Solution concept and Technology value chain

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1. Solution concept and technology value chain objectives

Partners collaborate in an innovation project because they are not able alone to design a specific innovation that exhibits the desired value to its potential customers. The innovation involves mobilising knowledge, technologies and know-hows that are not concentrated within a single pair of hands. Consequently, different classes of actors, often led by the main beneficiary from the innovation, decide to collaborate to design and prototype the innovation up to a certain level of maturity.

In an innovation project, it is mandatory to clarify what are the different technologies involved, how they complement each other's and how they deliver functional capabilities. One key objective is also to clarify how these functional capabilities generate value differentiation regarding existing solutions. Without value differentiation your innovation has no chance to reach the market! A state-of-the-art (SotA) analysis must be conducted as well as an identification of the scientific challenges raised by the integration. It is mandatory to perform the analysis in advance, before submitting a project proposal to avoid working on challenges that have already been solved, or not involving the appropriate partners or the right technology providers, or working on an innovation which has no real value differentiation.

Two main assets allow capturing and analysing what will be engineered in the project and how it will be done:

- The solution concept <u>captures in a synthetic way the vision shared by the partners of the solution</u> that will be assembled and experimented during the project and the rationale for it.
- The technology value chain <u>captures the way the partners intend to collaborate during the project to elaborate the targeted solution</u>. The description of the technology value chain occurs once the solution concept is defined; it extends the description of the solution concept, identifying the challenges raised by the solution concept that must be addressed during the project execution and capture the approach to tackle them.

It is clear that a solution concept is not in any means an intangible vision of what a project intends to experiment during the project. A research project may encounter difficulties of many different natures: partners leaving the project, scientific challenges more difficult than expected to solve or that would involve extra effort or extra knowledge not adequately represented in the consortium etc. Therefore, the consortium must admit that the solution concept is a vision that may evolve during the project lifetime; it reinforces the need to capture the solution concept because the project needs to maintain a shared understanding of what is experimented and what is its value. In this context, one benefits of the solution concept is to maintain that shared understanding.

When preparing a project, the solution concept should be captured upfront and then the technology value chain should be designed based on it.

In the next section we will first clarify what is a solution concept, and then we will describe how a technology value chain should be designed for it and how it relates to the solution concept.

2. Solution concept design

2.1. An easy start

A solution concept is a cohesive abstract representation of a project's innovation allowing reasoning on the different issues raised in the previous section. E.g. a drawing can be used as a free form representation of the solution concept design. Using a drawing does not cause extra burden of learning a notation, of its semantic and fighting to apply it to the current problem. The intent of the drawing is to be a starting point explaining how the combination of technologies, collectively build an entity which implements an innovation.

To enable reasoning, a solution concept drawing must fulfil several characteristics:

- A solution concept represents an entity which exhibits a consistent unique capability of value from the perspective of a user that is either a human being or something integrating or interacting with it.
- The solution concept may be material or immaterial like a car or a loan, can be of any complexity ranging from system of systems, down to system, equipment, component or device, like a car or a knife. It can be either active, exhibiting behaviour like a PC game or passive like a fork. However, for all these examples, these entities deliver a consistent unique promise to its user: a capability to transport people, increase immediate buying capability, cut things, entertain people or eat in a clean way.
- The technologies which are at the core of the innovation and that are brought or evolved by the project's partners should be easily identified and outlined in the abstract representation. These technologies may be software, hardware, processes, algorithms, data repositories, metamodels or whatever plays an essential role in the delivered innovation. Such technologies include obviously the elements which are necessary for delivering the innovation and understanding the overall consistency of the solution concept, even there will not be any specific research on those elements.
- The interfaces between the different technologies should be identifiable in the description of the solution concept. These interfaces may be immaterial such as software interfaces or functions exhibited by materials, or material such as material interfaces or mechanical interfaces. The interfaces need to expose how functions are expected to be delivered to other parts of the design by key technology elements from the solution concept.
- The organisation of the involved technologies of the solution concept should allow understanding how the unique capability provided by that solution concept is delivered.

In the following we will show two examples of solutions concepts drawings.

The first example stands in the Model Based Engineering domain.

Figure 1 represents a software adapter technology whose unique capability is to allow interfacing model-based design environments to timing analysis tools.

As design environments and analysis environments do not share the same semantic for graphical notations, there is a need to transform design models into timing analysis models aligned with the semantic of analysis tool models. For that purpose, the adapter is structured around two key components:

- A transformation engine whose role is to transform models from one semantic to another one,
- A pivot model which integrates both semantics from the input design model and from the timing analysis model into a single intermediate representation.

The transformation engine is a generic tool using transformation rules which define for a specific couple of input metamodel and output metamodel how the transformation must be realized.

A graphical editor complements the adapter allowing the design of analysis models from scratch when they cannot be obtained from a design tool.

Figure 1 represents the whole set of transformation steps allowing the projection of a specific design environment model into a specific timing analysis environment. A first transformation allows the import of the design model (input model) into its corresponding representation in the pivot model (on the figure, the left part of the pivot model). The second transformation occurs on the pivot model itself: the design model is transformed into an analysis model which contains all the necessary elements with the timing semantic allowing a specific analysis tool to perform an analysis (on the figure, the right part of the pivot model). This is called *Semantic Gap Resolution.* The last transformation takes as input the right part of the pivot model to generate the right output format for the analysis tool (output model). The Model Based Design (*MBD) / Analysis Adapter Framework* is the generic part of the solution concept, while the Import and Export technical elements are the domain specific adapters to the modeler and timing analysis tool: Reference (3) and (4) in Figure 1.

The second example stands in the computing domain.

Figure 2 represents a multicore processor where each individual core is represented by a tile. Tiles can be associated to parts of a reconfigurable area (FPGA) where a computing accelerator can be configured at run-time.

A resource and monitoring computing layer manage the allocation of the accelerators onto the reconfigurable area depending on the software code needs.

A Kernel and virtualisation layer exhibit a computing capability to a virtual code-mixing standard code to be executed on the tiles and accelerator specific code to be executed on specific accelerators.
A compiling tool chain complements the processor with generation capacity both for the code to be executed on the tiles, the code to be executed on the FPGA and the bit stream which configures the FPGA area to make dedicated accelerators.

Both solution concepts describe 1) what are the roles and what is the organisation of the technology components of the solution concepts, 2) what are the functions provided by the inner building blocks to the other parts of the solution concept and 3) what are the interfaces between the various parts involved.

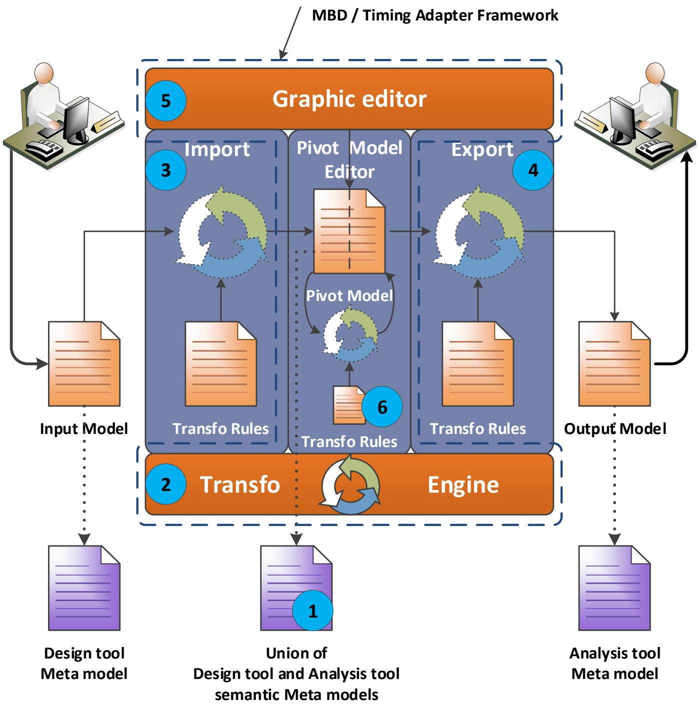

Figure 1 Solution concept of a timing analysis adapter

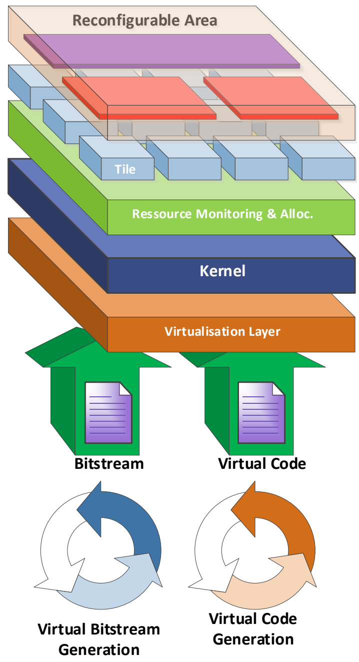

Figure 2 Solution concept of a multicore processor with reconfigurable accelerators

A solution concept is not only captured by a free style graphical representation; the drawing is just a very practical support for discussion and reasoning, but it has also to be captured in a more formal way in order to reveal how the technical elements of the proposed concept are linked to the value generated from the end user perspective. This is an important step because value description is a key information to steer the project:

- It allows comparing the innovation at stake with the competition.
- It allows reasoning and monitoring on how the value can be affected by adverse events during the lifetime of the project: 1) when partners have to leave the project, 2) when technological choices are part of the project and may impact that value generated or 3) when scientific challenges cannot be solved as expected.

It is almost impossible to explain directly how a set of technical elements collectively provide a tangible value to an end user, essentially because technical elements cannot be perceived by an end user. Technical elements are perceived through the functions which are delivered by them and then, by exercising several functions, several <u>essential properties</u> of the innovation of value from the perspective of the end-user can be generated. Therefore, capturing the value of a solution concept occurs in two steps: first by a functional analysis, and second by a value analysis. Of course, the analysis is not just one way. It should be conducted in bilateral manner in order to revisit the functions and technical elements when the value expressed does not provide satisfaction or cannot be traced back from functions and technical elements.

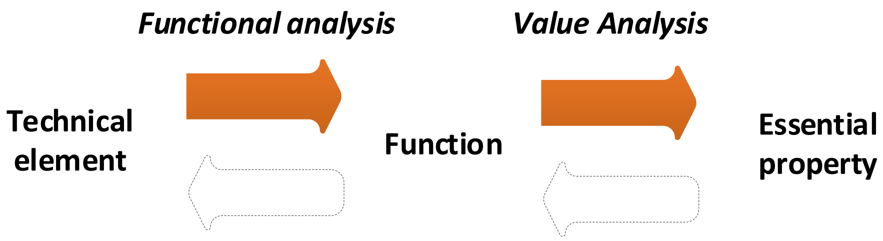

Figure 3 Linking technical elements with essential properties

2.2. Functional Analysis capture

To support capturing the corpus of information for functional analysis, we make use of Suh matrix[1]; Suh matrix have been widely used to support functional analysis through decades and fits very well to our purpose. Suh matrices allow capturing:

- The identification of the technical elements of the solution concept: As already mentioned, the core inner technical elements involved in the delivery of the functions of the solution concept must be identifiable in the solution concept picture. The solution concept is considered here as a white-box for that perspective.
- The identification of the functions produced by combinations of technical elements. A function is a visible elementary utility from the perspective of a higher order user entity (end-user, hosting system etc.)
- The identification of which technical elements contribute to which functions by using traceability links. I.e. technical elements of the solution concept which allow exhibiting the functions.

In a Suh matrix, the columns capture the functions of the solution concept while the lines correspond to the technical elements of the solution concept. The cells of the matrix contain a cross or arrow whose semantic is to identify the set of technical elements which are the contributors to the production of a function of the solution concept.

E.g. in Figure 4, the “Technical element 1” is contributor of the “Function 1” and “Function 3”and “Technical element 2” contributes to the “Function 1” and “Function 2”. “Function 1” is delivered by a combination of “Technical element 1” and “Technical element 2”. etc.

	Function 1	**Function 2**	**Function 3**
Technical element 1	↗		↗
Technical element 2	↗	↗	
Technical element 3			↗

Figure 4 Suh Matrix

[1] Nam P. Suh, MIT professor in the 90s’: The Principles of Design, based on theory of Axiomatic Design. Suh's approach proposes an after-the-fact evaluation of particular solutions. It provides criteria for ideal technical systems from the point of view of the designer and the user.

The below Figure 5 shows an example of a Suh matrix for the solution concept of the timing analysis adapter presented before.

	Function / Technical Element	Timing analysis adapter: Editor of temporal Performance model	Design model import	Temporal analysis model export	Semantic Gap Resolution	Timing semantic configurability
1	Metamodel + semantic for pivot model	↗	↗	↗	↗	
2	Transformation Engine		↗	↗	↗	↗
3	Import: Importer lib + extension from design tool		↗			
4	Export: Exporter lib + extension for analysis tool			↗		
5	Graphical editor: Graphical edition pluggin + extension for pivot model edition	↗				
6	Transformation rules of pivot model editor: Transformation semantic rule package from input MM to output MM + execution order				↗	

Figure 5 Technical element → Function Suh Matrix of the timing analysis adapter

2.3. Value Analysis

Suh matrix can be used in a hierarchical way to support the Value Analysis task. We will use it by capturing the causality links between functions and essential properties.

The following Figure 6 describes how the two Suh matrixes connect each other's:

Value Analysis	Essential property 1	Essential property 2	Essential property 3
Function 1			↗
Function 2	↗		↗
Function 3		↗	↗

Functional analysis	Function 1	Function 2	Function 3
Technical element 1	↗		↗
Technical element 2	↗	↗	
Technical element 3			↗

Figure 6 Relationship between Suh Matrixes

In the value analysis Suh matrix, the elements are:

- The functions which are the elementary utilities visible from the perspective of an end-user.
- The essential properties which are defined from the end-user perspective as tangible benefits delivered by the solution concept. The essential properties are associated to the entire solution concept. It is worth to note that essential properties can be in different types: functional and non-functional. Performance, cost quality, manufacturability, safety etc. are all valid essential property types.
  Identifying the essential properties of a solution concept is not a trivial task. As a rule of thumb, you should consider that you have identified and formulated an essential property when you ask yourself:
  - Is this essential property a benefit of using the solution concept? Does it have a value for the end-user?
  - Does this benefit differentiate the solution concept from existing solutions or existing practices?

  If the answer is “Yes” for both questions and you are able to formulate a convincing explanation to clarify why “Yes”, then you have defined an essential property on its own right.

It is of utmost importance that all the important essential properties are clearly identified since they are elements that will convince the readers of the value of the project proposal, but more importantly you will be in a position to discuss with your marketing department about the business value of your proposed innovation with regard to their strategies. Also, the set of essential properties should allow being compared to what the competition propose in terms of essential properties. Therefore, you should be able to formulate what the unique selling proposition of your solution concept is in a very direct manner.

However, value generation is not only a technology question; it has also to do with business models, selling models, supply strategies, legal constraints etc. We must understand that we are focusing here only on value generated from technology, not from external environmental decisions and choices.

The below Figure 7 illustrates what could be the Value analysis matrix of the Timing Analysis adapter example.

	Essential property / **Function**	**Timing analysis adapter**				
		Needless training on Timing analysis	Automatic production	Errorless temporal design	Genericity & Flexibility	Configurability to design environments and analysis tools
1	Editor of temporal performance model				↗	
2	Design model import		↗			
3	Temporal analysis model export		↗			
4	Semantic Gap Resolution	↗	↗	↗		
5	Timing semantic configurability				↗	↗

Figure 7 Function → Essential property Suh Matrix of the timing analysis adapter

3. Technology value chain design

Once the concept of solution has been formulated, the second step is to identify the challenges - technical or scientific- which are raised and that must be studied and tentatively solved during the project occurrence. These challenges must be studied in a specific order because some results may impact the scope of the work for other challenges to be solved or just because the work follows an integration approach. The objective of the technology value chain is to capture this web of dependencies in a synthetic way for all the project technical activities.

A technology value chain diagram is a partially[2] oriented graph where each node of the graph represents a project activity that targets a particular technical or a set of technical elements of the concept of solution. Activities occur in a certain order which means that some activities depend on the results from others. The graph captures all the technical activities that must be performed in order to address the scientific and technological challenges raised by the solution concept. Dependencies between activities must be captured, which means that at the end, we generate a graph where all activities are linked together by a web of connections.

The Figure 8 represents the kind of technology value chain that we can design for a solution concept. In Figure 8, we choose some possible constructions which are allowed for a technology value chain. We will discuss later the consistency with the solution concept.

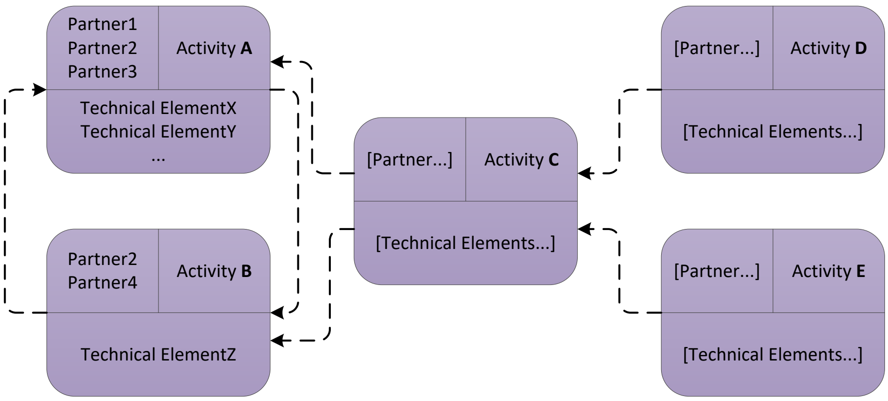

Figure 8 A technology value chain diagram

Each node of the diagram describes an activity along with the following attributes:

- The name of the activity,
- The list of partners which are involved in the activity,
- The list of technical elements forms the solution concept on which the activity applies. For consistency purpose, it is important to note that one should take care that the technical elements referenced in the technology value chain must be the ones defined in the Suh

[2] In graph theory, to make it simple, partially oriented graphs have a top, a bottom but there may be cycles between elements of the graph.

matrices of the solution concept. If not, it would introduce confusion and ambiguity to the project.

Note: The scope of the activities which are captured in the Technical value chain are only technical while in the project there are additional activities to be handled which are necessary but are not technical at all such as dissemination, project management and so on.

Note: The activities of a technology value chain map correspond to the work packages of a project's workplan very nicely. To keep the project manageable, the number of activities should not reach ten. Four to six activities should be common values for the number of activities.

For what concerns the connections between activities:

- The dependency between two activities is represented by a dash arrow. For example, Activity C depends on Activity A and Activity B. A dependency does NOT capture timing information as is the case in a PERT chart. In a PERT chart, the arrow is orientated from the ending activity to the starting activity, so it is orientated in the opposite way as for a dependency graph. In the dependency graph, it does not mean that the activity which depends on another one should start AFTER that activity ends. It can start DURING the execution of the activity on which it depends. However, a technology value chain provides a lot of information that can be used to build a PERT, a Gantt chart or a WBS (Work Breakdown Structure).
- Some activities may be interlinked both ways as it can be seen between Activity A and Activity B. This means that some knowledge acquired during the exercise of the two activities needs to be exchanged for the interlinked activities to complete. This is also another difference compared to a PERT chart as in a PERT chart this type of circular dependency is not allowed.

The diagram of the technology value chain is not a standalone representation. It must be completed by a textual description. Each activity needs to be described with 1) what is the partners purpose in the activity execution, 2) what is the goal of the activity, 3) what are the specific challenges raised by this activity with regard to the state of the art and 4) how they relate to the different technical elements which are mentioned in the activity node.

In Figure 9, the timing analysis adapter technical value chain diagram is displayed, showing six activities where all the project's partners are involved. All the technical elements are the ones that are uniquely identified in the Suh matrix, thus insuring there is no ambiguity between the solution concept structure and the approach for the project execution.

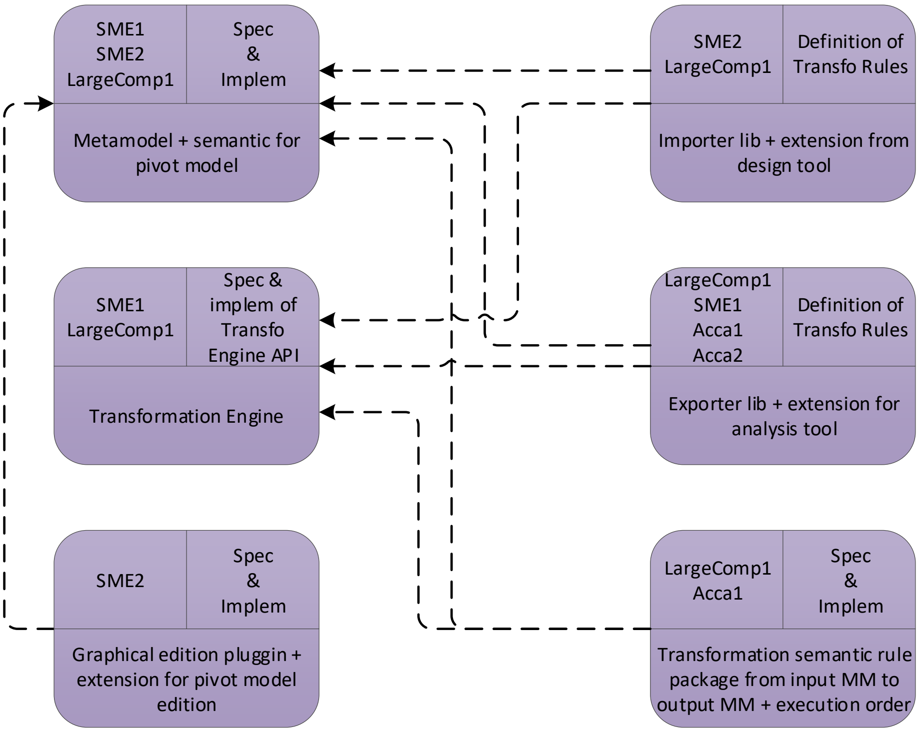

Figure 9 Technology value chain diagram of the timing analysis adapter

To complement the technology value chain diagram, each activity could be described by following the document template proposed here bellow:

Activity name:	<Name>		
Activity goal:	<Goal description>		
Technological / scientific challenge:	<Challenge description>		
Involved technical elements:	<List of technical elements from the solution concept>		
Partner name:	<Name>	**Partner purpose in the task:**	<Description>
Partner name:	<Name>	**Partner purpose in the task:**	<Description>
Partner name:	<Name>	**Partner purpose in the task:**	<Description>
…			

Figure 10 Template for describing an activity from the technology value chain

4. Implementation rules

ITEA projects are labelled through a two-stage process. The two stages help consortia optimising their effort for building meaningful projects that exhibit true innovation and finding their ways to markets.

During the PO phase the priority is to be as clear as possible on these two aspects:

- What is the innovation?
- What will be the future offers delivered to market(s) from the results of the project?

Thus, the PO objective is to clarify the WHAT.

The FPP objective is to clarify HOW the consortium intends to proceed to generate the innovation and prepare it for market adoption. This includes, activity organisation and dependencies, effort allocation, and detailed activities description that on can in the work packages descriptions.

Therefore, different representations should be delivered during the PO and at FPP phases. The following Figure 11 clarifies this.

	Free style graphical representation & explanation	**Functional Analysis + Value Analysis Matrix & explanations**	**Technology value chain**	**Activity description**
PO	√	√		
FPP	Revised version (If necessary)	Revised version (If necessary)	√	√

Figure 11 Call implementation rules

Video instruction link

https://vimeo.com/455766939