

## **4.1.Final publishable summary report**

---

### **1 Introduction**

This report corresponds to the Final Report of the LeanPPD project. Since project coordinator noticed a misprint in the Deliverables titles, this deliverable has been re-named as **D8.5 – Final Report** which corresponds to *D8.4 – Final Public Report*, according to the Annex I of the project (pp.33). Complementary to this report, the Project Coordinator is providing the last Periodic Report of the project titled as **D8.4 – Periodic Report (M48)** (*D8.5 – Final Report*) which shows the progress of the project during the last reporting period of the project, that is, from M37 to M48.

This deliverable aims to include apart from general information of project objectives and research followed, the results achieved during the whole lifecycle of the project, four years. It also covers a list of the dissemination activities that have been developed during these four years period. And lastly, the future plans for exploitation.

### **2 Executive summary**

The project has addressed the need of European manufacturing companies of a new model that go beyond lean manufacturing to ensure the transformation of the enterprise into lean environment. This is to response to the customers and market demands of value creation incorporating sustainability, culture and customisation. A significant change in enterprise performance can come from the adoption of lean thinking throughout the entire product life cycle.

The aim is to develop a new model based on lean thinking that consider entire product life cycle, providing a knowledge based environment to support value creation to the customers in term of innovation and customisation, quality as well as sustainable and affordable products.

This has been called Lean Product and Process Development (LeanPPD) paradigm. The required knowledge for value creation in LeanPPD model has been developed based on the European standard and open architecture to ensure data and knowledge integrity and to provide a lean environment across the product life cycle and the supply chain. The project proposes to develop novel set-based lean design tools that ensure the concurrent consideration and development of lean product design as well as it associated lean manufacturing system.

The user driven approach has been ensured by the five business cases (BC) provided by the end-users from different sectors in the consortium. These BCs served to derive requirements upon the tools, methodology and models being developed, to test the solutions developed and have served as industrial demonstrators of the proposed concept.

### **3 The LeanPPD project and objectives**

Generally speaking, LeanPPD project was challenged with implementing and sustaining lean within the Product Development process. The main aim of LeanPPD project was to develop a new model and its associate tools based on lean thinking that consider entire product life cycle, providing a knowledge based user-centric design and development environment to support value creation to the customers in term of innovation and customisation, quality as well as sustainable and affordable products.

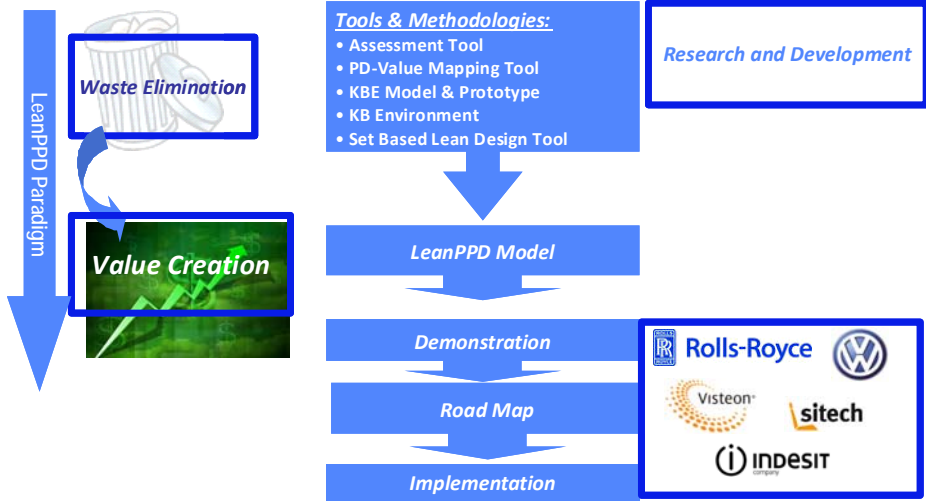
To achieve this aim, the LeanPPD project has addressed the development of an integrated set of tools and model adapted from previous national, European and International projects together with the

development of new innovative ones. The research methodology of this LeanPPD proposal has been based on the development of two main elements:

- 1) The LeanPPD paradigm including the Lean Product & Process Development model
- 2) The development of its associated tools and guidelines.

The tools and techniques developed within the project enabled the five industrial partners to streamline their current PD processes. Future exploitation and dissemination of the tools and techniques will allow other European companies to benefit from the research project. LeanPPD has been carried out by a European consortium including partners from manufacturing industry, ICT providers and Research, Technological and Development partners, and coordinated by TECNALIA (Spain). The partners are coming from United Kingdom, Germany, Spain, Switzerland, Italy and Poland.

*LeanPPD model* was conceptualized expecting to address some research challenges (see Figure 1).



**Figure 1: LeanPPD project overview**

The first research challenge concerned the measurement of the readiness level of adoption of lean thinking principles in current industrial practice of product design and development processes by proposing a performance measurement approach that integrates human resources, technology factors and processes of an enterprise.

To understand how product and process development is structured and what is needed to streamline the process to maximise value creation constituted the second challenge of this project. Hence, the project addressed the mapping of product development process to measure the values from the customers’ point of view and estimate the cycle costs, including the manufacturing and in service components.

A third challenge was to enable manufacturing companies to balance the need to react to value creation opportunities against the efficiencies to deliver them effectively, this means with the quality demanded, under budget and on time (nor after or before the milestone agreed). This is achieved, as any engineering decision taken based on proven knowledge and experience, to reduce risk and maximise utilisation of resources of both the enterprise and its supply chain.

Lastly, the fourth aim was to ensure the concurrent generation of lean product and process design as well as, the design of its associated lean manufacturing system that is highly responsive to the changing market requirements and production technologies.

**4 Main S & T results/foregrounds**

Based on the aforementioned challenges, the main results of the project, from a general perspective, were:

**A self-assessment tool for Lean Product & Process development – ‘Lean T<sup>2</sup> Transformation Toolkit’**

Lean thinking and applications always have been a continuous improvement effort. Lean product and development needs a continuous tracking of PD performances to enable companies to lead their journey to LeanPPD. This tool aimed at providing a ready-made platform to assess the maturity level of companies in the application of lean thinking in new product design and development.

The tool uses a five step change process to help partner companies identify their “AS-IS” state and define a roadmap (TO-BE) beyond “lean thinking”. Quantitative and qualitative key performance indicators (KPIs) have been developed to create the proposed 5 levels of the LeanPPD Self-Assessment Tool. This tool is based on the balanced scorecard model. Further, the tool proposes an anonymous benchmarking method that companies can use to compare their performances with other similar industries. The tool is already available in web-based form for easy usage by the Industrial partners.

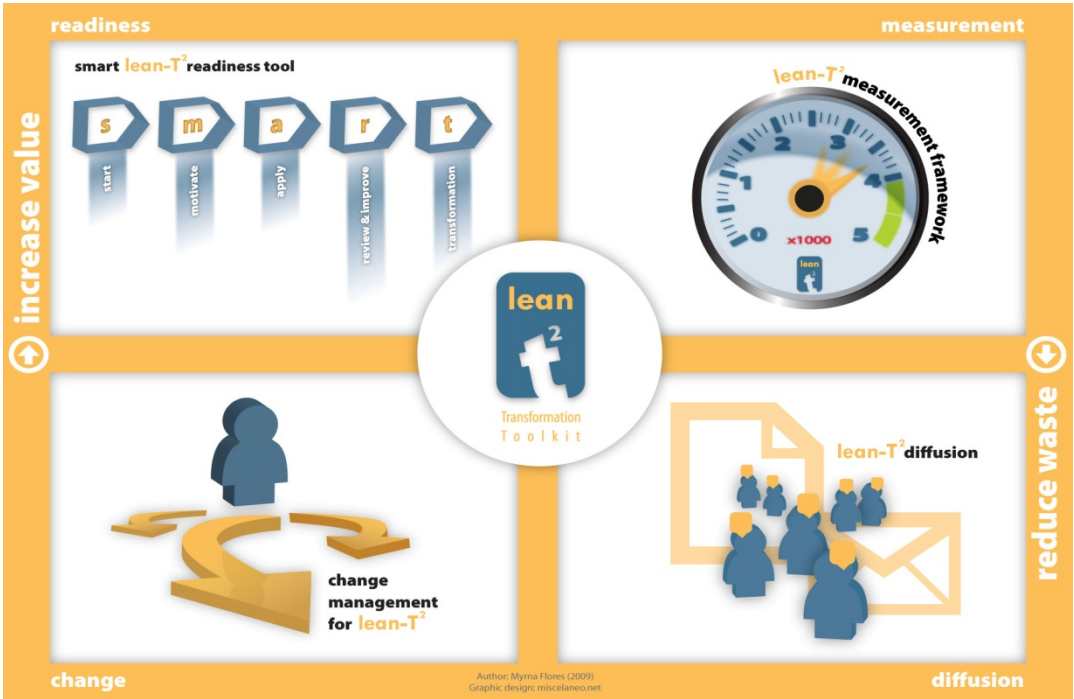


Figure 2: Lean Transformation Toolkit - LeanT<sup>2</sup>(source: Deliverable 1.3)

**A product development value mapping tool for Lean Product & Process development – called VIWET ‘Value Identification and Waste Elimination Tool’.**

The LeanPPD project has developed an innovative value mapping tool called Value Identification and Waste Elimination Tool (VIWET) At its core the tool makes use of the Role Activity Diagramming

Technique (Figure 3) to create pictorial representations of collaborative processes such as the design process. A VIWET file provides a single integrated repository for graphical, textual and numerical descriptions of both the current state and future state processes and provides a range of analysis tools in order to facilitate the progression from current to future state. The electronic data can be easily exported for use in other software within an organisation which makes use of process data for example ERP systems.

The process of creating a model begins with a data gathering activity then leads to the creating of a Social Network Diagram. Afterwards interviews identify key concepts and attributes that are highlighted in the VIWET Transcript analysis tool (Figure 3). One of the key features of VIWET is that is not just a tool for creating pictures of processes. It also has an underlying data model which allows the capture of time, cost and resource information and other information types. Gantt charts (Figure 4) can be drawn and used to see the effect on the overall lead time of time reductions to any particular activity. The VIWET software seeks to identify the possible wastes in an activity, and also the user of the system gets advice on how to eliminate that type of waste and hence improve the activity. Improvement actions can be documented and reported within the system. This leads to the design of the future state process.

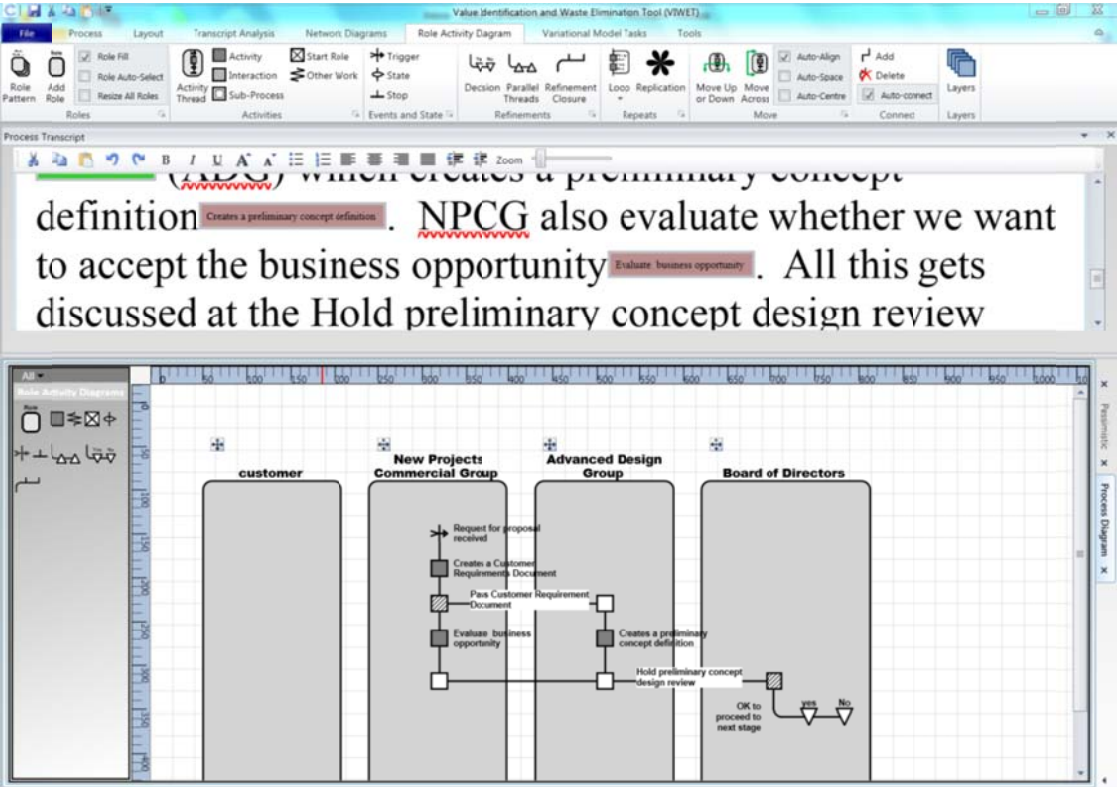
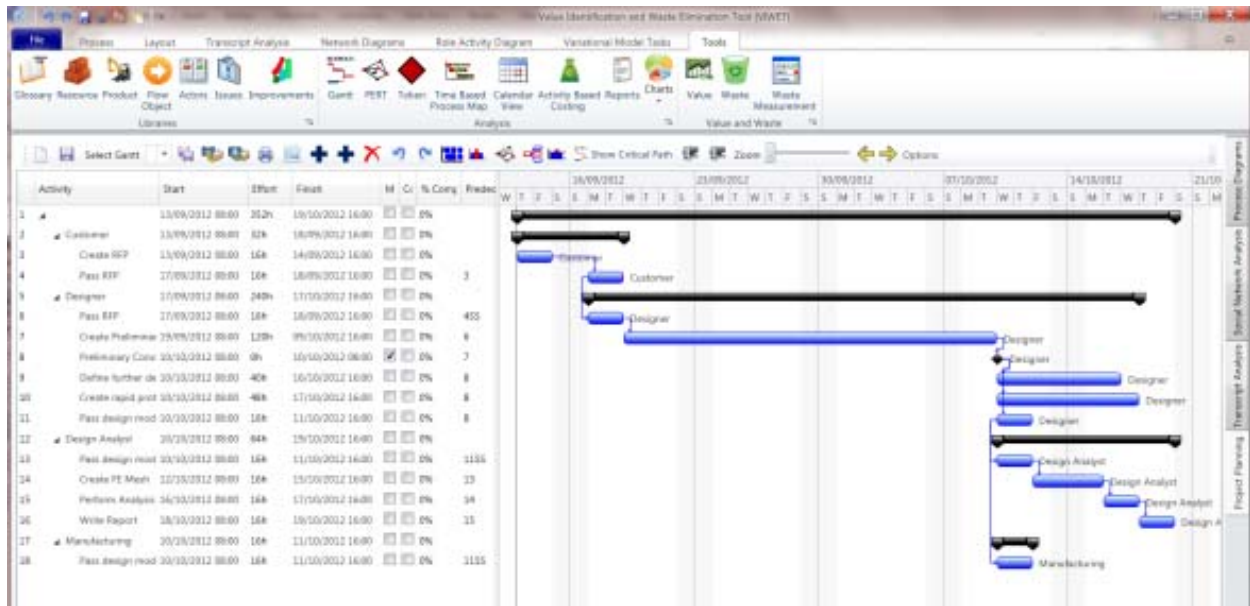


Figure 3: VIWET showing transcript editor and Role Activity Diagram (source: Deliverable 2.5)



**Figure 4: Gantt chart generated from a Role Activity Diagram within VIWET(source: Deliverable 2.5)**

**KBE System Architecture Reference Model for LeanPPD and KBE prototype for LeanPPD**

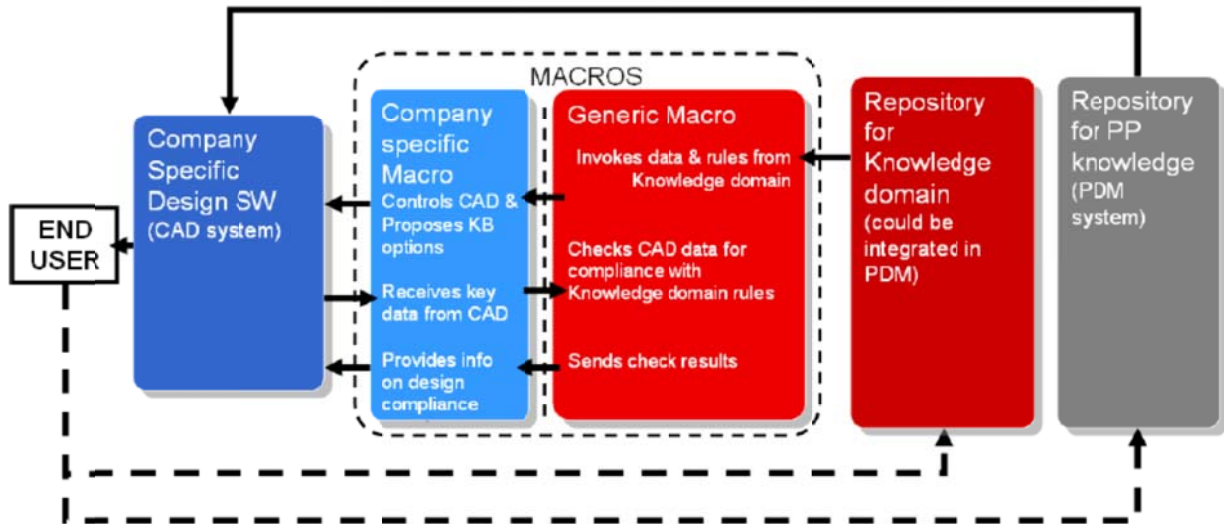
The objective was to implement a Knowledge Based Engineering (KBE) prototype which would enable a lean development process and generate lean product designs, by incorporating interactive support for existing rules (currently described in textual format, as guidelines) in the tools used for design, as well as by providing an estimation of costs involved in building a part using different methods.

Regarding the verification of design rules, currently designers have to manually check the fulfilment of such design rules. For instance, when welding a part out of subparts, the distance from a welding nugget to the edge of the sheet must conform to certain rules. Because a part can be very complex, built out of many subparts, with lots of welding spots needed, the manual check of even one such design rule would take a prohibitively long time.

The KBE tool automatically performs the check for multiple such rules, informing the designer visually where a problem occurs and what can be done in order to alleviate it. For certain rule violations, the actions taken have been automated, so multiple problems can be resolved with only a click from the designer.

Furthermore, after the designer has been informed about a rule violation and has performed actions to correct it, the verification can be performed again; this way, the designer is not only in-formed about existing problems, but after taking actions to solve them, he receives immediate feedback regarding his solution.

The design rule verification part of the tool was developed as an integrated plugin in the CATIA system, which is widely used for designing parts, increasing the tool’s applicability. It allows design departments to check for the fulfilment of design rules faster and, furthermore, to correct potential deviations from design rules in less time than they would in the absence of the KBE tool. Moreover, renewed verification of the rules and immediate feedback gives confidence to the designer that the actions taken to solve the identified problems have been correct and applied in all necessary places (Figure 5).



**Figure 5: Architecture of KBE prototype (source: Deliverable 3.4)**

The cost estimation part of the KBE tool allows the designer to compare estimated costs for welding together a certain part. In the implemented prototype, the designer can choose between two methods of welding: spot or laser. The costs for producing a by using with one or the other method are then computed, based on information from CATIA (the characteristics of the material used, which influences the parameters of the welding process) and from the PDM/PLM solution used by the designer (information related to the hierarchical composition of the part out of its subparts).

The cost estimation tool has been implemented as a Microsoft Excel VBA application. It takes as inputs files exported from CATIA and the PDM/PLM solution, as well as some parameters that have to be configured by the designer in Microsoft Excel (for instance, the costs of operating a welding machine), and outputs the estimated costs for building the part using the two welding methods. This allows the designer to be flexible and choose the most appropriate welding method for a certain part, minimizing the involved costs.

The working KBE prototype has been developed based on the generic requirements for a KBE tool defined by the Lean Knowledge Life Cycle, as well as on the functional requirements described by the industrial partners of the project.

### **Lean design guidelines for Lean Product Design**

Lean Design Guidelines tool is to be used through concept development, and system convergence phases in the SBCE Model. Lean Design guidelines initially seeks to define lean design and list the key principles as well proposing a four phased process which designers can easily follow to achieve a lean design. In greater details Lean Design Guidelines were explored and described in D4.3 of LeanPPD project.

Finding from the literature review and industrial field study, resulted in the formulation of the lean design definition and the key principles of lean design (which have been validated with industry during regular visits and the Lean PPD workshop held in CU the 22nd September, 2012).

#### **a) Lean Design definition:**

Maximise customer value representation; ensuring the elimination of harm to its end user and to environment of operation, as well as assuring waste and resources are minimised during manufacture

**b) Lean Design objective:**

To achieve a product realisation scheme placing direct attention on geometry that maximises stakeholder values along the product lifecycle. Ensuring it is developed and produced with minimum waste and resources and with no harm to the operator and environment.

**c) Lean Design principles:**

- a. Maximise customer value through geometrical reasoning
- b. Formulate a product architecture that minimises complexity and ensures manufacturability and being able to assemble
- c. Ensure the proposed realisation scheme simultaneously considers lean manufacturing
- d. Eliminate harm to the (a) end-user, (b) manufacture, (c) service
- e. Minimise waste for (a) manufacture, (b) service
- f. Minimise resources (a) manufacture, (b) operation, (c) service

**d) Generic Lean Design Process:**

The generic lean design process serves as the core stone of the Lean Design Guidelines. The generic lean design process consists of four phases, subdivided in to a number of activities that ensure a systematic process is employed to achieve the lean design objectives. Details of the individual parts are provided in the proceeding sections:

**Define:** the design objective, and aim to establish the fundamentals before applying the lean design principles

**Design:** generate - modify the geometry based on the lean design principles to maximise value in the most cost effective way (without compromising functionality and quality)

**Refine:** identify ‘non lean’ characteristics and take necessary geometrical alterations to ensure manufacturability

**Finalise:** ensure the design meets all the lean design objectives and is frozen

**Lean product and process development model (so called LeanPPD model)**

By the time the challenges were effectively addressed by RTD partners, the LeanPPD model was constructed based on an identified list of forty seven lean product development enablers (principles, methods, tools, and techniques) that have been described by the researchers and practitioners in the project’s deliverables.

The core enablers are those that have received the most attention in the literature and appear to be the most distinctive elements to characterise a complete product development system (Figure 6):

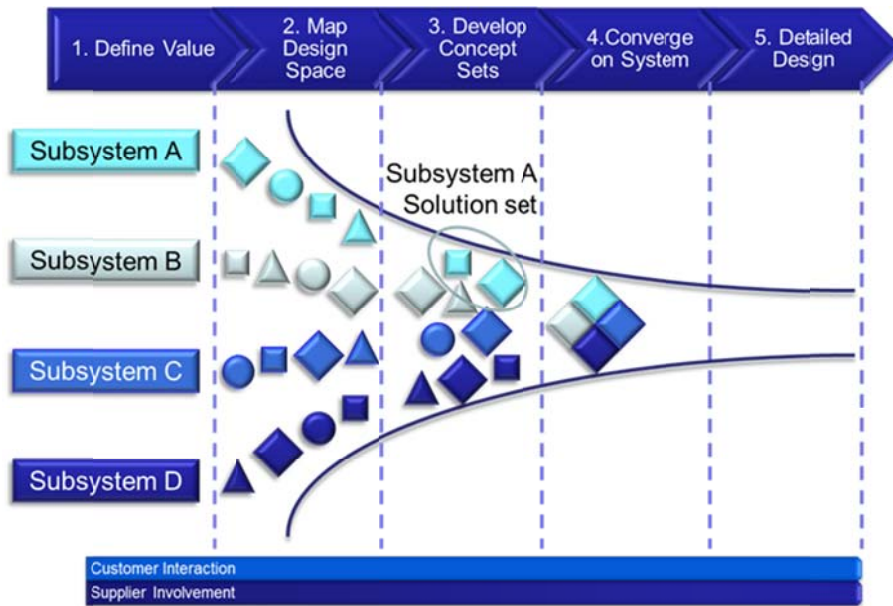


**Figure 6: The LeanPPD Model with its Core Enablers (source: Deliverable 5.1)**

1. A development process: **Set-Based Concurrent Engineering (SBCE)**
2. Vision, strategy and planning: **Value-Focused** planning and development
3. A leadership system: **Chief Engineer technical project leadership**

4. People, infrastructure, and other capabilities: **Knowledge-Based Environment**
5. The organisational culture: **Continuous Improvement**

After a critical analysis of the SBCE principles and the various descriptions of the SBCE process, a number of phases were defined in order to represent the SBCE process. Although the phases may appear similar to some traditional product development models, the activities within them are unique and thus the phase names are intentionally different from traditional ones. Figure 7 illustrates graphically the SBCE baseline model that has been developed based on the captured principles. Customers and suppliers are involved throughout the product development process.



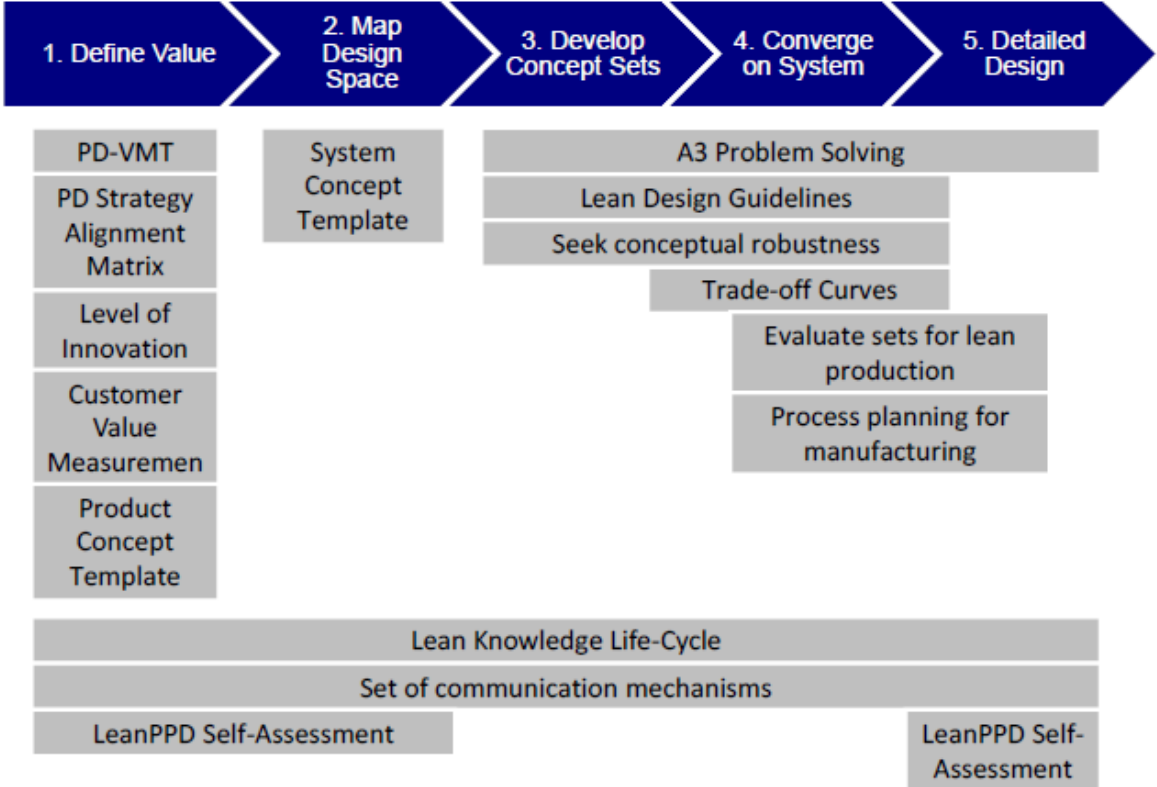
**Figure 7: SBCE Baseline Model (source: Deliverable 5.1)**

The SBCE Baseline model is broken down further into activities as depicted in Figure 8. Activities were initially defined by embodying LeanPPD principles and practices into steps in the process.

1. Define Value	2. Map Design Space	3. Develop Concept Sets	4. Converge on System	5. Detailed Design
1.1 Classify projects	2.1 Identify sub-system targets	3.1 Extract (pull) design concepts	4.1 Determine intersections of sets	5.1 Release final specification
1.2 Explore customer value	2.2 Decide on level of innovation to sub-systems	3.2 Create sets for sub-systems	4.2 Explore possible product system designs	5.2 Manufacturing provides tolerances
1.3 Align project with company strategy	2.3 Define feasible regions of design space	3.3 Explore sub-system sets: simulate, prototype & test	4.3 Seek conceptual robustness	5.3 Full system definition
1.4 Translate value to designers (via product definition)		3.4 Capture knowledge and evaluate	4.4 Evaluate possible systems for lean production	
		3.5 Communicate sets to others	4.5 Begin process planning for manufacturing	
			4.6 Converge on final system	

**Figure 8: SBCE Baseline Model - Activity view (source: Deliverable 5.1)**

Tools and enablers were identified or developed to support each activity in the SBCE Baseline Model (Figure 9).



**Figure 9: A scenario of applicable tools and enablers for each phase of the SBCE baseline model (source: Deliverable 5.1)**

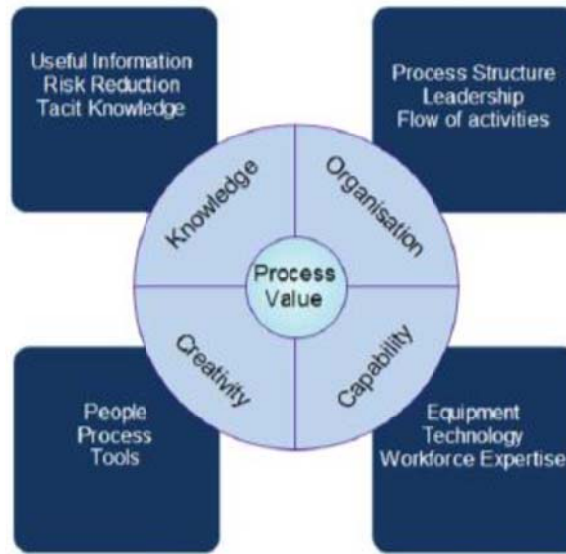
Those tools were selected based on various criteria and numerous researches including industrial case studies. LeanPPD model provides a workable flow of activities for a PD project that is principle-based and can also be supported by company practices. The process may also be customised for each company in which it is implemented. That was proven by some case studies where LeanPPD model was implemented and tailored for each one of them.

In Figure 9 a scenario of tools and enablers throughout entire product development process is shown. It must be mentioned that some of the tools and enablers were developed in other tasks of the LeanPPD project (e.g. Lean Knowledge Lifecycle was developed in Task 320) and some have been developed specifically for the SBCE baseline model. These tools and enablers are presented for each stage of the SBCE baseline model following by examples and descriptions:

A possible scenario of used tools and enablers for the **Define Value phase** of the SBCE model covers:

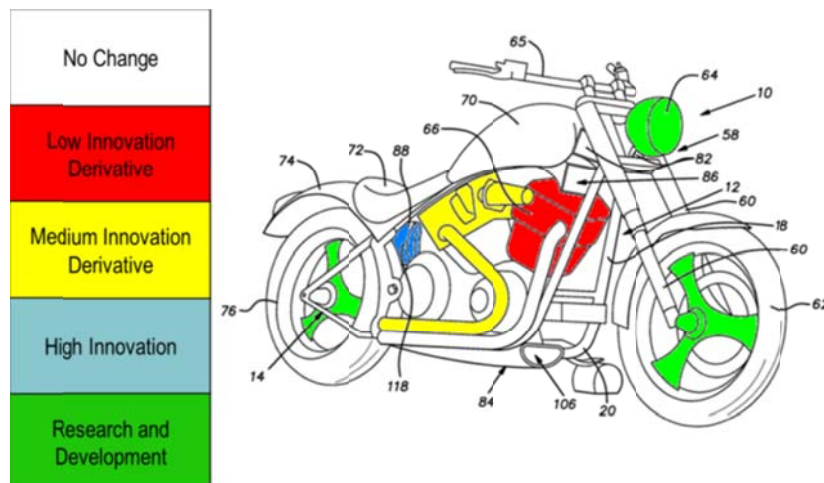
- PD-value mapping tool and VIWET (explained above);
- Product Development Strategy Alignment Matrix: This tool is to be used in the first stage of the SBCE Model which is the Define Value phase. The PD strategy matrix is required to identify strategic benefits that can be sought from projects. This would enable a project team to focus not only on customer value but also what is referred to as ‘process value’. Process value is that which enhances the process of product development and the

organisation’s capability to develop products. The matrix structures strategic goals around four categories as the Figure 10 shows.



**Figure 10: The PD Strategy matrix (source: Deliverable 5.1)**

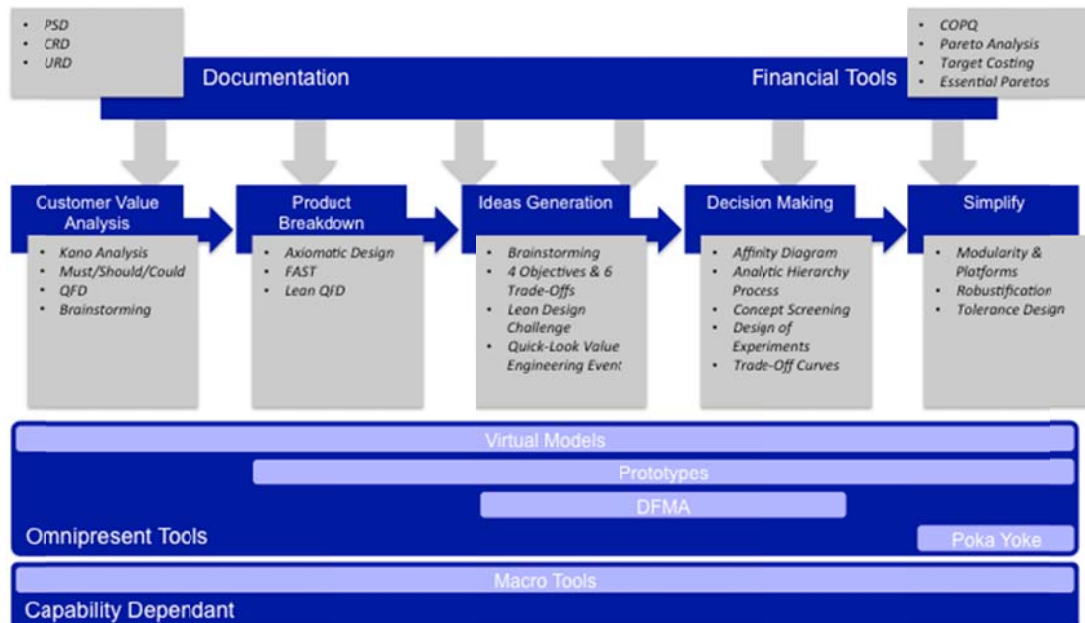
- Level of Innovation: This tool is to be used in the first stage of the SBCE Model which is the Define Value. An example of the tool is called an “Innovation Classification Diagram” is shown in Figure 9, and it communicates the level of innovation required for different subsystems and components during a project. This tool supports the focus on value that is sought, preventing both over-engineering and underengineering. The approach that was developed adopts the level of innovation numbering scheme employed in the project classification matrix. The levels are colour-coded, and subsystems and components may subsequently be labelled to visually communicate the planned focus for innovation efforts in a particular project.



**Figure 11: Innovation Classification Diagram (source: Deliverable 5.1)**

- Customer Value Measurement: The Customer Value Measurement tool is to be used in the first stage of the SBCE Model which is the Define Value. It suggests a selection of design

tools in order to help the designers to analyse the design scenarios. It is a framework with the objective to help companies implement simpler lean design tools in order to witness how effective simple changes can be. The conceptual framework required to develop this approach is the basis of the customer value translation process and is shown in Figure 12.



**Figure 12: Customer Value Translation Conceptual Framework (source: Deliverable 5.1)**

The tools were categorised according to a point in the design process.

There are a few tools that omnipresent regardless of the design scenario, namely: virtual models; prototypes; Design for Manufacture and Assembly (DFMA); and Poka Yoke, and there is capability-dependant, so-called macro tools (e.g 6σ).

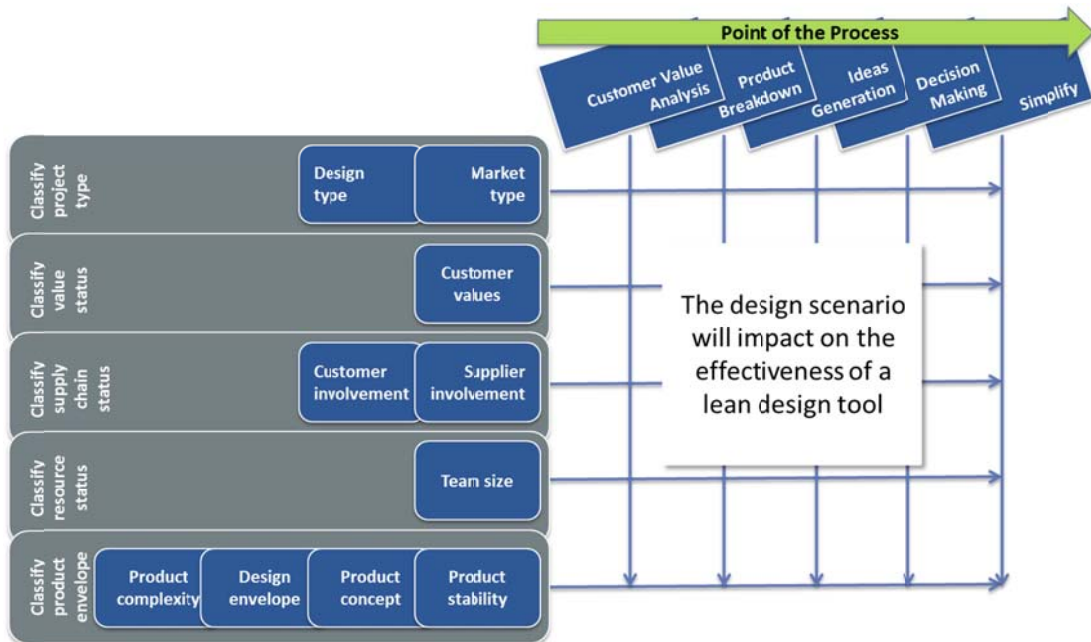
There are many different design scenarios that impact the effectiveness of a chosen design tool. Therefore, consideration was given to a number of design scenarios believed to affect the choice of design tool as show in Table 1.

**Table 1: Breakdown of design scenarios**

Classify Project Type	Design Type	Lean Design	Leaner Design	Leaned Out Design
	Market Type	New market	Established & Non-Competitive	Established & Competitive
Classify Value Status	Customer Values	Unknown	Reasonable Knowledge	Established
Classify supply chain status	Customer Involvement	Distant	Medium Involvement	High Involvement
	Supplier Involvement	Distant	Medium Involvement	High Involvement

Classify Resource Status	Team Size	Limited Resource	Medium Resources	High Resource
Classify Product Envelope	Product Complexity	Low	Medium	High
	Design Envelope	Restrictive	Medium	Free
	Product Concept	New	Infancy	Established
	Product Stability	Unknown	Stable	Repeat Offender

Figure 13 shows the consideration of different design scenarios which will have impact on the effectiveness of a lean design tool.



**Figure 13: Consideration of Different Design Scenarios (source: Deliverable 5.1)**

Following on from this conceptual framework, an Excel spread sheet allows users to input a design scenario and to see which lean design tools are recommended. A screen shot of this tool is shown in Figure 14.

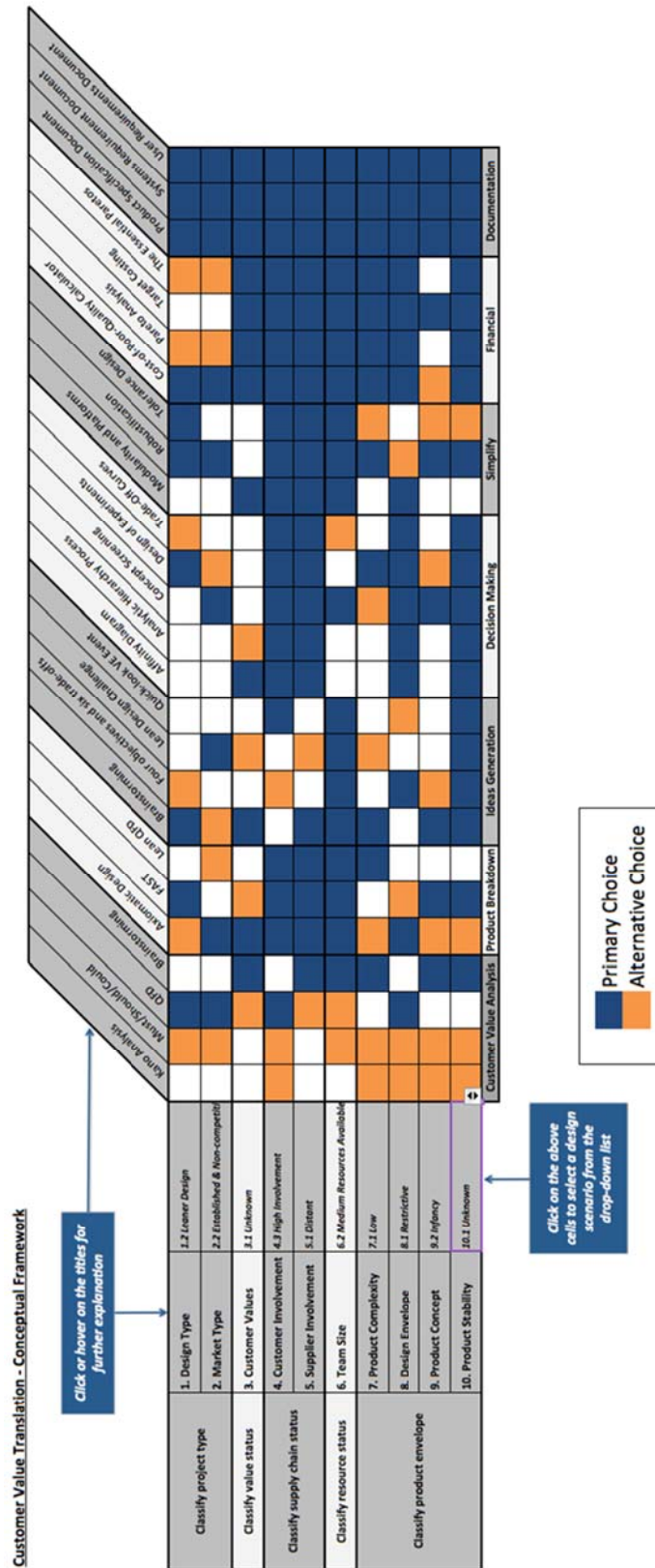
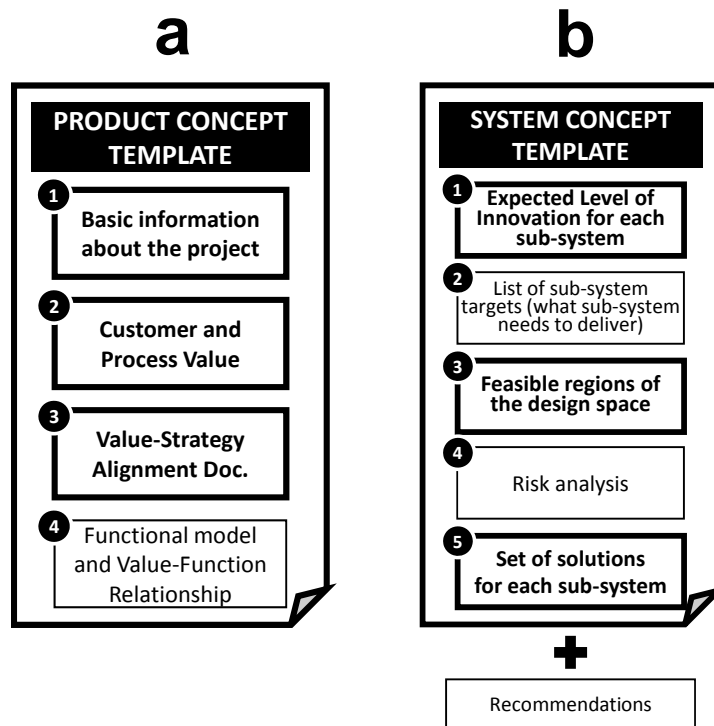


Figure 14: Screen shot of the customer value translation conceptual framework tool (source: Deliverable 5.1)

With the use of this conceptual framework a design team has quick, simple access to a decision tool that can reduce resources spent on wasteful processes or wasteful product design tools.

A possible scenario of used tools and enablers for the **Map Design Space phase** of the SBCE model covers:

- Product and System Concept Template: Product Concept Template is to be used at the end of the first PD phase and the System Concept Template is to be used at the end of the second PD phase. The purpose of both templates is to have a uniformed and structured format to enable smooth information flow between different PD phases. The templates incorporate the most important information produced during the product development and present them on the most efficient and easy understandable way. The example of both templates is presented in Figure 15.



**Figure 15: Example of the Product (a) and System (b) Concept Template**

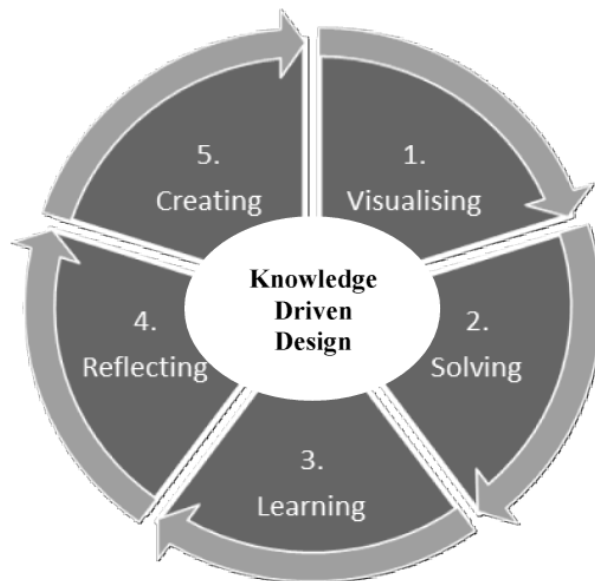
A possible scenario of used tools and enablers for the **Develop Concept Sets phase** of the SBCE model covers:

- A3 Problem Solving (A3 LAMDA): The A3 Problem Solving approach is to be used through concept development, system convergence, and detailed design phases of the SBCE process. There are several problem solving approaches already existing as shown in Table 2.

**Table 2: Table with comparison of different problem solving approaches**

The Features	Actions	Problem Solving Approaches					A3LAMDA
a) Visualise the necessary process and information to address the problem.	Visualising	A3	8D	PAF	RCA	5 Whys	
b) Present the generation and implementation of the solutions.	Solving			X	X	X	
c) Provide the process of the learning cycle for knowledge creation.	Learning	X	X	X	X	X	
d) Present the reflection from the lessons learned.	Reflecting	X	X	X	X	X	
e) Create useful knowledge concisely from those actions to be shared and communicated.	Creating	X	X	X	X	X	

The A3 thinking approach aims to solve design problems by providing a new A3 template (A3LAMDA) that supports knowledge-driven design (Figure 17) gathered from the integrated actions of visualising, solving, learning, reflecting and creating to aid the generation of lean product design (Figure 16). The idea is to encourage the designers to perform those actions by visualising the problem in order to create useful knowledge efficiently by using a new A3 template.



**Figure 16: Knowledge-drive design steps**

1. Visualising –this action uses a new A3 template provided from the A3 thinking approach to visualise the problem, solution and knowledge captured
2. Solving –this action solves the problem by following the elements provided by the A3 thinking approach sequentially structured and illustrated on a new A3 template
3. Learning –this action based on the LAMDA learning cycle guides its users on how to solve a design problem and to emphasize knowledge creation

4. Reflecting –this action is based on the term reflection which means to support the problem solvers in turning their experience or understanding both whilst and after solving the problems into proper learning

5. Creating –this action uses a new A3 report to represent the provision of the useful knowledge gained from the above actions to be shared and communicated

A3 thinking approach provides the A3LAMDA template for knowledge creation and problem solving which consists of the following ten elements:

- (1) Team
- (2) Background
- (3) Current condition
- (4) Future goal
- (5) Containment
- (6) Root-cause analysis
- (7) Proposed solutions
- (8) Implementation plan
- (9) Prevent recurrence, and
- (10) Follow-up action

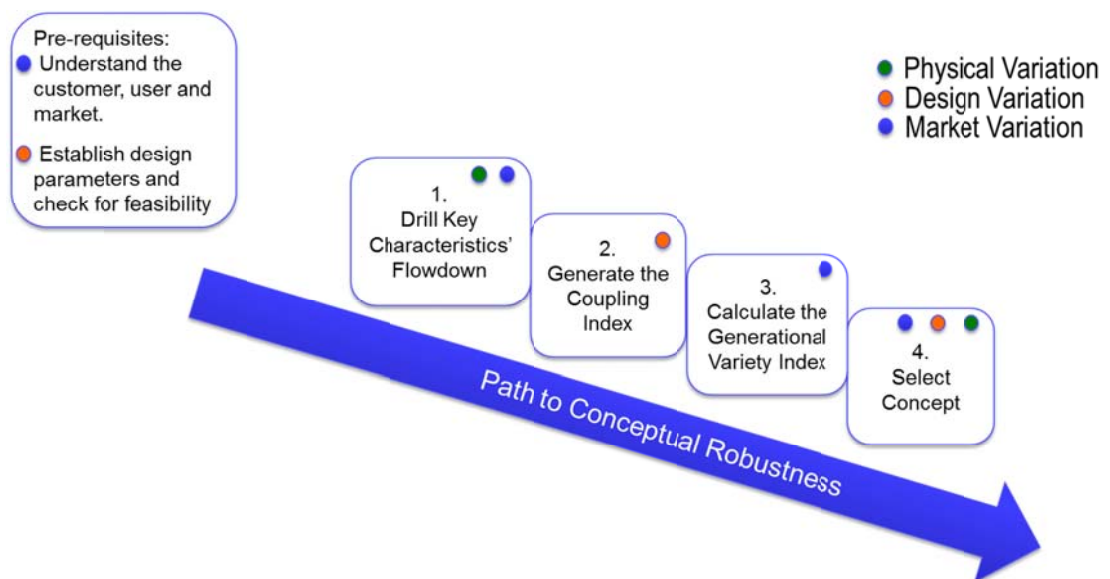
The implementation for all the elements is be guided by the LAMDA (Look-Ask-Model-Discuss-Act) learning cycle as a continuous improvement process as shown in Figure 16;**Error! No se encuentra el origen de la referencia.** The first step in the A3 thinking approach encourages the designers to perform the first (visualising), second (solving) and third (learning) actions in order to support knowledge driven design. Visualising the necessary information and solving the problem using the LAMDA learning cycle provides the useful knowledge to offer effective decision making for the future project in a knowledge-rich environment. However, at this step, the designers are also encouraged to reflect on their actions and represent it in the right columns in a reflection on action (ROA), which is explained in the end of this section. Second section is knowledge capture and sharing. The second section in the A3 thinking approach continues with the fourth and fifth actions as shown in Figure 16: reflecting and creating. These two actions aim at capturing the created knowledge after problem solving, and hence enabling such knowledge to be shared. The goal of the reflection section is to guide the problem solvers to take their first step in the A3 thinking approach, which is to represent their lessons learned. Hence, the creation of knowledge is measured efficiently; for example, why it is important, and by whom and when the knowledge should be used.

Figure 17 presents an example of an A3LAMDA template.



- **Seek Conceptual Robustness:** This tool is to be used through concept development and system convergence phases in the SBCE model. Robustness is defined as to offer stability in three forms of variation in product development: physical, design and market. Emphasizing on robustness as a means to shorten significantly development times and the ease of future developments (Sobek et al. 1999). Followed is the brief describing the three forms of variation:
  - Physical variation is depicted as that popularized by Taguchi, in which designs are functional with disregard to material wear, manufacturing variations or even weather changes.
  - Design variation goes in hand with the flexibility of concepts within the design team. This means creating designs that work well regardless of what the rest of the team decides to do.
  - Market variation refers to design susceptibility to changes in demand or competition. Therefore robustness can be generated by applying strategies to decrease this susceptibility, such as shorter development cycles, manufacturing flexibility and standardization. A design that can consider future changes in customer requirements or that can be sold to the clients in a short period of time will be less susceptible to market variation (Cabello et al., 2012).

Figure 18 presents the Seek Conceptual Robustness tool.

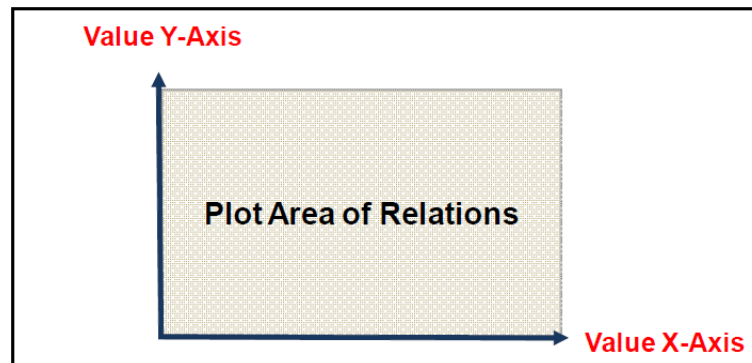


**Figure 18: Seek Conceptual Robustness**

After understanding the customers' needs and establishing the design parameters the following should be done:

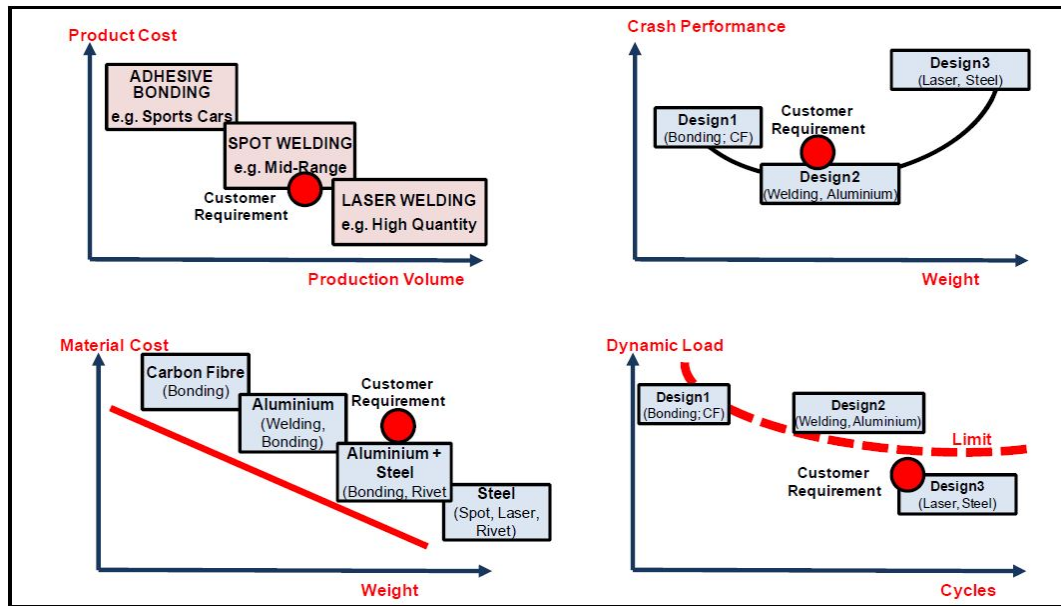
- Generate an overall view of the product, components and processes;
- Understand the relationship amongst components;
- Evaluate risk in the product;
- Mitigate as much as possible;
- Evaluate the product over future periods;

- Select the optimal design concept.
- Trade-Off Curves: Trade-off curves are to be used through system convergence phase in the SBCE Model. The technique is used to visually display multiple (3 max) design characteristics in one simple graph by plotting its relations as show in **Figure 19**. The creation of Trade-Off Curves has to consider basic technical principles in order to ensure their relevance. For example, the values for the X-Axis are in general used for values such as time, cycles, frequencies etc. The Y-Axis represents the values as a function of X, for example speed, torque, load etc.



**Figure 19: Basic principles of Trade-Off Curves**

The PD engineers' main objective is to design a product that fulfils the customer requirements. These requirements are usually provided to the PD engineers in forms of explicit specifications, such as performance, package and appearance. Mapping these customer requirements against the created TOCs, illustrated in Figure 20 as a red dot, will indicate the current capabilities to offer a potential design solution. However, a conflict between different TOCs is in reality unavoidable, which means that a number of potential design solutions can be extracted, each corresponding best to a certain customer requirement. As shown in Figure 20, in terms of product cost and production volume, spot welding is the most preferred method; on the other hand, with regards to crash performance and weight a previous design made from aluminium is preferred. The conflict arises in the fact that aluminium cannot be spot welded in an efficient way. The role of SBCE would be to narrow down these potential solutions and reach a final design.



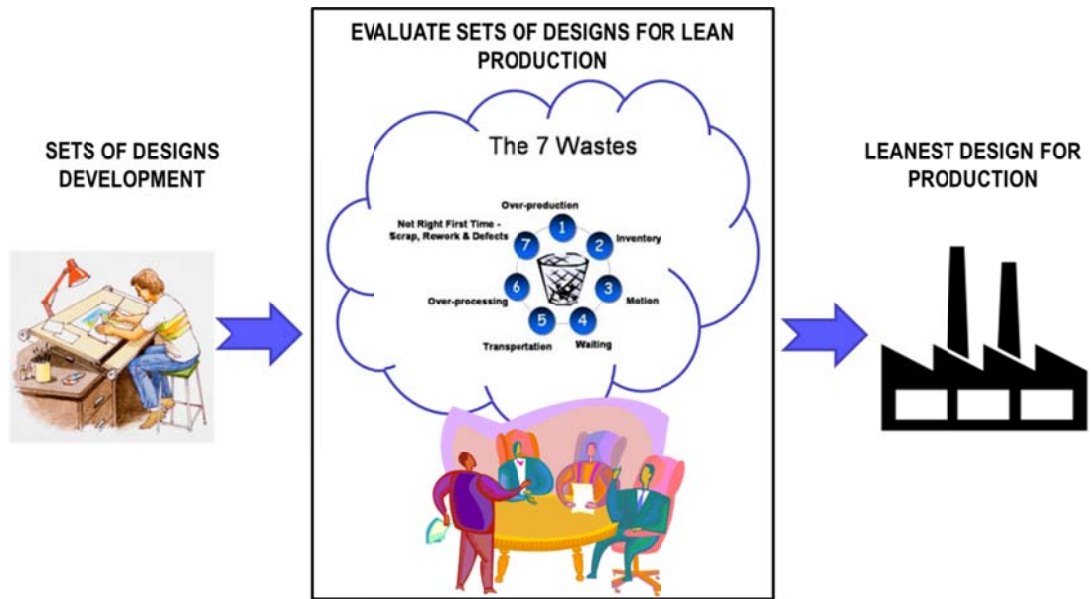
**Figure 20: Use of TOC in Product Design and Development**

In greater details Trade-Off curves were explored and described in D4.4 titled as Knowledge model and tool to support decision taking in SBLDT of the LeanPPD project.

A possible scenario of used tools and enablers for the **Converge on System and Detailed Design** phases of the SBCE model covers:

- Evaluate Sets for Lean Production methodology: this tool is to be used to illustrate how a set of designs can be evaluated against a lean manufacturing point of view. The methodology and the associated matrix help designers to evaluate different components/subsystems/products that satisfy customers'. This methodology has been designed to be implemented while the concurrency of product and process development is coming to its last steps; this means that the conceptual design of the sets and a preliminary idea of their manufacturing process have to be clear.

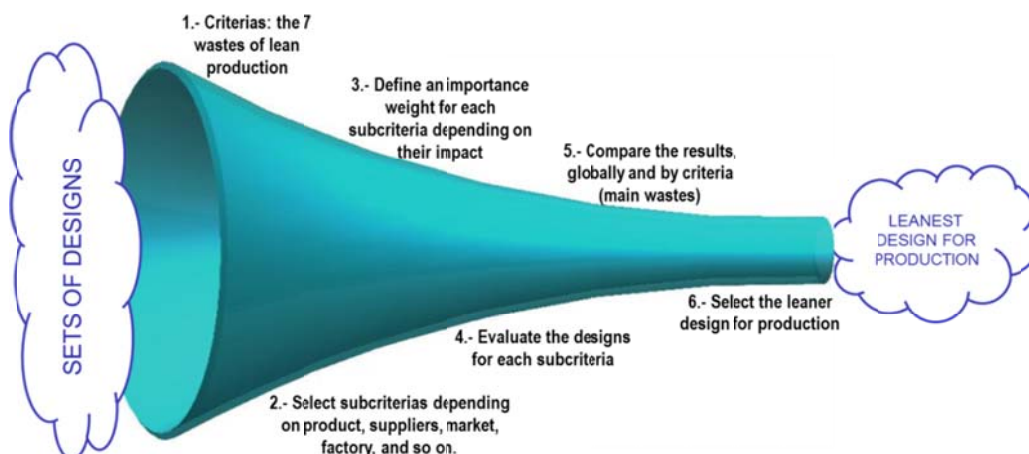
The approach of evaluating sets of lean design for lean production is illustrated in Figure 21. It is very important to establish an appropriate team. This team could vary for different enterprises but as a general team, the assistants should be: the chief engineer, the designers, manufacturing engineers, and sourcing engineers. The methodology is prepared to develop through an event (meeting); the duration of this meeting will take from 4 to 6 hours, depending on product complexity and the quantity of designs to be compared.



**Figure 21: Approach of evaluating sets of lean design for lean production**

The methodology measures the seven main wastes of each design during manufacturing process (Over-production, Waiting, and Transportation, Over-processing, Inventories, Movement and Making defective products). The process of evaluating sets of lean design for lean production can be seen in Figure 22. The steps are as follows:

1. Criteria: the 7 wastes of lean production
2. Select sub-criteria depending on product, supplier, market, factory, etc.
3. Define an importance weight for each sub-criteria depending on their impact
4. Evaluate the designs for each sub-criteria
5. Compare the results, globally and by criteria (main wastes)
6. Select the leaner design for production



**Figure 22: Process of evaluating sets of lean design for lean production**

Figure 23 shows the sections of the matrix for evaluating sets of lean design for lean production, and also the 30 sub-criteria inside the 7 criteria.

**CRITERIAS & IMPORTANCE WEIGHT FOR EACH DESIGN: SUBCRITERIA**  
**SUB-CRITERIAS & WEIGHT %**

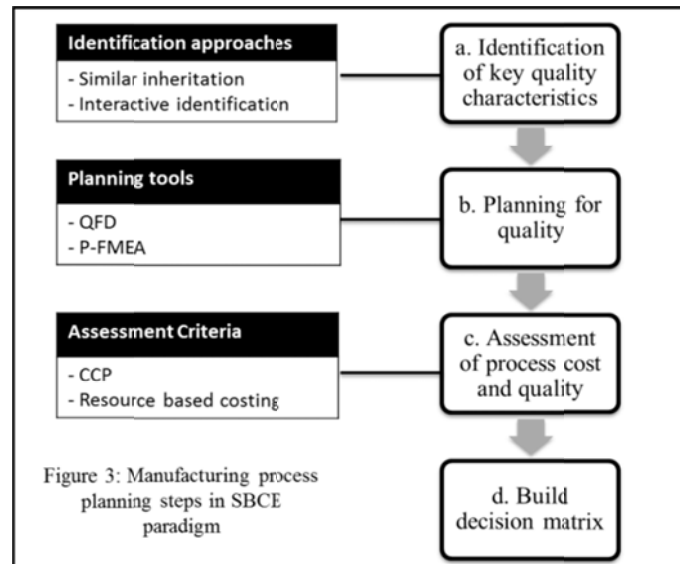
Motorcycle tires	Picture	EVALUATION & SCORE			
		Importance Weight	Design A	Design B	Design C
<b>Criteria to evaluate the designs</b>					
<b>Over Production</b>	↑	11%	4.3	6.3	7.0
* lack of documentation			0.47	0.69	0.77
* batches		4%	1.0	5.0	7.0
* pre-processes (long lead-time)		3%	5.0	7.0	7.0
* lack of reliability in processes		4%	7.0	7.0	7.0
<b>Waitings</b>		12%	6.0	6.5	5.0
* lack of materials		3%	7.0	7.0	3.0
* lack of documentation		3%	7.0	7.0	3.0
* huge variability in process times		3%	5.0	5.0	7.0
* a set-up necessary in machinery		3%	5.0	7.0	5.0
<b>Transportation</b>		6%	6.3	3.7	3.0
* strange shape to transport		2%	5.0	3.0	0.06
* high weight in batch container		2%	7.0	3.0	0.06
* difficult part manipulability		2%	7.0	5.0	3.0
<b>Over Processing</b>		15%	5.8	5.4	3.8
* inadequate raw material		3%	7.0	5.0	5.0
* excessive accurate dimensional tolerances		3%	5.0	5.0	3.0
* excessive accurate geometrical tolerances		3%	7.0	7.0	5.0
* inadequate operations sequence defined		3%	5.0	5.0	3.0
* inadequate machinery parameters defined		3%	5.0	5.0	3.0
<b>Inventories</b>		20%	7.0	5.0	5.4
* lack of standardization		4%	7.0	5.0	3.0
* lack of modularisation		4%	7.0	5.0	7.0
* high variability of parts in different references		4%	7.0	5.0	7.0
* high quantity of different parts		4%	9.0	5.0	5.0
* unbalanced workshops		4%	5.0	5.0	5.0
<b>Movement</b>		12%	5.7	6.3	5.0
* lack of automation		4%	5.0	7.0	5.0
* long distances among the needed cells		4%	7.0	5.0	5.0
* has subcontracted processes		4%	5.0	7.0	5.0
<b>Making Defective Products</b>		24%	5.9	5.6	3.6
* inadequate tools defined		4%	5.0	5.0	5.0
* inadequate machines		4%	5.0	5.0	3.0
* machines with an incorrect set-up		4%	7.0	5.0	3.0
* lack of poka-yokes		4%	7.0	5.0	3.0
* lack of virtual prototyping		2%	7.0	7.0	3.0
* lack of rapid prototyping		2%	5.0	7.0	3.0
* need of reviews		4%	5.0	5.0	5.0
<b>TOTAL</b>		100%	6.0	5.6	4.24

**Figure 23: Matrix of evaluating sets of lean design for lean production**

- Process planning for manufacturing: this tool is to be used to start Manufacturing Process Planning for SBCE process is shown in Figure 24. The methodology includes four steps:
  1. Identification of key quality characteristics for alternative set of designs
  2. Planning for process quality using an integrated Quality Function Deployment (QFD) approach and a Process Failure Mode and Effect Analysis (P-FMEA)
  3. Assessment of process quality and cost for each set of designs using CCP (composite process capability) index (Chin et.al. 2003)

4. Build a decision matrix relating conceptual design alternatives with respect to process-chain alternatives

The methodology is designed assuming that designers are following a SBCE paradigm, and have already explored alternative set of conceptual designs. Moreover, at the start of the methodology, process planners already have important elements of manufacturing process alternatives to produce the conceptual designs.



**Figure 24: Steps of the proposed methodology to start process planning for SBCE process**

### **LeanPPD Set of Communication Mechanisms**

Set of communication mechanisms tool is to be used during all phases of the SBCE Baseline Model. The Set of Communication Mechanisms is a tool to support companies in selection of the most appropriate communication mechanism(s) for their specific needs. An internet based simple-to-use decision support tool has been developed to fulfil this objective as shown in Figure 25.

The Communication Mechanism Box selection criteria are the following:

1. Mechanism was developed within LeanPPD or not (LeanPPD only)
2. Number of people
3. Timeframe
4. Type of teams
5. Team composition
6. Multi-language teams
7. Project phase (Start of project / scope definition, Concept Preliminary design, Development, Validation, Process assessment and improvement)
8. Time zone
9. Specific task (Business plan, Concept definition, Concept definition: Scope Definition and Establishing Functionality, Concept definition: Translate Product Requirements, Concept definition: Planning, Concept definition: Summarise Concept and pass it to the designers, Design Concept, Design: Calculate Cost for designed part, Visualisation of Different Products Concepts, Compare different alternatives, To design spot welding construction,

Describe Technical Specifications of a Product, Changing Process, Managing CAD Data, Time Progress, Development process assessment)

It is likely that the main benefits of the provided decision support tool will be a reduction of time and efforts needed to select the appropriate communication mechanism(s), as well as a reduction of lead time and costs in the product/process development by applying appropriate mechanisms to support communication within teams, etc. The developed decision support tool is open for further extensions, both in a direction of adding further communication mechanisms and in a direction of adding/modifying the selection criteria aiming to meet specific company's needs.

# Communication Mechanism Box

LeanPPD only      Multi-Language Teams  Yes  No  
 Number of people:       Project Phase:   
 Timeframe:       Time Zones:   
 Type of Teams:       Specific Task (if applicable):   
 Teams Composition:      

SMART Lean-T2 Readiness Tool	Lean-T2 Measurement Framework	VTWET tool	LeanPPD-PAT (process analysis tool)	Check sheets	KBE tool	Decision making support SW tool	Trade-off curves	Tool to decide on the level of innovation of sub-systems/components (PSD SS/CD)
Methodology to capture customer voice into set of designs	Value-added activities table	SBLD part history management tool	A3 problem solving template and approach	Design concepts matrix	Alignment PD strategy matrix	Product concept template	Business Plan template	Sub-system concept template
Design specification template	Enablers Implementation Requirements and Risk Analysis Template	Chief engineer's concept paper	Support for informal (experience based) knowledge sharing in collaborative environment (e.g. Wiki, Forum, social media)	Support for knowledge sharing in structured/Formal database system (e.g. PDM / PLM)	Communication tools for collaborative decision making including visual analytics	Knowledge modelling for sharing	Ontologies/folksonomies	E-Mail
Skype / ICQ / Chat / Messenger	Web conferencing tools (e.g. WebEx, Net viewer, etc.)	Blogging/Microblogging / Forum	Social Networks / Media	Team noticeboards	Digital Mockups / Virtual Prototypes	Physical Prototypes		

SBCE Baseline Model

■ most recommended  
■ recommended  
■ not recommended  
■ not applicable

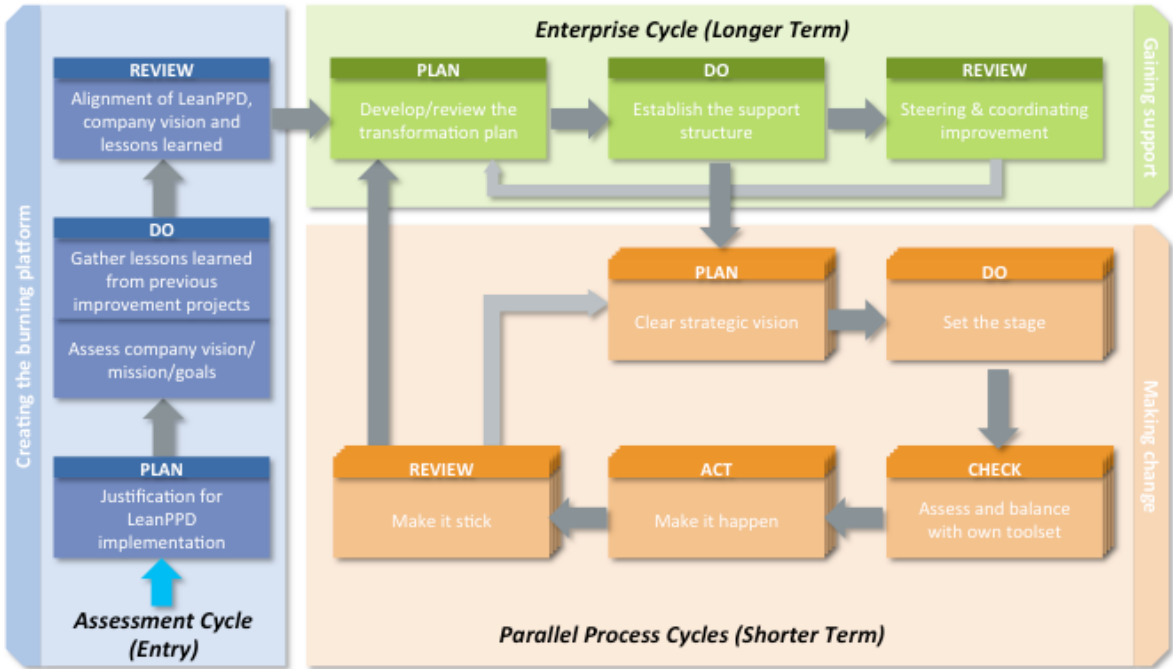
Figure 25: Set of Communication Mechanisms web based tool (source: Deliverable 5.2)

## Lean PPD implementation roadmap

The LeanPPD Implementation Roadmap brings together all of the elements of the LeanPPD project into a single, concise visual tool. Aimed at industrialists, the roadmap consists of a step by step process through which any team member can follow the concept of the LeanPPD project and the elements contained within it. There are many technology roadmaps successfully in existence but there are a limited number of lean implementation roadmaps. Five key texts discuss the advantages and design concepts that are used in the design of the LeanPPD roadmap. These range from the use of a simple Plan Do Check Act cycle to the use of a phased approach to implementation. Each method presented has aided in the development of the LeanPPD roadmap.

As 70-75% of change processes ‘fail’ the concept of change management is used within the roadmap. Elements used include the use of behavioural change through shaping and identifying and breaking down the workforce to understand who will be the key players (and resisters) to change.

The roadmap (Figure 26) is broken down into a top-level roadmap detailing three main sections to follow, namely: an assessment cycle, an enterprise cycle and parallel process cycles. This short, medium and long term split allows a company to obtain results whilst remaining focussed on the bigger picture. With the assessment cycle the focus is on understanding what is the current shape of the business compared to where they wish to get. The enterprise cycle ensures that full support is obtained and maintained throughout its on-going implementation. Finally, the parallel process cycles bear the brunt of the improvement process with full implementation of the LeanPPD tools and techniques. These parallel processes are broken down further into sub roadmaps, designed to assist companies who may be weak in some areas of the LeanPPD project.



**Figure 26: LeanPPD implementation roadmap – overview (source: Deliverable 5.4)**

This roadmap is intended for practitioners of the LeanPPD project and those who are interested in supporting and developing the tools that have arisen from the project. Whilst the tools are aimed at the manufacturing sector, the approach presented and the change management section apply to many people who are looking to implement a lean process of any format. By following the advice of the LeanPPD Implementation Roadmap, it is envisaged that businesses will more effectively reduce lead times, through the elimination of waste, and increase product/process robustness where a high level of customer value is attained.

## 5 Potential impact and the main dissemination activities and exploitation of results

The proposed project intended to create an innovative new production model beyond Lean Manufacturing based on a new lean thinking paradigm. Key concept of this new paradigm is innovatively shifting from “waste reduction” to “value creation” allowing manufacturers to change their strategic and product focus quickly in response to market trends and demands developing distinct core competencies to fulfil changing requirements.

LeanPPD expects to have a decisive impact on the productivity of the European industry in a two steps approach: i) Big OEM will use LeanPPD model and tools, will assimilate the new paradigm and ii) will expand the Model throughout the whole value chain including SME providers.

LeanPPD focused on three large industrial sectors (Automotive, aerospace and house appliances) covering in that way a higher portion of European industry. Successful implementation of the new system in these sectors through the 5 BCs has undoubtedly proved the validity of the research results.

Posterior wide scale application of the new model would allow a considerable leap forward to the European manufacturing industry in terms of productivity and added value. In particular, SMEs within the supply chain will largely get integrated into the LeanPPD System so achieving benefits as increased production capability, capacity and responsiveness, improved manufacturability as well as decrease in raw materials and energy consumption. Obviously, the complexity of the approach and the big impact of expected results make impossible to approach the project on a local or national basis but on the contrary it has to develop in a trans-national pattern.

As far as dissemination activities are concerned, since the beginning the project, many dissemination activities have been performed by the project partners, under the coordination of the WP leader. Hereafter, some of the numbers able to describe the performed activities:

- 48 papers presented at International Conference. 3 papers are under review for coming conferences.
- 10 papers have been submitted to International Journals. They are currently under review, at different stages (3 at a second stage, 7 at a first stage).
- 1 Special Issue has been launched, within the International Journal of Product Development. It will be available by the end of 2014.
- 10 publications have been published in commercial journals (mostly of them in Italy).
- 15 scientific events (special sessions, workshops, seminars) have been organised or co-organised. One of them will be executed after the end of the project.
- More than 30 lectures have been performed by the different RTD partners on the project topics. Approximately more than 400 students have been trained on the LeanPPD concepts.
- More than 20 M.Sc. students have debated their final assignments / thesis on LeanPPD subjects. 5 Ph.D. students debated (or will debate in the next months) their thesis on LeanPPD topics.
- 6 training workshops have been performed, involving also companies outside the consortium. More than 60 persons have been trained using the training kit developed in task 620.
- LeanPPD has been presented to more than 40 industrial events, at national and international level. Most of them have been specifically organised (or co-organised) by LeanPPD partners.

- LeanPPD has been presented to more than 100 industrial companies, with specific presentations and / or workshops.
- Some national industrial communities related to Lean Product Development are running quite regularly, in Italy, Spain, Switzerland and UK, supported by the LeanPPD partners.

A LeanPPD Newsletter has been created and it has been published 3 times so far. It is distributed through the project website and using LinkedIn social media. A dissemination kit (tagged bags, pens and USB keys) has been distributed to all the partners for marketing purposes.

Moreover a general dissemination is also made integrating the LeanPPD solution within the “road-show events” that are done regularly by SIS demonstrating their products in different cities of Spain. Furthermore, an important event for the marketing is the meeting of the ‘Users Club’ in the Technological Park of Bizkaia, where customers are made familiar with the recent products and services. SIS also demonstrates the LeanPPD solution out of Spain through its commercial network.

Tecnalia and SIS have contacted some Spanish Industries to disseminate LeanPPD project using the Lean Assessment Tool developed in the project. Action plans have been defined with the Lean Assessment Tool.

Regarding exploitation of results, the consortium began to define LeanPPD results’ typology and their readiness level. In a second step the exploitation strategy of each LeanPPD Partner was defined and the consortium agreed to create an Exploitation Consortium. This Exploitation Consortium defined an Exploitation Plan and the potential customer search and identification has been initiated.

The LeanPPD has been a 4 year R&D project where researchers and industrial partners have worked together in order to develop a new model based environment to support value creation to the customers in terms of innovation and customisation, quality as well as sustainable and affordable products, The project proposal was to develop novel set-based lean design tools that ensure the concurrent consideration and development of lean product design as well as it associated lean manufacturing system.

The user driven approach has been ensured with the five business cases (BS) provided by the end-users from the different sectors of the industrial partners in the consortium. The BCs have served to derive requirements upon the tools, methodologies and models developed and also will help exploitation activities after the end of the project. The benefits obtained by the implementation of LeanPPD results prototypes in these industries are the key for capturing potential customers’ interest.

The initial proposal has been successfully obtained by the end of the project in month 48. There have been develop several results, some of them as methodologies, other as IT tools and other for games as training material. The list of LeanPPD results are listed below:

ID	WP	Exploitable Results
<b>METHODOLOGIES</b>		
1	400	Methodology to generate Trade-off curves
2	300	LeanKLC Methodology
3	200	PD-VM Methodology
4	500	SBCE Process

<b>5</b>	400	Lean Design Guidelines
<b>6</b>	500	LeanPPD Implementation Methodology and Risk Analysis Tool
<b>7</b>	500	LeanPPD Implementation Roadmap
<b>IT TOOLS</b>		
<b>8</b>	300	KBE
<b>9</b>	200	VIWET
<b>10</b>	100	Lean-T <sup>2</sup> SMART Readiness Tool
<b>11</b>	200	Lean-T <sup>2</sup> Measurement Framework
<b>12</b>	200	Process Analysis Tool
<b>13</b>	400	SBCE SW tools - Knowledge Management
<b>14</b>	400	SBCE SW tools - Decision Support
<b>15</b>	400	Communication Mechanisms Box
<b>GAMES</b>		
<b>16</b>	600	MyWaste (Game)
<b>17</b>	600	LeanPPD Game (Game)
<b>18</b>	600	SBCE Game
<b>19</b>	600	LeanAirTronix (Game)
<b>MODEL</b>		
<b>18</b>	600	Lean PPD model

According to the Exploitation strategy, partners are committed to exploit internally and externally to the Consortium the Lean PPD results. The main objective of the exploitation task is the joint of exploitation agreements among partners including a full Business Plan for those partners who will have turnovers in a future with its exploitable results. This information is organised in an Exploitation Plan. In order to cover the whole European market, vendors in other regions can be identified and agreements with them can be also signed if required.

Once the units of analysis were decided and the global Business Models scenario established, the LeanPPD project offering needs to be confronted with the main benefits provided by each Exploitable Result mentioned above and outlines a basic offering made of a logical sequence of them all. The following offerings have been decided by the partners as value propositions:

### **Offering 1: Basic LeanPPD Workshop**

The Management and Dissemination of a Professional Workshop (initially in Switzerland and Spain), hereafter referred to as “Basic LeanPPD Workshop” or BLW (with a subscription fee) for the dissemination of the Lean Product and Process Development concept at a basic level.

Tecnia and SIS would be in charge of disseminating and organising these BLW in Spain, while EPFL would organise them in Switzerland.

The BLW will consist of:

1. A first introductory explanation of the Lean PPD Model. CU would provide, at least during the first year of the post Exploitation strategy, free documentary support and, depending on the case, in-presence support of Dr.Ahmed Al-Ashaab and/or people from his team (travel and accommodation costs to be covered by the Workshop organisers).
2. A Webex connection in which one of the LeanPPD consortium industrial partners (VISTEON) will provide a first-hand testimony of the benefits that the Lean PPD approach can provide for companies.
3. A brief explanation/demo of the main features of the Lean T2 SMART Readiness Tool (as a “hook”) to conduct interested companies towards EPFL through the Lean Analytics Association). EPFL would provide basic information on the Tool for the seminar.
4. A summary presentation of the available Games and eventually the practice with one of them (if they can be used online) as a first introduction for those attendants willing to use these games within their company as part of their own awareness-raising process towards the LeanPPD concepts and benefits. POLIMI would provide both a summarised information on the games and the hosting of basic informative content about them on an specific website.

#### Sharing of generated income

The income generated by these BLWs will be shared among partners according to their dedication and their ownership rights through a % scheme to be discussed among the post Project Exploitation Committee partners. The specific figures of the % scheme will be reflected in the Transfer of Rights Agreement.

#### Follow-up and Capitalisation

- Part 1 of the BLW:
  - Companies and Organisations especially interested in deepening their knowledge of the Lean PPD Model would be forwarded to Cranfield University to receive a Full, high level LeanPPD Workshop.
- Part 3 of the BLW:
  - Companies interested in being assessed by the Lean T2 Smart Readiness Tool would be forwarded to EPFL, which would implement and, at the same time, offer them the possibility of becoming members of the Lean Analytics Association.
  - Workshop organisers (TEC, SIS) bringing leads to EPFL which finally receive the Lean T2 SMART Readiness Tool Services and/or become LAA members will be given a 15% commission.
  - ATB would collect all the data from potential customers and actual LAA members and will put them available for the post Project Exploitation Committee partners.
  - The diagnosis provided by the Lean T2 SMART Readiness Tool will derive on an action plan to improve specific processes in the companies. EPFL would recommend partners in the consortium (SIS) to implement the improvements derived from the action plan within their companies. The result of this service would provide business

back to other partners (i.e. SIS and CU) by means of recommending them consultancy partners in the LeanPPD philosophy.

- If any potential customer being derived from EPFL to SIS and/or CU wish to receive a more detailed consultancy service beyond the scope of the Exploitable Results selected for this first iteration, the post project Exploitation Committee would meet and agree a second iteration including new Exploitable Results to be incorporated to the offering.
- Part 4 of the BLW:
  - Companies interesting in using the Games inside their companies as part of an Awareness Raising process prior or in parallel with the implementation of the LeanT2 SMART Readiness Tool will be offered the second redirected to partners SIS and POLIMI to offer them an in-house training/practice activity (see offering 2).

### **Offering 2: In-house training activity through LeanPPD Games**

A customised game session will be hosted by the interested company and conducted by SIS and/or POLIMI.

#### Contents

1. The session will consist in the setting up of a gaming activity with the customer company real data. A prior preparatory workload will have to be considered to customise the game session to the company data and specificities. The amount of workload dedicated to this task will be accounted for in terms of income sharing (see next point).
2. In the medium term it would also be desirable to generate enough income to produce an off-line “table version” of the games.

#### Sharing of generated income

The income generated by these “gaming sessions” will be shared among partners according to their dedication and their ownership rights through a % scheme to be discussed among the post Project Exploitation Committee partners. The specific figures of the % scheme will be reflected in the Transfer of Rights Agreement.

#### Follow-up and Capitalisation

Should anyone potential customer being derived from the BLW to SIS and/or POLIMI wish to receive a more detailed consultancy service beyond the scope of the Exploitable Results selected for this first iteration, the post project Exploitation Committee would meet and agree a second iteration including new Exploitable Results to be incorporated to the offering.

### **Offering 3: Provision of interactive learning content for Universities and Business Schools**

An interactive learning set of tools that will be offered to Business Schools and Universities.

#### Contents

The offering would consist in the setting up of a gaming activity for University and/or Business School students (in groups no bigger than 20) with realistic company data to learn and raise awareness

of the importance of Lean Product and Process Development issues. A prior preparatory workload will have to be considered to customise the game session to a learning environment. The amount of workload dedicated to this task will be accounted for in terms of income sharing (see next point).


#### Sharing of generated income

The income generated by the provision of this learning content will be shared among partners according to their dissemination efforts, their workload dedication to the adaptation of the course, and their ownership rights through a % scheme to be discussed among the post Project Exploitation Committee partners. The specific figures of the % scheme will be reflected in the Transfer of Rights Agreement.

#### Follow-up and Capitalisation

Dissemination of this training content will be made by partners interested. Should anyone potential University of Business Schools is interested in having access to some other offering beyond the scope of the Exploitable Results selected for this first iteration, the post project Exploitation Committee would meet and agree a second iteration including new Exploitable Results to be incorporated to the offering.

## 6 LeanPPD details: contact details and address of the project website

<b>Acronym</b>	LeanPPD 																																							
<b>Title</b>	Lean Product and Process Development																																							
<b>Research area</b>	NMP-2007-3.1-1 Beyond Lean Manufacturing – New Industrial Models for Product and Process Life Cycle Technical content / scope																																							
<b>Call ID</b>	FP7-NMP-2007-Large Collaborative Project																																							
<b>Project ID</b>	214090																																							
<b>Project Costs</b>	7.658.978€																																							
<b>Commission Funding</b>	5.266.800€																																							
<b>Duration</b>	48 months (01/02/2009 - 31/01/2013)																																							
<b>Project Coordinator:</b>	<p>Dr. Mikel Sorli</p> <p>Fundacion Tecnalia Research &amp; Innovation  Parque Tecnológico de Miramón, Paseo Mikeletegi, 2  20009 Donosti, Gipuzkoa, Spain - <a href="http://www.tecnalia.com">www.tecnalia.com</a>  Tel: +34 946 400 450 (Ext. 614849)  <a href="mailto:mikel.sorli@tecnalia.com">mikel.sorli@tecnalia.com</a></p>																																							
<b>Project website:</b>	<a href="http://www.leanppd.eu">www.leanppd.eu</a>																																							
<b>Project partners:</b>	<table border="1"> <thead> <tr> <th>Beneficiary name</th> <th></th> <th>Country</th> </tr> </thead> <tbody> <tr> <td>Fundación Tecnalia Research &amp; Innovation</td> <td><b>TECNALIA</b></td> <td>ES</td> </tr> <tr> <td>Cranfield University</td> <td><b>CU</b></td> <td>UK</td> </tr> <tr> <td>Rolls-Royce</td> <td><b>R-R</b></td> <td>UK</td> </tr> <tr> <td>University of Warwick</td> <td><b>WARWICK</b></td> <td>UK</td> </tr> <tr> <td>Institut für angewandte Systemtechnik Bremen</td> <td><b>ATB</b></td> <td>D</td> </tr> <tr> <td>Volkswagen AG</td> <td><b>VW</b></td> <td>D</td> </tr> <tr> <td>Ecole Polytechnique Fédérale de Lausanne</td> <td><b>EPFL</b></td> <td>CH</td> </tr> <tr> <td>Visteon Engineering Services Ltd</td> <td><b>VES</b></td> <td>UK</td> </tr> <tr> <td>SISTEPLANT</td> <td><b>SIS</b></td> <td>ES</td> </tr> <tr> <td>Politécnico of Milano</td> <td><b>POLIMI</b></td> <td>I</td> </tr> <tr> <td>Indesit</td> <td><b>INDESIT</b></td> <td>I</td> </tr> <tr> <td>SITECH Sp. So. o.</td> <td><b>SITECH</b></td> <td>PL</td> </tr> </tbody> </table>	Beneficiary name		Country	Fundación Tecnalia Research & Innovation	<b>TECNALIA</b>	ES	Cranfield University	<b>CU</b>	UK	Rolls-Royce	<b>R-R</b>	UK	University of Warwick	<b>WARWICK</b>	UK	Institut für angewandte Systemtechnik Bremen	<b>ATB</b>	D	Volkswagen AG	<b>VW</b>	D	Ecole Polytechnique Fédérale de Lausanne	<b>EPFL</b>	CH	Visteon Engineering Services Ltd	<b>VES</b>	UK	SISTEPLANT	<b>SIS</b>	ES	Politécnico of Milano	<b>POLIMI</b>	I	Indesit	<b>INDESIT</b>	I	SITECH Sp. So. o.	<b>SITECH</b>	PL
Beneficiary name		Country																																						
Fundación Tecnalia Research & Innovation	<b>TECNALIA</b>	ES																																						
Cranfield University	<b>CU</b>	UK																																						
Rolls-Royce	<b>R-R</b>	UK																																						
University of Warwick	<b>WARWICK</b>	UK																																						
Institut für angewandte Systemtechnik Bremen	<b>ATB</b>	D																																						
Volkswagen AG	<b>VW</b>	D																																						
Ecole Polytechnique Fédérale de Lausanne	<b>EPFL</b>	CH																																						
Visteon Engineering Services Ltd	<b>VES</b>	UK																																						
SISTEPLANT	<b>SIS</b>	ES																																						
Politécnico of Milano	<b>POLIMI</b>	I																																						
Indesit	<b>INDESIT</b>	I																																						
SITECH Sp. So. o.	<b>SITECH</b>	PL																																						