way the need to invest in new infrastructures for building a network of collaboration.
Links to IMAGINE Methodology	IMAGINE blueprint model, DMN methodology
Final Assessment	Critical and Unlikely → Low Risk

Identifier	R24
Risk	Implementation of long cycles of effort consuming training curricula for employees in order to develop their skills and talents for business opportunities that may be spontaneous, not long lasting.
Applies to	HR Department
Initial Assessment	Marginal and likely → Moderate Risk
Avoidance / Mitigation Strategies	In order to respond to this risk, enterprises that become members of a DMN should focus on their core competences and carefully describe their expertise and their skills. Training for developing new skills can come as a sub-activity in order to increase the engagement in a DMN, however it should not be a priority by itself. In addition, based on the information available on the Partner BP, proper partners that have already specialisation in certain areas can be selected in the early stages.
Links to IMAGINE Methodology	Partner blueprint
Final Assessment	Marginal and Seldom → Low Risk

Identifier	R25
Risk	Inability to manage short-term business contracts with employees that are needed to carry out specific operations, due to labour legislation issues.
Applies to	HR Department
Initial	Marginal and Seldom → Low Risk

Assessment	
Avoidance / Mitigation Strategies	This risk can be mitigated by carefully selecting the people and their skills in order to build an adequate pool of resources and effectively engage these people in the day to day operation. Moreover, the careful indication of resource availability in the DMN Partner BP alongside with the realistic description of core competences and skills will guarantee the fair and efficient request for resourcing power from every partner, which will in turn minimise this risk.
Links to IMAGINE Methodology	Partner blueprint
Final Assessment	Marginal and Unlikely → Low Risk

Identifier	R26
Risk	Indirect disclosure of sensitive financial data over the network, as competitors could be able to reverse-calculate such data based analysing historic pricing quote data provided by the enterprise.
Applies to	Financial – Accounting Department
Initial Assessment	Critical and Likely → High Risk
Avoidance / Mitigation Strategies	This risk can be mitigated through utilisation of security barriers in the IT infrastructure that will be employed for the collaboration of the various entities. Moreover, in order to strengthen security, the information that will be carried through the blueprints will be available through different views, securing in such a way that only the appropriate partners have access to specific views, in order to keep information on a "need to know" basis and to not compromise sensitive information to third parties. The Partner BP and the Quality Assurance BP will have a critical contribution to the mitigation of this risk, as the information regarding these issues will be available in a structured and safe way only to the appropriate DMN members.
Links to IMAGINE Methodology	Partner blueprint, Quality Assurance blueprint
Final Assessment	Critical and Unlikely → Low Risk

Identifier	R27
Risk	Failure of the Financial – Accounting department to allocate financial resources in a balanced and effective way between DMN and non-DMN projects, impeding the enterprise to take advantage of external business opportunities and leading to a DMN lock-in situation.
Applies to	Financial – Accounting Department
Initial Assessment	Marginal and Seldom → Low Risk
Avoidance / Mitigation Strategies	This risk can be minimised by carefully organising different accounts in order to be able to respond also to demand created outside the DMN.
Links to IMAGINE Methodology	-
Final Assessment	Marginal and Unlikely → Low Risk

Identifier	R28
Risk	Degradation of the company's reliability in case of not being able to respond to the requirements of collaborative manufacturing projects by reserving the necessary budget
Applies to	Financial – Accounting Department
Initial Assessment	Critical and Seldom → Moderate Risk
Avoidance / Mitigation Strategies	This risk can be addressed through securing the necessary funds for the operation in a DMN, based on the requirements set by the SLAs and the SLOs of the Partner BP that should be signed upon becoming members of a DMN.
Links to	Partner blueprint

IMAGINE Methodology	
Final Assessment	Critical and Unlikely → Low Risk

Identifier	R29
Risk	Failure of the Maintenance Department to plan (both on a short-medium and long term basis) and carry out its operations and reciprocate to the requirements of collaborative manufacturing projects undertaken by the DMN.
Applies to	Maintenance Department
Initial Assessment	Critical and Seldom → Moderate Risk
Avoidance/ Mitigation Strategies	This risk can be mitigated through the proper design and implementation of end-to-end business processes and the exchange of adequate information regarding production schedules and delivery dates. The Manufacturing BP, as well as the end-to-end Process BP can help towards the direction of avoiding such a risk.
Links to IMAGINE Methodology	End-to-End Process blueprint, Product blueprint
Final Assessment	Critical and Unlikely → Low Risk

In the following table concentrated information on the total of the aforementioned risks is provided:

Table A - 14: DMN Risk Assessment Table

Risk	Risk Severity	Risk Probability	Initial Assessment	Final Assessment after Avoidance/ Mitigation Activities
R1	Critical	Likely	High	Moderate
R2	Marginal	Likely	Moderate	Low
R3	Critical	Occasional	High	Low
R4	Critical	Likely	High	Low
R5	Critical	Likely	High	Low
R6	Marginal	Likely	Moderate	Low
R7	Critical	Likely	High	Moderate
R8	Marginal	Occasional	Moderate	Low
R9	Marginal	Likely	Moderate	Low
R10	Marginal	Occasional	Moderate	Low
R11	Marginal	Occasional	Moderate	Low
R12	Critical	Likely	High	Low
R13	Critical	Seldom	Moderate	Low
R14	Marginal	Seldom	Low	Low
R15	Critical	Likely	High	Moderate
R16	Marginal	Likely	Moderate	Low
R17	Critical	Likely	High	Moderate
R18	Marginal	Unlikely	Low	Low
R19	Marginal	Likely	Moderate	Low

Risk	Risk Severity	Risk Probability	Initial Assessment	Final Assessment after Avoidance/ Mitigation Activities
R20	Critical	Likely	High	Moderate
R21	Critical	Likely	High	Moderate
R22	Critical	Likely	High	Low
R23	Critical	Likely	High	Low
R24	Marginal	Likely	Moderate	Low
R25	Marginal	Seldom	Low	Low
R26	Critical	Likely	High	Low
R27	Marginal	Seldom	Low	Low
R28	Critical	Seldom	Moderate	Low
R29	Critical	Seldom	Moderate	Low

From the above-presented analysis, higher-level risks accrue, which can be considered as cumulative risks. Their own assessment and avoidance/ mitigation strategies are presented below:

Identifier	CR1
Risk	Incorrect / Inappropriate partner selection (regardless of the role of the partner in the network) when forming / populating the DMN.
Applies To	Logistics, Purchasing, Quality Assurance, R&D, IT, Maintenance
Initial Assessment	Critical and Likely → High Risk
Avoidance/ Mitigation Strategies	This risk can be confronted through the provision of accurate partner profiles with sufficient information and the formation of SLAs, SLOs and contracts with well-defined terms as far as quality assurance is concerned. This process is facilitated by the structure of the Partner BP. Moreover, the Quality Assurance blueprint, aids the effectiveness and stability of the Quality Assurance procedure throughout the whole DMN, regardless the partner/ department responsible for it, and operates as an input for early detection mechanisms for identifying quality issues at the very first steps of their occurrence.
Links to IMAGINE Methodology	Partner blueprint, Quality Assurance blueprint
Final Assessment	Critical and Seldom → Moderate Risk

Identifier	CR2
Risk	Indirect / Involuntary disclosure of sensitive / important / private data or practices over the network.
Applies To	Production, Logistics, Sales – Marketing, Quality Assurance, IT, Financial – Accounting
Initial Assessment	Critical and Likely → High Risk
Avoidance/ Mitigation Strategies	This risk can be mitigated through utilisation of security barriers in the IT infrastructure that will be employed for the collaboration of the various entities. Moreover, in order to strengthen security, the information that will be carried through the blueprints will be available through different views, securing in such a way that only the appropriate partners have access to specific views, in order to keep information on a "need to know" basis and to not compromise sensitive information to third parties. The Partner BP and the Quality Assurance BP will have a critical contribution to the mitigation of this risk, as the information regarding this issues will be available in a structured and safe way only to the appropriate DMN members.
Links to IMAGINE	Partner blueprint, Quality Assurance blueprint

Methodology	
Final Assessment	Critical and Seldom → Moderate Risk

Identifier	CR3
Risk	Distortion of the balance among the DMN members, as specific partners may take advantage of the shared knowledge, develop individual skills and intellectual assets and try to outshine their collaborators.
Applies To	Production, R&D
Initial Assessment	Critical and Likely → High Risk
Avoidance / Mitigation Strategies	The aforementioned risk can be successfully mitigated through the introduction of the right strategic and tactical management processes. Well-designed contracts concerning management of the acquired shared knowledge are also required in order to eliminate the competitive threats, as well Intellectual Property (IP) issues. The contribution of End-to-End Process BP is critical to these risks too, as it assures the management and control of the whole network.
Links to IMAGINE Methodology	End-to-End Process blueprint
Final Assessment	Critical and Seldom → Moderate Risk

Identifier	CR4
Risk	Competitive threats regarding various enterprise aspects after the termination of the DMN relationship.
Applies To	Production, Purchasing, R&D
Initial Assessment	Critical and Likely → High Risk
Avoidance / Mitigation Strategies	Similar to CR3, the above-mentioned issue can be successfully mitigated through the adoption and application of an effective DMN management methodology, supported by the End-to-End Process blueprint. Contractual agreements concerning management of the acquired shared knowledge, valid even after the termination of DMN relationships, are important in order to eliminate the competitive threats, as well as any Intellectual Property issues.
Links to IMAGINE Methodology	End-to-End Process blueprint
Final Assessment	Critical and Seldom → Moderate Risk

Identifier	CR5
Risk	Loss of the company's credibility and damage of its corporate social responsibility profile, in the case of personnel dismissals as a result of the automation of the logistics operations.
Applies To	Production, Logistics
Initial Assessment	Marginal and Likely → Moderate Risk
Avoidance / Mitigation Strategies	This risk can be converted into a benefit by employing the human resources, formerly occupied in the logistics operations in more administrative and decision-making tasks.
Links to IMAGINE Methodology	-
Final Assessment	Marginal and Seldom → Low Risk

Step 6

Having performed the analysis consisting of the first five steps of the risk analysis and assessment methodology, we can conclude that, after successful implementation of the proposed avoidance/ mitigation strategies, the majority of the risks (regardless their initial assessment) result to the "Low Risk" level, which is the most desirable risk level.

The risks that, even after the application of the avoidance/ mitigation strategies, seem to remain as challenges for the participating enterprises (and the DMN in general) are the following:

- Information leaks about capabilities, availability and capacity can be harmful if this information gets to competitors (Production Department, R1),
- Collapse of an order due to an ineffective supplier. In case a supplier fails to keep up e.g. with the time-plan of an order and manages to conceal this fact, the whole network can be adversely affected (Purchasing Department, R7),
- Disclosure of critical information and exposure of the company's weak points as far as quality assurance is concerned (Quality Assurance Department, R15),
- Loss of control as suppliers develop critical skills and loss of Intellectual Property (R&D Department, R17),
- Competitive threats after the termination of the DMN relationship may appear. (R&D Department, R4),

The aforementioned risks should be treated with special care when forming and managing a DMN, in order to ensure the smooth and effective operation of the network. In any case, the elements and the information contained in the blueprints, in accordance with the application of a well-defined DMN management methodology are the keys for successfully handling those risks. The four kinds of blueprints introduced by the IMAGINE Project (namely the End-to-End Process BP, the Partner BP, the Manufacturing BP and the Quality Assurance BP) affect the whole lifecycle and operation of a DMN, and work proactively towards avoiding/ mitigating almost every one of the aforementioned risks.

E.4 Views from the IMAGINE Living Labs

E.4.1 Aerospace and Defence Industry Living Lab

The main benefits as seen from the Aerospace and Defence Industry Living Lab are the following:

- Efficient and accurate dynamic monitoring facilitating delays prediction and allowing agile and optimal end-to-end process reconfiguration.
- Facilitates the distribution of responsibilities, the coordination of logistics and the concentration of efforts within competence domains.
- Advantages of applying common quality assurance standards and policies and to evaluate and enforce them continuously during the whole manufacturing process.
- Automation of evaluation tests based on unified and global criteria can be performed over each process segment, allowing a global coherence of the expected minimal quality levels.
- Benefits in capitalising and creating innovation and knowledge within virtual research and development departments.

Associated risks and mitigation are the following:

- Risks of reconfiguration oscillations and instability when governance is distributed. Special attention needs to be consecrated to the end-to-end business process regulation and governance definition.
- Uncontrolled knowledge sharing and confidentiality issues. Strict security and confidential strategies need to be enforced and continuously evaluated within the whole collaboration.
- Difficulties in carrying out the adequate adaptation actions when the quality levels or service level agreements are not respected. These adaptation actions needs to be decided and planned in advanced in order to mitigate this risk. Moreover, adequate responsible needs to be identified and informed as soon as SLA violations are detected in order to allow to efficient reconfiguration
- Interoperability and scalability issues can affect the DMN IT infrastructure. An adequate design of the IT platform supporting the DMN including non-functional requirements as well as the existing IT systems resources will help to reduce such risk.

E.4.2 Automotive Industry Living Lab

The Automotive Living Lab will operates as a simulated production network for cars replicating the live layout of a manufacturing chain along its main lifecycle phases with a detailed focus on inbound and spare parts management.

The introduction of the DMN concepts and technology will lead to the following benefits:

- Rapid answer to variation in volumes, quality problems and supply interruption
- Reduction of stock-out due to supply chain interruption, leading to reduced costs
- Further integration with Tier 1 suppliers: continuous visibility on the supplier production and logistics, leading to reduced costs in working capital
- Improved selection of suppliers based on external certification, eventually reducing risks and favouring the emergence of best suppliers
- Automatic/semi-automatic support to unexpected events, leading to reduced time and costs

- Integrating the practices of the internal audit and supplier audit units (OEM) with external certification companies
- Building on new competences from the certification company (CC)
- Eventually further standardisation of purchasing and supplier selection processes
- From the supplier side, early production planning will be eased, thanks to early sharing of OEM production volumes data and technical data
- From the supplier side, increased business opportunities will be achieved by participating to the DMN.

In the meanwhile, new risks are expected to rise:

- Disclosure of critical data to potential suppliers due to their early involvement in the supply chain (production forecast, designs) may lead to loss of company competitiveness
- Selection of supplier done by external party may be less than optimal. Furthermore the liability of the certification company should be addressed.
- The OEM departments will have to face change management and rely on an external platform to come with unexpected events
- The responsibility of certification will be left to external companies, leading to increased risks due to the mismanagement of automotive–specific risks dimensions
- The OEM may lose internal skills (supplier management, risk management)
- The OEM departments may face a proliferation of tools (supplier management, risk management).

E.4.3 Furniture Manufacturing Industry Living Lab

The Furniture Manufacturing Industry Living Lab is focused in furniture manufactures, but includes the entire value chain from purchasing to product delivery. The furniture sector is characterised by products with shorter and shorter lifecycles. As a result, time-to-market is essential to benefit from premium price. And in this aspect, DMN may help furniture companies that make up this sector to be more competitive.

The furniture companies are investing in machinery for production but the information flow along the supply chain is still managed in a very traditional way, losing information and producing lots of errors. A DMN would bring to furniture related SMEs high performance in supply chain management giving high-added value to this traditional industry by creating Virtual enterprises networks.

The biggest problem derives from the change in the way of working when adopting a DMN, because in such an innovation may cause a major change in the way of working in many departments of an enterprise. Another problem that we can find is the fact that furniture companies don’t want to share information that for they is private in a more public context.

E.4.4 Engineering Sector Living Lab

The WMCCM Living Lab consists of around 350 engineering businesses that have been competence profiled. The idea of considering and mapping their competencies rather than focussing on their existing products is very novel to many of them. The problem with focussing on products is that it limits the opportunities open to you. The other problem many of the WMCCM Living Lab companies have is that they do not plan their workload. Getting new business tends to be a "sales" activity which they reluctantly engage in only when they have to, as for example higher wages for staff need to be covered. Focussing on competencies and capability, and driving opportunities to them via the DMN totally changes the mind-set. It then becomes an engineering challenge, not a sales challenge. This better suits an engineering/manufacturing business. Thus, the sales department changes and becomes a pre-engineering department and a partner relationship department.

Working more closely with partners via a DMN may require a different type of capability in the IT area for the SME businesses in the Engineering Sector Living lab. The administrative section of the business will require to be more prepared for collaboration so legal and SLA type documents must already exist and be able to be easily modified according to the DMN supply chain created. As a result, the changes for an average SME are subtle but deep in their outlook and attitudes.

E.4.5 Domain-agnostic, multi-site factory Living Lab

The GEMLab 2.0 Living Laboratory is a domain-agnostic institution in order to facilitate as many industry sectors as possible. As using a more complete approach to the digital factory world is usually accompanied by the employment of several professional tools, most companies employing these services at an advanced level are mid-sized up to big players. The DMN creation enables these companies to react fast to occurring opportunities, which otherwise might be lost in the complexity of their IT landscape. Also there are huge additional benefits to be gained by adding the suppliers of the medium or bigger companies into the creation of the digital models. Another aspect is the possibility to use the DMN to enable the GEMLab 2.0 Living Lab to target SMEs specifically. This will be enabled by creating the means of fast DMN creation throughout the supply chain and therefore circumventing the huge costs of complete digital toolsets and the respective work force required to create usable digital models.

If the creation of the DMNs is really easy and fast applicable even for small partners inside of the supply chain, it will enable SMEs to target a whole new clienteles. As the created digital models are employed throughout the whole DMN lifecycle, almost all departments can be affected by their creation. In the course of this project, there is a focus on the planning side.

E.5 Templates for Reaction Protocol

Table A - 15: Continuous Benefits Recording Template

Enterprise Name:		Type of Enterprise:[7]			DMN Name:[8]				Sector:[9]					
Metric	Improvement Direction	Initial Value	1st Measurement				2nd Measurement				Nth Measurement			
			Date	DMN Size[10]	Current Value	Difference to initial values11	Date	DMN Size	Current Value	Difference to initial values	Date	DMN Size	Current Value	Difference to initial values
Total Profitability	⇑													
Total operational & manufacturing cost	⇓													
Cost due to quality issues	⇓													
Total productivity	⇑													
Financial exposure of partners	⇓													
Required investments by partners	⇓													
Product development lead time	⇓													
Product development cost	⇓													
Time for contractual formalisation	⇓													

[7] OEM/Supplier/etc
[8] Name of the DMN where the enterprise participates
[9] Automotive/Furniture/Engineering/Industry Agnostic/Aerospace & Defence, etc
[10] Provide the size (entities) of the DMN
[11] Percentage

Manufacturing lead time	⇓													
Co-operation processes efficiency	⇑													
Product cycle times	⇓													
Life cycle costs	⇓													
Maintenance costs	⇓													
Total Profitability	⇑													
Time for manufacturing network design, re-configuration, re-engineering (N-KP 1)	⇓													
Time to market (N-KP 2)	⇓													
Time for multi-site factory design, re-configuration, re-engineering (F-KP 1)	⇓													
Time-to-production (F-KP 2)	⇓													
Cost for multi-site factory design, re-configuration, re-engineering (F-KP 3)	⇓													
Ramp-up time (F-KP 4)	⇓													
Process Capability Index Cp (F-KP 5)	⇑													
Resource utilisation (O-KP 1)	⇑													
Delivery time (O-KP 3)	⇓													

Table A - 16: Continuous Risk Recording Template

Enterprise Name:			**Type of Enterprise:**[12]				**DMN Name:**[13]				**Sector:**[14]				
Risk	**Applicable**[15]	**Initial Mitigation Performed**[16]	**Risk Occurrence #1**				**Risk Occurrence #2**				**Risk Occurrence #n**				
			Date	**Description**[17]	**DMN Size**[18]	**Mitigation Performed**[19]	**Date**	**Description**	**DMN Size**	**Mitigation Performed**	**Date**	**Description**	**DMN Size**	**Mitigation Performed**	
R1															
R2															

[12] OEM/Supplier/etc
[13] Name of the DMN where the enterprise participates
[14] Automotive/Furniture/Engineering/Industry Agnostic/Aerospace & Defense, etc
[15] Yes/No
[16] Please Specify if the avoidance/ mitigation plans mentioned above have been applied (or if other)
[17] Describe the risk and the conditions under which it happened
[18] Provide the size (entities) of the DMN
[19] Describe the actions performed to mitigate the risk

Table A - 17: Continuous Risk Recording Template

Enterprise Name:		**Type of Enterprise:**[20]			**DMN Name:**[21]		**Sector:**[22]	
			Affects					
Process/Department	**Interoperability Level Change**	**Observed Benefits**	**Metrics**	**KPI's**	**Cost of Process/Department Operation**	**Revenue of Process/Department Operation**	**Investment Performed**	**Rectified TCO**

An example of the use of Table A-17 is the following:

Enterprise Name:	ABC	**Type of Enterprise:**	SME		**DMN Name:**	DMN1	**Sector:**	Furniture
			Affects					
Process/Department	**Interoperability Level Change**	**Observed Benefits**	**Metrics**	**KPI's**	**Cost of Process/Department Operation**	**Revenue of Process/Department Operation**	**Investment Performed**	**Rectified TCO**
Procurement	None-> Medium	Fast selection of suppliers for each project/product and network setup	Manufacturing lead time (5%)	• N-KP2 - 2% • F-KP-1 - 2%	150.000 €	150.000 €	15.000 €	15.000€ – ((150.000€ *0,05)+(210.000€*0,02) = 3.300€

In order to increase the current interoperability level from none to medium there has to be 15k€ investment cost. However thanks to improvement in manufacturing lead time and the time to market, reengineering etc, the expected cost of the project will be reduced by 5% and the revenue is increased by 2% (a total 11.7k€ cost reduction) so the adjusted investment drops to 3.3k€. The company can decide to invest to this improvement now.

[20] OEM/Supplier/etc
[21] Name of the DMN where the enterprise participates
[22] Automotive/Furniture/Engineering/Industry Agnostic/Aerospace & Defense, etc