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Strategical and multidisciplinary steering of aeronautical projects on the basis of shared value model and innovation process

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présentée par
Ndrianarilala RIANANTSOA

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***Strategical and multidisciplinary steering of aeronautical
projects on the basis of shared value model and innovation
process***

***Pilotage stratégique et multidisciplinaire de projets
aéronautiques, basé sur un modèle de valeur et de processus
d'innovation intégré***

soutenue le : 12 juin 2012

devant un jury composé de :

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Référence : 2012ECAP0026

DEDICATION

*“To my parents
and all my family
for encouraging me
to pursue my dreams
for so long
and
far from home”*

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EXTENDED SUMMARY

Developing a new commercial aircraft has mainly been driven by *technological findings and performances*. The primary objectives of new program development have above all been the achievement of the *aircraft mission* (i.e. range, cruise speed and passengers capacity), the respect of the *certification rules*, and the minimization of the *aircraft costs* (i.e. operational costs for the customers, industrial costs for the manufacturer). All of these objectives contribute to the *strategy of mass production* in the civil aviation industry, and are well supported by *engineering and technological domains*. Today, the globalized competition between the aircraft manufacturers leads to a change of the new aircraft development strategy: a strategy combining *mass production* and *product customization* is required. Indeed, it is a necessary *transformation* to adapt to the *business landscape* evolution. At first, *a wider variety of customers needs, business models and business strategies* has now to be taken into account. For instance, the range of customers includes nowadays banks or financial organizations, leasing companies, private jet operators, charters, freight operators, and aircraft services providers. The airlines can adopt low cost or highly differentiating strategies. New customers come from the emergent countries and present new types of needs: it corresponds to new constraints and missions due to their geographical location (i.e. environmental and weather constraints), and due to the specificities of their air traffic demands (i.e. density and volatility of passengers...). At second, *new competitors* from the emergent countries have to be faced up in the civil aviation market. There is then a greater worldwide challenge of being the most *competitive and differentiating*. The *highest added values* have to be ensured to the stakeholders, in comparison with the competitors, and from the beginning of any new aircraft development program. Nevertheless, this fundamental request of differentiation should not trigger off high *industrial costs and risks*. The *technological maturity* of the aircraft has to be well managed through its all development process. It is as much important as the *development cost, lead time, and the reliability of the aircraft* depend on this factor, and have a great impact on the manufacturer brand image and performances. Therefore, the innovation process has to be well steered by both the *business and market value* (i.e. market pull approach) and by the *technological findings and performances* (i.e. technology push approach). At the preliminary phase of an aircraft development program, there is a need of defining the pertinent *innovation strategies* that ensure both *high value creation* to all stakeholders and enough *aircraft architecture maturity*. Such strategies have to be explored and built by *multidisciplinary teams* in a collaborative way (i.e. Marketing, Engineering, R&T, Business Management,...). A methodology is needed to support these teams for their common understanding, sharing, and exploration of their multidisciplinary knowledge, for their convergence and decisions on aircraft strategies and architectures. A systematic integration of the Business and Engineering related domains would then permit to specify *robust aircraft technical definitions* at the beginning of any new development program. It appears to be now a prerequisite in the aviation industry, for the *industrial cost and risk minimization*, and for the *success of the innovation launches* on the market.

Two kinds of scientific literatures have been analyzed to deal with this industrial issue. Both of them describe methods and tools dedicated to the management of the *Fuzzy Front End* stage, or the preliminary stage where the *business and engineering challenges* have to be explored and stated. The first one is related to the management approaches of the *Strategic Marketing* domain. The second one gives an insight on the *Conceptual Design* approaches.

Strategic Marketing approaches aim at defining strategies to struggle against external threats, stay competitive in the market, and capture value for the organizations. In this domain, *Innovation Marketing* methods consist in delivering products that create *higher values* to the customers than the competitors. They tend to maximize the *capacity of differentiation* of the products and services in comparison with the traditional ones. Different methods are suggested to make business and market analysis, and formulate marketing strategies. They are broadly based on the analysis of *internal forces* and *weaknesses* of the organization (i.e. BCG matrix, SWOT matrix, Porter Value Chain), and of the *external opportunities* and *threats* on the market (i.e. PESTEL analysis, technological benchmark, trends analysis). The definition of the marketing strategy has to be deduced from such analyses, and elicit the value objectives of a program: specification of the stakeholders to be satisfied, the market segments to be targeted, the value types to be brought, and the means to be activated. This task is implemented at the *Product Planning stage* of the *New Product Development Process*. The challenge at this stage is to generate *innovative and differentiating* business models and strategies. The *Blue Ocean Strategy* is one of the interesting approaches to be analyzed for this purpose since it supports well the exploration of *new business* that go *outside the box*, or beyond the *market boundaries*.

At the beginning of the Design Engineering process, the *Conceptual Design* stage aims at supporting the *systematic design* of *architectural solutions*. The Conceptual Design begins with the specification of *formal design problems*: this task is helped by several methods based on product functions description (i.e. functional analysis, FAST diagram, NIST and SADT diagram). It consists then in generating, representing and analyzing *design solutions*: several methods of generation (i.e. brainstorming, morphological analysis, mind mapping, Triz), of formalization (i.e. sketches, 2D/3D modeling, And-Or graph) and of design choices (i.e. Prométhée, Analytical Hierarchy Process) are suggested to support this activity. The Conceptual Design methods are first of all dedicated to the *design engineers* to support their daily tasks, which deliver the product requirements, technical definitions and architectures. The Conceptual Design is also the phase for selecting the *relevant technologies* to be introduced into the future product, which are developed by the parallel R&T process. The challenge of the Conceptual Design is the synthesis of product architectures that have to be robust for the whole *New Product Development Process*. The *technological concepts* must be robust in terms of *maturity* and *value creation*, to ensure the success of the *innovation process*.

The analysis of the state of the art shows that the *Product Planning* and *Conceptual Design* stages are partially achieved in the preliminary phase of a development project. It increases the probability of generating *poor value creating and unfeasible* product strategies and

concepts. Indeed, most of the methods and tools suggested in the literature help in building links and connections between these stages in a *transaction mode*: only partial information on the business value and the technological maturity is exchanged from one stage to the other, or between the Business team and the Engineering team. In other words, the models described in the state of the art represent a collaboration between the multidisciplinary teams on the basis of *iterative and customer/supplier interactions*. Such interactions are characterized by *raising conflicts* between the objective of maximizing *the product value* in the Product Planning stage, and the objective of maximizing *the product technological maturity* in the Conceptual Design stage. From the literature proposals, it is then quite difficult to ensure the definition of *robust product architectures* at the end of the preliminary phase both for the Product Planning and Conceptual Design stages.

The purpose of our research work consists in supporting a more efficient integration of the *Product Planning* and *Conceptual Design* stages. Our methodological proposal, called *Concept-to-Value (CtV)*, is based on a *KPS-Value* model for *Problem, Solution and Knowledge*. At first, this model permits to establish *a common language* in the preliminary phase, which can be used to describe and formalize *multidisciplinary generated elements*. Through this language, it is then possible to explore, capture and share *Business and Engineering Knowledge, Problems and Solutions*. At second, the *KPS-Value* model allows to deploy *a system of metrics and evaluation protocols* that aims at assessing the *level of maturity* of the multidisciplinary teams. This level of *collaboration maturity* depends on the evaluation of the multidisciplinary generated elements through developed metrics: the level of *completeness*, of contribution to *value creation*, of contribution to *differentiation*, and of *convergence*. At third, the *KPS-Value* model is implemented through *an integrated process* in four main steps: *primary knowledge acquisition, value drivers and features analysis, value strategies analysis, and architectural solutions steering*. The originality of the *CtV methodology* relies on the harmonious combination and implementation of innovation approaches, such as: the *knowledge based design*, the *reflexive design* that exploits *design artifacts* representation, the *CK Theory*, and the *Radical Innovation Design*.

The *CtV methodology* is applied on three industrial test cases: exploration of new concepts of systems installation, understanding the contribution to differentiation of laminar wings technologies, and exploration of aircraft reconfigurations.

The *first case* illustrates the integrated exploration of Business and Engineering knowledge, and the way they are exploited to define common strategies and concepts. Existing tools are used for knowledge acquisition and rationale capture, such as: *Trizacq* tool, also named STEPS (developed by researchers of LGéCo of INSA Strasbourg and commercialized by Time-To-Innovate); *DReD* platform (a tool for design rationale capture developed by researchers of Cambridge Engineering Design Center). An Excel tool is also developed to support the evaluation of the value contribution and completeness of the multidisciplinary exploration.

The *second case* permits to deploy the methodology with the support of other methods of knowledge acquisition such as the *functional analysis* and the *systemic approach*. It permitted to illustrate the identification of the *differentiating drivers* of a technology, and the evaluation of its contribution to *differentiation* against the competitors. Different *technological strategies* are also suggested and assessed, with some *recommendations* on the knowledge to be acquired to maximize the value creation.

The *third case* experiments the methodology for the specification of *systems options packaging* for airlines. It consists in validating some optional suggestions and exploring new ones that really create value and are relevant for different *airlines profiles*. Besides, *various stakeholders* have to be taken into account like the airport, the staff and crew, and the suppliers. With the involvement of multidisciplinary teams, the outputs of the test case correspond to proposals of *innovative business strategies*, *identified relevant technologies*, and *new technological research areas*.

Throughout these three test cases, the CtV methodology deployment has brought different types of *industrial added values*. At first, its application has allowed to enrich the exchanges and knowledge sharing between the multidisciplinary teams. At second, it has reinforced the expansion of knowledge and exploration of innovation opportunities. At third, it has enhanced the convergence between the multidisciplinary views. Finally, at fourth, it has strengthened the reactivity of the multidisciplinary teams on the different proposals of strategies and solutions. Practically, new types of generic ways of thinking, methods and tools are deployed and to be further developed on EADS innovation projects. Some *prototypes of collaborative tools* are then suggested and tested for the support of the CtV methodology deployment. The potential further research works consist in establishing the links between the CtV methodology outputs, and existing methods and tools deployed in latter stages of the development process. The exploitation of the CtV results by more quantitative approaches of value analysis in the product detailed design phase represents one of the future research axes.

RESUME ETENDU

Les projets de développement d'avions civils sont surtout pilotés par les *performances technologiques*. Les objectifs premiers consistent à assurer la *mission de l'avion* (comme le rayon d'action, la vitesse de croisière et la capacité), le respect des *règles de certification*, et la *minimisation des coûts*, tels que les coûts opérationnels et industriels. Tous ces objectifs visent au final à la réalisation d'une *stratégie de production de masse* technologique, et sont bien supportés par les techniques d'optimisation issues de *l'Ingénierie-Produits*. De nos jours, la compétition mondiale entre les constructeurs aéronautiques amène à un changement de stratégie : passer à une stratégie combinée de *production de masse* et de *personnalisation*. C'est une transformation stratégique nécessaire pour s'adapter à *l'évolution du marché aéronautique*. Tout d'abord, une plus grande variété de *besoins opérationnels*, de *modèles* et de *stratégies d'affaires* voit le jour. Par ailleurs, de *nouveaux concurrents* provenant des pays émergents sont d'autant plus à considérer qu'ils acquièrent de plus en plus de part de marché. Il est donc primordial dans ce contexte d'être suffisamment *compétitif* et *différenciant*. Il est nécessaire d'assurer une *création de valeur ajoutée* suffisante pour toutes les *parties prenantes* d'un projet d'innovation, par rapport à la concurrence, tout en maîtrisant les *risques inhérents*, tels que la maturité technologique, les coûts, les délais et la sécurité. Le *processus d'innovation* doit être piloté de manière descendante par la *valeur perçue* réellement par les clients, et de manière ascendante par *les performances des technologies disponibles*. Dans les phases amont des projets, des stratégies efficaces de *création de valeur* et de *maturité technologique* doivent être identifiées conjointement par des équipes pluridisciplinaires regroupant le Marketing, le Programme, l'Ingénierie, la Recherche et la Production. Une méthodologie est nécessaire pour aider ces équipes à partager leurs connaissances, à explorer de nouvelles voies d'innovation et à converger vers des concepts à la fois robustes et différenciant.

Ce contexte industriel a amené à analyser deux types d'approches dans la littérature scientifique, dédiées à la gestion de la phase préliminaire d'un projet d'innovation. Le premier relève du domaine du *Management Stratégique*. Le deuxième concerne les approches de *Conception Conceptuelle*.

Le *Management Stratégique* regroupe des méthodes et outils permettant aux organisations de définir des stratégies pour rester compétitives face aux différentes menaces du marché, et capturer de la valeur. Dans ce domaine, le *Marketing de l'Innovation* aide à la définition de produits créateurs de *valeurs supérieurs* à ceux des concurrents. De ce fait, l'objectif est d'accompagner la définition et le déploiement de *stratégies de différenciation* dans les projets de développement. Différentes méthodes et outils sont suggérés pour analyser le marché, le contexte économique, les forces et faiblesses, les risques et opportunités des organisations, et pour formuler des stratégies marketing. Ces stratégies décrivent des objectifs de création de valeurs pour un programme: spécifications des parties prenantes à satisfaire, des segments de

marché visés, des différents types de valeurs à apporter, et des moyens à activer. Cette tâche est mise en œuvre dans la phase dite de *Planification Produit* du *Processus de Développement de Nouveau Produit*. Le défi consiste dans cette phase à générer des stratégies et modèles d'affaires suffisamment *innovants et différentiant*. La *Stratégie Océan Bleu* est l'une des approches analysées dans la littérature permettant d'explorer de *nouvelles stratégies* en dehors des frontières traditionnelles des produits, des services et du marché.

Au début du processus d'*Ingénierie de la Conception*, la phase de *Conception Conceptuelle* consiste à définir des *architectures de solutions*. Elle commence par la spécification formelle de *problèmes de conception* des produits et services, à travers leurs descriptions fonctionnelles. Des *solutions de conception* sont alors générées, représentées et analysées. Différentes méthodes de génération (comme le brainstorming, l'analyse morphologique, Triz et les cartes cognitives), de représentation (comme les sketches, la modélisation 2D et 3D, les graphes en ET et OU), et de prise de décision (comme les méthodes Prométhée et AHP) sur des concepts de solution sont implémentées au cours de cette phase. Ces méthodes sont surtout dédiées aux *ingénieurs en conception* pour faciliter leurs activités de définition des *exigences et des architectures* des produits. Le défi de la *Conception Conceptuelle* est de parvenir à la synthèse de *concepts architecturaux* suffisamment robustes en termes de *maturité technologique* et de *création de valeurs*.

L'analyse de la littérature montre que la *Planification Produit* et la *Conception Conceptuelle* ne sont que partiellement intégrées dans les phases amont des projets d'innovation. Cela augmente la probabilité de générer des stratégies et concepts *irréalisables, trop ambitieux* ou *peu différentiant*. En effet, la plupart des méthodes et outils de la littérature n'établissent des connexions entre ces deux approches que suivant un *mode de transaction* : les informations sur la valeur et la maturité technologique ne sont pas traitées intégralement, et sont transmises de manière partielle entre les deux équipes responsables, dites de « *Business* » et d'« *Ingénierie* ». La collaboration entre ces équipes est surtout basée sur *des interactions itératives*, entre *clients et fournisseurs*. De telles interactions suscitent un conflit entre l'objectif de maximiser la *valeur du produit* définie dans la *Planification Produit*, et l'objectif de maximiser la *maturité technologique du produit* évaluée dans la *Conception Conceptuelle*. Par cette intégration partielle, la littérature ne permet pas ainsi d'assurer des *concepts de produits* suffisamment *robustes* en termes de *Preuve de Valeur* et *Preuve de Concept* dans les phases amont des projets d'innovation.

Le but de ce travail de recherche consiste à définir une méthodologie pour mieux intégrer la *Planification Produit* et la *Conception Conceptuelle*. Notre proposition nommée « *Concept-to-Value* » (CtV) est basée sur un modèle « *KPS-Value* » décrivant les *Connaissances*, les *Problèmes*, les *Solutions* générées dans un projet d'innovation, ainsi que leurs *valeurs* respectives. Ce modèle permet d'établir un langage commun dans la phase préliminaire d'un projet, pour décrire et formaliser des *livrables de conception* pluridisciplinaires. A travers ce langage, il est alors possible pour les équipes « *Business* » et « *Ingénierie* » d'explorer, de capturer et de partager leurs *Connaissances*, *Problèmes* et *Solutions*. Par ailleurs, le modèle « *KPS-Value* » permet aussi de déployer un *système de métriques* et de *protocoles*

d'évaluation dédiés à l'évaluation de *la maturité de la collaboration* entre les équipes. Le niveau de maturité dépend de l'évaluation des *objets intermédiaires de conception*, générés collectivement, à travers des métriques telles que : le niveau de *complétude*, de contribution à la *création de valeur*, de contribution à la *différentiation*, et de *convergence*. Enfin, ce modèle est mis en œuvre dans *un processus collaboratif et intégré* composé de *quatre étapes* : *acquisition primaire de connaissances*, *analyse des leviers de valeurs et des composants technologiques*, *analyse des stratégies de valeurs*, et *pilotage des solutions architecturales*. L'originalité de la méthodologie CtV vient de la combinaison efficace d'approches en Management de l'Innovation, telles que la *Conception basée sur les Connaissances*, la *Conception Réflexive*, la *Théorie CK* et la méthodologie « *Radical Innovation Design* ».

La méthodologie CtV est appliquée sur trois cas d'étude industriels dans l'aéronautique. Le premier consiste à explorer de nouveaux concepts d'installations de systèmes d'avion. Le deuxième vise à comprendre la contribution à la différenciation des technologies d'ailes laminaires. Enfin, le troisième correspond à l'exploration de concepts innovants de reconfiguration d'avion.

A travers ces cas, le déploiement de la méthodologie CtV a apporté différents types de *contributions industrielles*. Son application a permis d'enrichir les échanges et partages de connaissances entre les équipes pluridisciplinaires. De plus, elle a renforcé l'expansion des connaissances et l'exploration de nouvelles opportunités d'innovation. Par ailleurs, elle a accentué la convergence entre les différentes vues pluridisciplinaires. Enfin, cette méthodologie a amélioré la réactivité des équipes de projets face aux diverses propositions de stratégies et solutions. D'un point de vue pratique, de nouveaux types de raisonnements, de travaux collaboratifs et d'outils ont été générés et déployés au sein d'EADS. En perspective, les futurs travaux de recherche peuvent porter sur l'établissement de liens entre les résultats de la méthodologie CtV, et les méthodes et outils existants déployés dans les phases plus détaillées du processus de développement. En vue de raffiner progressivement le pilotage par la valeur, une exploitation plus quantitative des résultats de déploiement de la méthodologie CtV ouvre sur de nouveaux axes de recherche.

TABLE OF CONTENTS

1	Introduction to the industrial issue	20
1.1	From Design-to-Weight to Design-to-X management in the detailed design phase of aeronautical projects.....	20
1.2	From Design-to-X management in the detailed design phase to value management in the preliminary design phase.....	22
2	A Research-Action approach for actual changes in aeronautical innovation projects.....	25
2.1	The conjoint collaboration between industrial and academics research centers	25
2.2	The challenging demand of new industrial process, methods and tools definition for value management.....	25
2.3	The Research-Action protocol.....	26
2.4	The Research-Action means and tasks	27
3	Airbus practices analysis: inefficient integration of the Business and Engineering in the preliminary phase of complex aeronautical projects.....	31
3.1	The growing complexity of innovation management in aeronautical projects	31
3.1.1	The traditional practices: the technology push by the Engineering team	31
3.1.1.1	Engineering requirements and architectures definition by the Design team 31	
3.1.1.2	New technologies development by the R&T team	34
3.1.2	The evolutionary practices: enhancement of the value management by the Business team.....	36
3.1.3	The contradictions between the Business and Engineering teams objectives....	37
3.1.4	The uncertainty in a distributed process of decisions.....	39
3.2	The weaknesses and challenges of the collaborations between the Business and Engineering teams	39
4	State of the Art analysis: unsuccessful integration of the Product Planning and Conceptual Design stages in the innovation process	42
4.1	Description of the innovation challenges in organizations.....	42

4.2	Description of the preliminary phase of the innovation process, the Fuzzy Front End stage	43
4.3	Description of the Product Planning stage	46
4.4	Description of the Conceptual Design stage	47
4.5	Partial integration between Product Planning and Conceptual Design stages	48
4.6	Lack of systematic and integrated steering of Knowledge, Problems and Solutions in both stages	49
5	Description of the CtV methodology for systematic and integrated steering of the Product Planning and Conceptual Design stages	52
5.1	A Value based model for Knowledge, Problem and Solution representation, integration and analysis (KPS-Value model)	52
5.1.1	The Value based Knowledge model (K-Value model)	53
5.1.1.1	A model for multidisciplinary knowledge requests representation	53
5.1.1.2	A model for Business knowledge representation	55
5.1.1.3	A model for Engineering knowledge representation	57
5.1.1.4	A model for Engineering and Business knowledge integration and evaluation	57
5.1.2	The Value based Problem model (P-Value model)	61
5.1.2.1	A model for integrated business and engineering problems representation	61
5.1.2.2	A model for integrated business and engineering problems analysis	61
5.1.3	The Value based Solution model (S-Value model): a model for architectural solutions representation and assessment	63
5.2	Four steps process for systematical steering of Knowledge, Problems and Solutions (CtV process)	65
5.2.1	Global description of the CtV process	65
5.2.2	First step: primary knowledge acquisition	68
5.2.3	Second step: Value Drivers and Features analysis	69
6	Comparison of the Concept-to-Value methodology with the solutions of the state of the art	90

6.1	Value management of innovation: a value-based top-down and bottom-up approach	90
6.2	Innovation intermediate objects representation and value management.....	90
6.3	Innovation expansion: value-based steering of explorations.....	92
7	Case studies implementation.....	94
7.1	The initial perimeters of CtV implementation.....	94
7.2	The criteria for CtV implementation analysis	97
7.3	Systems Installation case study	101
7.3.1	Formulation of the initial project statement	101
7.3.2	Implementation of the CtV process.....	101
7.3.2.1	Primary knowledge acquisition.....	101
7.3.2.2	Value drivers and features analysis.....	103
7.3.2.3	Value strategies analysis	110
7.3.3	Evaluation of the CtV methodology implementation	120
7.4	Laminar wing technology case study	123
7.4.1	Formulation of the initial project statement	123
7.4.2	Implementation of the CtV process.....	123
7.4.2.1	Primary knowledge acquisition.....	123
7.4.2.2	Value drivers and features analysis.....	124
7.4.2.3	Value strategies analysis	126
7.4.3	Evaluation of the CtV methodology implementation	126
7.5	Aircraft reconfiguration case study	128
7.5.1	Formulation of the initial project statement	128
7.5.2	Evaluation of the CtV methodology implementation	129
8	Industrial validation of the Concept-to-Value methodology.....	131
8.1	Definition of the validation protocol	131
8.2	Presentation of the results.....	132

8.2.1	Convergence characteristics	132
8.2.2	Trends characteristics	135
8.2.3	Medium characteristics	138
9	The Concept-to-Value methodology as a response to a benchmark of today expectations on innovation management	141
9.1	Description of the objectives and protocol of the industrial benchmark	141
9.2	Description of the main conclusions of the industrial benchmark	142
10	General conclusion	144
11	Personal publications	147
12	References	148
13	Annex	155

TABLE OF FIGURES

Figure 1: DtX deployment in A350 program	22
Figure 2: From Design-to-X to Concept-to-Value management	23
Figure 3: A/C missions positioning: range VS capacity	31
Figure 4: A/C development process	32
Figure 5: Examples of A/C global and local architectures.....	33
Figure 6: Traditional A/C preliminary design process.....	33
Figure 7: TRLs process for new technologies development	35
Figure 8: The concurrent works of the Business and Engineering teams	38
Figure 9: Weaknesses in the current interactions between the Business and Engineering teams	40
Figure 10: From iterative process to co-innovation and agile collaboration.....	41
Figure 11: The Value based KPS model	52
Figure 12: The Value based K model.....	60
Figure 13: The Value based P model	63
Figure 14: The Value based S model	65
Figure 15: The four steps of CtV process	67
Figure 16: Three different entry points into the CtV pro	96
Figure 17: CtV test cases positioning.....	97
Figure 18: 5 Tizacq modules for knowledge acquisition	103
Figure 19: Direct influences matrix	107
Figure 20: The influences on the value dimensions of independent drivers (white) and selected ones (yellow).....	110
Figure 21: Graphical representation of the contributions of strategies on each dimension ...	114
Figure 22: Completeness degrees of strategies (blue) and selected drivers (red) for the airline	114

Figure 23: Completeness degrees of strategies (blue) and selected drivers (red) for the manufacturer.....	114
Figure 24: Global completeness degrees of strategies (blue) and selected drivers (red)	115
Figure 25: Value contributions of the strategies to the manufacturer	115
Figure 26: Value contributions of the strategies to the airline	115
Figure 27: Value contributions of the strategies to the stakeholders	115
Figure 28: Example of visualization of the rationale based on selected drivers elicitation ...	116
Figure 29: example of rationale describing the value chains from a driver to a value dimension	117
Figure 30: Synthesis of the CtV process results.....	119
Figure 31: The developed Excel based tool for CtV process support	122
Figure 32: Laminar wings and turbulent wings	123
Figure 33: Stakeholders value dimensions and business drivers	125
Figure 34: Distributions of participants answers on convergence characteristics (%).....	134
Figure 35: Distributions of participants answers on trends characteristics (%).....	137
Figure 36: Distributions of participants answers on medium characteristics (%).....	140

LIST OF TABLES

Table 1 : DtX approach VS CtV approach.....	24
Table 2: The Research-Action protocol	30
Table 3: Top Level A/C Requirements	32
Table 4: Knowledge requests model	54
Table 5: Examples of stakeholders, customers descriptors and profiles.....	70
Table 6: Types of relations between the Business and Engineering elements.....	71
Table 7: Example of semi-quantitative assessment of the relations.....	72
Table 8: Criteria of assessment of CtV methodology implementation	100
Table 9: Characterization of knowledge requests	102
Table 10: Examples of parameters with their corresponding subjects.....	104
Table 11: Examples of parameters with their corresponding types	104
Table 12: Examples of parameters with their corresponding levels	105
Table 13: Examples of parameters with their corresponding domains	105
Table 14: Examples of qualified influences between parameters	106
Table 15: Stakeholders value dimensions	108
Table 16: Examples of independent Value Drivers	108
Table 17: Examples of contributions of the independent drivers (the selected ones are in yellow).....	109
Table 18: Definition of the value strategies	111
Table 19: Value contributions and completeness degrees of Value Strategies.....	113
Table 20: Convergence characteristics.....	135
Table 21: Trends characteristics.....	137
Table 22: Medium characteristics	140

ACRONYMS

CtV	Concept-to-Value
KPS model	Knowledge Problem Solutions model
A/C	Aircraft
TLARs	Top Level Aircraft Requirements
DtX	Design-to-X
DtC	Design-to-Cost
DtW	Design-to-Weight
Wt	Weight
NRC	Non Recurring Cost
RC	Recurring Cost
R&T	Research and Technology
TRL	Technology Readiness Level

1 Introduction to the industrial issue

1.1 From Design-to-Weight to Design-to-X management in the detailed design phase of aeronautical projects

The development of new airplanes in Airbus has been above all led by *technological performances*. From the mission statement on the range and the capacity, the development of a new aircraft has been mainly driven by *weight objectives*. *Design-to-Weight* (DtW) methodologies and tools were developed and deployed in Airbus to support the *weight convergence* between several engineers working on different domains (i.e. avionics, power supply, wings, fuselage, cabin, landing gear...). DtW is also dedicated to manage the collaboration with the *Airbus suppliers*. It consists in steering and reporting the aircraft weight evolution: a *weight convergence plan* is defined for all the design actors and represents the *route to weight targets*; the *weight impacts* of all the *design choices and alternatives* at intermediate levels are evaluated and integrated at the aircraft level. The DtW is deployed at the detailed design phase which aims at specifying the aircraft components after freezing a global architecture at the preliminary design phase. It supports both the process of generation and validation of *components redesign ideas* and the management of the gap to weight targets.

In balance with the DtW which focuses only on the achievement of the customers expected mission, *Design-to-Cost* (DtC) approach is developed and applied in Airbus to take the *industrial performances* into account. DtC practices aim at steering the aircraft design by *industrial costs objectives* (i.e. development and manufacturing costs). On the one hand, deployed in the detailed design phase, it is based on the evaluation and integration of the *costs impacts* of aircraft components choices and alternatives. On the other hand, the challenge of DtC approach consists also in finding new ideas of aircraft components redesign to both meet the *design requirements* and achieve the *costs objectives*. To deal with this issue, S. Angeniol contributed through her PhD thesis works in Airbus [1] in describing, analyzing and building models of *design problems and solutions*, which can be used to generate automatically *redesign ideas* for costs reduction. A tool called OSIRIS is developed in the framework of the PhD to capture various *engineering knowledge* (i.e. design problems, solutions, context, redesign ideas...) from previous development projects, and to support their reuse for DtC deployment in current projects.

To consider both industrial and technological performances, *Design-to-X* (DtX) practices are developed for DtC and DtW integration. DtX consists in steering aircraft design from weight and costs objectives. Design alternatives may represent opportunities of costs or weight reduction, but also risks of costs or weight increase in comparison with an *aircraft reference*. They are generated, modified and evaluated progressively in a new development project through issued *redesign ideas* (i.e. DtX items) of an *aircraft baseline*, which is the first aircraft version at the detailed design phase. Design trades are made on such ideas to select those that represent much more opportunities (i.e. costs and weight reduction) than risks (i.e.

costs and weight increase). In any case, the risks represented by each idea have to be mitigated. The redesign ideas are classified in different categories:

- *Category A*: significant positive impacts (i.e. costs or weight reduction) with little negative impacts (i.e. costs or weight increase)
- *Category B*: positive and negative impacts are equivalent
- *Category C*: significant negative impacts (i.e. costs or weight increase) with little positive impacts (i.e. costs or weight reduction)

From the previous classification, different results may be obtained:

- Ideas belonging to *Category A* are selected and implemented to modify the current aircraft baseline or reference (i.e. the globally sized aircraft defined at the beginning of the design phase)
- Ideas belonging to *Category B* are improved: either the positive impacts have to be emphasized, or the risks have to be mitigated.
- Ideas belonging to *Category C* are rejected

A *DtX tool* is developed to support the DtX practices. It is deployed in A350 program to support the collaboration between the *program managers* who define the costs and weight objectives, on the one hand, and the *Airbus and suppliers engineers* that generate the design ideas on the other hand (see Figure 1). Indeed, DtX tool helps the program managers to steer the aircraft design by costs and weight by defining a convergence plan for both performances (i.e. costs and weight targets planning over the time), and supports the engineers to report them the evolution of the gaps to targets.

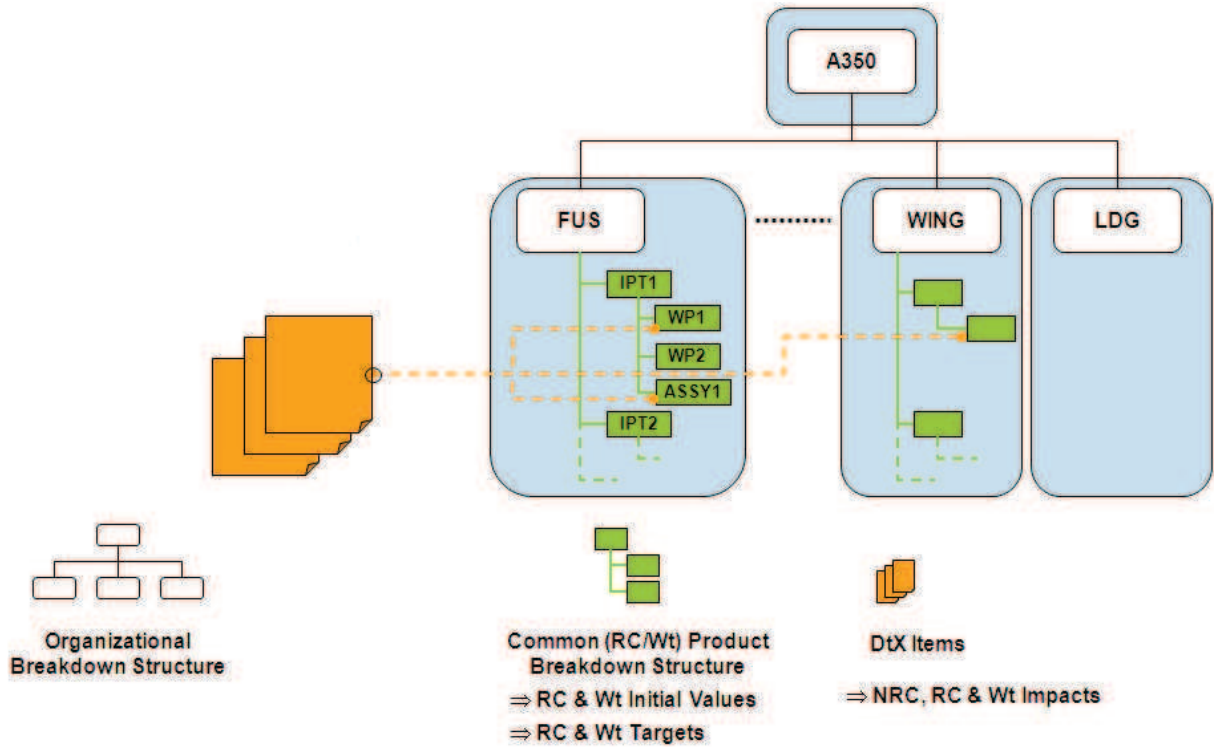


Figure 1: DtX deployment in A350 program

1.2 From Design-to-X management in the detailed design phase to value management in the preliminary design phase

DtX principle consists already in merging technological and industrial performances, which contribute to Airbus and the customers satisfaction. In this sense, it can be associated to a value based management of a new development program. Nevertheless, other types of performances may have to be taken into account to better understand the value created by an aircraft to unconsidered stakeholders like the passengers, the airports, the public and media. One can quote values such as the environmental impact, the cabin comfort, the employee well being. Besides, DtX is deployed at the detailed design phase and only starts after the specification of an aircraft baseline (i.e. a globally sized aircraft) that must be optimized in terms of costs and weight through new redesign ideas generation. Since the design freedom is dramatically restricted, DtX methodology does not permit to achieve high performances improvement. There is then a need to focus the value analysis in earlier phase of the new airplane development process. Since the industrial objective consists in developing a methodology in conceptual design phase and in considering in a wider way the value creation, our proposal is called *Concept-to-Value* (see Figure 2 and Table 1).

The figure hereafter illustrates the differences in the *level of innovation* and *value achievement* of the *Design-to-X* and *Concept-to-Value* methodologies. Design-to-X focuses above all on the detailed design phase and allows steering the redesign of a quite well defined

product component. This methodology is then based on an initial design baseline, and on assumptions that it must be redesigned to achieve precise cost and weight objectives. Redesign ideas are then captured with their cost and weight impacts (i.e. reduction or increase), ranked through different categories and selected. The research project of Concept-to-Value methodology development was launched by Airbus to apply such *value-based design steering approach* in much more upstream phase. By changing the scope in the New Product Development process, the challenges in terms of innovation and value creation get *more ambitious*. Indeed, the Concept-to-Value should permit to radically innovate, change the concepts in terms of business or design solution, address other types of objectives for high value creation than just costs and weight. In opposition to Design-to-X where the innovation perimeter is well defined by costs and weight objectives, and an initial product baseline, the Concept-to-Value must lead to explore, analyze and rank the business objectives and design concepts in the perspective of value creation maximization.

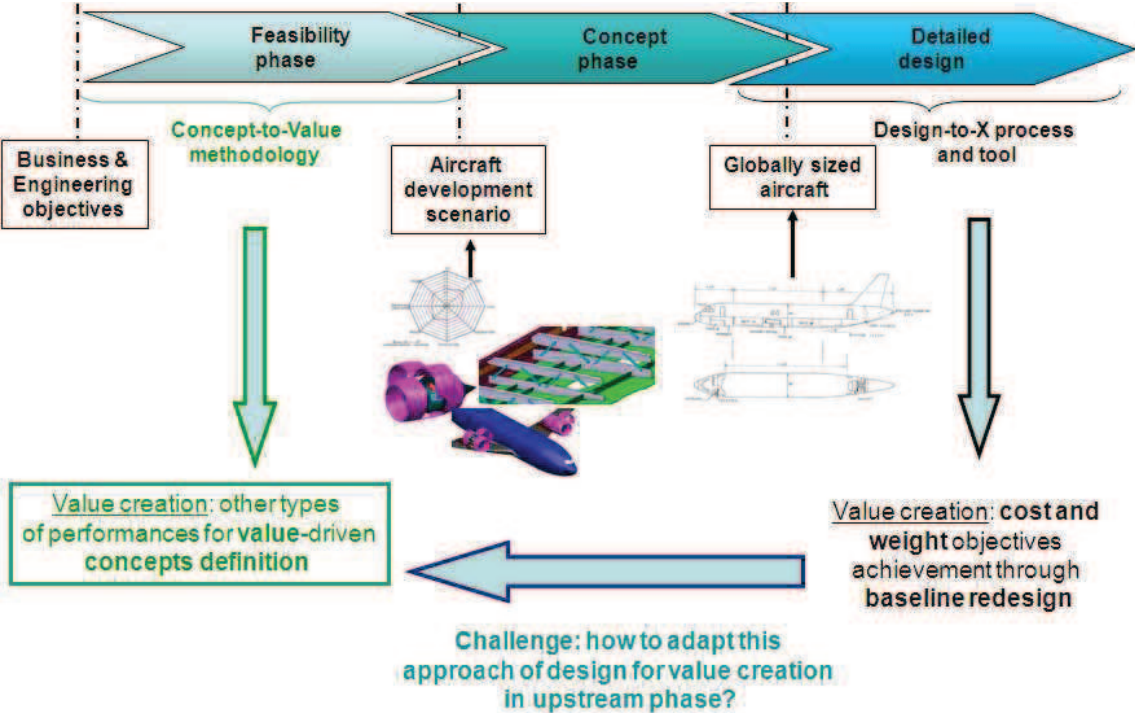


Figure 2: From Design-to-X to Concept-to-Value management

In summary, the value-based methodology Concept-to-Value (CtV) should be developed and deployed in the preliminary phase of innovation process in order to (see Table 1):

- Enrich the description of the sources of value creation
- Take multiple stakeholders into account
- Explore and define the business objectives to reach higher values

- Explore and define alternatives of innovative aircraft concepts

The differences between the DtX and CtV approaches are stated by the following points:

- At first, the level of design freedom: the DtX approach allows only refining in details a design baseline whereas the CtV approach consists in generating radically innovative design concepts
- At second, the degree of business objectives exploration: the CtV approach permits to define other business objectives than just costs and weight
- At third, the level of design evolutions capture and reporting: the DtX approach focuses only on the generation and optimization of detailed redesign ideas whereas the CtV approach leads to challenge globally the design concepts
- At fourth, the level of design evaluation: the CtV approach consists in considering the overall values of all relevant stakeholders, and leads to explore several business and design alternatives to maximize the value creation

Table 1 : DtX approach VS CtV approach

Design-to-X approach	Concept-to-Value approach
Detailed design of aircraft components	Conceptual design of aircraft
Design to cost and weight objectives	Design for global values achievement
Steering of redesign ideas	Steering of design concepts
Evaluation and aggregation of redesign ideas impacts on cost and weight	Modeling and evaluation of concepts values

2 A Research-Action approach for actual changes in aeronautical innovation projects

2.1 The conjoint collaboration between industrial and academics research centers

The so-called *Concept-to-Value* research project was launched by the integrated research center of EADS, which is named *Innovation Works*. In collaboration with the research department ‘Laboratoire de Génie Industriel’ (LGI) of Ecole Centrale Paris, the main expected results correspond to the definition of a *practical methodology* and to its *feasible deployment* on the Airbus innovation projects, through a *Research-Action* approach. Indeed, *Innovation Works* aims at enabling *technological and knowledge transfer* from upstream research projects to the different *operational processes* of EADS Business Units such as Airbus. The involved LGI research team aims at leading research projects by analyzing actual industrial issues and demands, and to actually implement *organizational changes*. *The social acceptance and usage* of the new suggested methods and tools has then to be ensured, and their positive impacts on the *organizations performances* must be evaluated. Besides the scientific foundation of the research results from the critical analysis of the literature, the *Concept-to-Value* project has to be validated by proving its *social added-value*: the increased *performance* and *well being* of both the *organizations individuals* and *collaborative groups*.

The participation of EADS *Innovation Works* in the *Crescendo* European research project leads also to choose a *Research-Action* approach. Indeed, this project involves both industrial and academics research centers. The implied industries consist of aeronautical groups, which are namely EADS, Volvo and Rolls Royce. The involved academic research centers are namely composed of INSA of Toulouse, the University of Southampton and the University of Lulea. The main objective of the *Crescendo* partners consists in developing systematic methods and tools for value steering in aircraft design projects and within the framework of extended enterprise. The leading idea corresponds to the establishment of a *unique value model* that is built and shared by the aircraft manufacturer and suppliers: such value model would permit to design and optimize the values of the *global and local aircraft systems*, in a collaborative and distributed way. The *Crescendo* project aims at improving actually the collaboration between Airbus and its suppliers for the values increase of aircraft design projects.

2.2 The challenging demand of new industrial process, methods and tools definition for value management

The analyzed industrial field for the *Research-Action* implementation represents the preliminary phase of future aircraft programs. The operational customer of the research work

in Airbus is the department responsible of the technical and business definitions of future aircrafts, called *Future Programs Development*. It leads all the innovation *preliminary activities* to *challenge the current aircraft* concept, to set *new standards*, to get *higher perceived differentiation*, to *bring more values* to all the aviation stakeholders, namely the customers and Airbus. It requests then to Innovation Works a support for *the steering of various innovation projects*, which define the systems of future aircrafts (at global or local level), to achieve these ambitions. Several Airbus functions are dedicated to collaborate with the *Future Programs Development* department, to tend to implement practically this *innovation strategy*: the *R&T department*, the *engineering Center of Competencies* (Fuselage, Wings, Power Plant...), the *marketing and strategy department*, the *aircraft integration architects*, etc. The Concept-to-Value project consists then namely in analyzing the *current practices* of the previous functions, and in providing them with the *relevant methods and tools* to be applied on concrete projects.

The Concept-to-Value project is moreover in total adequacy with an internal Airbus project of engineering process and tools improvement. This project has the objective of reducing the development costs, time, and maximizing the stakeholders satisfaction of new aircraft development programs. A planning of new engineering global organization must then be defined to improve the Airbus *new product development process*.

Finally, the participation to the Crescendo research project confirms the objective of actually better supporting *the value creation of design projects*, which also can trigger off the collaboration with several partners and suppliers.

2.3 The Research-Action protocol

As mentioned by B. Yannou [86], the *Research-Action* approach is strongly linked to the expectation of an *industrial added-value* of a research project. The objectives consist most often in improving design methods and tools in an industrial context. B. Yannou suggests a *Research-Action* protocol in four steps [86] on which we have been inspired, and that we break down into more steps to be more detailed. Our aspiration in the research project is namely to achieve a sufficient validation of the proposals through different industrial test cases and a pertinent protocol, and to describe perspectives or plans for their deployment at the global organization level.

The agreed *Research-Action* protocol to conduct the Concept-to-Value research project is decomposed in six steps:

- *First step*: analysis of ‘*As Is industrial practices*’ and formulation of ‘*industrial issues*’
- *Second step*: analysis of ‘*scientific literature*’ and formulation of academic ‘*generic problems*’

- *Third step*: definition of ‘*new generic solutions proposals*’ and comparison with existing ‘*generic solutions*’
- *Fourth step*: deployment of the ‘*new generic solutions proposals*’ on ‘*industrial test cases*’
- *Fifth step*: validation of the ‘*new generic solutions proposals*’
- *Sixth step*: strategic planning of ‘*industrial changes deployment*’ on the organization process, methods and tools

This protocol is also used as a guideline for this report establishment, and thus helps the reader to understand its structure.

2.4 The Research-Action means and tasks

The *first step* of the protocol above has been led by actually taking part of *Airbus operations*, in order to analyze the current practices and issues. The first operation consists in deploying the Design-to-X (DtX) methodology and tool (see chapter 1) on the detailed design phase of Airbus programs. Some contributions have then been brought to the Airbus Design-to-X team, which is responsible of the operation. By being involved in this team, several operational tasks are implemented, such as: the organization and running of DtX communication and learning sessions; the participation to sessions for comparison of DtX to other methods and tools best-practices in the detailed design phase; the participation to the DtX Tool improvement. This first operation has permitted to understand the current Airbus best practices in value management of innovation projects: the *weight* and *cost* are the main *value drivers* that are the most captured, followed, aggregated and optimized, in the *detailed design* phase (see chapter 1). This analysis has allowed starting assumptions on the needs of more *extended* and *flexible* methodology for value management, in the preliminary design phase (see chapter 1). Therefore, some contributions have also been brought to a second Airbus operation on the *value analysis* of aircraft systems, in the *preliminary design phase* of *Airbus Future Programs*. By being involved in the Value Engineering team that is responsible of this second operation, the undertaken operational tasks consist in meeting the different *implied actors* and gathering all the *relevant information* on the preliminary design phase. It has permitted to focus the analysis on the collaboration between the *Marketing*, the *Business*, the *Program Management*, the *integration Architects*, the *engineering designers* and the *R&Ts*, which appears as quite *informal*, *unilateral* and *rigid*, and delivers often *poor value or maturity of technological concepts* (see chapter 3). In addition, the participation to the *Value Network* forums, regrouping different EADS innovation projects members, has allowed confirming the analysis of the practices and the weaknesses in the preliminary design phase (see chapter 3).

The *second* and *third steps* of the protocol are achieved namely by being involved in the LGI (Laboratoire Génie Industriel) Lab of Ecole Centrale Paris. The scientific literature is

analyzed through relevant research axes, is further explored through the participation to design conferences and research groups sessions, and through the visits of external research labs (see chapter 4, the list of publications and external labs collaborations). Moreover, the second and third steps of the protocol are also implemented by being part of the EADS Innovation Works department that is specialized in systems engineering research. Concrete contributions have been brought to this department by participating to upstream research projects, such as “*the improvement of requirements engineering*”. This project aims at analyzing the possibility to apply the principles of “*Lean Engineering*” described by McManus [87] on the *requirements engineering process*, and requested for the *aeronautical industry* by Walton [41]. The objectives are namely to define a methodology to improve the requirements writing for their better *common understanding, retrieval, reuse, minimization and consistency*. The contribution to this project has consisted in building a methodology that optimizes the *values created by the specified requirements*. A state of the art focuses then on the methods and tools that support a *value-based requirements engineering*. In addition, such contribution has also been brought to the European project CRESCENDO, which namely aims at defining a *value generation methodology* in design projects. Our involvement in this project is dedicated to the analysis of the scientific literature, and the proposal of a methodology of *requirements establishment for value generation*.

The *fourth step* of the protocol is implemented by supporting the Airbus *Value Engineering team*, which is responsible for the *value analysis* of future aircraft systems. The mission is to create and steer a *CtV experts team* represented by the *systems engineering department* of EADS Innovation Works, and by the Airbus *Value Engineering team*. The CtV team deploys the CtV methodology on three Airbus test cases, specifies and suggests CtV tools prototypes (see chapter 5). The applications on the different test cases have to cover and illustrate the complete CtV methodology. The applications have also been run to validate the CRESCENDO project findings, to which contributions have been brought. Besides, in order to actually deploy the CtV methodology on Airbus practices, a *multidisciplinary team* is built for a given CtV pilot case, which has no expertise in the methodology, but which has *to implement it by itself* with the support of the *CtV team* and the prototyped *CtV tools*. In this way, the *multidisciplinary team* learns how to *deploy the CtV methodology by doing*.

The *fifth step* of the protocol has been achieved by analyzing the *technical results* of each implementation test case. The *technical results* are described namely in terms of capacity to explore *new business strategies*, *new technological concepts*, assess their *added-values* in comparison with the existing ones, and to formulate the needs for *further technological research* or *market analysis* in the perspective of *higher value generation*. Moreover, a *formal questionnaire* is built and submitted to a set of multidisciplinary actors of preliminary design projects, for the validation of the *industrial value adding* of the CtV methodology. This industrial added-value is also confirmed by a *benchmark* on the *innovation management practices* of several French leading industries. This benchmark has permitted to conclude on the necessity to support efficiently *multidisciplinary teams* from the beginning of innovation projects, and with a flexible and integrated methodology as CtV.

The *sixth step* of the protocol has been implemented by anticipating and planning the *required organizational changes* in Airbus for *value management improvement* in innovation projects. In total adequacy with the Airbus strategy of engineering process and tools improvement, the perspective consists in giving officially a *permanent mission* to the built CtV team, for the *systematic deployment* of the CtV methodology on new aircraft R&T and program innovation projects. The increase of the resources allocated to the CtV team is then planned, as well as the continuous improvement of the CtV tools for their industrial use at further extent. Moreover, assessments of the consistency of CtV with existing EADS value methods and tools have been made: it has been stated that CtV methodology allows getting useful inputs for other more quantitative or detailed design-based value methodologies (see chapter 6). Finally, the built Value Network is to be the official structure for the CtV methodology wider spreading and comparison to other EADS value initiatives. For this purpose, the Value Network has then to grow up progressively.

The different steps, means and actions of the *Research Action* protocol are summed up in the table below.

Table 2: The Research-Action protocol

STEPS	MEANS	TASKS
<i>First step</i>	Involvement in the Design-to-X team Involvement in the Value Engineering team Involvement in the Value Network	Deployment of the Design-to-X process and tool in the detailed design phase Participation to aircraft systems value analysis in the preliminary design phase Participation to forum sessions around value initiatives and projects
<i>Second and third step</i>	Involvement in the LGI lab of Ecole Centrale Paris Involvement in the EADS systems engineering research department Involvement in the CRESCENDO European research project	Participation to conferences and research groups sessions Collaboration with external research labs Participation to EADS upstream research projects Participation to the scientific state of the art and definition of methodological proposal for CRESCENDO
<i>Fourth step</i>	Involvement in the Value Engineering team Involvement in the CRESCENDO findings application Creation of the CtV Experts team Creation of a multidisciplinary team for each CtV application project	Deployment of the CtV methodology on three test cases
<i>Fifth step</i>	CtV deployment technical results Establishment of a questionnaire on CtV assessment by multidisciplinary actors Involvement in a benchmark of industrial practices in innovation management	Analysis of the technical CtV deployment results Submission of a questionnaire for CtV methodology validation
<i>Sixth step</i>	Adequacy to the continuous improvement strategy for the internal engineering process and tools Consistency with existing EADS value methods and tools Value Network extension	Strategic planning for CtV methodology extended deployment Confirmation of the consistency with existing EADS value methods and tools Further CtV communication and spreading

3 Airbus practices analysis: inefficient integration of the Business and Engineering in the preliminary phase of complex aeronautical projects

3.1 The growing complexity of innovation management in aeronautical projects

3.1.1 The traditional practices: the technology push by the Engineering team

3.1.1.1 Engineering requirements and architectures definition by the Design team

In the aeronautical industry, the main objectives have long time been the achievement of the *aircraft (A/C) mission*, the *certification rules* and the *A/C technological performances*. Indeed, the traditional management of new A/C development projects has mostly consisted in implementing *technological differentiation strategies* in the competitive market through *A/C mission new positioning or improvement* (see Figure 3). These strategies are described by high level *engineering objectives* on *generic A/C mission characteristics* such as the capacity (i.e. the number of seats), the range, the minimum speed for take-off and landing, the maximum cruise speed, the stability degree and the specific consumption. They are named in Airbus as *Top Level A/C Requirements* (see Table 3), hereafter denoted TLARs, and defined during the *conceptual or architectural design phase* of the *A/C development process* (see Figure 4). Being part of the Design team working for a given new A/C development program, the *A/C integration architects* are charged in specifying the TLARs, which are the first needed inputs for the design process.

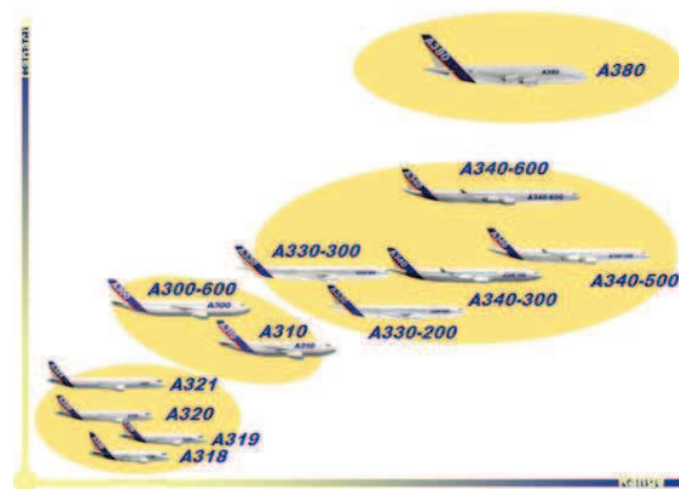


Figure 3: A/C missions positioning: range VS capacity

Table 3: Top Level A/C Requirements

Examples of aircraft performances	Units
Range	[nm]
PAX capacity (2-class)	
Initial Cruise Altitude Capability	[ft]
Maximum Cruise Altitude	[ft]
Time to climb to initial cruise altitude	[min]
Take-off field length	[ft]
V _{app}	[kt]

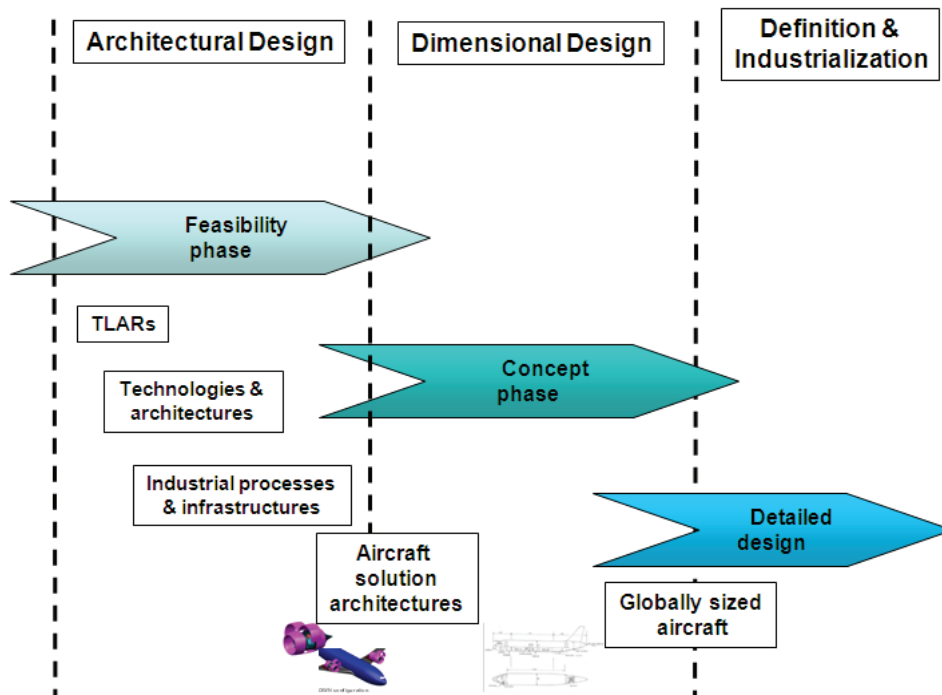


Figure 4: A/C development process

Such technical requirements are managed in DOORS platform, and represent *product functions* in Functional Requirements Documents (i.e. FRD) or in Functional Description Documents (i.e. FDD), and technological performances objectives at global and local A/C level. In particular for A/C systems, the requirements are also called *Systems Product Strategies* and are described in Top Level Requirements Systems Documents (TLRSD). Some Generic Top Level Requirements (i.e. GTLARs) are established as generic requirements parameters which can be instantiated for different A/C programs.

Supported by experts in different engineering fields, such as the aerodynamics, the structure, the avionics, the systems installation and the power systems, the *A/C integration architects* supervise the definition of different global or local *A/C architectures* from the technological

requirements. The solutions architectures are mainly designed from the *reuse or the improvement of past technological best practices*: it allows to ensure a high level of *maturity, reliability* of the defined technologies, and so of the *A/C safety*. These architectures represent namely geometrical shape, components structure, material type, technology type, relative position between components, surface quality (see Figure 5 for some global and local views of architectures). In addition, the architects are also responsible for the specification of the process and tools of the A/C parts manufacturing and integration.

The A/C integration architects work on the identification of the most important design parameters or *Key Design Drivers* (i.e. KDD) that drive the exploration of different architectural solutions. The Design team is responsible of the A/C configuration management for a given program: it refines, changes and updates an initial A/C architectural concept, called *A/C baseline*, in an Engineering Baseline Description document (i.e. EBD). Several alternative A/C concepts or *A/C standards* can be analyzed in parallel of the A/C baseline. For A/C systems configuration, a Master List describes the systems that are to be installed as *basic* (i.e. those that are mandatory for the A/C and not removable), as *standard* (i.e. the systems that are automatically specified for the A/C but removable) or as *optional* (i.e. systems that are not automatically specified for the A/C, but that can be added).

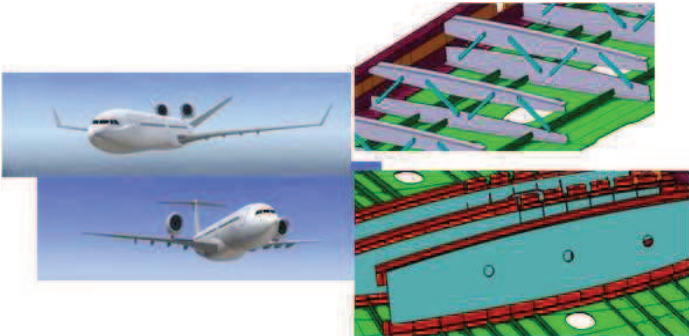


Figure 5: Examples of A/C global and local architectures

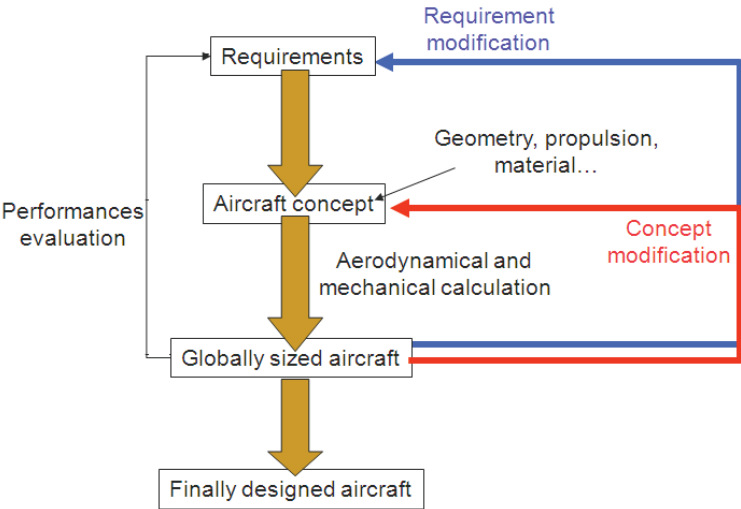











Figure 6: Traditional A/C preliminary design process

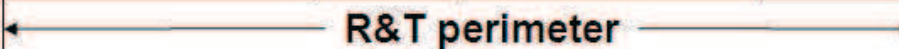
Aerodynamic and mechanical calculation methods are used to define globally *sized A/C alternatives* that achieve the targeted technological performances (see figure 6). Engineering loops are then performed to optimize the targets achievement of the A/C sized concepts either by changing the A/C architectures or the requirements.

As long as the market differentiation is mainly based on the A/C mission and technological performances, this *traditional technology based design process* seems to be efficient and fluent. One of the main symbols of this approach was the Concorde. Indeed, among all the commercial airplanes, it achieved the best A/C mission performances, such as the high speed and low speed performances. Nevertheless, despite its high technological performances, it was not economically interesting for airline companies since it dramatically increased the operating costs due to its high fuel consumption. The A350 program illustrates also at its beginning this technology push design process. It was initiated and designed by selecting and combining various technological best practices from previous A/C programs. The Business and Marketing departments ensure then afterwards that the technologies with their related performances create sufficient values to all the program stakeholders.

3.1.1.2 New technologies development by the R&T team

Part of the Engineering team, the R&T department is responsible for the supervision of the research works on new technologies development. Different technological research projects, called *Differentiating Technology Projects* (i.e. DTPs), are intended to study the *feasibility* and *maturity* of the technologies supporting new A/C functions and improving the A/C performances. The new technologies development is managed through the *Technology Readiness Level* (i.e. TRL) process, which mainly consists in improving their industrial feasibility and maturity (see Figure 7). The optimization of the *technological performances* and the maximization of the *proof of concept* of the new technologies –i.e. the proof that it works! – are then the most important objectives of the R&T team. In contrary with the Design team, the R&T team works are not dedicated to a specific new A/C development program: the latter team may develop new technologies for several various programs. Being part of the design team, the A/C integration architects select the relevant technologies developed in the DTPs, which have to be implemented for a given program, mainly on the basis of their performances and TRLs. From this viewpoint, the definition of the A/C *Key Design Drivers* and *solutions architectures* of a program can be considered as the result of a *bottom-up* or *technology-push* approach: it promotes the technological performances, and the degree of feasibility and maturity of the technologies. This type of approach can be opposed to the *top-down approach* that tends to maximize the *proof of value* –i.e. the proof that it creates value! – instead of the *proof of concept*.

EADS shared TRLs	 1	 2	 3	 4	 5	 6	 7	 8	 9
Description	Basic principles observed and reported	Technology concept and/or application formulated	Analytical and experimental critical function and/or characteristic proof of concept	Component and/or breadboard validation in laboratory environment	Component and/or breadboard validation in relevant environment	System/subsystem model or prototype demonstration in a relevant environment	System prototype demonstration in a operational environment	Actual system completed and flight qualified through test and demonstration	Actual system "flight proven" through successful mission operations
Definition	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development.	Invention begins. Once basic principles are observed practical applications can be invented. The application is speculative and there is no proof or detailed analysis to support the assumption.	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology.	Basic technological components are integrated to establish that the pieces will work together. This is relatively "low fidelity" compared to the eventual system.	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so that the technology can be tested in a simulated environment.	Representative model or prototype system, which is well beyond the breadboard tested for TRL 6, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness.	Prototype near or at planned operational system. Represents a major step up from TRL 6, requiring the demonstration of an actual system prototype in an operational environment, such as in an aircraft, vehicle or space.	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development.	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation.
Airbus Maturity Phase	Discover		Understand	Adapt		Validate	Refine		

 **R&T perimeter**



 Mandatory in Airbus system
 Optional in Airbus system

Figure 7: TRLs process for new technologies development

3.1.2 The evolutionary practices: enhancement of the value management by the Business team

The *value based approach* has risen with:

- the appearance of *new types of customers* (low cost, VIP airlines, leasing companies)
- a *globalization of the aviation market* around the world through the new demands of the emergent countries
- the *change of the economical, social and legacy environment* (increase of the petroleum and raw material costs, change of the moneys rates exchanges, certification rules on CO2 emissions, noise)
- the *increase of the world-wide competition* between the manufacturers (introduction of new competitors...)
- the *evolution of the interactions* between the aircrafts and the external systems (autonomous aircrafts...)
- the *evolution of the business model* (increase of the level of services offered to the airlines, development of leasing business model...)

The technology based design approach is consequently insufficient to address the needs of such changing external environment and define pertinent differentiation strategy among the competitors.

This evolution of the aviation market leads to a deeper analysis of all the potential opportunities of *business value creation* and to *their systematic integration* in the technological development strategies. Such integration has to be well managed in order to improve the probability of creating *high value to the so called project stakeholders*: the targeted airline companies, end-users and other actors of the airplane lifecycle. The challenge consists in identifying new business strategies that create or improve other types of values than the A/C mission or safety to the airlines (like the environmental impact, the image, the security, the autonomy and the service level), but also the manufacturer values (like the standardization, the image, the employee welfare and the environmental protection), and that are based on *potential technological means*. In other words, *technological development strategies* must be stated to create *superior values* to the customers in comparison with the competitors, and to improve the manufacturer's competitiveness.

In the preliminary phase of a new product development project, A/C solutions architectures have then to be defined both from an analysis of *proof of value* (their potential business value for the customers and the manufacturer) and of *proof of concept* (their technological feasibility). For instance, some A/C systems can create value only for some *specific airlines profiles*. Autonomous A/C with advanced technological systems would then target airlines

operating in poorly supported or risky environment, whereas basic systems A/C with low operating costs would target low cost airline companies. Consequently, an efficient procedure for *tracking the contributions* of design concepts (functional or organic choices) to the entire airplane value has to be supported. An *explicit enriched representation* of the *value model* and of the *targeted stakeholders* has to be built. A *strategical alignment* should be ensured between *marketing business strategy* and *low level technological strategies* that drive design concepts development.

The business team is responsible for the definition of the *business strategy* or the business marketing case. It is supported by the Marketing, Business Intelligence, Future Programs and New Business Development departments. The business strategy highlights the high level objectives of value creation for the stakeholders, which are called *Top Program Objectives* (TPOs). For instance, the TPOs may correspond to the reduction of the A/C operating cost for the new airplane in comparison with a previous one, by playing on contributing factors like the fuel per seat and the time for brakes cooling during the A/C turnaround on ground. The TPOs embrace various types of values like brand image, environment friendliness, safety, security and comfort. Some of them are predefined as standard values of the customers and named A/C Key Characteristics.

3.1.3 The contradictions between the Business and Engineering teams objectives

Today, two different types of teams work in parallel from the beginning of a new project to the definition of the A/C solutions architectures: the *business team* and the *design team* (see figure 8). This project management mode corresponds to a transition between technology push management and market pull management.

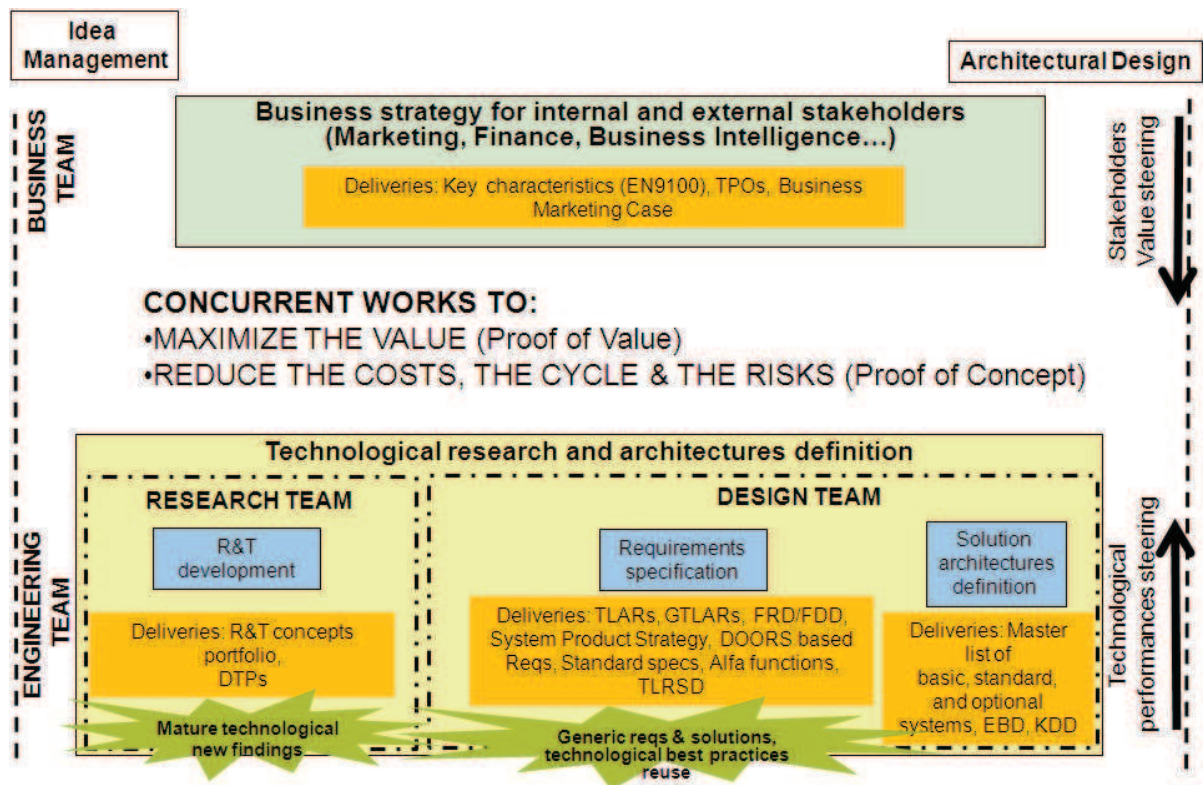


Figure 8: The concurrent works of the Business and Engineering teams

The objectives of these teams consist in defining new business ideas on the one hand, and technological ideas on the other hand. Both of them work on the idea management process which gives inputs to the architectural design processes.

As mentioned before, the first explanation of the collaborations with the business team is the enhancement of the *value based management* of the technologies: the preliminary phase must be pulled by the business value. The business team leads then a *value pull* process.

Moreover, other factors explain the collaborations with the design team. It ensures the technological performances of the aircraft, and implements then a *technology push* process:

- *the complexity of the airplane projects:* the number of aircraft components, the multidisciplinary knowledge or domains (systems, structure, systems installation...)
- *the high development cost and life cycle* of aircraft programs
- *the certification rules and standardization for safety*
- *the great similarity between the aircraft missions*

The previous factors lead the manufacturer to specify *generic technical requirements or solutions*, which can be *reused* on any A/C program, reuse *technological best practices* from previous ones, or select the *new technologies that are the most mature* from the R&T projects.

Currently, the technology push process leads to the definition of several *A/C requirements and solutions* at the very beginning of a new program, and so independently to the business strategies. Nevertheless from a total value pull perspective, the *A/C requirements and solutions* should be specified from the business strategies. The program management has then to find relevant way to integrate successfully the both approaches.

3.1.4 The uncertainty in a distributed process of decisions

The other aspect of the complexity in new aeronautical project corresponds to the *uncertainty in the decisions chain*. At a given stage of an A/C program, *a set of decisions* is made on some *Business* (i.e. like the A/C range and capacity) and *Engineering parameters* (i.e. like the A/C fuselage material, wings architecture, the engines type and positions) of the project. But other parameters may remain undefined, such as the *targeted customer profiles* (i.e. the customers strategy and business model, their operational geographical regions and routes) and the *technological features* of A/C systems avionics and cabin configuration. Due to the product complexity in the aeronautical industry (i.e. the complexity of the related business and design), the number of decisions to be taken and partitioned all along the development cycle is very important. Since they are taken by *several different actors* both from Business and Engineering teams and in *a distributed way*, the risk consists then in obtaining future remained decisions that are not *consistent* and *robust* in terms of *value creation* (i.e. *Proof of Value*), *feasibility* and *maturity* (i.e. *Proof of Concept*). Indeed, on the one hand, some future Business decisions may be *too ambitious* and may not rely on sufficient *mature technologies*: in this case, the business objectives of value creation may lack a significant *Proof of Concept*, which often leads to development costs and delay dumping. On the other hand, some future Engineering decisions may be taken without considering the Business strategies, which often leads to the production of *poor values* to the stakeholders. Consequently, in an industrial context where the *future decisions are too fuzzy* and *too broadly described*, it becomes necessary to anticipate them at each project stage gate by *exploring and evaluating* several *business and technological strategies*. Such future alternative strategies have to be anticipated in a conjoint manner by the Business and Engineering teams. Besides, due to the long cycle of the A/C development, some previously taken decisions may not be valuable or pertinent any more with changes in the organization's interior environment (i.e. like the knowledge, capacity and corporate strategy) and exterior environment (i.e. like the exchange rate, the raw materials price, the demands evolution, the entry of new competitors) in the time. One can then state that the management of the uncertainty in the future main decisions of a development project represents a great challenge of the aeronautical industry. It has to be handled with a well supervised collaboration between the Business and Engineering teams in the preliminary design phase.

3.2 The weaknesses and challenges of the collaborations between the Business and Engineering teams

The current interactions between the business and design teams mainly occur through documents exchanges (Word, Excel or PowerPoint) in a *customer/supplier* transaction mode. The traditional situation consists in the delivery of a given business strategy to the design team, which returns its *technical feasibility* assessment and proposition on the basis of technological means or capacity. The business case and architectural solutions are then defined in an *iterative process* between the two teams, which successively corresponds to business proposition – technical assessment and proposition – business reformulation. Such process mainly leads to *conflicting interactions* between the business and design teams: both of them mainly build their own view on the product strategy, and tend to maximize their *own objectives*, which are either the *technological performances*, or *the business value*. It often drives to non-optimal strategy and architectural concepts: by pulling the product definition only from value maximization perspective, the business case may be too ambitious and technically unfeasible (development cycle and cost objectives are not achieved!); by only pushing the technological performances, the solutions may not be adapted to the market, and may not really create enough value (see figure 9). Such unsuccessful results come from the *lack of transparency* between the two disjoint processes: each of them is seen as a *black box* from one another.

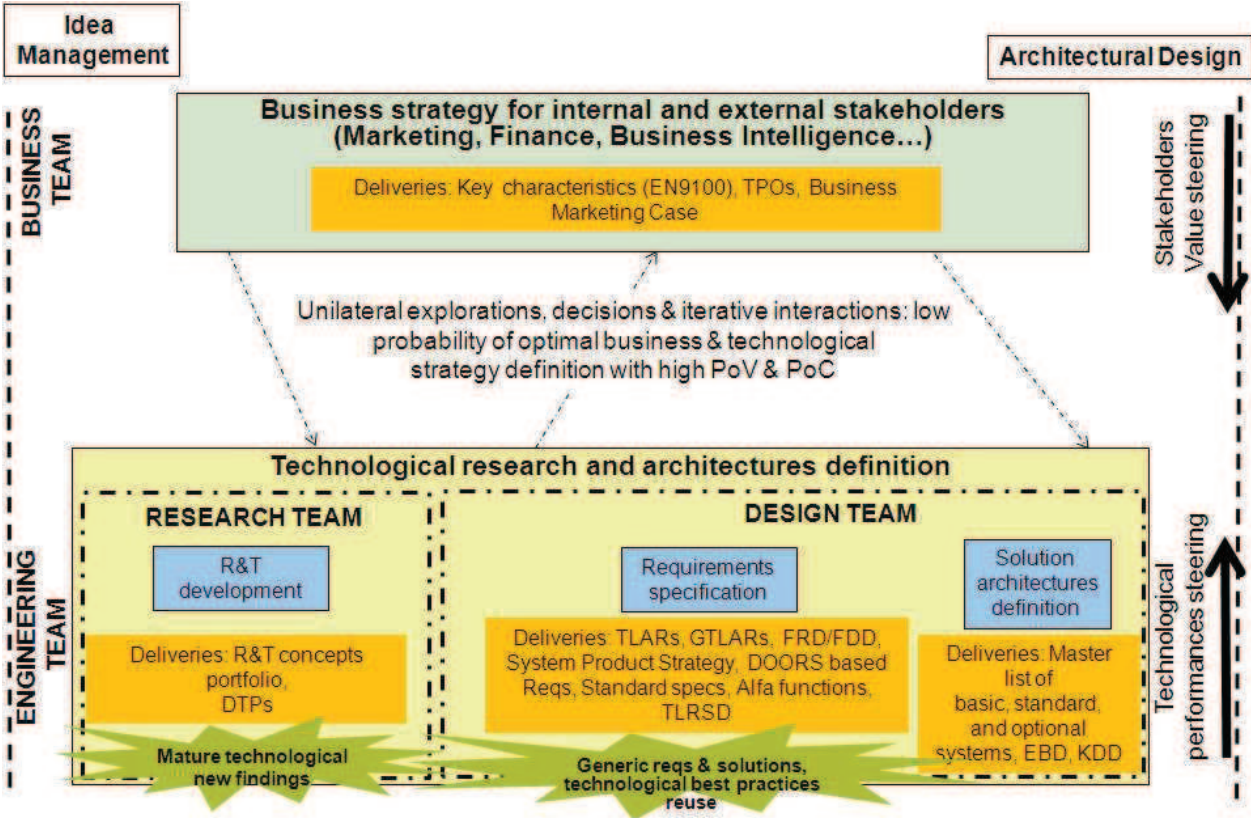


Figure 9: Weaknesses in the current interactions between the Business and Engineering teams

To sum up, the current interactions between Business and Engineering teams are vertical, linear, iterative, disjoint and based on customer-supplier relationships.

Different captured questions or comments characterize the current collaboration:

- “Both teams write Christmas letters”
- “There are collaborations between black boxes”
- “How to save the facilities?”
- “Are there holes in the racket”
- “DtC, DtW, DtX...and what else?”
- “How to provide value with some technologies?”
- “Do we create enough value?”
- “How to do things right at the first time?”
- “How to be more proactive and less reactive at new program launch?”

The industrial challenge consists in implementing an efficient and reliable collaboration mode, to move from a *partial integration* to a *total integration* of business and design works. The purpose is to enhance the information sharing and integration on *potential business values*, and *potential technological means*: the business and technological strategies are then defined in a *common* and *agile* way (*co-innovative* and *agile management*), which allows to explore both innovative concepts and business, and ensure both reliable *proof of value* and *concept*. The collaborative and flexible definition of the strategies (see Figure 10) permits to maximize the probability to identify high value and feasible innovation strategies.

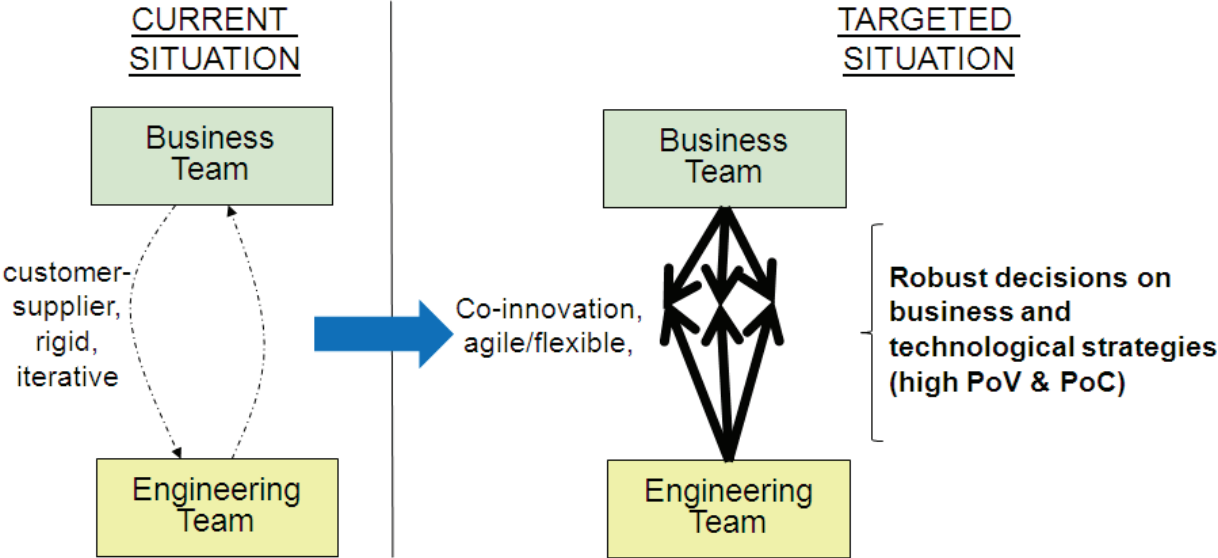


Figure 10: From iterative process to co-innovation and agile collaboration

4 State of the Art analysis: unsuccessful integration of the Product Planning and Conceptual Design stages in the innovation process

4.1 Description of the innovation challenges in organizations

Innovation is seen as an important condition for many organizations survival by Yannou [27]. Marchesnay [39] and Godet [63] consider also *innovation* as a *strategical change* of an organization within a given context (i.e. position in the value chain, competition threats, market maturity and market leadership) to impact on its external environment. Several works from *Organization Science* focus on its nature, the different ways to foster it, and the current organizational challenges.

From Yannou [27], in order to introduce successfully *new products and services* on the market, *innovation has to be well managed* in the organizations. Since it is not only related to the creative potential of individuals, and exclusively due to random explorations and inspirations, innovation must be organized, structured, planned and steered in an efficient and systematic way. Successful innovation leads an organization to adapt its corporate strategy, structure, management, competencies and processes.

Three main types of processes contribute to the innovation: the *R&D process* that explores and develops new technologies; the *product portfolio management* that defines the product lines, programs and strategies; the *New Product Development process* that consists in designing in details the product, the related services and required manufacturing infrastructures. Innovative organizations have then to well manage the interactions between these processes.

Several levels of the organization, which namely contributes to the processes of support, may participate in these innovation processes: the executive managers, the middle management, the marketing, the engineers, the designers, the researchers, the customers support, the manufacturing department... Innovation management consists in steering efficiently the collaboration between the involved *multidisciplinary teams*.

Innovation can have multiple forms. Indeed, it can produce new *technological products* on the market, but also can deliver *new services*, change *the business models and strategies*. Many research works currently define methods for developing *Product Service Systems* as supported by Kim [77], and for generating new business strategies from *Case-based Reasoning* approach [76].

In order to ensure the success of innovation, organizations have also to manage it by *value*. By considering the *Value Chain* model built by Porter [7], *Value Management* is dedicated to steer all the organizations activities, such as the innovation process, to maximize the achievement of their *ambitions, global objectives or policies*. The importance of the modeling

and alignment to the organization *ambitions, global objectives or policies* is also described by Elhamdi [74]. From a *systemic perspective*, *values* must be delivered to the different stakeholders in relation with an innovative organization: i.e. the organization itself, the customers, the suppliers, the certification organisms and the public. Boly in [75] suggests a *systemic approach* that should be applied in organization management to well evaluate and steer the *innovation performances*.

As mentioned by Boly [75], the main research issues on *innovation management* are related to the *management of the collaboration* between *multidisciplinary actors*, and to the development of practical *methodologies and tools* to support their activities [75]. These issues have above all to be dealt with at the most crucial phase of the innovation process, *the preliminary phase*.

4.2 Description of the preliminary phase of the innovation process, the Fuzzy Front End stage

The *preliminary phase*, or the first entry stage into the *process of innovation*, is also called in the literature the *Fuzzy Front End* (FFE), the *pre-phase* [78], the *pre-development* [79], the *pre-project activities* [82], or the *Front End of Innovation* (FEI) [80]. Even if it may not represent the most significant part of the development cost, Crawford [81] considers that it can consume a great part of the development time, where the *main outcomes* and *performances* of an innovation project are committed like the cost, the time to market, the product's nature, the revenues and the market [70].

The FEI stage corresponds to the stage of *idea generation, selection* through *opportunities identification, analysis* and *technological concepts exploration*. It presents the *greatest opportunities* and *freedom degree* for the overall innovation process. From Murphy et al. [83], in complex industrial environment, it corresponds to the stage where the stakeholders can abandon the innovation projects, or launch them officially through the *New Product Development Process* (NPDP). Indeed, the NPDP begins after clearly defining:

- the *objectives of the projects* such as the customers needs to fulfill, the positions in comparison with the competitors, the development and manufacturing costs, the time to market,
- but also the *necessary resources* to be used and deployed like the available technologies to be implemented,
- and the *competencies, technological research areas, and conceptual architectures* to be further developed.

The FEI stage corresponds then to the *explorations, analyses* and *choices* of previous *innovation deliverables*. A deep research work by Cooper et al. [79] revealed that “*the greatest differences between winners and losers were found in the quality of execution of pre-*

development activities". Two key elements were identified as crucial for the innovation success: the *quality of execution* of pre-development activities, and the definition of the relevant *project* and *product* prior to the development phase. Until the end of the FEI, the innovation outputs are *uncertain and fuzzy*, and must be defined by *multidisciplinary teams*. Beyond the degree of information precision, the FEI and NPDP are currently *quite different* in terms of structure and organization. As opposed to the FEI, Cooper et al. [71, 79] describe the NPDP as a *formal and well-structured process* with the establishment of a clear project deliverables, activities and resources plan: it is related in the literature to a *Stage and Gate process* model.

It is still doubted that the preliminary phase can really be managed. As raised by Verganti [82], some researchers and practitioners fear to cope with the conflicts between the *creativity and the systematization*. The FEI stage is then most of the time led in a dynamic way, without any formalization. Besides, Rosenthal et al. [78] precise that the FEI management is rather more difficult for *radical innovation* than for *incremental innovation*. Indeed, *radical innovation* implies much greater uncertainties on the market and the technologies than *incremental innovation*. Though, several research works as Koen's ones [80] tend to deal with the issue by suggesting *models of process, information or influencing factors*, to reduce the *informal, ambiguous, fuzzy, and mysterious* aspect of the preliminary phase of the innovation process.

The *New Concept Development* model (NCD) proposed by Koen [68] provides a *common language and definitions* of the FEI. It describes *five key steps* of the FEI, which are the *opportunity identification*, the *opportunity analysis*, the *idea genesis*, the *idea selection*, and the *concept and technology development*. These steps are in interactions and produce different ideas. The NCD model is also based on a *common engine* that powers the five steps: it namely consists of the senior and executive-level managers. The *organization culture* that is also represented by the engine has a great impact on the results of the five steps. The NCD model prescribes also to take into account the *environment* or the external *influencing factors*: they represent the competition, the technologies evolution and maturity, the market rules... First of all, this model is quite interesting since it presents a *set of generic innovation steps* which run continuously and several times through different cycles. These steps represent a *common framework* for the collaboration of multidisciplinary teams involved in the FEI. The application of this model in several industrial test cases has shown the importance of the *organizational culture and managerial leadership* in the success of innovation projects (i.e. importance of the engine). It also proves the need in the preliminary phase to integrate the *business and product strategy* when identifying *new opportunities*. The *technological development management* is also seen as vital for the entry into the NPDP: the technologies have to be managed efficiently for the assessment of their maturity, business value and costs. Indeed, the technological management should ensure the selection of the mature, reliable and consistent technologies that will be further developed and included in the final product. Describing the FEI stage, Rosenthal et al. model [78] completes the NCD model by representing the following process: *opportunity identification and assessment, idea*

generation, executive reviews, product strategy formulation and communication, product definition, and project planning.

Several methods can be used to generate ideas in the FEI stage. They may be generated from *marketing approach* using SWOT analysis described by Scholes et al. [48], from *consumer trends analysis* or *usage context representation* defined by Yannou [31]. Besides, they can be generated from *technological benchmark approach* (i.e. internal R&D technologies exploitation or competitors technologies investigation), from *problem-solving techniques* (i.e. TRIZ methodology, Functional Analysis System Technique) [3] or from *creativity techniques* (i.e. brainstorming, customers focus groups, analogical or metaphorical reasoning, concepts blending and morphological analysis) [3, 84, 4]. Some research works are even dedicated to understand and overcome the *design fixations effects* raised by Viswanathan et al. [85], and which reduce in some extent the ideation process. The need of finding the good ideas in the FEI stage to be developed in the NPDP is well stated by Cooper et al. [71]: “if the idea was mundane to start with, don’t count on your process turning it into a star!”. Multiple models for ideas screening are then suggested to support the FEI stage. These models combine different types of evaluation criteria. At first, *subjective criteria* are assessed from the user personal experience (i.e. novelty, originality, environmental compliancy, modernity, friendly, beauty). At second, *engineering criteria* permit to evaluate the achievement of the requirements and constraints by the solutions (i.e. design conformance, design for reliability, for manufacturing, assembly, diagnosis and cost). At third, *business or marketing criteria* are used to assess the *organization* and *customers values* (i.e. new market shares, new business revenues, new alliances, employees welfare, brand image, acknowledgment, operations and services efficiency) as explained by Marchesnay [39]. Yang’s research works [23] show that as far as the evaluations are complete, rich and certain, the probability of success of the innovation projects is high.

As mentioned by Ishmael et al. [72], one of the greatest challenges in this phase consists in generating ideas by being both *innovative* and ‘*staying in the box*’. In other words, the main goal is to be *highly creative in the box*: the ‘*box*’ represents *the boundaries* to consider for the new products or services to be developed, such as the organization strategies and resources, the environment, the rules, the market... Not considering these factors into account leads to a high risk of non value creation from the developed products and services! The ideas generated out of the box may then be shallow and non realistic. Some researchers on this domain as Moseley et al. [73] state that: “*To have the true value, the creative idea must make sense and must work*”. The main objective is then to stay in the ‘*box*’ to make sense, and to be highly innovative: it is one of the foundations of the *lateral thinking* [73]. One can raise in the literature the growing research interests on the interactions in the couple *Value-Innovation*. Founded by Chan and Mauborgne [8], the *Blue Ocean Strategy* principles from *innovation marketing* domain describe the *differentiation* perceived by the customers. *Differentiation* is a strategy for being competitive, which leads to *innovation* and *resulted value adding*. Besides, like Ishmael et al. [72], more and more researchers state that thinking of the “*box*” for ensuring the value tends also to power the *innovation and creativity*. Indeed, the constraints of

fitting to the “*box*” may trigger off new product or services solutions. Nevertheless, *Blue Ocean Strategy* recommends also that the “*box*”, which represents namely the business model or strategy, should be *challenged as much as possible*. Therefore, Chan and Mauborgne [8] recommend to define “*new business frontier*”, to disturb “*the competition rules*”, but always by taking into account some constant constraints like costs, risks and resources.

All the previous research works converge to the conclusion that the FEI stage has to be managed with the involvement and collaboration of different types of *innovation teams*. There is a clear distinction of two main types of teams: the *Business team*, which explores and defines *Business or marketing strategies*, and the *Engineering team*, which explores and develops *technologies and architectural solutions*. Despite all the models developed in the literature, there is a lack of a methodological support for steering in a practical way the integration of both teams. Analyzed namely by Boujut and Blanco [10], the *multidisciplinary intermediate objects* are not well represented so that they can be *understood, shared and integrated* easily. There is a need of *practical tools and metrics* for *generating, analyzing and integrating* them, and of a *collaboration process* for their *maturity management*. Before the specification of a new methodological proposal, the Business and Engineering teams activities and challenges in the preliminary phase are analyzed, which respectively refer to the *product planning* and *conceptual design* stages in the literature.

4.3 Description of the Product Planning stage

In the *Management Science* literature, Marchesnay [39] describes the *Strategic Management* domain that deals with the definition and implementation of *corporate and business strategies* for enterprises.

From Johnson and Scholes [40], the *corporate strategy* describes the fundamental goals or the general policy of an organization. It corresponds to the highest levels of the organization objectives and is oriented to internal values creation, such as the *social values*, the *market brand*, the *market position*, the *shares values* and the *economical profitability*. The beneficiaries of this type of strategy are the organization shareholders and employees.

The *business or marketing strategy* described namely by Millier [42, 43] relates to the business objectives, activities and market positioning for the corporate strategy achievement. Godet [63] states that it defines the way the organization practically acts on its market environment, and creates value for internal and external stakeholders. It leads namely to the identification of different *Strategical Business Units*, or the strategic organization activities in the market [39]. Since the end of 70’s, several *Strategic Marketing methods* help in defining such strategies to struggle against the market concurrency and for the organization competitiveness in mid and long term. These methods get more and more importance with the industrial development increase in USA, the saturation and decrease of the products demands: such observations have been made for instance in the market of household electrical appliances. The business strategies have then to be well defined from an efficient diagnostic

of the external and internal environment through methods like: the 5 forces of Porter [7], the BCG matrix [48, 40], the PESTEL method [48, 49], the SWOT matrix [48, 50] and the Porter Value Chain [7]. The general purpose of business strategies definition is the exploitation of the *external opportunities*, the reduction of the *external threats*, the development and use of the *internal strengths*, and the deletion of the *internal weaknesses* [39]. Rodrigues et al. [51] define various types of marketing strategies: external organization growth (by absorbing some of its competitors), internal costs reduction (by rationalizing its internal processes), competitors leaderships neutralization (by developing products or services with similar values or performances) and *marketing differentiation*. The marketing differentiation strategy consists in breaking the market competition rules, setting up an uncontested market place from differentiating product or service features. Chan and Mauborgne [8] explain that such strategy aims at creating much *higher value* than the competitors, increasing the market shares and attracting new customer profiles. A relevant products diversification strategy has then to be found in order to give the maximum success chance to the products portfolio on the market.

Kaplan and Norton [52] describe the *strategic planning*, which consists in identifying *the means and actions* to be deployed in order to achieve the business and corporate strategies. It corresponds to anticipate the different knowledge and competencies to acquire, the technologies to be developed and the internal processes to be set up. Different technological strategies may be described for technological development and acquisition actions: fusion-acquisition, internal technological research projects, open innovation with external research centers, detection and recruitment of high potential researchers and consultancy of technological benchmarking agencies.

4.4 Description of the Conceptual Design stage

From *Design Engineering* domain, several researchers as Stone et al. [44], Pahl and Beitz [45] state that the conceptual design stage begins by specifying *the new product requirements* and ends by defining the *technical architectures*. Many research works suggest to build at this stage functional [19, 14], structural [13, 11, 15, 16, 46] and behavioural models of the product. This process is composed of a succession of design problems formulations, and design solutions generations and analysis. Indeed, Yannou [56] mentions that the functional and structural representations of the product evolve in parallel. Besides, Product architectures may be found in a *systematic* or *intuitive* way. On the one hand, the design solutions may be generated from a systematic combination of local solutions from divided local design problems [3]. On the other hand, Nagai and Taura [4] show that the solutions can be issued from random approaches based on designers' creativity enhancement and exploitation. From Motte [33] literature analyses, the conceptual design is also seen as a permanent iteration between a *convergent* and *divergent* process. It is a divergent process as it has to widespread the exploration of design solutions from a design problem. It is also a convergent process as it filters the explored solutions by selecting the best ones in regards to the specified problems.

On the contrary to the Product Planning, the Design Engineering methods that support the Conceptual Design are mainly dedicated to the Engineers. Motte [32], and Thompson et al. [38] point out that such methods support their designing tasks and improve their well-being. From Vanderplaats [47], the research works in this field help the designers in reformulating the stakeholders expectations into *explicit engineering problems*, and in maximizing the *product performances* and *quality* in respect to these problems. At the beginning of the conceptual design, models of *engineers preference* or *utility* described namely by Deborah et al. [53], H'Mida et al. [54] and Liebers [55] are frozen, and help them all along the process in analysing the design solutions.

Andrew et al. [46] analyze the *Model-Based Systems Engineering* (MBSE) methods and tools. They tend to support the collaboration of different multidisciplinary engineers. Moreover, Hoffmann [15] describes the top-down part of the V cycle of the *Systems Engineering process*. At this phase, the MBSE help the designers in building, combining, sharing, transforming, verifying and validating product systems models. In a conclusion, its main objective consists in designing *conforming, reliable, robust* [22, 24] and *cost effective* [3] complex product systems.

4.5 Partial integration between Product Planning and Conceptual Design stages

In an increasing competition, pure Engineering Design is not enough to deliver sufficient business value in a new product development process. Indeed, the designers should not be considered any more as isolated and must take into account other functions outputs in the organization, like the Marketing, Finance and Business Intelligence.

The conceptual design needs then to be integrated to the product planning. Explained by Motte [32] and Yannou [27], the business team plays the role of providing the *proof of value* of technologies, and of indicating the strategies for its maximization. Besides, the design team is responsible for the *technical feasibility* of the business strategies: their *proof of concept* must be validated by the engineers.

In the literature, models of new product development process tend to integrate the product planning and conceptual design stages. Many models which primarily described the design engineering process add the product planning stage. Indeed, the guideline on “Systematic Approach to the Design of Technical Systems and Products” [57] is now denoted “Systematic Approach to the Development and Design of Technical Systems and Products” [58]. Pahl and Beitz’s chapter on “Process of planning and designing” [45] is now renamed “Product development process” [59]. Ulrich and Eppinger’s book is named “Product Design and Development” [60]. Ullman’s mechanical design process includes product planning and product development [61]. The main distinction in the two stages remains that the design process relates to product centered activities and information, and that product planning to

research and experiences on the external and internal environment (technological and economical benchmark, market demands analysis, corporate strategy, etc.).

Nevertheless, as raised by Yannou [35, 27], the integration between the product planning and the conceptual design is partially achieved in the current models of new product development process. They mostly consist in making the most important and strategic decisions for value creation in the product planning stage, and in implementing are made simple design choices in the conceptual design stage. Such poor integration describes *vertical* or *customer-supplier* interactions between the business and design teams [27]. The two processes occur then separately, and are linked only by a *marketing brief* or a *business strategy* transferred by the business team to the design team [35]: each of them is seen as a black box by the other one. Consequently, the business and technological strategies are not optimal, and several iterative interactions may occur between the teams to solve this issue: the business strategy is often too ambitious and so technically unfeasible, which leads to exceed the costs and cycle objectives; the technical strategy and architectures may also be defined to maximize the technological performances, but may not create real perceived values and differentiation to the stakeholders. These suboptimal outcomes of low proof of value and concept are triggered off by the *conflicting interactions* between the business team, which tends to maximize the *business value*, and the design team, which tends to maximize the *technological performances*.

There is a lack of appropriate methodology in the literature for a *total and systematic* integration of the product planning and conceptual design stages. Some systematic methodologies are suggested but support mainly vertical collaborations and so partial integration. The Balanced Score Cards method (BSC) of Kaplan and Norton [52, 62] is namely implemented in an organization to specify its internal activities from objectives of value creation to the stakeholders. It helps to deploy and refine the Key Performance Indicators, and to align the organization activities to its corporate and business strategies. The strategic planning assigns the different technologies to develop and knowledge to acquire at the end of the product planning stage. The Quality Functional Deployment (QFD) [29] is another broadly used systematic method that supports customer-supplier or vertical interactions between the business and design teams. It helps the design team in progressively refining the marketing brief delivered by the business team into technical requirements and parameters. Since the business strategy and the technical parameters are managed in a sequential and separate manner, by, at first, the business team and, at second, by the design team, there is a very low probability of converging to optimal business and technological strategy with high proof of value and high proof of concept.

4.6 Lack of systematic and integrated steering of Knowledge, Problems and Solutions in both stages

CK Theory of Hatchuel [5] is proposed to describe a global framework of the product development process based on parallel exploration of the design concepts and knowledge. It is a quite interesting design theory since it integrates well the product planning and conceptual

design stages. This theory suggests a parallel exploration of concepts and knowledge in the both stages and in a fully integrated manner. From CK Theory, the starting point of a *design process* is an *initial concept* that has no *logical property* –true or false– and may be related to a *business statement* or a *technology scenario*. *Partitioning tasks* are then performed to *add product properties* or *features* to the initial concept in order to generate various *partitioned concepts* with a *higher degree of maturity* in terms of business and technical proposal description. The partitioning process in the *Concepts space* –C space– needs further *investigations* or *explorations* in the *Knowledge space* –K space–. Such knowledge acquisition namely leads to *market analysis* –customer profiles and values identification, competitors benchmarking, trends analysis and strategic prospective, etc– and to *technological analysis* –technological benchmark, prototyping experiences, numerical and physical simulation and evaluation, etc–. The partitioning process may be *divergent* –in this case, the business and technical concepts are innovative– or *convergent* – the business and technical concepts are stable and conventional the business and technical concepts are innovative. The works of concepts partitioning and knowledge exploration are iterated until the defined concepts are sufficiently mature, get a logical property and belong to the K space: the concepts can be *true* –the proof of concept and value which has been provided shows that it works! – or *false* – the proof of concept and value which has been provided shows that it does not work! –. A decision is finally taken to choose the best *true* concepts that create the highest values.

CK Theory gives an interesting theoretical description of the *concepts* and *knowledge* evolution process, which come from both the product planning and conceptual design stages. It suggests a better integration of the two stages in order to converge to reliable, high value, feasible *business and technical concepts*. Nevertheless, this theory stays at a very high level of description and does not support the *practical tasks* to be performed systematically by the business and engineering teams. A more *practical approach* is needed to systematically steer the *integration tasks* on concepts and knowledge of the business and engineering teams. The following research question can then be formulated: what are the *generic business and engineering models* that support the *integrated explorations of concepts and knowledge*?

Besides, new research works are implemented on the efficient management of the *Intermediate Objects*, which are generated, modified and shared within an innovation project. Boujut and Blanco [10] explain the *reflexive design theory*, which describes the evolutions of the *Intermediate Objects* through *cognitive transactions* between the designers and these objects [10]. As mentioned by Lonchamp [67], the interactions with the intermediate objects, which represent product artifacts, are needed to power the innovation projects evolution, and should be captured as *project rationale*. Yang's research works [23] prove the importance of their *quality*, *completeness* and *certainty degree* for the innovation success. Through the *Radical Innovation Design principles*, Yannou et al. [27, 35] state that different types of *product artifacts* should be generated and well managed. The *intermediate objects* have then to be generated to expand the *Knowledge*, and to be captured in knowledge book (i.e. trends maps, technological charts, concepts maps, market segments, value chain, patents collection,

design principles and innovation mechanisms collection...). They also must be formalized and captured for the exploration of *Problems* (i.e. business model, business plan, technological roadmaps, functional and technical specifications...) and *Solutions* (i.e. storytelling, operational scenarios, conceptual briefs, draft, architectures...). They are to be collaboratively *produced, analyzed and shared* in the preliminary phase and by multidisciplinary teams. Their *quality* and *maturity* have to be improved progressively in order to ensure high proof of value and concept achievement. They have to be managed and integrated by the business and engineering teams.

There is a need of a methodology that systematically implements the CK Theory and the RID principles. An *integrated methodological approach* should then allow the business and engineering teams to systematically represent, steer and integrated their *acquired knowledge*, their *explored problems* and *solutions*, and the *values* generated for *the stakeholders*.

Hereafter, a methodology called *Concept-to-Value* (CtV) is proposed to deal with this academic issue.

5 Description of the CtV methodology for systematic and integrated steering of the Product Planning and Conceptual Design stages

5.1 A Value based model for Knowledge, Problem and Solution representation, integration and analysis (KPS-Value model)

Our *Concept-to-Value methodology* is based on a generic model representing, on the one hand, *the multidisciplinary knowledge, the problems and the solutions*, and, on the other hand, *the potential values* they generate for the stakeholders (see figure 11). This model allows *describing* the different *Intermediate Objects*, which are generated both in Product Planning and Conceptual Design stages, *integrating* them in a systematic way, and *assessing* them in terms of *potential of value creation*.

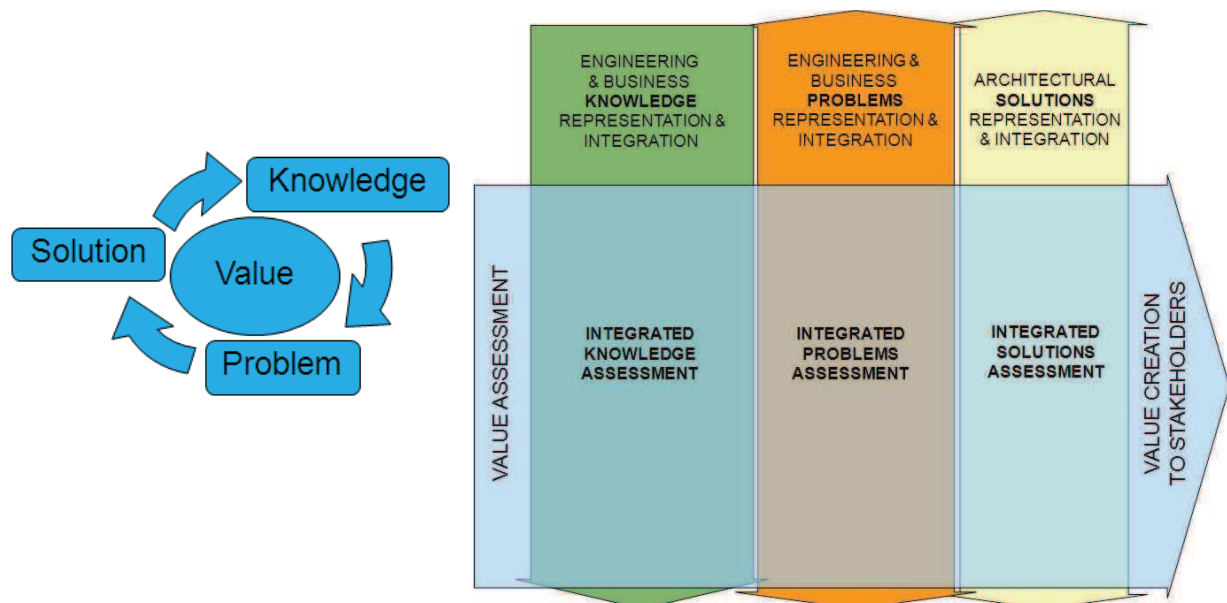


Figure 11: The Value based KPS model

This Value based KPS model should be used both by Business and Engineering teams to systematically *represent, integrate and analyze* their *knowledge, problems and solutions*:

- The *Knowledge, Problems and Solutions* from Business and Engineering teams are *described through the model* to make them *understandable* for each team (i.e. common language);
- The *Knowledge, Problems and Solutions* from Business and Engineering teams are *integrated through the model* in order to *explicit the relative contributions of engineering to business*;

- The *Knowledge, Problems and Solutions* from Business and Engineering teams are analyzed through the *model* to assess their value contribution;

The goal of our research works is to use the KPS-Value model in different sorts of project situations or for different types of project objectives:

- 1st type of project objective: the starting point is an *existing technology* or a set of *technological requirements* to be analyzed. *Knowledge* has then to be acquired and integrated in an efficient manner from the business and engineering teams, which allows evaluating the *values of the technologies and requirements*, suggesting *new pertinent business and technological strategies*, and defining *new architectural solutions*;
- 2nd type of project objective: it consists in *innovating from a scratch*. *Knowledge* must be acquired in a collaborative way to specify *integrated strategies*, and to develop *innovative and high value technologies*;

The KPS-Value model is to be usable in different industrial situations where the engineering and business teams must collaborate in a systematic and integrated way.

Hereafter, the generic KPS-Value model is described in details so as to support a systematic approach of Product Planning and Conceptual Design stages steering.

5.1.1 The Value based Knowledge model (K-Value model)

5.1.1.1 A model for multidisciplinary knowledge requests representation

The *strategical knowledge* is acquired through some specific *knowledge requests*. The K-Value model describes the *requests characteristics* that support the *investigation process* in Product Planning and Conceptual Design stages (see Table 4). This model allows also capturing the *project rationale and history* that explains the generation of *knowledge intermediate objects*. It permits to deploy a *question based approach* in the both stages, and respectively to formulate knowledge requests and acquire answers. Based on the requests model of Aurisicchio [66], the K-Value model incorporates additional elements to better support an *integrated investigation process* of the business and engineering teams. It relies then on a wider definition of the *requests characteristics*:

- The *objective* can be oriented, on the one hand, to the *technological* or *business environment* analysis, and, on the other hand, to the *internal* or *external environment* analysis.
- The *subject* correspond namely to product, service, enabling product, process or business model.

- The *type* of answers describes namely performances, functions, scenarios or structural parameters (i.e. physical parameters).
- The *method* of knowledge acquisition is related to the practical way or tool used to capture the knowledge in regards with the *objective, subject, type, level* and *domain* of the request.

The K-Value model suggests *additional requests characteristics* in comparison with existing models of the literature:

- The *requests level* assigns the knowledge acquisition to the right *organization level* or to the right *product level*
- The *domain* identifies the pertinent knowledge field to involve in the investigation process (i.e. business, structure, systems, industrialization...)

Requests characteristics	Definitions
objective	Requested information on the technological (i.e. technological solutions with their advantages and inconveniences) or business environment (i.e. the stakeholders and customers expectations), and on the internal (i.e. internal best practices) or external environment (i.e. competitors strengths and weaknesses)
Subject	Object on which some information is requested (i.e. product, service, enabling product, process, business model, stakeholder, customer profile)
Type	Type of the requested information (i.e. function, performance or quality, structural parameter, scenario, customer characteristic, solution feature)
Level	Level of the involved organization or the product concerned by the information acquisition (i.e. program level, A/C level, subsystem level, component level)
Domain	Knowledge or functional field related to the requested information (i.e. business, structure, systems, systems installation)
Method	The way or the tool to be used to acquire and capture the information in regards with the objective, subject, type, level and domain of the request (i.e. functional analysis, systemic analysis, problems and solutions networks)

Table 4: Knowledge requests model

5.1.1.2 A model for Business knowledge representation

The captured knowledge is namely related to *business information*. Different types of business elements can be formalized: i.e. the *stakeholders*, the *customers descriptors* and *profiles*, the *value dimensions* and the *business value drivers*.

These *business elements* are described hereafter:

- *The stakeholders*

They represent the external and internal entities to which value has to be created. The global stakeholders to be satisfied are generally the manufacturer, the suppliers that contribute to the design and manufacturing chains (i.e. the engine manufacturer), the customer (i.e. the airline, or financial company), the users (i.e. the passengers and the personnel working around or inside the product) and the external environment (i.e. the airport, the certification organism, the public or media).

- *The customers descriptors and profiles*

The customers can be segmented through different characteristics, such as the capacity, the range, the business model, the class (i.e. low cost, VIP, business class, premium...) or the existing fleet importance. The characteristics that can have an impact or influence on the perceived value of a solution or service by the customers are defined as *customers descriptors*. For instance, the type of class is a relevant customer descriptor since the importance level of the cabin comfort depends namely on it. The *customer profiles* are defined to segment the market demand by making *instantiations and combinations* of the different customers descriptors: for instance, a business class airline operating for long range. The *customer profiles* must then highlight the differences in the perception of the products or services values from the customers viewpoint, and in relation with the differences of their characteristics.

- *The set of value dimensions or end values of a stakeholder*

They represent a set of shared and consensual high level measurement criteria used for assessing the value of a given stakeholder. The value dimensions have then to be as independent as possible, at the same level and to cover as much as possible the value perceived by a stakeholder.

- *The value dimension weight.*

It describes the level of importance of a value dimension perceived by a stakeholder.

- *The value dimensions characterization as basic or differentiating.*

From a given stakeholder and profile perspective, a value dimension can be considered as basic in opposition to differentiating, since its fulfillment do not provide *added values* or *superior satisfaction* than the *basic solutions*. The *basic solutions* represent conventional solutions in a given market (i.e. for a given type of customers and product) or solutions that respond only to its minimum constraints (i.e. the certification rules or the basic expectations). Nevertheless, a *basic dimension* can be very important as its poor satisfaction level (under a given threshold) can trigger off a great disappointment of the stakeholder: such dimensions are also denominated as *core and basic values*, or *must to have values*. The *differentiation and importance levels* of a dimension are then *complementary and not equivalent*: sufficient contributions have to be brought to the all important dimensions, and above all to the *differentiating* ones. These basic and differentiation notions are inspired from the Kano models [64] of satisfaction and dissatisfaction: one can associate the *differentiating dimensions* to the Kano “*performance*” or “*delighting*” criteria, and the *basic dimensions* to the Kano generic implicit needs. For instance, “*airplane safety*”, “*certification*” and “*mission*” can be considered as *basic dimensions* for most of airlines profiles: they use then over dimensions like “*operating costs*”, which are so considered as differentiating, to choose between two competing aircrafts, which must originally fulfill the *basic needs*. The level of differentiation of a product can be defined as its *capacity degree* to create higher satisfaction than basic solutions, and is measured through *differentiating value dimensions*. Thus, the purpose is to focus the innovation effort, for a given targeted customer profile, on the *pertinent differentiating dimensions* on which the architectural solutions must contribute in a significant way.

- *The business value drivers.*

They correspond to the Business team parameters that contribute to the value dimensions in a positive (improvement of the dimensions) or negative way (degradation of the dimensions). They represent levers that are activated in different ways to specify alternative *business strategies*.

- *The level of market contestation of the business drivers.*

It corresponds to a semi-quantitative scale which describes *the level of novelty* of a business driver, or the *level of competition of the market* on it. Inspired from the Blue Ocean Strategy method [8], it is used to identify the *potential business drivers* that contribute the most to *differentiation*.

5.1.1.3 A model for Engineering knowledge representation

The captured knowledge is also related to *engineering information*. Different types of engineering elements can be specified: i.e. the *engineering value drivers* and the *technical architectural features* (i.e. instantiated technical functions or solutions).

These *engineering elements* are described hereafter:

- *The engineering value drivers.*

They correspond to the Engineering team parameters that contribute to the value dimensions in a positive (improvement of the dimensions) or negative way (degradation of the dimensions). They represent levers that are activated in different ways to specify alternative *engineering objectives* or *technological strategies*.

- *The technical features.*

The technical features describe technical functions or solutions that can be chosen and combined to represent different product architectures at global or local level.

5.1.1.4 A model for Engineering and Business knowledge integration and evaluation

Finally, the K-Value model is dedicated to *integrate the engineering and business knowledge*. It consists in *assessing semi-quantitatively* and capturing the *positive and negative correlations* between the *multidisciplinary elements* through matrix based approaches [29, 30]. In other words, the *contributions of engineering elements to business elements* are described through *semi-quantitative scale* (i.e. little, medium or high positive or negative impact), in *a relative way* in comparison with *a product reference* (i.e. an internal best practice or anterior similar product), and from the *viewpoint of a given stakeholder or customer profile*.

After the *matrix-based integration* of the *Business* and *Engineering elements*, the K-Value model permits then to analyze them with the following *value metrics*:

- *The level of contribution of a value driver to a value dimension.*

It consists in a *positive* (i.e. for positive impact) or *negative* (i.e. for negative impact) *scalar* that represents the *semi-quantitative degree* and *sense of impact* of a value driver (i.e. business or engineering) on a value dimension.

- *The level of independence of a value driver.*

It permits to select the *most independent drivers* (i.e. business or engineering) to the others so as to get freedom in their manipulation to positively impact on the value dimensions.

- *The level of influence of a value driver.*

It allows selecting the drivers that influence the most the value dimensions in an *absolute way*, i.e. without considering the sense of the impacts. Such selection is necessary in a very complex project where several parameters can be identified and when global business or engineering strategies have to be defined.

- *The level of importance of a value driver.*

It represents the consolidation of a value driver's negative and positive contributions to all dimensions. This consolidation can be positive or negative: whether it is positive, the value driver improves more the value dimensions than it degrades; if it is negative, it degrades more than it improves. The *most important drivers* for the different stakeholders and profiles have to be selected to maximize the value creation.

- *The level of contribution to differentiation of a value driver.*

The contribution of a value driver to a differentiating value dimension can be *differentiating* or not (i.e. basic): it depends on the related value driver and the considered stakeholder or profile. *Differentiating contribution* means that it participates in the customer satisfaction increase in comparison with the *basic solutions*. For instance, the positive contributions of a value driver, which are imposed by 'certification' or 'security' rules, could not be considered as differentiating: indeed, they are conventional, and commonly shared by any product. The level of contribution of a value driver to

differentiation is highly linked to its *level of novelty*. The more a value driver is uncontested or new in the market, the more the probability is that it contributes to differentiation. This value metric represents then the consolidation of all the *differentiating contributions* of a driver to *differentiating value dimensions*. This level can vary depending on the considered customers profile.

- *The level of contribution to basic values of a value driver.*

By definition, the contribution of a value driver to any basic value dimension is always basic (i.e. not differentiating). The level of contribution of a value driver to basic values represents the consolidation of all its *basic contributions* to the value dimensions.

- *The key or strategic value drivers.*

They correspond to *the selected drivers* that are the *most independent, influencing, important* and that contribute *more to differentiation* than to basic values. Such *strategic value drivers* are used to create *high value* to the manufacturer and *high differentiation* to the customers.

- *The level of completeness of the strategic value drivers.*

It represents the *degree of covering* of the value dimensions by the *strategic value drivers*. It is equal to the *division between the sum of the weights of the value dimensions*, on which the strategic drivers globally contribute positively, and the *total sum of all value dimensions weights*. The knowledge acquisition process can then be steered in order to maximize this *completeness level*.

- *The level of differentiation of the strategic value drivers.*

It corresponds to the consolidation of all *strategic drivers differentiation levels*. The knowledge is also acquired by making sure that *enough strategic drivers* are discovered to create sufficient value to the stakeholders, and above all differentiation to the customers.

- *The contribution of a technical feature to a value dimension.*

It consists in a positive (i.e. for positive impact) or negative (i.e. for negative impact) scalar. It represents *the semi-quantitative degree and sense of impact* of the choice of a feature on a value dimension.

- *The level of contribution to differentiation of a technical feature.*

The contribution of a *technical feature* to a *differentiating value dimension* can be *differentiating* or not (i.e. basic): it depends on the related feature and on the considered customer profile. *Differentiating contribution* means that it participates in the customer satisfaction increase in comparison with *basic solutions*. For instance, the contributions of a feature, which are imposed by ‘*certification*’ or ‘*security*’ rules, could not then be considered as *differentiating*: indeed, they are conventional, and shared by any product. The level of contribution of a feature to differentiation represents the consolidation of all its *differentiating contributions* to *differentiating value dimensions*. This level can vary depending on the considered customer profiles.

The components of the K-Value model can be summed up by the figure below (see Figure 12).

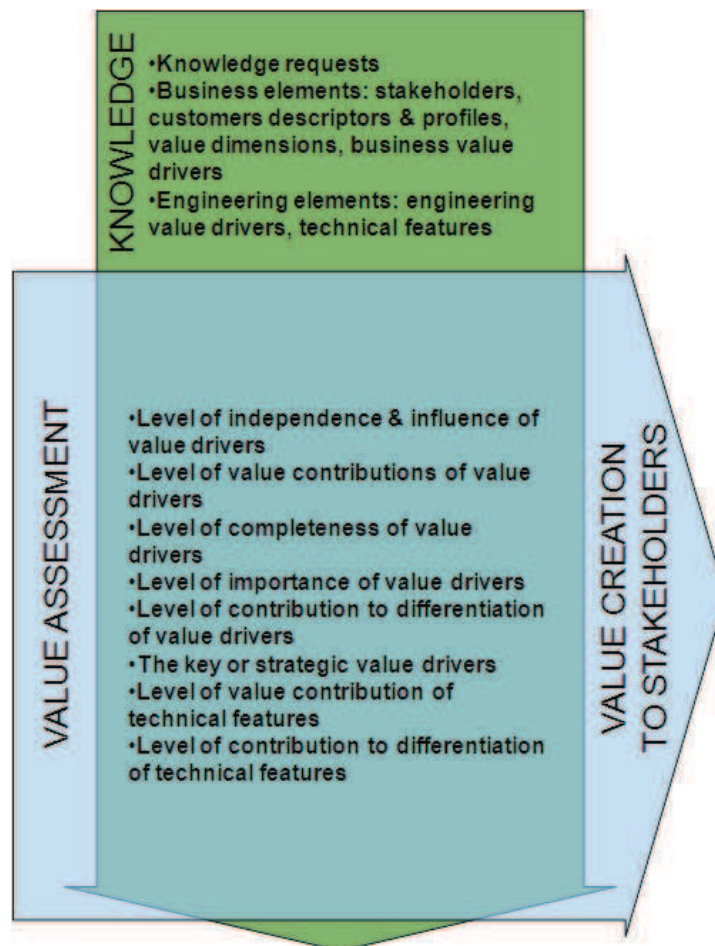


Figure 12: The Value based K model

The *Business* and *Engineering elements* are more or less perceived by the different stakeholders. By definition, the most perceived objects are the *value dimensions*.

In addition, the *business value drivers* and some *engineering value drivers* such as the external product functions or operations are also well perceived by the stakeholders. The *top-down* integration of the Business and Engineering elements consists in building links between the stakeholder and customer profiles, and such perceived elements. The *bottom-up* integration consists in establishing links between the *technical features*, which are less perceived by the stakeholders, and the more visible drivers.

The value-based K model supports in fact the both *top-down* and *bottom-up* integration approaches, and the *value analysis* of the *integrated knowledge*.

5.1.2 The Value based Problem model (P-Value model)

5.1.2.1 A model for integrated business and engineering problems representation

After the knowledge acquisition, representation, integration and assessment, the *business and engineering problems* have to be formulated, integrated and evaluated.

The P-Value model represents the *business strategies* that are defined by the business team, as well as the *engineering objectives or requirements* that are specified by the engineering team. It describes the *generic or stable* engineering requirements that are generated at each development program, but also the *strategic requirements* that are specific to a given program and contribute the most to a *differentiation*.

The value based P model (P-Value model) is used to elicit the *value strategy* –i.e. the strategy of value creation- behind a given business or engineering problem. A *value strategy* is precisely defined as a set of *actions* and *objectives* on *pertinent business and engineering value drivers*, to influence targeted *value dimensions* of given *stakeholder and customer profiles*. The objective is to define aligned strategies for both business and engineering domains.

For such strategy formulation, it is required to have proceeded to efficient knowledge acquisition. Indeed, the stakeholders, the customer profiles, the value dimensions and the strategic value drivers have to be preliminarily identified to build *high value creating strategies*.

5.1.2.2 A model for integrated business and engineering problems analysis

The P-Value model has also to support the assessment of the defined value strategies, to ensure high value creation for the stakeholders and the customer profiles.

The value assessment is based on the following *metrics*:

- *The level of contribution of a value strategy to a value dimension.*

It may be a positive or negative quantity and results from the consolidation of the contributions to a value dimension of the set of objectives put on the drivers of a value strategy. It depends on the considered stakeholder or customer profile.

- *The level of completeness of a value strategy.*

It describes the degree of covering of the value dimensions by a value strategy. It is equal to the division between the sum of the weights of the value dimensions on which the value strategy contributes positively, and the total sum of all value dimensions weights. It is inherent to the considered stakeholder or customer profile.

- *The level of contribution of a value strategy to differentiation.*

It corresponds to the consolidation of all the differentiating contributions of a value strategy to differentiating value dimensions. It can be calculated for a given stakeholder or customer profile.

The purpose of the P-Value model consists in representing the *business and technological value strategies*, and in assessing them to maximize their *levels of completeness and contributions to differentiation*.

Nevertheless, in some program cases, the goal may simply consist in achieving the *highest completeness level* of the business and technological strategies, but not in maximizing their *differentiation degrees*: indeed, in such situation where the customers value dimensions can all be defined as basic, a *neutralization strategy* may be preferred rather than a *differentiating one* in order only to break the *competitors leadership* and reduce *industrial costs and risks*.

The components of the P-Value model can be summed up by the figure below (see Figure 13).

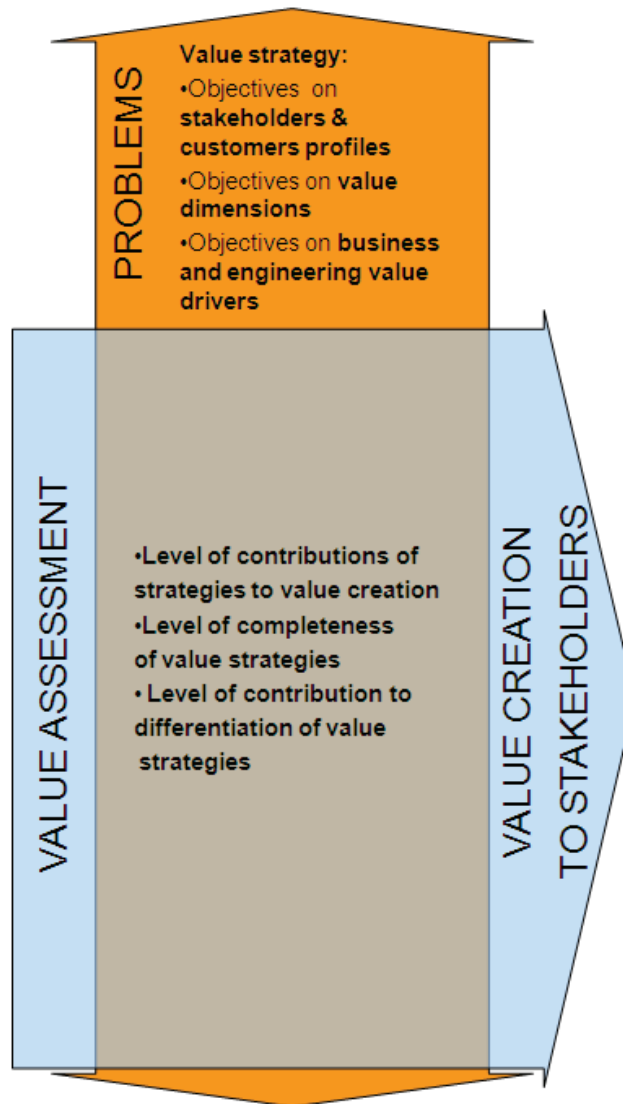


Figure 13: The Value based P model

5.1.3 The Value based Solution model (S-Value model): a model for architectural solutions representation and assessment

Finally, the S-Value model describes the *architectural solutions* that should match the best *value strategies*. The S model represents the *product, service, process* and *operations* solutions: the solutions are represented in terms of *structures* and *behaviors*. It describes namely the *technical architectures* that support *different operations* or *process* as combinations of *technical features*, which correspond to *technical functions* or *solutions*.

The *value-based S model* (S-Value model) permits to assess different *quality metrics* to steer the *architectural solutions* definition:

- *The level of gap to strategy of an architectural solution*

The value based S model allows measuring the *consistency or gap* between the *solutions architectures* and the *technological and business strategies*. This gap is evaluated on the basis of the differences between *the objectives* set on the strategic drivers or the value dimensions, and their *actual degrees of achievement* by the solutions. This metric can also be used to estimate the *completeness level* of the technical features instantiated by a solution architecture.

- *The level of value contribution of an architectural solution*

On the basis of the contributions of the technical features, the S model permits to evaluate the contribution to a set of value dimensions of a solution architecture. It corresponds to the consolidation of the contributions of all the instantiated features to the value dimensions. It can be calculated for a given stakeholder or customer profile.

- *The level of contribution to differentiation of an architectural solution*

On the basis of the contributions of the technical features, the S model allows evaluating the contribution to differentiation of a solution architecture. It corresponds to the consolidation of the differentiating contributions of all the instantiated features to the differentiating value dimensions. It can be calculated for a given stakeholder or customer profile.

The components of the S-Value model can be summed up by the figure below (see Figure 14).

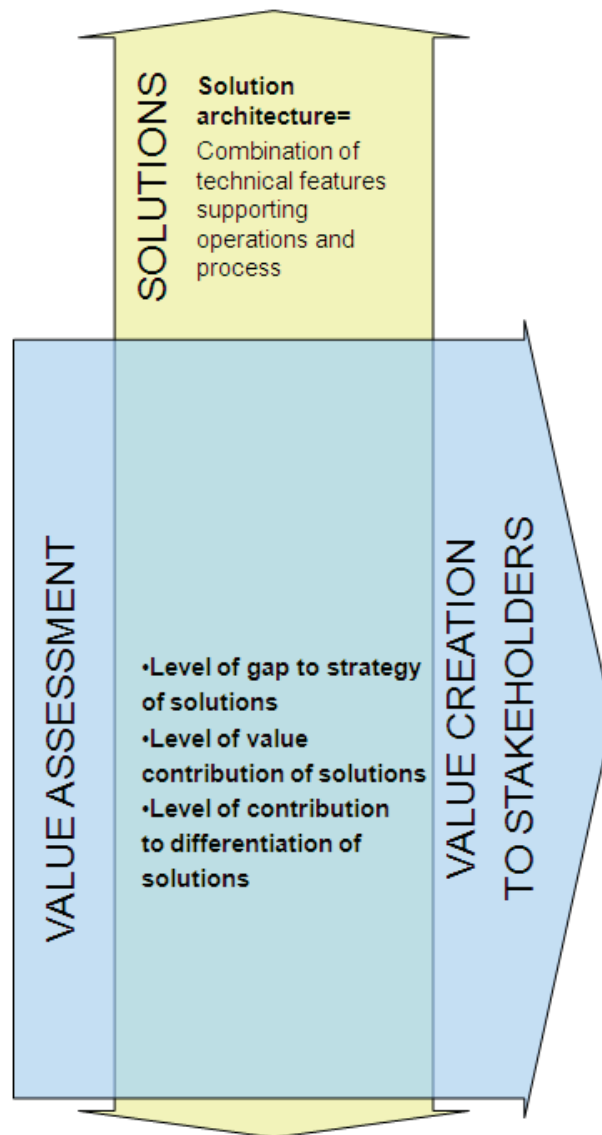


Figure 14: The Value based S model

5.2 Four steps process for systematical steering of Knowledge, Problems and Solutions (CtV process)

5.2.1 Global description of the CtV process

The KPS-Value model is suggested to provide a *common language* to the Business and Engineering teams. A four steps process is defined to implement systematically the KPS-Value model and to steer the collaboration between the both teams.

The CtV process deploys the KPS-Value model *in four steps* (see figure 15):

- *Primary knowledge acquisition*

- *Value drivers and features analysis*
- *Value strategies analysis*
- *Architectural solutions steering*

The *primary knowledge acquisition* step starts with the specification of an *initial project statement*. The *K-Value model* is used to steer and capture the multidisciplinary knowledge both from business and engineering teams. This step produces then *characterized knowledge* to be analyzed, such as the *stakeholder and customer profiles*, the *value dimensions*, *drivers* and *technical features*.

The *value drivers and features analysis* step *integrates the multidisciplinary knowledge* and analyzes their *potential values* on the basis of the *K-Value model*. It allows namely the computations of the *value contributions*, the *level of differentiation*, the *level of completeness*, the *level of importance*. These two first steps correspond to a systematical implementation of the *investigation process* of RID [27, 35].

The *value strategies analysis* step builds and assesses different *value strategies* on the basis of the *P-Value model*. The relevant *business and technological strategies* that maximize the value and the differentiation are then selected. This step systematically implements the *problem setting* phase of RID [27, 35].

The *architectural solutions steering* step steers the development of the *architectural solutions* in respect with the selected *value strategies*. It allows then implementing the *S-Value model*. It systematically deploys the *problem solving* phase of RID [27, 35].

The CtV process tends to describe a way to steer systematically the collaboration between the business and engineering teams. Indeed, the *product planning* and the *conceptual design* are managed in an *integrated manner* from the *multidisciplinary knowledge explorations* (i.e. primary knowledge acquisition step) to the *solutions explorations* (i.e. architectural solutions steering step). At the different CtV steps, the KPS-Value model is used to either *represent* the generated intermediate objects (i.e. common description language), to *integrate* them, or to *analyze* them.

The following sections describe in details each step of the CtV process.

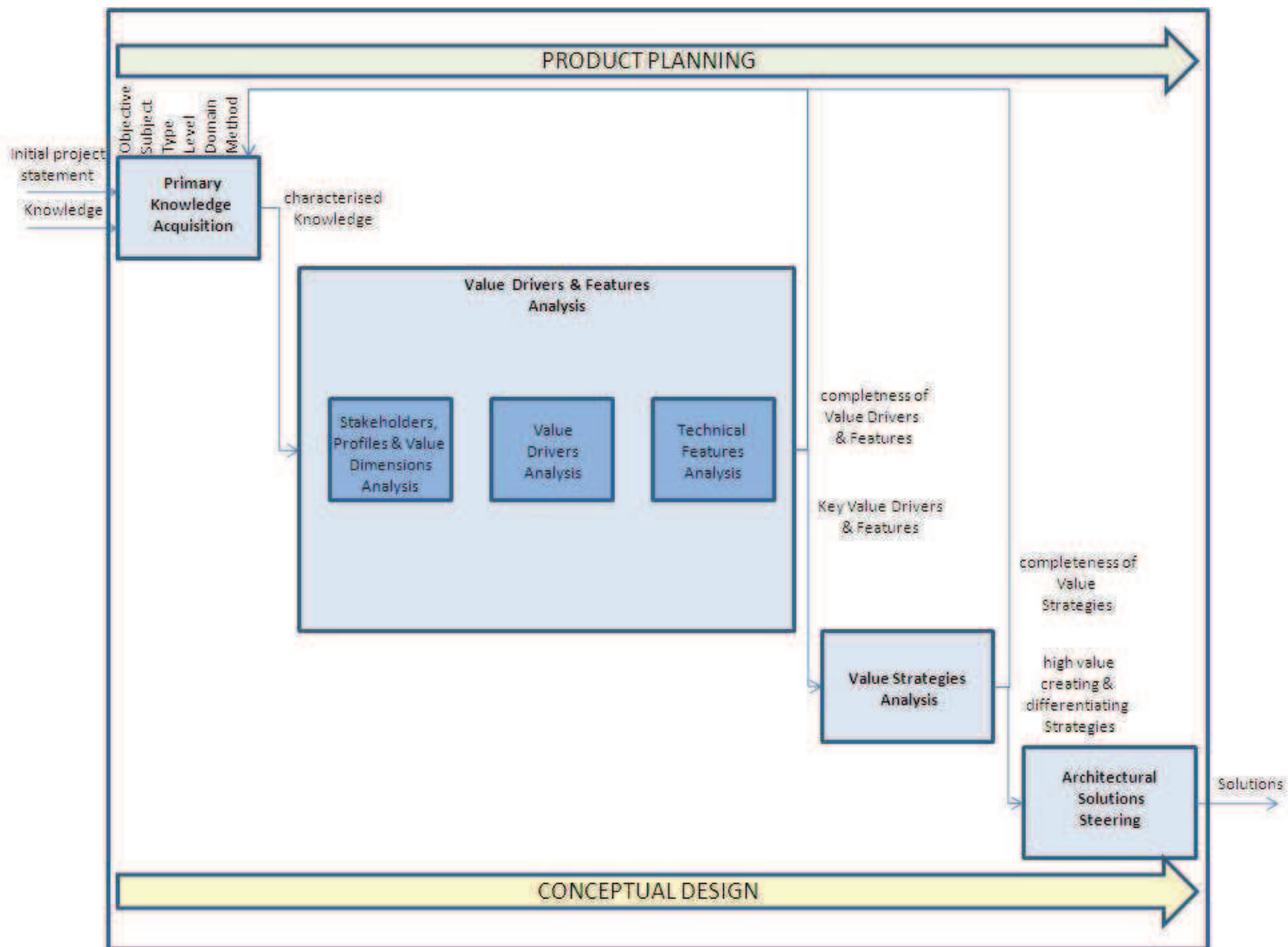


Figure 15: The four steps of CtV process

5.2.2 First step: primary knowledge acquisition

This step begins with the *initial statement of the project* [34]. It describes the initial context and objectives of the innovation project:

- The *product level* at which innovation has to be steered
- The initial *business and technological constraints* to be taken into account
- The *actors and knowledge fields* to involve
- The *stakeholders* to be targeted and satisfied

These initial pieces of information permit to narrow the *scope of the project*, to define a *broad perimeter of the problem*, in which *relevant value strategies* have to be defined, and to better orientate the *knowledge acquisition requests* [66].

From this initial statement, *knowledge requests* are formulated and answered through different methods.

Different types of knowledge acquisition methods exist and may be implemented depending on the *requests objectives* [66]. These objectives can be oriented to *technological* or *business environment* on the one hand, and, to *internal* or *external environment* on the other hand.

The *technological environment* analysis is mostly performed by the Engineering team through methods like: Triz [6], Functional Analysis [3], FBS graphs [11], FAST diagrams [56], And-Or graphs [13], SADT diagram [56] and Morphological Analysis [56].

The *business environment* analysis is above all implemented by the Business team through methods like: BCG matrix [48, 40], SWOT matrix [48, 50], 5 Forces of Porter [7], Trends Analysis [65] and PESTEL model [48, 49].

The first main purpose of this step consists then in *characterizing the knowledge requests* through the *common language* description supported by the K-Value model (see Table 1). The latter permits to have a *common understanding* of the requests and the *expected knowledge* to acquire.

Besides, this step supports also the *knowledge* acquisition through *Design Rationale* capture methods such as DReD diagrams [12]. The idea is to enable and track a *question based approach* by representing *the iterations* between the formulated questions and the answers. The DReD diagrams represent the links between raised questions and generated answers, and capture then all the *knowledge acquisition history* [67].

The second main purpose of this step is the *representation of the acquired knowledge* through the common language supported by the K-Value model.

5.2.3 Second step: Value Drivers and Features analysis

This step begins after the production of *characterized knowledge* through the K-Value model. The required inputs are namely:

- the *potential stakeholders* to be satisfied, which are generally the *manufacturer*, the *customer* (i.e. the organization that buy the product and services), the *end-users* (i.e. the passengers), the *staff and crew* (i.e. the personal that works inside or around the product) and the *external environment* (i.e. the airport, the certification organisms and the society).
- the *customers descriptors* like “*range*”, “*class level*” or “*business model*”, which have an impact or influence on the *perceived value* of a solution or service. The descriptors can be classified in *two different categories*: the *first category* describes the *global organization* of the customer (i.e. initial internal and external environment) before the product or service acquisition; the *second category* represents its *expected usage* of the product or service. This classification is inspired of the existing methods of *Systemic Analysis* [69] for complex systems analysis, and of *Usage Surfaces Modeling* for customers expected usage analysis [31].

In the aeronautical domain, the different descriptors are namely (see Table 5):

- For the description of the *global organization of the customer* (i.e. to answer the question “*who is the customer?*”): the *business model*, *maintenance means*, *fleet importance* and *alliances networks*.
- For the description of the *expected usage* of the product or service (i.e. permitting to answer the question “*how and where is the product or service used?*”): the *range*, *capacity*, *utilization rate*, *class level*, *airports infrastructures*, *ETOPS constraints*, *geographical constraints*, *weather conditions* and *regions temperature*.

Potential *customer profiles* are then generated to segment the market demand by making different instantiations and combinations of the *customers descriptors* (see Table 5). The *customer profiles* must highlight the *differences in the perception* of the products or services values according to their specificities.

Table 5: Examples of stakeholders, customers descriptors and profiles

Stakeholders	Customers descriptors	Customer profiles
<p><i>Manufacturer</i></p> <p><i>End-user</i> (i.e. passenger)</p> <p><i>Customer</i> (i.e. buyer)</p> <p><i>Staff</i> (i.e. cabin crew, refueling crew, flight crew...)</p> <p><i>External environment</i> (i.e. certification organisms, airports, society...)</p>	<p><i>Business model:</i> leasing company, airline company, financial organization, cargo company...</p> <p><i>Maintenance means:</i> level of resources for the A/C maintenance (i.e. low, medium or high)</p> <p><i>Fleet importance:</i> extent of the existing fleet (i.e. low, medium or high)</p> <p><i>Regions temperature:</i> extreme temperatures (i.e. very hot or cold) or tempered temperatures.</p> <p><i>Airports infrastructures:</i> level of equipments, facilities and services for the customers (i.e. low, high and medium)</p> <p><i>Range :</i> regional/short, medium, long</p> <p><i>Class level:</i> VIP (premium or business), economic, low cost or charter</p>	<p><i>First profile:</i> low cost, low maintenance means and regional airline operating in very cold regions and in low infrastructure airports...</p> <p><i>Second profile:</i> VIP, long range and high maintenance means airline company operating in very hot regions and in developed infrastructures airports...</p> <p><i>Third profile:</i> standard, medium maintenance means and long range leasing company in tempered regions...</p>

This CtV process step starts also with the description of other *business and engineering elements* from the knowledge acquisition: the potential *value dimensions*, the potential *business value drivers*, the potential *engineering value drivers* and the potential *technical features*.

The first main objective of this step consists in *building and representing the links* between the captured *business and engineering elements*. Different *types of relations* between the elements can be described, such as *causality, performance, functional, hierarchical and aggregation relationships* (see Table 6). The relations types are defined from the knowledge requests characteristics. *Contribution links* between them are then assessed through a *semi-qualitative scale* and captured *within matrices* (see Table 7): positive and negative *matrix coefficients* are set to represent both *desired and undesired influences* between the elements, in comparison with *a given product reference*, and for a *given stakeholder or customer profile*. The elements structuring and integration are then inspired of existing *matrix based approaches* such as QFD [29], Structural Analysis [30].

Table 6: Types of relations between the Business and Engineering elements

Relations types between the elements	Definitions
<i>Causality relationship</i>	Causality relation between elements of the <i>same type</i> and at the <i>same level</i> (i.e. between a ‘ <i>quantity</i> ’ and a ‘ <i>volume</i> ’, a ‘ <i>number of components</i> ’ and a ‘ <i>number of tasks</i> ’, a ‘ <i>time</i> ’ and a ‘ <i>cost</i> ’, a ‘ <i>weight</i> ’ and a ‘ <i>level of comfort</i> ’)
<i>Performance relationship</i>	Relation between an element describing <i>performance</i> (i.e. business or technological) and an element of <i>another type</i> (i.e. between a ‘ <i>quantity</i> ’ and ‘ <i>a level of consumption</i> ’, between a ‘ <i>volume</i> ’ and a ‘ <i>level of comfort</i> ’)
<i>Hierarchical relationship</i>	Relation between elements of the <i>same type and subject</i> but at <i>different levels</i> (i.e. between ‘ <i>A/C wings weight</i> ’ and ‘ <i>A/C weight</i> ’)
<i>Aggregation relationship</i>	Relation between an element and a more aggregated one at the <i>same level</i> , of the <i>same type and subject</i> (i.e. ‘ <i>A/C turn around time cost</i> ’ and ‘ <i>A/C operational cost</i> ’)
<i>Functional relationship</i>	Relation between an element of <i>functional type</i> , and an element of <i>structural or solution feature type</i>

Table 7: Example of semi-quantitative assessment of the relations

Influence on Of	Element 1	Element 2	Element 3	Element 4	Element 5	Direct influence
Element 1	0	-2	0	0	0	2
Element 2	0	0	-1	0	0	1
Element 3	0	0	0	2	1	3
Element 4	0	0	0	0	0	0
Element 5	0	0	0	0	0	0
Direct dependence	0	2	1	2	1	

Legend:

2	high & positive contribution
1	medium & positive contribution
0	no contribution
-1	medium & negative contribution
-2	high & negative contribution

For instance, the previous table means that:

- When the *element 1* relatively evolves in the desired way (i.e. in comparison with a product reference), then the *element 2* relatively evolves in the undesired way (i.e. in comparison with a product reference)
- When the *element 3* relatively evolves in the desired way (i.e. in comparison with a product reference), then the *element 4* relatively evolves also in the desired way (i.e. in comparison with a product reference)

The *integration of the Business and Engineering elements* permits to validate, change or complete the definitions of *value dimensions* and *value drivers* through matrix based operations:

- *Validation of the Value Dimensions*

The identified Value Dimensions correspond mainly to the parameters that have low direct influences to the other parameters (see Table 7). Indeed by definition, they represent the highest level of satisfaction criteria of the global stakeholders, which have to be at the same level, independent and complete as much as possible.

- *Validation of the Value Drivers*

The Value Drivers correspond to the parameters that have direct or indirect influences on the Value Dimensions (see Table 7).

The *integration of the business and engineering elements* allows also evaluating them on the basis of the KPS-Value model and through matrix operations:

- *Level of independence of the Value Drivers*

The level of independence of a Value Driver is higher as the levels of its direct and indirect dependences are lower (see Table 7).

- *Level of influence of the Value Drivers*

The level of influence of a Value Driver on the Value Dimensions can be assessed for given stakeholders. It corresponds to a weighted sum of the absolute influences on the considered Value Dimensions (see equation 1).

The influence of value driver d is given by formula (1).

$$Influence(d) = \sum_{l \in VD} weight_l \times AbsoluteInfluence(d, l) \quad (1)$$

$d \in vd$

Where,

- vd is the set of Value Drivers
- VD is the set of Value Dimensions

- $AbsoluteInfluence(d,l)$ is the absolute influence of the driver d on the Value Dimension l
- $Weight_l$ is the importance level of the Value Dimension l

The $AbsoluteInfluence(d,l)$ of the driver d on the Value Dimension l is given by formula (2).

$$AbsoluteInfluence(d,l) = abs\left(\sum_{n=N} A^n(d,l)\right) \quad (2)$$

Where,

- $A^n(i,j)$ represents different power levels of the parameters influences matrix $A(i,j)$ and describes then all the indirect influences between the parameters
- N is the maximum level of the series $A^n(i,j)$ before its convergence to the null matrix in the case there is no influences loop between the parameters.
- $abs()$ is the absolute function

From equations (1) and (2), the influence of value driver d is deduced in formula (3).

$$TotalInfluence(d) = \sum_{l \in VD} weight_l \times abs\left(\sum_{n=N} (A^n(d,l))\right) \quad (3)$$

$d \in vd$

Where,

- vd is the set of Value Drivers
- VD is the set of Value Dimensions
- $Weight_l$ is the importance level of the Value Dimension l
- $A(i,j)$ is the direct influences matrix
- $abs()$ is the absolute function
- N is the maximum level of the series $A^n(i,j)$ before its convergence to the null matrix in the case there is no influences loop between the parameters

- *Level of importance of the Value Drivers*

The level of importance of a Value Driver depends on the comparison between its *total positive* and *negative contributions* to the Value Dimensions. The level of importance can be assessed for given stakeholder and customer profiles. The *total positive* and *negative contributions* of a driver correspond respectively to the weighted sum of its positive and negative contributions to the Value Dimensions.

The total negative contribution of a driver d is given by formula (4).

$$TotalNegativeContribution(d) = (-1) \times \sum_{l \in NVD(d)} weight_l \times \left(\sum_{n=N} A^n(d, l) \right) \quad (4)$$

$$d \in vd$$

Where,

- $A(i, j)$ is the direct influences matrix
- vd is the set of Value Drivers
- $NVD(d)$ is the set of Value Dimensions on which the driver d has negative contributions (i.e. $(\sum_{n=N} A^n(d, l)) \leq 0$, for all Value Dimensions $l \in NVD(d)$)
- $Weight_l$ is the importance level of the Value Dimension l
- N is the maximum level of the series $A^n(i, j)$ before its convergence to the null matrix in the case there is no influences loop between the parameters

In the same way, the total positive contribution of a driver d is given by formula (5).

$$TotalPositiveContribution(d) = \sum_{l \in PVD(d)} weight_l \times \left(\sum_{n=N} A^n(d, l) \right) \quad (5)$$

$$d \in vd$$

Where,

- $A(i, j)$ is the direct influences matrix
- vd is the set of Value Drivers

- $PVD(d)$ is the set of Value Dimensions on which the driver d has positive contributions (i.e. $(\sum_{n=N} A^n(d,l)) \geq 0$, for all Value Dimensions $l \in PVD(d)$)
- $Weight_l$ is the importance level of the Value Dimension l
- N is the maximum level of the series $A^n(i, j)$ before its convergence to the null matrix in the case there is no influences loop between the parameters

It is worth noting that the contributions of a driver on Value Dimensions can vary depending on the customer profiles. For instance, the reduction of the driver “A/C brakes cooling time during the turn around time” leads to a reduction on the dimension “turnaround time” only for “short range” customer profile: indeed, this driver is a dimensioning factor of the ground turnaround time only for short range companies. Consequently, the importance level of a value driver is really linked to a customer profile.

The *level of importance of a driver* is higher as its total positive contribution is more important than its total negative one. Different *categories of importance level* can be used for its assessment:

- *the importance level is high (A)* in the case of higher total positive contribution than the total negative contribution
- *the importance level is medium (B)* in the case of equivalence between the total positive contribution and the total negative contribution
- *the importance level is low (C)* in the case of higher total negative contribution than the total positive contribution

One of the main goals of the CtV methodology is to identify and select the *most important Value Drivers* for the *different stakeholders and profiles*.

- *Identification of differentiating or basic Drivers*

The *differentiating and basic drivers* are identified by comparing their *contributions both to differentiation and basic values*. On the one hand, one can define a *differentiating Value Driver* as a driver with a higher contribution to *differentiation than to basic values*. On the other hand, a basic driver contributes more to *basic values than to differentiation*.

The contribution of a driver to differentiation is given by formula (6).

$$DifferentiationContribution(d) = \sum_{l \in PDVD(d)} weight_l \times \left(\sum_{n=N} A^n(d, l) \right) \quad (6)$$

$$d \in vd$$

Where,

- $A(i, j)$ is the direct influences matrix
- vd is the set of Value Drivers
- $PDVD(d)$ is the set of Value Dimensions on which the driver d has positive and differentiating contributions (i.e. $(\sum_{n=N} A^n(d, l)) \geq 0$, for all Value Dimensions $l \in PDVD(d)$)
- $Weight_l$ is the importance level of the Value Dimension l
- N is the maximum level of the series $A^n(i, j)$ before its convergence to the null matrix in the case there is no influences loop between the parameters

The contribution of a driver to basic values is given by formula (7).

$$BasicContribution(d) = \sum_{l \in PBVD(d)} weight_l \times \left(\sum_{n=N} A^n(d, l) \right) \quad (7)$$

$$d \in vd$$

Where,

- $A(i, j)$ is the direct influences matrix
- vd is the set of Value Drivers
- $PBVD(d)$ is the set of Value Dimensions on which the driver d has positive and basic contributions (i.e. $(\sum_{n=N} A^n(d, l)) \geq 0$, for all Value Dimensions $l \in PBVD(d)$)
- $Weight_l$ is the importance level of the Value Dimension l
- N is the maximum level of the series $A^n(i, j)$ before its convergence to the null matrix in the case there is no influences loop between the parameters

The contributions of a driver to differentiation or basic values depends on the customer profiles: differentiating and basic drivers are then identified for précised profiles. In order to build a high differentiating business strategy for a given profile, numerous corresponding differentiating drivers must be found.

- *Level of completeness of Value Drivers*

Inspired from the research works by Yannou et al. [31, 36] on usages surfaces covering, the level of completeness of a set of value drivers corresponds to its *degree of covering* of the Value Dimensions. It is defined as the relative sum of the weights of the Value Dimensions that are positively influenced by the set of drivers.

The level of completeness of a set of value drivers is given by formula (8).

$$CompletenessLevel = \frac{\sum_{l \in TPVD} weight_l}{\sum_{l \in VD} weight_l} \quad (8)$$

Where,

- VD is the set of Value Dimensions
- $TPVD$ is the set of Value Dimensions on which the drivers have positive total contributions (i.e. $\sum_{d \in vd} (\sum_{n=N} A^n(d,l)) \geq 0$, for all Value Dimensions $l \in TPVD(d)$)
- $Weight_l$ is the importance level of the Value Dimension l

This metric is assessed for given stakeholders or customer profiles. The objective is to identify value drivers and even strategical value drivers that positively contribute to a maximum number of value dimensions. The knowledge acquisition step may then be implemented several times as long as the completeness level is not sufficient.

- *Level of differentiation of Value Drivers*

Calculated for given stakeholders or customer profiles, this metric allows ensuring that the identified differentiating drivers globally contribute enough to differentiation. It depends on the number of differentiating drivers, on their levels of contributions to differentiation and on their levels of market contestation. This definition is consistent with the Blue Ocean Strategy that suggests putting the effort on the differentiating drivers to maximize the perceived added values.

The level of differentiation of a set of differentiating Value Drivers is given by formula (9) and (10).

$$DifferentiationLevel = \sum_{d \in dvd} DifferentiationContribution(d) \times ContestationLevel(d) \quad (9)$$

$$DifferentiationLevel = \sum_{d \in dvd} \left(\left(\sum_{l \in PDVD(d)} weight_l \times \left(\sum_{n=N} A^n(d,l) \right) \right) \times ContestationLevel(d) \right) \quad (10)$$

Where,

- *dvd* is the set of differentiating Value Drivers
 - *ContestationLevel()* is a quantitative function of the contestation level of the Value Drivers. It permits to give more importance to uncontested value drivers.
 - *PDVD(d)* is the set of Value Dimensions on which the driver *d* has positive and differentiating contributions (i.e. $(\sum_{n=N} A^n(d,l)) \geq 0$, for all Value Dimensions $l \in PDVD(d)$)
 - *Weight_l* is the importance level of the Value Dimension *l*
 - *A(i,j)* is the direct influences matrix
 - *N* is the maximum level of the series *Aⁿ(i, j)* before its convergence to the null matrix in the case there is no influences loop between the parameters
-
- *Level of importance of the Technical Features*

The level of importance of a *Technical Feature* (i.e. a technical function or solution describing an architecture component) depends on the comparison between its *total positive* and *negative contributions* to the Value Dimensions. The level of importance can be assessed for given stakeholder and customer profiles. The *total positive* and *negative contributions* of a feature correspond respectively to the weighted sum of its positive and negative contributions to the Value Dimensions.

The total negative contribution of a feature *f* is given by formula (11).

$$TotalNegativeContribution(f) = (-1) \times \sum_{l \in NVD(f)} weight_l \times \left(\sum_{n=N} A^n(f, l) \right) \quad (11)$$

$$f \in TF$$

Where,

- $A(i, j)$ is the direct influences matrix
- TF is the set of Technical Features
- $NVD(f)$ is the set of Value Dimensions on which the feature f has negative contributions (i.e. $(\sum_{n=N} A^n(f, l)) \leq 0$, for all Value Dimensions $l \in NVD(f)$)
- $Weight_l$ is the importance level of the Value Dimension l
- N is the maximum level of the series $A^n(i, j)$ before its convergence to the null matrix in the case there is no influences loop between the parameters

In the same way, the total positive contribution of a feature f is given by formula (12).

$$TotalPositiveContribution(d) = \sum_{l \in PVD(d)} weight_l \times \left(\sum_{n=N} A^n(d, l) \right) \quad (12)$$

$$d \in vd$$

Where,

- $A(i, j)$ is the direct influences matrix
- TF is the set of Technical Features
- $PVD(f)$ is the set of Value Dimensions on which the feature f has positive contributions (i.e. $(\sum_{n=N} A^n(f, l)) \geq 0$, for all Value Dimensions $l \in PVD(f)$)
- $Weight_l$ is the importance level of the Value Dimension l
- N is the maximum level of the series $A^n(i, j)$ before its convergence to the null matrix in the case there is no influences loop between the parameters

It is worth noting that the contributions of a feature on Value Dimensions can vary depending on the customer profiles. For instance, the addition of “automatic aircraft braking after landing” feature contributes to the reduction of the “turnaround time” of short range flight operations: it allows decreasing the needed time for brakes cooling on ground, which is a dimensioning factor of the turnaround time. Consequently, the importance level of a technical feature is really linked to a customer profile.

- *Identification of differentiating or basic Features*

The differentiating and basic features are identified by comparing their contributions both to differentiation and basic values. On the one hand, one can define a differentiating Technical Feature as a feature with a higher contribution to differentiation (i.e. it contributes to higher satisfaction than basic or conventional solutions) than to basic values: in other words, a differentiating feature can be seen as a “nice to have” feature. On the other hand, a basic feature, which can be considered also as a “must to have” feature, contributes more to basic values than to differentiation.

The contribution of a feature to differentiation is given by formula (13).

$$DifferentiationContribution(f) = \sum_{l \in PDVD(f)} weight_l \times \left(\sum_{n=N} A^n(f, l) \right) \quad (13)$$

$f \in TF$

Where,

- $A(i,j)$ is the direct influences matrix
- TF is the set of Technical Features
- $PDVD(f)$ is the set of Value Dimensions on which the feature f has positive and differentiating contributions (i.e. $(\sum_{n=N} A^n(f, l)) \geq 0$, for all Value Dimensions $l \in PDVD(f)$)
- $Weight_l$ is the importance level of the Value Dimension l
- N is the maximum level of the series $A^n(i, j)$ before its convergence to the null matrix in the case there is no influences loop between the parameters

The contribution of a feature to basic values is given by formula (14).

$$BasicContribution(f) = \sum_{\substack{l \in PBVD(f) \\ f \in TF}} weight_l \times \left(\sum_{n=N} A^n(f, l) \right) \quad (14)$$

Where,

- $A(i, j)$ is the direct influences matrix
- vd is the set of Technical Features
- $PBVD(f)$ is the set of Value Dimensions on which the driver f has positive and basic contributions (i.e. $(\sum_{n=N} A^n(f, l)) \geq 0$, for all Value Dimensions $l \in PBVD(f)$)
- $Weight_l$ is the importance level of the Value Dimension l
- N is the maximum level of the series $A^n(i, j)$ before its convergence to the null matrix in the case there is no influences loop between the parameters

The contributions of a feature to *differentiation or basic values* depends on the *customer profiles: differentiating and basic features* are then identified for précised profiles. In order to support *high differentiating business strategies* for given profiles, numerous corresponding *differentiating technical features* must be found.

The *knowledge acquisition* may be *refined and updated several times* in order to obtain a *high level of differentiation of the identified drivers and features* for the stakeholder and customer profiles.

In a summary, in the perspective of added values creation, this CtV process step consists in *extracting pertinent value drivers and technical features* for the different stakeholder and customer profiles in a *multi-objective view*.

Indeed, the target is to find out the drivers and features that are:

- *the most independent*
- *the most influencing*
- *the most important*
- *the most differentiating*
- *the most uncontested in the competitive market*

The value drivers corresponding to such criteria are defined as *strategical value drivers*, which are selected for relevant *value strategies* building. At this step, it should also be ensured that the *level of importance*, *completeness* and *differentiation* of the *strategical value drivers* and *technical features* are sufficient for value creation. Such indicators allow to really steer the knowledge acquisition in the so-called fuzzy front end stage (i.e. the product planning and conceptual design) described in the literature [68], and of the RID methodology [27, 25].

5.2.4 Third step: Value Strategies analysis

This CtV process step permits to implement the P-Value model: it consists in defining and assessing *the Value Strategies* from the identified Value Dimensions, Drivers and Stakeholders. A strategy is *a set of choices and objectives* on Stakeholders, Value Dimensions and Drivers. It can then aim at creating value for only *specific customer profiles* or *global stakeholders*.

A value strategy is defined by formula (15).

$$ValueStrategy = (S, P, VDT, vdt) \quad (15)$$

Where,

- *S* is a set of global stakeholders
- *P* is a set of customer profiles
- *VDT* is a set of choices or objectives (i.e. low, medium or high improvement) on Value Dimensions
- *vdt* is a set of choices or objectives (i.e. low, medium or high improvement) on Value Drivers

A *Value Strategy* can be *differentiating or basic* depending on the *differentiating or basic* characteristics of the chosen Value Dimensions and Drivers for the targeted Stakeholder and customer profiles.

The target of this step is to define *highly differentiating strategies* for the different stakeholders or customer profiles. It aims to build strategies by putting high level objectives on the identified strategical drivers.

The different quality metrics of the P-Value model are defined hereafter:

- *Level of value contribution of a strategy*

The total level of value contribution of a strategy corresponds to the weighted sum of its contributions to the Value Dimensions.

The value contribution of a strategy s to the Value Dimension l is given by formula (16).

$$StrategyContribution(l, s) = \sum_{d \in vd(s)} O_d \times \left(\sum_N A^n(d, l) \right) \quad (16)$$

$$l \in VD$$

Where,

- VD is the set of Value Dimensions
- $vd(s)$ is the set of Value Drivers of the strategy s
- $A(i, j)$ is the direct influences matrix:
- N is the maximum level of the series $A^n(i, j)$ before its convergence to the null matrix in the case there is no influences loop between the parameters
- O_d is the relative objective value between -1 and 1 and assigned to the driver d :
 - O_d equal to 0 means that the value of the driver d in the strategy is equal to a reference value
 - O_d equal to 1 means that the value of the driver d in the strategy is much better than a reference value
 - O_d equal to -1 means that the value of the driver d in the strategy is much worse than a reference value

The total contribution of the strategy s to the Value Dimensions is then given by formula (17).

$$TotalStrategyContribution(s) = \sum_{l \in VD} weight_l \times \left(\sum_{d \in vd(s)} O_d \times \left(\sum_N A^n(d, l) \right) \right) \quad (17)$$

Where,

- VD is the set of Value Dimensions
- $vd(s)$ is the set of Value Drivers of the strategy s
- $A(i, j)$ is the direct influences matrix

- N is the maximum level of the series $A^n(i, j)$ before its convergence to the null matrix in the case there is no influences loop between the parameters
- O_d is the relative objective value between $-I$ and I and assigned to the driver d
- $Weight_l$ is the importance level of the Value Dimension l

After evaluating the contributions of the strategies, their *consistency level* can be assessed. It consists in evaluating the consistency between the objectives of the strategies and their value contributions. A qualitative scale (low, medium and high) is used to assess this metric.

- *The level of completeness of a strategy*

The level of completeness of a strategy corresponds to the degree of covering of the Value Dimensions by the strategy. As the completeness degree of value drivers, it is defined as the relative sum of the weights of the Value Dimensions on which the strategy has positive contributions.

The level of completeness of a strategy s is given by formula (18).

$$CompletenessStrategyDegree(s) = \frac{\sum_{l \in PVD(s)} weight_l}{\sum_{l \in VD} weight_l} \quad (18)$$

Where,

- $Weight_l$ is the importance level of the Value Dimension l
- VD is the set of Value Dimensions
- $PVD(s)$ is the set of Value Dimensions on which the strategy s has positive contributions (i.e. $StrategyContribution(l, s) \geq 0$, for all Value Dimensions $l \in PVD(s)$)

- *The level of differentiation of a strategy*

As the level of differentiation of the value drivers, it corresponds to the weighted sum of the contributions to differentiation of the drivers used by a strategy. It depends on the number of differentiating drivers, their contributions to differentiation, their relative objectives and their levels of market contestation.

The level of differentiation of a strategy s is given by formula (19).

$$DifferentiationStrategy(s) = \sum_{d \in dvd(s)} DifferentiationContribution(d) \times O_d \times ContestationLevel(d) \quad (19)$$

Where,

- $dvd(s)$ is the set of differentiating Value Drivers used by the strategy s
- $ContestationLevel()$ is a quantitative function of the contestation level of the Value Drivers. It permits to give more importance to uncontested value drivers.
- O_d is the relative objective value between $-I$ and I and assigned to the driver d

The final expression of the level of differentiation of a strategy s is given by formula (20).

$$DifferentiationStrategy(s) = \sum_{d \in dvd(s)} \left(\left(\sum_{l \in PDVD(d)} weight_l \times \left(\sum_{n=N} A^n(d, l) \right) \right) \times O_d \times ContestationLevel(d) \right) \quad (20)$$

Where,

- $dvd(s)$ is the set of differentiating Value Drivers used by the strategy s
- $ContestationLevel()$ is a quantitative function of the contestation level of the Value Drivers. It permits to give more importance to uncontested value drivers.
- O_d is the relative objective value between $-I$ and I and assigned to the driver d
- $A(i, j)$ is the direct influences matrix
- $PDVD(d)$ is the set of differentiating Value Dimensions on which the driver d has positive and differentiating contributions (i.e. $(\sum_{n=N} A^n(d, l)) \geq 0$, for all Value Dimensions $l \in PDVD(d)$)
- $Weight_l$ is the importance level of the Value Dimension l
- N is the maximum level of the series $A^n(i, j)$ before its convergence to the null matrix in the case there is no influences loop between the parameters

In a summary, this step allows selecting the *most interesting strategies*. They correspond to:

- *The strategies contributing the most to value creation*
- *The most consistent strategies*
- *The most complete strategies*
- *The most differentiating strategies*

At the end of this step, other metrics are assessed to evaluate the *efficiency of the knowledge acquisition phase*. They correspond to the *maximum levels of completeness and differentiation of the strategies*. The knowledge acquisition phase may then be steered by the amplitudes of the *levels of completeness and differentiation of the strategies*.

The *maximum level of strategies completeness* is given by formula (21).

$$MaxStrategiesCompleteness = Max_s(CompletenessStrategyLevel(s)) \quad (21)$$

The *maximum level of strategies differentiation* is given by formula (22).

$$MaxStrategiesDifferentiation = Max_s(DifferentiationStrategyLevel(s)) \quad (22)$$

It is worth noting that the objective of this step is also to shrink the gaps between:

- *the maximum level of completeness of the strategies and the level of completeness of the identified value drivers*
- *the maximum level of differentiation of the strategies and the level of differentiation of the identified value drivers*

The lowering of those gaps leads to a more efficient use of the value drivers and so to a wider exploration of value strategies.

The results of this step may then lead to an implementation loop of the second CtV step to identify drivers with highest completeness and differentiation levels, or even of the first CtV step to get additional knowledge of higher quality.

5.2.5 Fourth step: Architectural Solutions steering

This last step of the CtV process consists in deploying the S-Value model. It allows steering the architectural solutions definition through the following value metrics: the *gaps between the specified solutions and the defined strategies*, the *value contributions of the solutions* and the contributions to differentiation of the solutions.

- *The gap to strategy of an architectural solution*

The assessed *gap to strategy* corresponds to a weighted sum of absolute distances between the objectives of the strategy and the actual values of the solution.

The gap to the strategy s of a solution o is given by formula (23).

$$GapToStrategy(s, o) = \sum_j weight_j \times abs(O_j - A_j) \quad (23)$$

Where,

- j represents a Value Dimension or a Driver
 - $weight_j$ is the relative weight of the Value Dimension j or a quantitative function of the importance level of the Value Driver j
 - O_j is the relative objective of the strategy s on the Value Dimension or Driver j
 - A_j is the actual value of the solution o on the Value Dimension or Driver j
-
- The *value contribution of an architectural solution*

The value contribution of an architectural solution corresponds to the consolidation of the contributions of all the instantiated features to the value dimensions. It can be calculated for a given stakeholder or customer profile.

The value contribution of an architectural solution o is given by formula (24).

$$TotalValueContribution(o) = \sum_{l \in VD} weight_l \times \left(\sum_{f \in TF(o)} \left(\sum_N A^n(f, l) \right) \right) \quad (24)$$

Where,

- VD is the set of Value Dimensions
 - $TF(o)$ is the set of Technical Features of the solution o
 - $A(i, j)$ is the direct influences matrix
 - N is the maximum level of the series $A^n(i, j)$ before its convergence to the null matrix in the case there is no influences loop between the parameters
 - $Weight_l$ is the importance level of the Value Dimension l
-
- The *contribution to differentiation of an architectural solution*

The contribution to differentiation of an architectural solution corresponds to the consolidation of the differentiating contributions of all the instantiated features to the differentiating value dimensions. It can be calculated for a given stakeholder or customer profile.

The contribution to differentiation of an architectural solution o is given by formula (25).

$$DifferentiationSolution(o) = \sum_{f \in dTF(o)} \left(\left(\sum_{l \in PDVD(f)} weight_l \times \left(\sum_{n=N} A^n(f, l) \right) \right) \times ContestationLevel(f) \right) \quad (25)$$

Where,

- $dTF(o)$ is the set of differentiating Technical Features used by the solution o
- $ContestationLevel()$ is a quantitative function of the contestation level of the Technical Features (i.e. degree of novelty in the competitive market). It permits to give more importance to uncontested technical features.
- $A(i, j)$ is the direct influences matrix
- $PDVD(f)$ is the set of differentiating Value Dimensions on which the feature f has positive and differentiating contributions (i.e. $(\sum_{n=N} A^n(f, l)) \geq 0$, for all Value Dimensions $l \in PDVD(f)$)
- $Weight_l$ is the importance level of the Value Dimension l
- N is the maximum level of the series $A^n(i, j)$ before its convergence to the null matrix in the case there is no influences loop between the parameters

The objective of this step is to lower *the gaps to strategies of the solutions*, to maximize their *value contributions* and their *contributions to differentiation*. In order to do so, loops of implementation of the other CtV steps may be steered to modify the strategies, to identify more interesting drivers and technical features by acquiring new knowledge.

These quality metrics of the S-Value model really permit then to supervise the knowledge acquisition, the strategies and solutions definition phases until the values of the final architectures are not sufficient.

6 Comparison of the Concept-to-Value methodology with the solutions of the state of the art

6.1 Value management of innovation: a value-based top-down and bottom-up approach

The Quality Functional Deployment (QFD) as Balanced Score Cards (BSC) are methodologies that explain the refinement of *high level needs or requirements* into *low level solutions characteristics*. They ensure the efficient contributions of *solutions alternatives* to global *initial objectives*, and support the alignment of an organization to them through the whole development process.

Based on matrix contributions assessment such as QFD, the CtV methodology uses *value metrics* to ensure as well alignment and contributions to high level objectives, which are called namely *Value Dimensions*. In the contrary to the QFD and BSC, the CtV methodology is not only focused on *the evaluation of solutions alternatives* contributions to given initial objectives (i.e. a bottom-up approach from solutions proposals), but also consists in really *steering the exploration of the solutions* (i.e. a top down approach for solutions exploration). Indeed, there is a support for the exploration of different *sets of initial objectives*, through the identification of several *potential Stakeholders*, *Value Dimensions*, *Customer profiles* and *Value Drivers*. More than just to understand the *values of the solutions alternatives*, this *top-down exploration* allows identifying *new innovation areas* where *added-values* can be brought: within such areas, research efforts have to be allocated to find relevant *technical functions and features*. The exploration of *Business objectives* toward the identification of *Business value drivers* is steered by value through *value metrics* like the *degree of completeness* (i.e. the degree of value dimensions recovery), the *degree of contributions to differentiation*, which have to be optimized. From this Business exploration, the *relevant innovation areas* that correspond to interesting *Business Value Creation Strategies* are defined, and represent *sets of initial objectives* to which *solutions alternatives* have to be generated and assessed. The *solutions alternatives generation* is also steered by value through the exploration of *Engineering Value Drivers*, of *Technical Features*, and through *value metrics* like the *degree of completeness*, the *degree of contributions to differentiation*, and the *gap to strategy*.

6.2 Innovation intermediate objects representation and value management

Several research works underline the need of representing the different *design artifacts* that evolve during the development process. Corresponding to *intermediate objects* that represent the final product, the design artifacts capture permit to describe and power the *design*

rationale. Indeed, they can be used for *design history* capture as recommended by Lonchamp [67], for *decisions making*, or for *design reengineering*. In addition, Boujut and Blanco [10] state that they also allow reinforcing the *design dynamics* through generated multiple *cognitive transactions* between them and the designer. Different types of transactions are analyzed in the literature, such as: knowledge requests, decisions making, design modifications, design evaluations. These iterative transactions between the designer and the design artifacts are at the basis of the *reflexive design theory*, from which the quality and quantity of the intermediate objects are as well the results of the *design process*, and also its dynamics enablers. Aurisicchio et al. [12] develops a typology of the knowledge requests, involved in a given type of reflexive design process, namely the *question-based design*. They bring then significant support to the *design rationale* management through the formal representation of design questions and the corresponding operations of knowledge acquisition. Their model is implemented on a tool called DReD (i.e. Design Rationale eDitor) that they developed, and which permits to represent *design objects* like *design questions*, *answers* and *decisions*.

At a given extent, the suggested CtV methodology is aligned with the principles of question-based design for design rationale support. The developed KPS model of CtV permits to represent *design knowledge* and *questions*. Indeed, the K model of CtV is built from Aurisicchio et al. model, and tends even to enrich the definitions of the following *requests characteristics* in the literature:

- The *objective* of the knowledge acquisition: it can be oriented, on the one hand, to the *technological* or *business environment* analysis, and, on the other hand, to the *internal* or *external environment* analysis.
- The *subject* of the knowledge acquisition: it can be a product, service, enabling product, process or business model.
- The *type* of answers: they can describe product performances, functions, scenarios or structural parameters (i.e. physical parameters).
- The *method* of knowledge acquisition: it can be related to the practical way or tool used to capture the knowledge in regards with the *objective*, *subject*, *type*, *level* and *domain* of the request.

Besides, the K model of CtV suggests *additional requests characteristics* in comparison with the existing ones of the literature:

- The *requests level*, which assigns the knowledge acquisition to the right *organization level* or to the right *product level*
- The *domain*, which identifies the pertinent knowledge field to involve in the investigation process (i.e. business, structure, systems, industrialization...)

The captured *knowledge objects* through the K model consist of *Business and Engineering elements* like *Stakeholders*, *Value Dimensions*, *Value Drivers*, *Customers Descriptors* and

Profiles, and *Technical Features*. In addition, the *Business Strategies* as well as the *Technical Strategies* are represented within the P model of CtV. Finally, the S model is dedicated to the representation of the *architectural solutions*, which are described as combinations of *Technical Features*.

To sum up, the benefits of the CtV methodology in comparison with other existing methods for intermediate objects capture like DreD consist in:

- enriching the *knowledge requests characteristics*
- building the representation of *multidisciplinary objects*, namely Business and Engineering objects, to *share multidisciplinary knowledge, problems and solutions*
- integrating the *multidisciplinary knowledge, problems and solutions*, which contributes in supporting, enriching and tracking the *design rationale and history*
- managing the evolutions of the *multidisciplinary objects* by value through the various CtV *value metrics*

The practical advantages of CtV methodology remain then in its usability by both *Business and Engineering teams*, in the enriched representation and integration of their *respective intermediate objects*, and in their steering for the *value perception* optimization.

6.3 Innovation expansion: value-based steering of explorations

There are *commonality points* between CtV methodology and most of the other innovation methodologies like KCP [5] and RID [34].

The first commonality is the fact that all supported innovation projects start from a given *scope*. Yannou suggests in RID methodology [34] to launch a project by defining an *innovation perimeter*, which may correspond to the description of an *ideal need*. Different *usage contexts* can then be explored inside a given *ideal need*, and lead to the development of technological solutions. Within the CK Theory described by Hatchuel [5] and its derived KCP methodology, the innovation process begins with an *initial concept*, which is refined progressively into different solutions alternatives. The CtV methodology is also deployed after the formulation of an innovation scope into which the KPS model is implemented.

The second commonality is related to the fact that the innovation methodologies suggest to start projects from the state of initial useful *knowledge* to be exploited. Indeed, RID methodology deployment begins by an investigation that leads to initial knowledge exploration and capture. CK Theory and KCP methodology starts with the inventory of existing and usable knowledge at disposal. The CtV methodology begins with the composition of a multidisciplinary project team, which participates in multidisciplinary knowledge exploration and representation.

Nevertheless, there are differences between CtV methodology and some of other innovation methodologies.

At first, in opposition to other methodologies like KCP, CtV methodology is not primarily based on *intensive knowledge expansion* for its deployment success. One of its main principles consists first of all in representing and integrating multidisciplinary knowledge from a given initial project team. In a consequence, it is not required to add or acquire breakthrough knowledge for innovation management. The more formal Business and Engineering objects representation and integration already give a greater probability to identify new business strategies and solutions within a given multidisciplinary team.

At second, unlike the other innovation methodologies such as KCP and Brainstorming methods, CtV methodology does not tend to enhance the *intellectual creativity* of each innovation project participant. Indeed, it supports the innovation mainly on the basis of multidisciplinary objects representation and integration. Instead of permitting to avoid the *cognitive fixation effects* that prevent from being individually creative [5], CtV methodology just allows sharing and integrating *objectives and ideas* within a multidisciplinary team. This better supported integration of several types of experts often triggers off the generation of innovative business strategies and technological concepts.

Finally, the main objective of the CtV methodology is not to achieve absolutely an *intensive concepts expansion*, which is though the primary target of methodologies like KCP. The CtV methodology consists in making an exploration of Value Creation Strategies and in focusing the innovation effort only on the areas where values can be brought and captured. The main objective of our suggested methodology is then to create value by defining it through Value Creation Strategies, and not to innovate: innovation has to be steered by value, can be generated, and is not then a primary target! Technological innovation may then be a consequence of the CtV methodology for high value achievement. Thus, depending on the explored Value Creation Strategies, innovation development may be relevant or not. For instance, innovation for aircraft passengers comfort may be more pertinent for Convenience Carriers than for Low Cost Carriers. In the same way, relevant Value Creation Strategies may be *differentiating strategies*, which lead to innovation expansion, or *neutralization strategies*, which lead to existing technologies development and technological leadership neutralization. In the contrary, *intensive innovation expansion* is the *first primary requirement* for methodologies such as KCP methodology and Triz explained by Altshuller [6]. Triz permits to solve *inventive design problems* through *design principles* and *technological evolutionary laws*, and KCP methodology pushes as much as possible to *conceptual divergence* from *existing solutions and objects*. In a summary, Value is more a *steering objective* than a *final output* of innovation for CtV methodology.

7 Case studies implementation

7.1 The initial perimeters of CtV implementation

The *initial project statement* of the CtV process describes the *perimeter of a test case* implementation. The main characteristic of the *deployment context* of the CtV methodology is the need of challenging both the *business objectives* and *architectural solutions* of a technological development project.

Different types of perimeters can be defined and may lead to different ways of implementation of the CtV methodology. They are characterized by:

- The *product level* of the value analysis, which can be *aircraft level*, *subsystems level* or *subcomponent level*
- The *origin* of the value study, which can be a *proposal of value strategy*, of *architectural solution*, or a *blank* (i.e. from a white paper)
- The *objective* of the test case may, which may consist in implementing a *bottom up* or *top down* analysis
- The *level of visibility* of the created values by the *external or internal stakeholders*

The CtV methodology can be applied both at *A/C or subcomponent level*. The three implemented test cases deal with the value based challenges of *local architectural concepts* (see Figure 18): some *functional and technical constraints* have then to be taken into account in the CtV process, and so for the definition of new value strategies and architectural concepts.

In addition, a value study may begin from an initial proposal of *architectural solution* or *value strategy*, or from a *white paper*: it corresponds to three different types of entries into the CtV process (Figure 16). Indeed, a project may consist in innovating from scratch and proposing radically new concepts: it mainly leads to *breakthrough* or *disruptive* differentiating concepts! In the contrary, a project may aim at assessing the *value contributions* of existing strategies or architectural solutions, and at challenging them by identifying new valuable ones. Anyway, described in the *initial project statement*, each of these entry types leads to the common implementation of the *Primary Knowledge Acquisition*, *Value Drivers and Features Analysis*, *Value Strategies Analysis* and *Architectural Solutions Steering* phases of the CtV process. The last phase is dedicated for the test cases that really deal with the analysis or challenges of architectural solutions.

Besides, a test case can consist in performing a *bottom-up* or *top-down* exploitation of the CtV process: the *bottom up* approach corresponds to the *evaluation* of the value contributions of

value strategies or architectural solutions; the *top down approach* deals with the challenges of suggested value strategies or solutions, and with the identification of new ones. The different applied test cases (Figure 17) implement both bottom-up and top-down approaches, in order to *evaluate suggested innovative concepts*, and to *challenge them* by defining new ones, through the consideration of all the pertinent stakeholders, value dimensions and drivers. The exploration of value dimensions and drivers is then much more extended in the *Primary Knowledge Acquisition* and *Value Drivers and Features Analysis* phases in the case of the top-down approach: new dimensions and drivers have to be identified!

Finally, the implementation of the CtV process may also depend on the level of visibility of the values by the internal or external stakeholders. This level of visibility is related to the type of A/C component to be designed, and explains the number or importance level of the found value dimensions of the external or internal stakeholders. For instance, the *Systems Installation* test case (see Figure 17) creates values that are more visible for the internal stakeholders: their relative value dimensions are then more important and numerous. In the contrary, the *Aircraft Reconfiguration* test case (see Figure 17) brings values that are more visible for the external stakeholders, and particularly for the *passengers and customers*: it is then pertinent to consider different *types of customer profiles* and to link them to their corresponding *differentiating* value strategies and solutions!

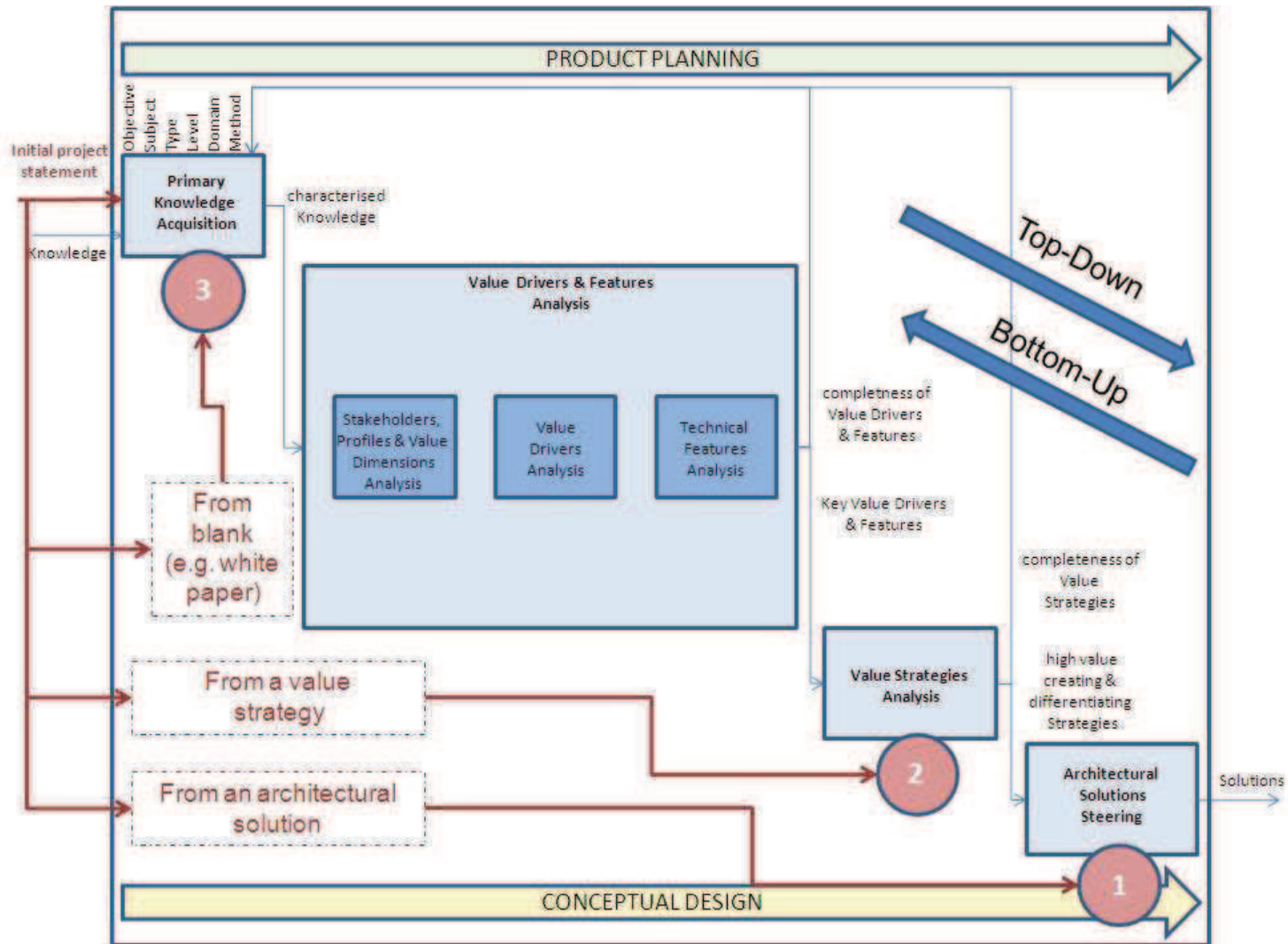


Figure 16: Three different entry points into the CtV pro

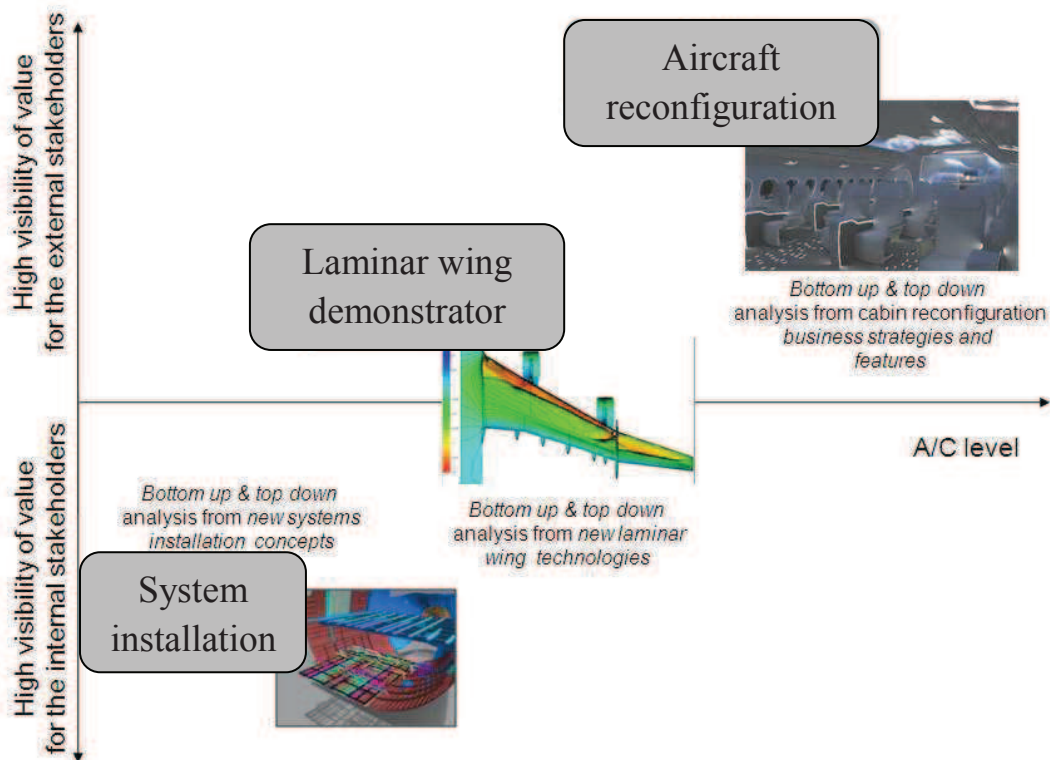


Figure 17: CtV test cases positioning

7.2 The criteria for CtV implementation analysis

Three different case studies permit to illustrate the CtV process and the KPS-Value model. The results of experimentations cover different parts of the CtV methodology, but they should globally address it entirely.

Different global criteria are then used to assess the degree of covering of the CtV methodology by each of the test cases, and so permit to assess their level of completeness and pertinence. These criteria allow measuring the degree of implementation of both the CtV process and the KPS-Value model.

The main criteria for the assessment of the CtV methodology implementation are clustered in four categories representing the four CtV process steps:

- Criteria for *Primary Knowledge Acquisition* step:
 - Definition and characterization of *knowledge requests*
 - Characterization and capture of *Business and Engineering elements*:

- Identification of the *global stakeholders*
 - Identification of the *customers descriptors and profiles*
 - Identification of the *value drivers* (Business and Engineering)
 - Identification of the *technical features*
- Criteria for *Value Drivers and Features Analysis* step:
 - Assessment of the *value drivers completeness* for *stakeholders*
 - Assessment of the *value drivers differentiation* for *stakeholders*
 - Assessment of the *value drivers* (completeness and differentiation) for *customer profiles*
 - Assessment of the *technical features* (importance and differentiation) for *stakeholder and customer profiles*
- Criteria for *Value Strategies Analysis* step:
 - Definition of *value strategies* (business and technological)
 - Assessment of *value strategies contributions* for *stakeholders*
 - Assessment of *value strategies completeness* for *stakeholders*
 - Assessment of *value strategies differentiation*
 - Definition and evaluation (value contributions, completeness, differentiation) of *specific value strategies* for given *customer profiles*
- Criteria for *Architectural Solutions Steering* step:
 - Definition of the *architectural solutions*
 - Assessment of the *gaps to strategies of the architectural solutions*
 - Assessment of the *value contributions of the architectural solutions*
 - Assessment of the *contributions to differentiation of the architectural solutions*

The previous criteria are assessed after each use case implementation. Table 8 shows that the three test cases globally cover well the CtV methodology, but respond to different criteria.

In addition to these criteria assessment, the different comments of the actors and stakeholders are captured on the perceived problems and benefits of the CtV methodology deployment on each test case.

On the one hand, a special focus is brought to the following types of problems:

- the difficulty of sharing a common language (adoption of the language)
- the difficulty of sharing a common process (adoption of the process)
- the difficulty of involving the related competencies or actors (interests of the actors)
- the difficulty of developing an adequate Information System to support the CtV process
- the time or resources needed for the CtV process deployment

On the other hand, the following various types of benefits are tracked:

- the convergence of the multidisciplinary teams on:
 - the business objectives values, completeness, differentiation degree and proof of concept
 - the technical solutions values, completeness and differentiation degree
- the integrated exploration of innovative concepts (i.e. new product, process or service)
- the integrated exploration of differentiating business strategies (i.e. new business model)
- the definition of solutions options packaging for the customers based on their values perceived by the stakeholders

Criteria of assessment of CtV methodology implementation		Systems Installation	Laminar Wing	Aircraft Reconfiguration
Criteria for <i>Primary Knowledge Acquisition</i> step	Definition and characterization of Knowledge Requests	✓	✓	
	Characterization and capture of Business and Engineering elements	✓	✓	✓
Criteria for <i>Value Drivers and Features Analysis</i> step	Assessment of the Value Drivers completeness	✓	✓	✓
	Assessment of the Value Drivers differentiation		✓	✓
	Assessment of the Value Drivers for each customers profile			✓
	Assessment of the Technical Features for each customers profile			✓
Criteria for <i>Value Strategies Analysis</i> step	Definition of Value Strategies	✓	✓	✓
	Assessment of Value Strategies contributions	✓	✓	✓
	Assessment of Value Strategies completeness	✓	✓	✓
	Assessment of Value Strategies differentiation		✓	✓
	Definition and evaluation of specific Value Strategies for given customer profiles			✓
Criteria for <i>Architectural Solutions Steering</i> step	Definition of the Architectural Solutions			✓
	Assessment of the gaps to strategies of the Architectural Solutions			✓
	Assessment of the value contributions of the Architectural Solutions			✓
	Assessment of the contributions to differentiation of the Architectural Solutions			✓

Table 8: Criteria of assessment of CtV methodology implementation

7.3 Systems Installation case study

7.3.1 Formulation of the initial project statement

The CtV process and KPS model are applied to support the review of *electrical and hydraulic systems installation* on civil airplanes. The initial problem perimeter consists in challenging the *current linear and sequential process* of systems installation on the A/C final assembly line. In this framework, new concepts are suggested to pre-install the *systems outside the assembly line on a metallic or composite module*, and then to assemble it in one shot on the A/C. Such concepts, which are referred to as *modular solutions*, aim at reducing the assembly cycle of the A/C by allowing parallel manufacturing tasks. This value study is initially required by the systems installation research team.

Different initial objectives are then formulated:

- Identify and assess the *value strategies* corresponding to the modular concepts
- Identify other value strategies that increase the *value contributions* for the stakeholders

The identified value strategies may impact the A/C structure, the systems architecture, the systems installation tools and process.

7.3.2 Implementation of the CtV process

7.3.2.1 Primary knowledge acquisition

Different knowledge requests are formulated and characterized (see Table 9). The *business and engineering knowledge* is acquired and captured by using *Trizacq* tool, also named STEPS, which is developed by researchers of LGéCo of INSA Strasbourg and commercialized by Time-To-Innovate.

Trizacq tool is used since it supports well *technological analysis* and innovation areas identification. The purpose consists in making a diagnosis of the *baseline solution* for systems installation: the structural architecture, on which the systems are installed, is so analyzed as well as the assembly process. The knowledge acquired from the technological diagnosis describes then different parameters instantiated by the current solution. Besides, the *Technological Evolutionary Laws* and the *contradiction principles of Triz* permit to identify other *innovative parameters* which are not exploited by the baseline concept.

Different modules of Trizacq (see Figure 18) allow answering knowledge requests such as: “*what are the current faced design problems and solutions?*” and “*what are the past and potential future evolutions of the A/C structure and systems installation?*”. The answers are

namely captured in modules of *problems-solutions causality diagrams* and *nine multi-screen representations*.

Table 9: Characterization of knowledge requests

Characteristics	Knowledge requests
<ul style="list-style-type: none"> - objective: technical parameters describing the baseline <li style="padding-left: 20px;">- subject: product <li style="padding-left: 20px;">- type: structural parameters & performance/quality <li style="padding-left: 20px;">- level: component - domain: structure, systems installation 	What is the internal mechanism and architecture of the initial system?
	What are the external interactions of the initial system?
<ul style="list-style-type: none"> - objective: technical & business parameters describing the baseline problems and solutions <li style="padding-left: 20px;">- subject: product, process (engineering, manufacturing, operating & maintenance) <li style="padding-left: 20px;">- type: structural parameters, performance/quality <li style="padding-left: 20px;">- level: A/C level, subsystems - domain: business program, structure, systems, systems installation 	What are the current problems?
	What are the current solutions?
<ul style="list-style-type: none"> - objective: technical & business parameters on the past and potential future evolutions of the baseline <li style="padding-left: 20px;">- subject: product, process (engineering, manufacturing, maintenance) <li style="padding-left: 20px;">- type: structural parameters, performances/quality <li style="padding-left: 20px;">- level: A/C level, subsystems, components - domain: structure, systems installation 	What are the past evolutions of the initial system, and its interactions with the external environment?
	What are the future potential evolutions of the initial system, and its interactions with the external environments?
<ul style="list-style-type: none"> - objective: technical parameters describing the potential evolutions of the baseline <li style="padding-left: 20px;">- subject: product, process (manufacturing) <li style="padding-left: 20px;">- type: structural parameters, functions <li style="padding-left: 20px;">- level: subsystems, components - domain: structure, systems, systems installation 	What are the technological evolution laws that can be applied?
<ul style="list-style-type: none"> - objective: technical & business parameters describing the baseline contradictions and potential solutions <li style="padding-left: 20px;">- subject: product <li style="padding-left: 20px;">- type: structural parameters, functions & performances <li style="padding-left: 20px;">- level: subsystems, components - domain: structure, systems, systems installation 	What are the existing encountered contradictions?
	What are the potential principles solving the existing contradictions?

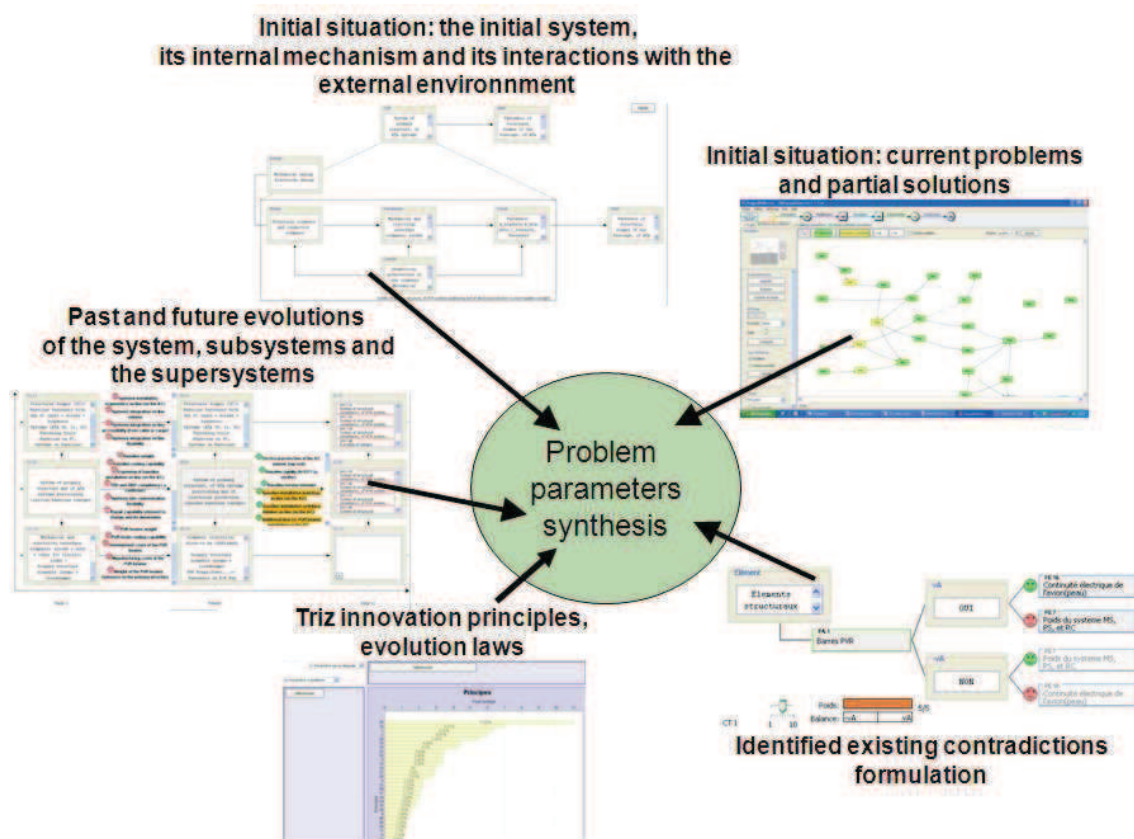


Figure 18: 5 Tizacq modules for knowledge acquisition

7.3.2.2 Value drivers and features analysis

From the *acquired and characterized knowledge*, 86 *business and engineering parameters* as well as *two global stakeholders* are identified with their corresponding characteristics, namely their *subjects* (see Table 10), *types* (see Table 11), *levels* (see Table 12) and *domains* (see Table 13).

The main targeted stakeholders are the aircraft manufacturer (i.e. Airbus) and the airline company.

Different types of relations are qualified between the parameters (see Table 14):

- *Performance relations*
- *Causality relations*
- *Hierarchical relations*
- *Aggregation relations*

Table 10: Examples of parameters with their corresponding subjects

Parameters characteristics						Parameters
Subjects						
Product	Enabling product	Process				
		Engineering	Manufacturing	Operating	Maintenance	
1						PVR beams fasteners number
1						PVR beams electrical function reliability and performance
1						structure elements material
		1				engineering planning delay (structure)
				1	1	A/C operational costs
1				1		A/C safety
	1					tooling cost (for structure & systems assembly & installation)
			1			A/C manufacturing cycle (industrial ramp-up)
			1			A/C manufacturing costs

Table 11: Examples of parameters with their corresponding types

Parameters characteristics			Parameters
Types			
Structural parameters	Functions	Performance/Quality	
		1	A/C operational utility
1			Number of ATA systems in the avionic bay zone
		1	robustness of the structure in assembly phase (cost and time addition)
1	1		structure multi-functional elements number (mechanical and electrical)

Table 12: Examples of parameters with their corresponding levels

Parameters characteristics			Parameters
Parameters level			
A/C	Subsystems	components	
		1	PVR beams fasteners number
		1	PVR beams electrical function reliability and performance
		1	structure elements material
1			A/C operational utility
1			A/C operational costs
1			A/C safety
	1		Assembly and systems installation life cycle (structure + systems)
	1		assembly and systems installation cost (structure + systems)

Table 13: Examples of parameters with their corresponding domains

Parameters characteristics				Parameters
Parameters domain				
Business	Structure	Systems	Systems installation	
	1		1	PVR beams fasteners number
	1		1	PVR beams electrical function reliability and performance
1				A/C automation of production
1				A/C engineering costs
1				A/C engineering cycle
1				A/C industrial risk
	1		1	Assembly and systems installation life cycle (structure + systems)
	1		1	assembly and systems installation cost (structure + systems)
1				A/C weight
		1	1	Number of ATA systems in the avionic bay zone

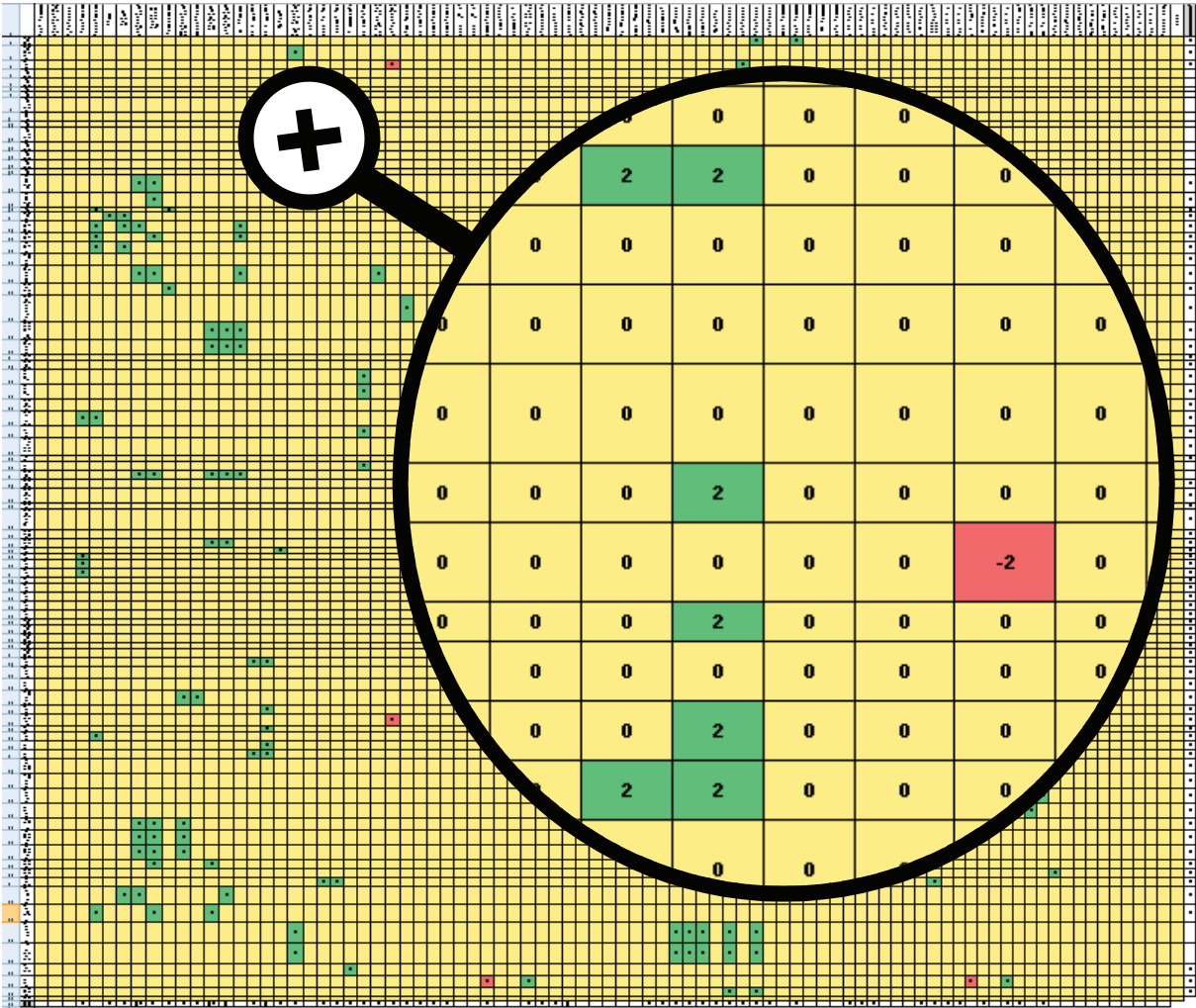
Table 14: Examples of qualified influences between parameters

Parameters	Influence characteristics						
	Influence types				Influenced parameters		
	Causality	Performance	Hierarchical	Aggregation	Parameter 1	Parameter 2	Parameter 3
PVR beams fasteners number		1	1		PVR beams fasteners weight	structure fasteners number	
PVR beams electrical function reliability and performance			1		ESN function reliability and performance		
structure elements material		1			structure elements weight	Degree of reuse of existing elements or of novelty (reuse of baseline and standard elements)	
Number of ATA systems in the avionic bay zone	1				routing zone volume		
robustness of the structure in assembly phase (cost and time addition)			1		A/C manufacturing cycle (industrial ramp-up)	A/C manufacturing costs	A/C industrial risk
environmental impact of manufacturing process				1	A/C green process		
Degree of reuse of existing elements or of novelty (reuse of baseline and standard elements)		1			degree of structure maturity	tooling cost	engineering planning delay (structure)

For instance, Table 14 explains that:

- The driver “*structure elements material*” has an influence on the driver “*structure elements weight*”. It is a *performance influence* between a structural parameter at A/C level (structure material) and a performance (weight).
- The driver “*PVR beams fasteners number*” has an influence on the driver “*structure fasteners number*”. It is a *hierarchical influence* between two structural parameters at different A/C levels, namely component and subsystem levels.

In addition to the qualification, the *influences* between the parameters are *quantified* using a *semi-quantitative scale*, and captured in a *square matrix* (see Figure 19):



- Legend:
- 2 high & positive contribution
 - 1 medium & positive contribution
 - 0 no contribution
 - 1 medium & negative contribution
 - 2 high & negative contribution

Figure 19: Direct influences matrix

For instance, one can extract the following statements from Figure 19:

- the driver “*PVR beams electrical function*” positively contributes to the driver “*ESN function*” (electrical protection of the A/C)
- the driver “*structure elements material*” (implementation of new material) negatively contributes to the driver “*degree of reuse of existing elements*”.

The calculation of the level of influence of the parameters permits to identify 12 *Value Dimensions* (see Table 15) of the global stakeholders.

Table 15: Stakeholders value dimensions

Airline company							
A/C operational utility		A/C operational costs		A/C safety		A/C availability	
Airbus							
Manufacturing values				Engineering values			A/C industrial risk
A/C manufacturing cycle (industrial ramp-up)	A/C manufacturing costs	A/C green process	A/C manufacturing ergonomics (blue collars discomfort)	A/C automation of production	A/C engineering costs	A/C engineering cycle	

From the value dimensions definition, 74 *value drivers* that contribute directly or indirectly to the value dimensions are identified.

The calculation of the *level of dependence* (see Chapter 5.2.3) of the value drivers allows identifying 30 *independent Value Drivers* (see Table 16).

Table 16: Examples of independent Value Drivers

Independent drivers							
systems installation location (modular)	modular structure elements	erosion protection capability	degree of stability (number of design modifications to implement)	adaptability to other A/C configurations	structure elements material	structure micro elements number	structure manufacturing cost

The contributions of the *independent drivers* on the value dimensions are calculated (see Table 17) from the direct influences matrix. The 15 *most influencing independent drivers* (i.e. with the highest levels of influence) are then selected (see Table 17).

Table 17: Examples of contributions of the independent drivers (the selected ones are in yellow)

Independent Value Drivers \ Value Dimensions	structure multi-functional elements number (mechanical and electrical)	multi-functional systems number (ATA, structural and electrical functions)	PVR beams electrical function reliability and performance	repairs duration (structure or A/C)	number of automated systems installation activities	structure assembly activities number on critical path
A/C operational utility	12	12	0	0	0	0
A/C operational costs	128	128	0	2	0	0
A/C safety	4	4	4	0	0	0
A/C availability	4	4	4	2	0	0
A/C manufacturing cycle (industrial ramp-up)	0	0	0	2	4	36
A/C manufacturing costs	0	0	0	0	4	68
A/C green process	128	128	0	0	0	32
A/C manufacturing ergonomics (blue collars discomfort)	0	0	0	0	6	20
A/C automation of production	0	0	0	0	2	0
A/C engineering costs	0	0	0	0	0	0
A/C engineering cycle	0	0	0	0	0	0
A/C industrial risk	0	0	0	2	0	0

Figure 20 shows that the influences of all the independent drivers correspond well to the influences of the 15 selected ones: it validates then the selection of the most influencing drivers on which the value study can be limited to act on the value dimensions.

The *completeness level* of the selected value drivers is 67%: indeed, 8 *value dimensions* out of 12 are positively influenced by the selection. Additional knowledge should then be acquired to find other independent and influencing drivers that positively contribute to the following value dimensions:

- *A/C operational utility*
- *A/C safety*
- *A/C availability*

- *A/C automation of production*

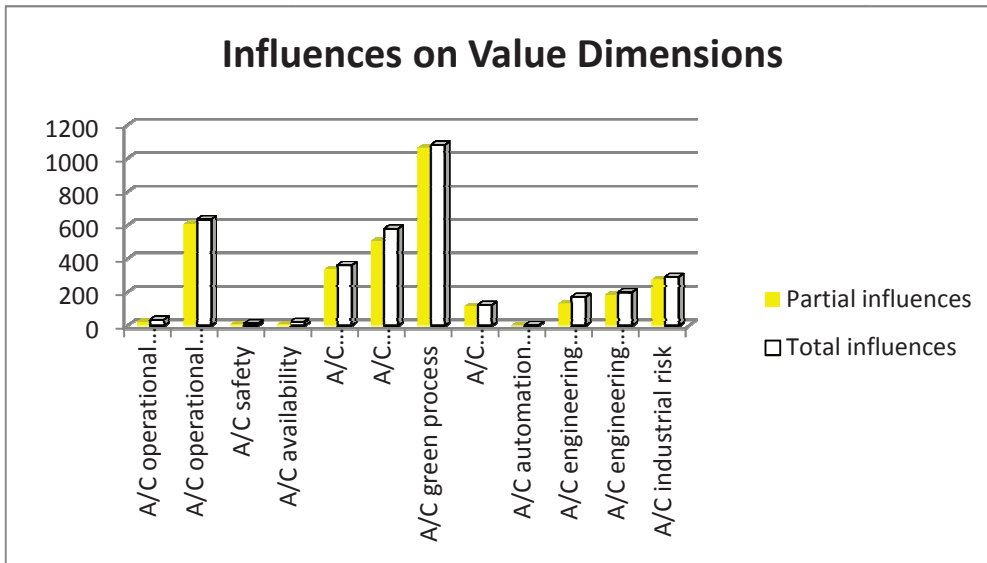


Figure 20: The influences on the value dimensions of independent drivers (white) and selected ones (yellow)

Only two of the selected drivers have low importance level (C) and can not be defined as *key drivers*, namely “number of micro-structural elements” and “number of innovative material elements for systems installation”. Indeed, the analysis of their value contributions explains that they have bad impacts on manufacturing and engineering performances: this is due to a low level of maturity of such technologies in the use case context. Therefore, even though their value contributions for the Airlines are positive by reducing the “A/C operational costs”, their global contributions for both of the stakeholders remain negative. Further research projects are then required to mitigate their negative impacts and reinforce their positive contributions.

7.3.2.3 Value strategies analysis

This step allows defining 7 *value strategies* of systems installation from the 15 *selected value drivers*. It consists in assigning various sets of relative and semi-quantitative objectives (between -1 and 1) on the selected drivers (see Table 18) in comparison with the reference concept.

In the following table, the *green/red* cases or *positive/negative* objectives illustrate the *conventional/opposite* senses of evolution of the drivers in comparison with the baseline: *conventional evolutions* represent improvements of the drivers and so predefined ways of their use for value creation.

Table 18: Definition of the value strategies

	structure multi-functional elements number (mechanical and electrical)	multi-functional systems number (ATA, structural and electrical functions)	PVR beams weight	PVR beams fasteners number	structure assembly activities number on critical path	Systems/primary structure interface points number	Systems/primary structure interfaces variant points number	systems routing change capability	different systems locations in the A/C	systems installation location (modular)	modular structure elements	degree of feasibility	degree of stability (number of design modifications to implement)	structure elements material	Structure micro-elements number
Baseline	x	x	=	=	=	=	X	=	x	x	X	=	=	=	x
Strategy 1: Metallic module	1	0	0	0	1	1	1	-1	0	1	0	0	0	0	0
Strategy 2: Composite module	0	0	0	0	1	1	0	-1	0	1	1	-1	-1	1	0
Strategy 3	0	1	1	1	1	0	0	0	0	0	0	-1	-1	0	0
Strategy 4	0	0	0	0	1	1	0	-1	1	1	1	-1	-1	1	0
Strategy 5	0	0	1	1	0	0	0	0	0	0	0	-1	-1	1	1
Strategy 6	1	0	1	1	1	1	1	-1	0	1	0	-1	-1	1	1
Strategy 7	1	0	0	0	1	1	1	-1	1	1	0	0	0	0	0

For instance, the “strategy 6” is characterized by:

- The increasing of the *number of multifunctional elements* (mechanical and electrical) in comparison with the baseline
- The decrease of the *capability of changing the systems routing* in assembly phase in comparison with the baseline

The strategies of the 2 suggested concepts of systems installation based on a *metallic and a composite module* are respectively described by the “*metallic module strategy 1*” and “*composite module strategy 2*”. One can notice from the previous table that:

- These concepts consist in reducing the *systems routing flexibility* in the assembly phase.
- The *composite concept* consists in decreasing the *degree of feasibility of the systems installation* in comparison with the *metallic or baseline concept*

Besides, 5 new strategies of systems installation are also identified:

- “Strategy 3”: it mainly consists in *adding mechanical and electrical protection functions* to the systems.
- “Strategy 4”: based on the *composite concept*, it mainly consists in installing the systems at *different locations* of the A/C except the nose fuselage.
- “Strategy 5”: it is mainly based on the *use of micro-structural elements*.
- “Strategy 6”: it mainly consists in *adding micro-structural elements* to the “*metallic modular strategy 1*”.
- “Strategy 7”: based on the *metallic concept*, it mainly consists in *installing the systems at different locations* of the A/C except the nose fuselage.

The value contributions of the strategies can be assessed for each stakeholder and globally for all of them. Table 19 and Figure 21 show the impacts of all the strategies on the different value dimensions.

The *completeness degrees* of the *values strategies* are then deduced and compared for each stakeholder and globally for all of them:

- Figure 22 shows that the *level of completeness degree* of the selected drivers *for the airline* is achieved by all the strategies.
- Figure 23 shows that the *completeness degree* of the selected drivers *for the manufacturer* is obtained by only the “strategy 7”

This difference between the completeness degrees for the airline and the manufacturer is explained by the low number of airline value dimensions and the systematic positive contributions of the selected drivers to them. Figure 24 compares the global completeness degrees of the value strategies with the drivers one. It highlights that the third step of the CtV methodology is well done since the global completeness degree of the drivers is achieved by a strategy. But, it also suggests that the *primary knowledge acquisition* and *value drivers analysis* steps should be implemented again in order to increase this degree and so to better cover the stakeholders value dimensions. In this industrial case, the manufacturer values should really be better covered.

Table 19: Value contributions and completeness degrees of Value Strategies

	Baseline	Strategy 1 : Metallic module	Strategy 2: Composite module	Strategy 3	Strategy 4	Strategy 5	Strategy 6	Strategy 7
A/C operational utility	0	12	0	12	0	0	12	12
A/C operational costs	0	128	160	288	160	224	352	128
A/C safety	0	4	0	4	0	0	4	4
A/C availability	0	4	0	4	0	0	4	4
A/C manufacturing cycle (industrial ramp-up)	0	200	172	20	300	-32	168	328
A/C manufacturing costs	0	336	232	16	424	-132	204	528
A/C green process	0	360	368	304	560	208	568	552
A/C manufacturing ergonomomy (blue collars incomfort)	0	84	84	20	116	0	84	116
A/C automation of production	0	0	0	0	0	0	0	0
A/C engineering costs	0	64	-60	-36	68	-164	-100	192
A/C engineering cycle	0	72	8	-16	136	-80	-8	200
A/C industrial risk	0	100	56	-8	216	-40	60	260

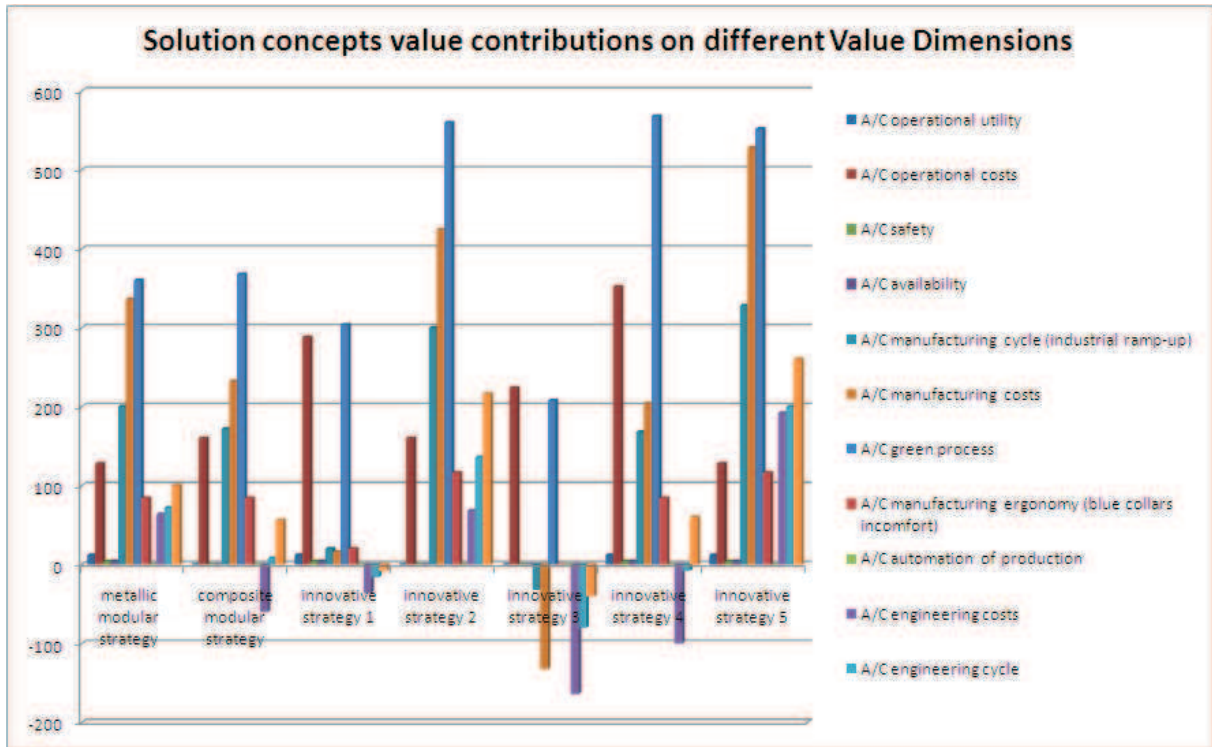


Figure 21: Graphical representation of the contributions of strategies on each dimension

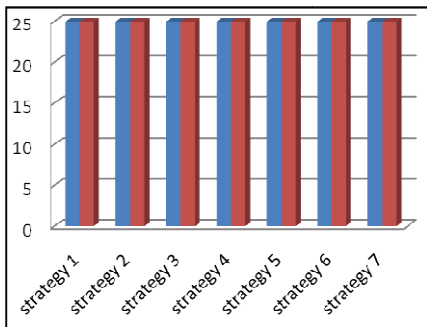


Figure 22: Completeness degrees of strategies (blue) and selected drivers (red) for the airline

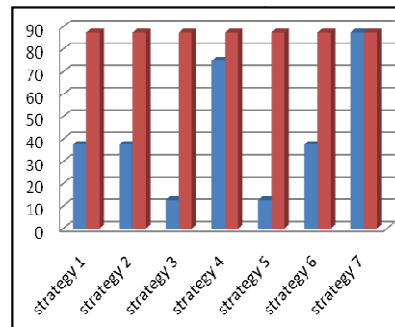


Figure 23: Completeness degrees of strategies (blue) and selected drivers (red) for the manufacturer

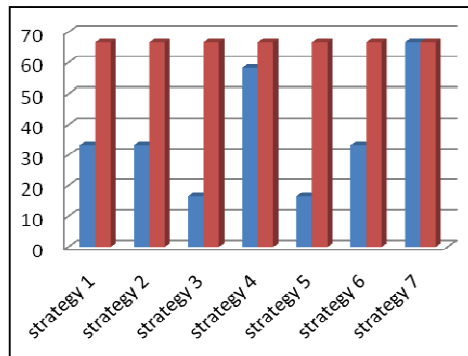


Figure 24: Global completeness degrees of strategies (blue) and selected drivers (red)

The total contributions of the strategies for the stakeholders are calculated: a positive total contribution of a strategy means that it creates more value than it degrades in comparison with the baseline; a negative contribution means that it degrades value more than it creates.

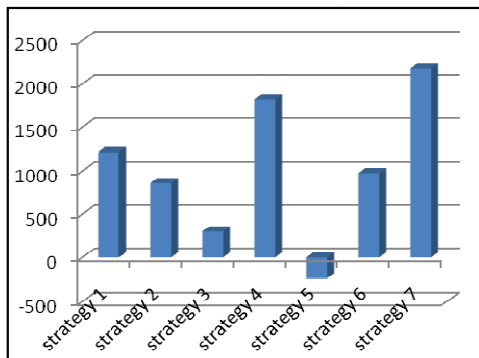


Figure 25: Value contributions of the strategies to the manufacturer

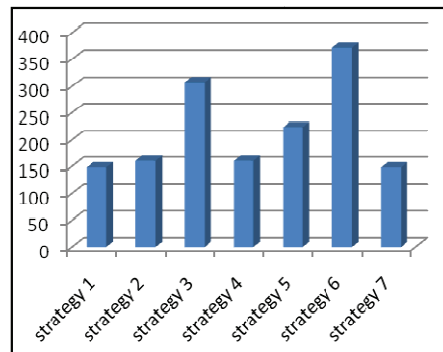


Figure 26: Value contributions of the strategies to the airline

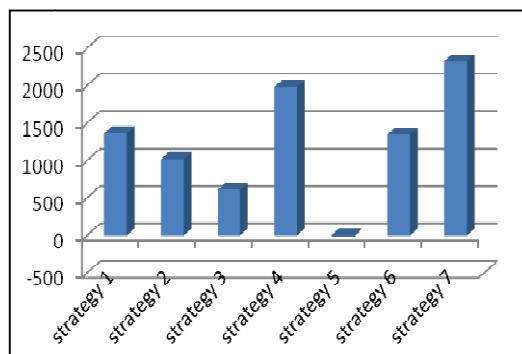


Figure 27: Value contributions of the strategies to the stakeholders

The last figures show that the “*metallic innovative strategy 7*” contributes more to value creation than the “*composite innovative strategy 4*”. It explains as well that the driver “*multi-locations of the systems in the A/C*” implemented for the ‘*strategy 4*’ and “*strategy 7*” permits to increase the values of the *metallic* and *composite modular* concepts. Figure 25 shows that the driver “*micro-elements*” implemented on the “*strategy 5*” decreases globally the value contribution and namely on the value dimensions “*A/C manufacturing*” and “*A/C engineering costs*”. Indeed, this driver is one of the two selected drivers that have a low level of importance (C) for both of the stakeholders. Although they are not defined as key value drivers, they are only selected for value strategies definition to illustrate the impact of the strategies using such drivers on total value contributions.

The value strategies identification allows understanding the value contributions of different associated concepts. The purpose is to be able to track easily for any new concept the value chain from the used drivers to the value dimensions. For instance, Figure 28 illustrates the elicitation of the different value drivers used by the metallic modular concept and their contributions to the value dimension “*A/C manufacturing costs*”: positive and negative contributions are then displayed.

Selected Concept	Metallic pre-grid				
Selected Value Dimension	A/C manufacturing costs				
Contributing Value Drivers	structure assembly activities number on critical path	Systems/primary structure interface points number	Systems/primary structure interfaces variant points number	systems routing change capability	systems installation location (modular)
Contributions level	68	4	12	-4	256
Total of contribution	336				

Figure 28: Example of visualization of the rationale based on selected drivers elicitation

This last figure means that the metallic modular concept contributes positively to the “*A/C manufacturing cost*” on the basis of the following used drivers which positively contribute to this value dimension:

- *Structure assembly activities number on critical path*
- *Systems/primary structure interface points number*
- *Systems/primary structure interfaces variant points number*
- *Systems installation location (modular)*

Nevertheless, the negative impact of the used driver “*systems routing change capability*” should be closely focused and mitigated: new knowledge is then required to generate new parameters, influences and ways to use them in order to limit this negative contribution.

Further comments can be made on the previous figure:

- The use of the driver “*systems routing change capability*” by the metallic modular concept contributes to increase the “*A/C manufacturing costs*” (negative contribution on the value dimension). Indeed, this driver is used in the undesired way in the metallic modular strategy, which consists in decreasing the “*systems routing change capability*”.
- The use of the driver “*systems/primary structure interfaces variant points number*” by the metallic modular concept contributes to decrease the “*A/C manufacturing costs*” (positive contribution on the value dimension)

Figure 30 details the rationale or value chain from the use of the driver “*systems/primary structure interfaces variant points number*” by the metallic modular concept to the impact on “*A/C manufacturing costs*” value dimension (i.e. decrease of the A/C manufacturing costs):

- The driver positively contributes to the “*robustness of the structure in assembly phase*” (i.e. improvement of the robustness) which also positively contributes to the “*A/C manufacturing costs*”
- The driver positively contributes to the “*tooling costs*” (i.e. reduction of the tooling costs) which positively contributes in return to the “*development cost*” (i.e. reduction of the development cost), and which also positively contributes to the “*A/C manufacturing costs*”

Selected Value Dimension	A/C manufacturing costs		
Selected Value Driver	Systems/primary structure interfaces variant points number		
Path1	robustness of the structure in assembly phase (cost and time addition)	A/C manufacturing costs	
Influences	2	2	
Total	4		
Path2	tooling cost (for structure & systems assembly & installation)	development cost (structure NRC cost)	A/C manufacturing costs
Influences	2	2	2
Total	8		

Figure 29: example of rationale describing the value chains from a driver to a value dimension

In a summary, the value strategies analysis step of CtV process points out that the most interesting concepts are the metallic and composite modular solutions that activate the driver “*multi locations of the systems in the A/C*” (i.e. systems distribution in the A/C). Nevertheless, this driver is not really usable to define an alternative strategy as it is fixed very early by the systems design team. It is then more a constraint parameter than a flexible value driver for systems installation strategy definition. It should therefore be deleted from the list of key value drivers. Consequently, the most possible valuable concepts are, respectively in the order of relevance, the metallic and composite concepts. Indeed, the analysis shows that the “*strategy 3*” (based on the integration of systems functions, and mechanical, electrical functions) does not contribute to create globally more value than the metallic and composite concepts. Finally, the use of the driver “micro structural elements” does not globally contribute to value creation due to the high additional cost for the implementation of such disruptive technology. This driver has then to be deleted from the list of key value drivers. Finally, Figure 30 sums up all the outcomes of the CtV methodology implementation

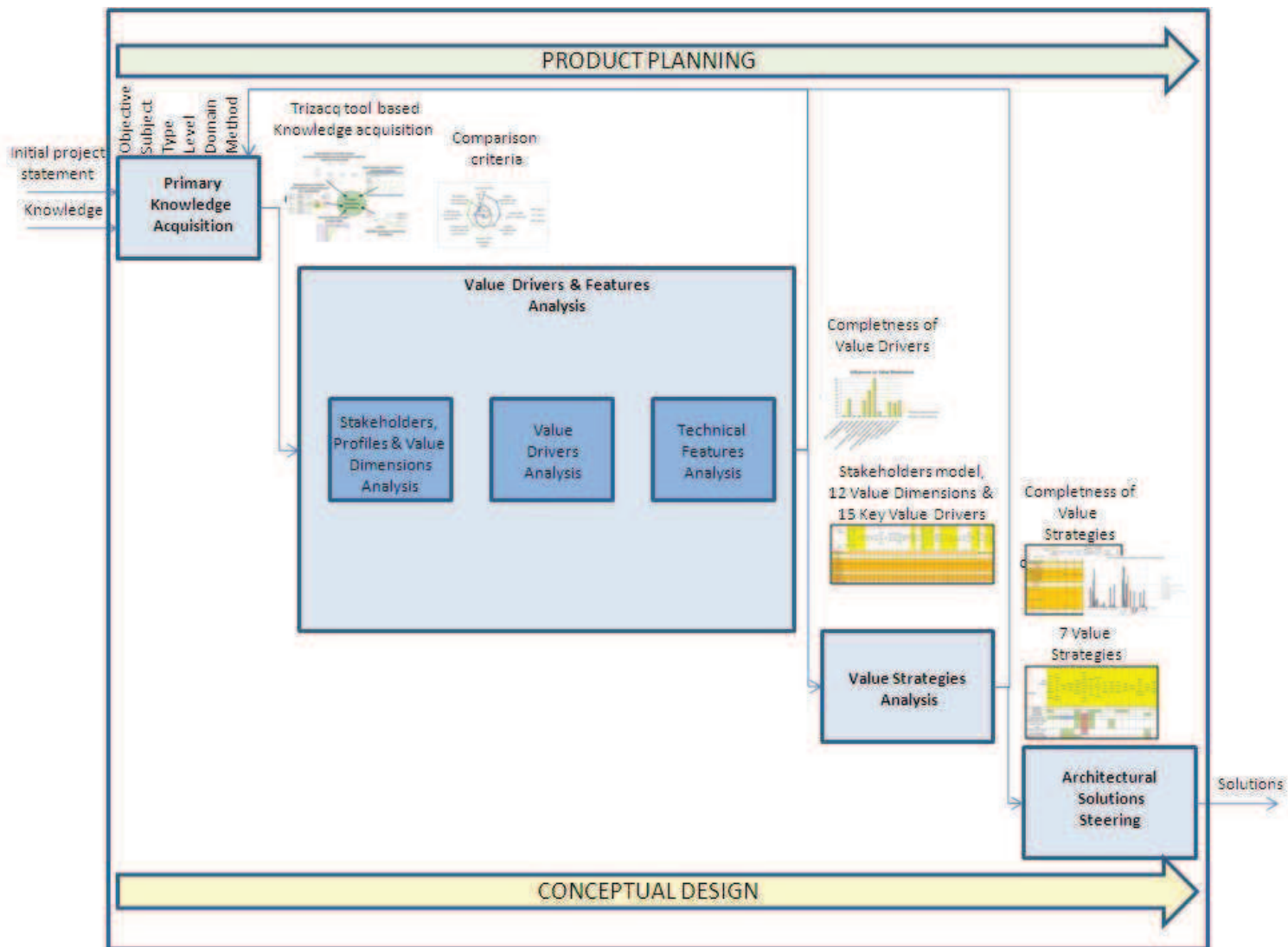


Figure 30: Synthesis of the CtV process results

7.3.3 Evaluation of the CtV methodology implementation

This use case permits to implement different notions of the CtV methodology. Based on the assessment criteria of CtV methodology implementation (see Table 8), it allows illustrating:

- The *primary knowledge acquisition* step with the formulation, characterization of knowledge requests, and of Business and Engineering parameters
- The *value drivers and features analysis* step with the identification of the global stakeholders, the value dimensions, the strategical value drivers with their level of completeness
- The *value strategies analysis* step with the definition of different value strategies and their level of value contributions, and completeness.

Though, some elements of the CtV methodology are not covered by the use case and need further industrial applications, such as:

- The identification of different *customer profiles*, of *strategical drivers* for each of them, and the assessment of their *level of differentiation*
- The definition of different *specific value strategies* for given customer profiles, and the assessment of their *level of differentiation*
- The definition of *architectural solutions* and the assessment of their *gaps to strategies*

In addition, some satisfaction comments are captured on the practical benefits of the CtV methodology:

- Elicitation of the *value drivers* and *consolidation* to the high level satisfaction criteria (i.e. the value dimensions)
- Identification of *pertinent alternative strategies* of value creation
- Illustration of the possibility to *track the value rationale* of concepts
- Capture and sharing of *experts knowledge*

Nevertheless, some issues are also identified for the CtV methodology deployment:

- The need of the involvement of *multidisciplinary experts* for knowledge acquisition and results validation
- The need of *tooling support* for data capture (capture of data rationale and divergences) and *consolidation* from the multidisciplinary teams

For the previous use case, a specific Excel tool is developed to support the CtV implementation. Different Excel sheets allow deploying the CtV process steps (see Figure 31). They are quite efficient to structure and compute the data, but do not support well a collaborative and distributed process. Besides, even if they are easily prototyped, they are not enough flexible for new data addition or new test case study implementation.

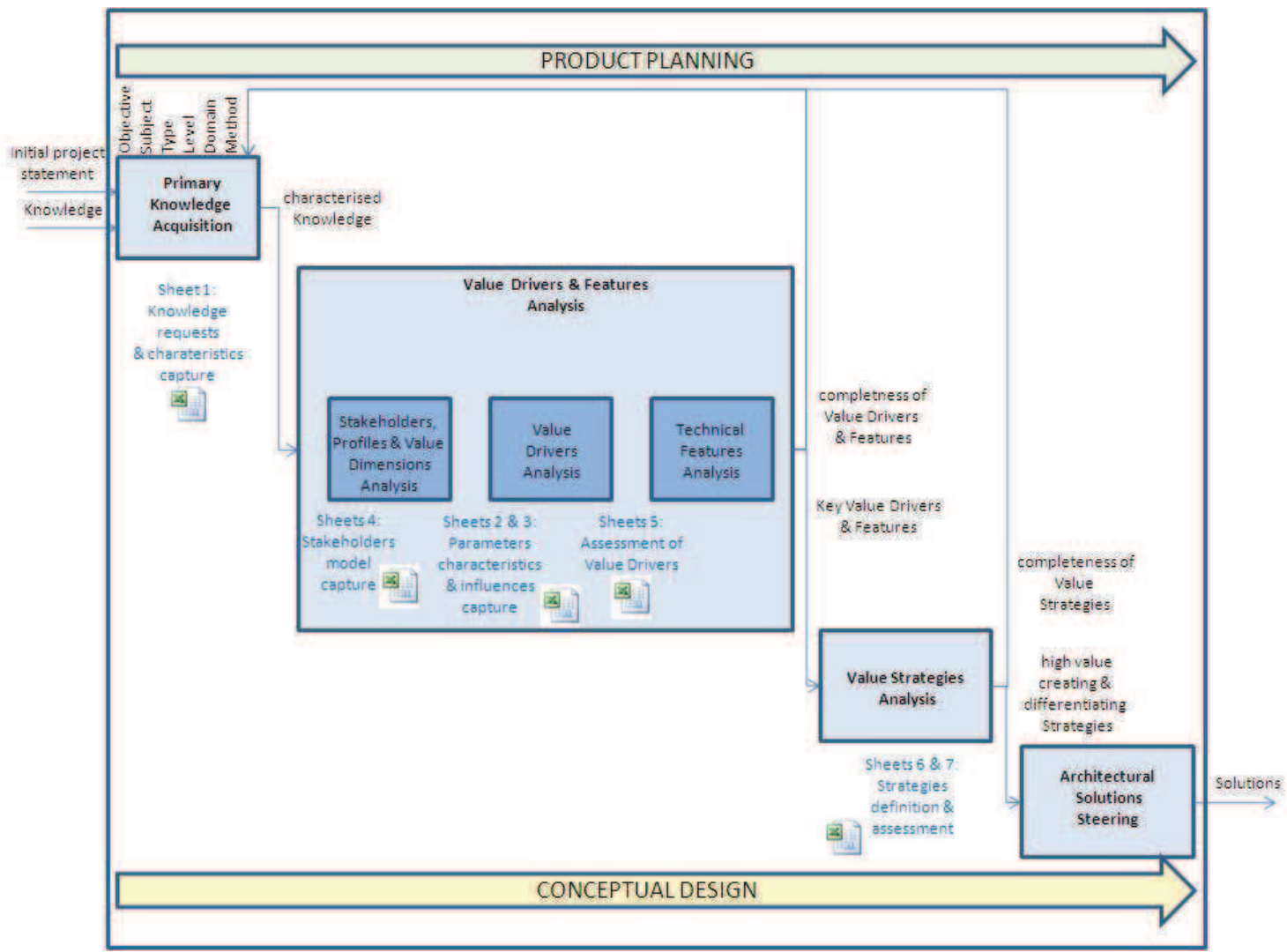


Figure 31: The developed Excel based tool for CtV process support

7.4 Laminar wing technology case study

7.4.1 Formulation of the initial project statement

The *Natural Laminar Flow technology* (NLF) is developed within an R&T project, whose objectives consist in increasing the *extent and robustness of the air laminar flow* over the airplane wings (see Figure 32), in specifying *architectural solutions, flight test demonstrators* and *industrial processes*. In such a context and to support these objectives, the purpose of our works is to identify and analyze the different *value strategies* in relation with this technology by using the *V-KPS model*.

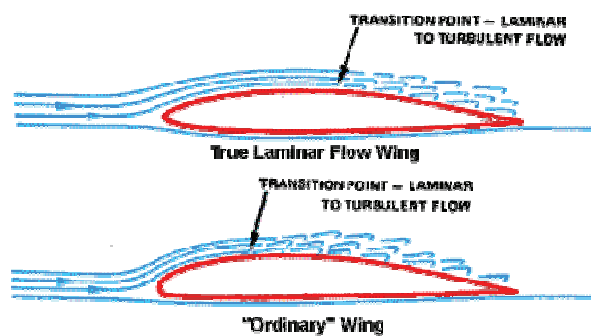


Figure 32: Laminar wings and turbulent wings

7.4.2 Implementation of the CtV process

7.4.2.1 Primary knowledge acquisition

Knowledge acquisition is conducted to identify the following types of information: the *stakeholders*, which are namely the *internal manufacturing stakeholders* (i.e. Marketing, Engineering, Manufacturing, Business Intelligence,...) and the *external stakeholders* (i.e. the airlines, the certification), the *business parameters* and the *design parameters*. Different *types of methods* are used to capture the acquired knowledge:

- a *systemic analysis of the wing life cycle* to identify the different stakeholders of each life cycle phase
- a *workshop* with some identified stakeholders to collect some needs and expectations on the laminar wing technology project.

- a *functional analysis* to identify the generic wing functions that are independent to the laminar or turbulent technology
- *analysis of existing documents* on both the laminar and turbulent technologies: their advantages and drawbacks, their design parameters and principles, and the predefined requirements for laminar wings prototyping and testing.

7.4.2.2 Value drivers and features analysis

From the *acquired knowledge*, the *value dimensions* with their relative weight and the *business drivers* with their *differentiating* or *basic characteristics* are identified (see Figure 33). Besides, *generic engineering drivers* are derived from the *functional analysis* of the wing at each of its life cycle phase. A *positive and negative quantitative scale* is used to assess the *level and sense of contribution* of each generic wing driver to each business driver. Some examples of generic wing drivers are: the *drag over the lift ratio*, the *roll control efficiency*, the *drag level in deceleration phase*, the *minimum speed for take-off and landing*, the *load cases distribution*, the *anti-ice efficiency*, the *leading edge protection against contamination*, and *against erosion*.

The contributions of the *wing generic drivers* to the *business drivers* allow generating the following results:

- the identification of the *most important generic wing value drivers*
- the identification of the *most differentiating generic wing value drivers*
- the evaluation of the *total value contributions* and the *completeness level* of all the generic drivers for each stakeholder

The *most important generic drivers* create value above all for the external stakeholders (i.e. the airlines and the regulation organisms): the *drag over lift*, the *drag level in deceleration phase*, the *minimum speed for take-off and landing*, the *load cases distribution* and the *leading edge protection against contamination*.

Two *strategic generic drivers* among these important drivers are selected as they highly contribute to differentiation, but only for the airlines. The knowledge acquisition process has then to be implemented again and steered in order to:

- increase the *completeness level of the generic drivers* for the manufacturer and the regulation
- identify *strategic value drivers* for the manufacturer and the regulation

In addition to the generic drivers, the knowledge acquisition permits also to identify some *specific value design drivers* that precisely describe the *laminar wings technology*. Such

specific drivers come from the analysis of the *existing requirements of the laminar wings* and from their comparisons with the turbulent wings. Some examples of specific wing drivers are: the *profile*, the *robustness*, the *sweep angle*, the *waviness*, the *roughness*, the *steps and gaps*.

From the *positive and negative correlations* between the *specific and generic wing drivers*, the following results are obtained:

- the identification of the *most important specific drivers* that contribute the most to the generic drivers
- the identification of the specific drivers that contribute the most to the two strategic generic drivers: such drivers can then be called *strategic specific drivers* (i.e. the profile, the sweep angle, the waviness, the extended cover availability)

Stakeholders	Value dimension	Business Drivers	Basic / Differentiating	Weight
Airlines	Operating cost	fuel consumption	D	9
	Mission	range	B	9
	Performance	high speed performance	B	4
		low speed performance	B	4
	Operation / Usability	TAT	D	6
	Maintainability	maintenance cost	D	6
		maintenance cycle	D	6
Image	Perception from passengers	D	3	
Regulation	Safety/certification	Performance rules respect	B	9
		Handling quality rules respect	B	9
		Protection against external threats respect	B	9
	Environmental impact	minimize ecological impact	D	3
		End of life recycling capacity	D	3
Manufacturer	Risk	Risk from supply chain		6
		Risk from purchasing		3
	Production cost	Manufacturing cost		6
		System installation cost		6
		Assembly cost		6
	Production rate	Assembly lead time		6
		System installation time		6
Industrial ramp up			6	

Figure 33: Stakeholders value dimensions and business drivers

7.4.2.3 Value strategies analysis

Four technological value strategies are defined from the specific strategic drivers on which *different semi-quantitative objectives* are assigned. These strategies describe *four concepts of laminar wings* which differ from one another only with two *specific value drivers* (i.e. the availability of extended cover and the capacity of removing the leading edge). Their *level of completeness and differentiation* are analyzed for each stakeholder. The following observations are then made:

- they globally more cover the *business strategy for the airlines* than for the other stakeholders.
- the strategy which uses both of the *specific strategic drivers*, which make the difference between the strategies, covers more the business strategy for the external stakeholders, and more precisely the *differentiating business strategy for the airlines*.

In a summary, the value strategies contribute mainly to the *differentiation for the airlines*. It is due to the fact that the *strategic specific drivers* used for the strategies definition are derived from the *two generic drivers* that are *strategic for the airlines*. The knowledge acquisition process should then be further implemented and steered in order to find *new generic and specific drivers* that are strategic for each stakeholder. After such improvement of the knowledge acquisition quality, *new value strategies* can be defined and used to steer and assess new wings architectural concepts.

7.4.3 Evaluation of the CtV methodology implementation

This use case permits to implement different notions and steps of the CtV methodology. Based on the assessment criteria of CtV methodology implementation (see Table 8), it allows illustrating:

- The *primary knowledge acquisition* step, which allows exploring and capturing several *Business and Engineering elements*, through different *knowledge enrichment means* in the test case (i.e. interviews, workshops, reports sharing and analysis,...)
- The *value drivers and features analysis* step, which permits to identify the *global stakeholders*, the *value dimensions*, the *strategical value drivers*, both from *Business and Engineering domains*, and which also allows assessing them (i.e. their level of completeness, importance, differentiation...)
- The *value strategies analysis* step, which leads to the definition of different *value strategies* integrating both *Business and Engineering views*, and to their assessment (i.e. level of value contributions, completeness, differentiation...)

Nevertheless, some elements of the CtV methodology are not covered by the use case and need further industrial applications, such as:

- The identification of different *customer profiles*, *strategical drivers* for each of them, and the assessment of their *level of differentiation*
- The definition of different *specific value strategies* for given *customer profiles*, and the assessment of their *level of differentiation*
- The definition of *architectural solutions* and the assessment of their *gaps to strategies*

In addition, some satisfaction comments are captured on the practical benefits of the CtV methodology:

- Elicitation of the *value divers* and *consolidation* to the high level satisfaction criteria (i.e. the value dimensions)
- Identification of *pertinent alternative strategies* of value creation
- Elicitation of the *differentiating value strategies* in opposition to the *basic ones*
- Illustration of the possibility *to track the value rationale* of concepts
- Capture and sharing of *experts knowledge*

Nevertheless, some issues are also identified for the CtV methodology deployment:

- The need of the involvement of *multidisciplinary experts* for knowledge acquisition and results validation
- The need of *tooling support* for data capture (capture of data rationale and divergences) and *consolidation* from the multidisciplinary teams

For the previous use case, a specific Excel tool is developed to support the CtV implementation. Different Excel sheets allow deploying the CtV process steps, structuring and computing the data, but do not support well a collaborative and distributed process. Besides, even if it is easily prototyped, it is not enough flexible for new data addition or new test case study implementation.

7.5 Aircraft reconfiguration case study

7.5.1 Formulation of the initial project statement

At the beginning of a future aircraft program, a list of systems to be installed on the aircraft already exists, and should be reviewed in order to reduce it and decrease the aircraft cost. Indeed, the initial purpose of CtV methodology deployment on the future program is to support the definition of a coherent *package of systems offers* from this list and for the airlines. The *systems package* is composed of:

- *Basic systems*: systems that are pre-installed on all A/C and can not be removed.
- *Standard systems*: systems that are pre-installed on all A/C, but can be removed
- *Optional systems*: systems that can be installed on an A/C on an airline demand

Different issues have then to be dealt with for the establishment and validation of the systems packaging:

- “*Are the systems offers consistent with the customer profiles?*”
- “*Are they complete?*”
- “*Are they enough differentiating?*”
- “*What are the pertinent strategies of further systems development?*”

All of these questions illustrate well the statement of the future program: “*The program is at the convergence of ‘haute couture’ and mass production*”.

The objective of the study is to apply the CtV methodology on the definition of systems offers within the limited scope of *aircraft reconfiguration*, and on the basis of identified and evaluated value strategies.

The test case aims initially at enabling *quicker aircraft reconfiguration*. The idea consists in reducing the time required for the aircraft reconfiguration, during the turnaround time (i.e. the time between the arrival of an aircraft at an airport gate and its new departure), during the night stops, or during the time out of service.

The *reconfiguration scenarios* may consist in:

- Reconfiguring the *facilities for the passengers* (i.e. seats, toilets...)
- Reconfiguring the *passengers specific systems* (i.e. the passengers’ video, audio systems...)

- Reconfiguring the *passengers basic systems* above the seats (i.e. the oxygen, crew call, reading light systems...)
- Reconfiguring the *power supply systems* (i.e. air and electrical systems)
- Reconfiguring the *crew systems* (i.e. galleys, trolleys, integrated cabin systems management...)
- Reconfiguring the *cockpit systems* (i.e. the avionics and information systems)

Some technical features are suggested from R&T projects, and evaluated through mainly weight, fuel consumption reduction, and capacity increase (i.e. the number of passengers). The great challenge is to understand, identify, analyze and improve the corresponding *value strategies* of the *solutions of reconfigurations scenarios* and *technical features*.

7.5.2 Evaluation of the CtV methodology implementation

This use case permits to implement different notions and steps of the CtV methodology. Based on the assessment criteria of the CtV methodology implementation (see Table 8), it allows illustrating:

- The *primary knowledge acquisition* step, which allows exploring and capturing several *Business and Engineering elements*, through different *knowledge enrichment means* in the test case (i.e. interviews, workshops, reports sharing and analysis,...)
- The *value drivers and features analysis* step, which permits to identify the *global stakeholders*, the *customer profiles*, the *value dimensions*, the *strategical value drivers*, both from *Business and Engineering domains*, and which also allows assessing them (i.e. their level of completeness, importance, differentiation...)
- The *value strategies analysis* step, which leads to the definition of different *value strategies* integrating both *Business and Engineering views*, with regards to different *customer profiles*, and with their *value assessment* (i.e. level of value contributions, completeness, differentiation...)

In comparison with the two other use cases, some elements of the CtV methodology are only covered by the previous one, such as:

- The identification of different *customer profiles*, *strategical drivers* for each of them, and the assessment of their *level of differentiation*
- The definition of different *specific value strategies* for given *customer profiles*, and the assessment of their *level of differentiation*
- The definition of *architectural solutions* and the assessment of their *gaps to strategies*

In addition, some satisfaction comments are captured on the practical benefits of the CtV methodology implementation:

- Elicitation of the *value drivers* and *consolidation* to the high level satisfaction criteria (i.e. the value dimensions) for the *different stakeholder and customer profiles*
- Identification of *pertinent alternative strategies* of value creation for different *customer profiles*
- Elicitation of the *differentiating value strategies* in opposition to the *basic ones* for different *customer profiles*
- Illustration of the possibility *to track the value rationale* of concepts
- Capture and sharing of *experts knowledge*

Nevertheless, some issues are also identified for the CtV methodology deployment:

- The need of the involvement of *multidisciplinary experts* for knowledge acquisition and results validation
- The need of *tooling support* for data capture (capture of data rationale and divergences) and *consolidation* from the multidisciplinary teams

For the previous use case, a specific Excel tool is developed to support the CtV implementation. Different Excel sheets allow deploying the CtV process steps, structuring and computing the data, but do not support well a collaborative and distributed process. Besides, even if it is easily prototyped, it is not enough flexible for new data addition or new test case study implementation.

8 Industrial validation of the Concept-to-Value methodology

8.1 Definition of the validation protocol

In addition to the *analysis of the technical results* of the three application test cases, a *formal protocol* is defined for the evaluation of the methodology by *its actual industrial users*. Detailed completely in the annex of this report, a *formal questionnaire* is built to ask them different *categories of questions*:

- *Category #1*: the benefits and drawbacks of the CtV methodology implementation on *the individual users works*
- *Category #2*: the impacts of the CtV methodology implementation on *the collaboration between multidisciplinary users*
- *Category #3*: the impacts of the CtV methodology implementation on *the outcomes of new A/C development programs and R&T projects*
- *Category #4*: the *novelty, constraints and adequacy of the CtV methodology deployment* in the industrial organization

In a summary, the previous *questions categories* allow to evaluate the CtV methodology through generic *types of industrial performances*:

- The *individual operations performances* (through category #1)
- The *collaborative operations performances* (through category #2)
- The *innovation projects performances* (through category #3)
- The *industrial deployment performances* (through category #4)

These four types of *industrial performances* must be sufficiently satisfied for considering our *research action* project results in an *industrial success*.

In consequence, the questionnaire has been submitted to several actors of *preliminary design projects* who actually use or deploy the CtV methodology. Several *kinds of actors* are targeted:

- The *first kind* of actors represents the *actual players* who are involved within an innovation project, and who implement the CtV steps. They namely contribute to the implementation of one of the three test cases described above.
- The *second kind* of actors is related to the *stakeholders* who request the deployment of the CtV methodology on innovation projects, but who do not participate in it directly.

Several presentations of the methodology and the practical results obtained by its implementation on the three test cases are made for the stakeholders.

- The *third kind* of actors corresponds to the *CtV methodology experts* who are responsible for its appropriate deployment on innovation projects. The CtV methodology principles, process and concepts are explained to them, in order to let them supervise its deployment on innovation projects and with the participation of different multidisciplinary players.

Moreover, the interviewed actors belong to *different multidisciplinary fields*:

- The *marketing*, which has the expertise on the current and future needs of the customers
- The *program management*, which leads the definition of the business objectives for the new A/C development programs
- The *A/C Architects*, who have the functions of specifying, integrating, evaluating and selecting the A/C technologies and architectures
- The *R&T department*, which is responsible of the exploration and evaluation of new A/C technologies
- The *Method & Tools department*, which is dedicated to the continuous improvement, and deployment of the Business and Engineering process and tools

Each of the previous fields is currently and will have to be well represented for the deployment of the CtV methodology on any innovation topic. The *Method & Tools department* supervises and ensures the appropriate deployment of the CtV methodology by a multidisciplinary team, composed of *A/C architects, marketers, program managers* and *technological researchers*.

The questionnaire composed of 35 questions is fulfilled by 7 Concept-to-Value users through individual interviews. We acknowledge that 7 is a weak number but this is the number of high level experts who have really acquired the concepts and tools of CtV methodology and started to use it in the 18 last months of my PhD. Each question permits to *assess qualitatively a characteristic* of the CtV methodology. The participants can answer each question by choosing *a level of a predefined qualitative scale* (i.e. “High”, “Medium”, “Low”, “Null”, “Less”), which describes how much they feel *the methodology is efficient on a given criteria*.

8.2 Presentation of the results

8.2.1 Convergence characteristics

A *first analysis* of the questionnaire (see Figure 34) answers shows that there is a *high convergence* between the participants on several characteristics of the CtV methodology. The *positive* (i.e. benefits) *and negative* (i.e. inconvenient) *aspects* (see Table 20) of the methodology that are agreed by every interviewee are then extracted.

On the one hand, *all the participants agree* on the following *positive aspects* of the CtV methodology about:

- The *individual performances*:

The *key concepts* are *clear*, and it is in *total adequacy* with their individual functions. It means that no one has difficulty to *understand the methodology*, and that everyone feels *involved* in its deployment whatever his/her own function.

- The *collaborative teams performances*:

It contributes to the improvement of the *teams information exchanges and intercommunication*. It leads then to *better awareness of the teams on potential business and solutions* to be explored, and on *their added-values and adequacy*. The methodology better supports the *decisions making*, even on the *business strategies*.

- The *innovation projects performances*:

It allows improving the *Proof of Value* of the R&Ts projects. The *value creation* of the *selected technologies* is more robust in the preliminary design phase.

- The *industrial deployment performances*:

It really corresponds to a *new process and tools* for EADS and Airbus. There is a strong need for *its systematic deployment* on all forthcoming *innovation projects*.

On the other hand, *all the participants agree* on the following *negative aspects* of the CtV methodology about:

- The *innovation projects performances*:

There is a *poor improvement* of the *Proof of Concept* of the R&Ts projects. The CtV methodology is much more perceived by all as a way to steer innovation by *value* than by *technological maturity*. The participants tend much more to use the methodology to optimize the values created by the technologies, than to ensure their maturity. This is due to the fact that the methodology consists globally in specifying relevant value creation strategies, for which adequate solutions have to be found.

- The *industrial deployment performances*:

The CtV methodology is *difficult to deploy* since it assumes a *radical change* in the *innovation process*, and in the *mindset of the innovation actors*. Indeed, they usually work in a disjoint and sequential manner. The Business and Engineering participants

work mostly in parallel by exploring business strategies and technologies independently and without systematically integrating them. The both teams punctually exchange information that represents partial preselected business strategies or technologies. The exchanges are only based on a customer-supplier relationship, which does not ensure the identification of concepts creating sufficient value. It is then difficult to change the current practices from disjoint multidisciplinary explorations to integrated multidisciplinary explorations.

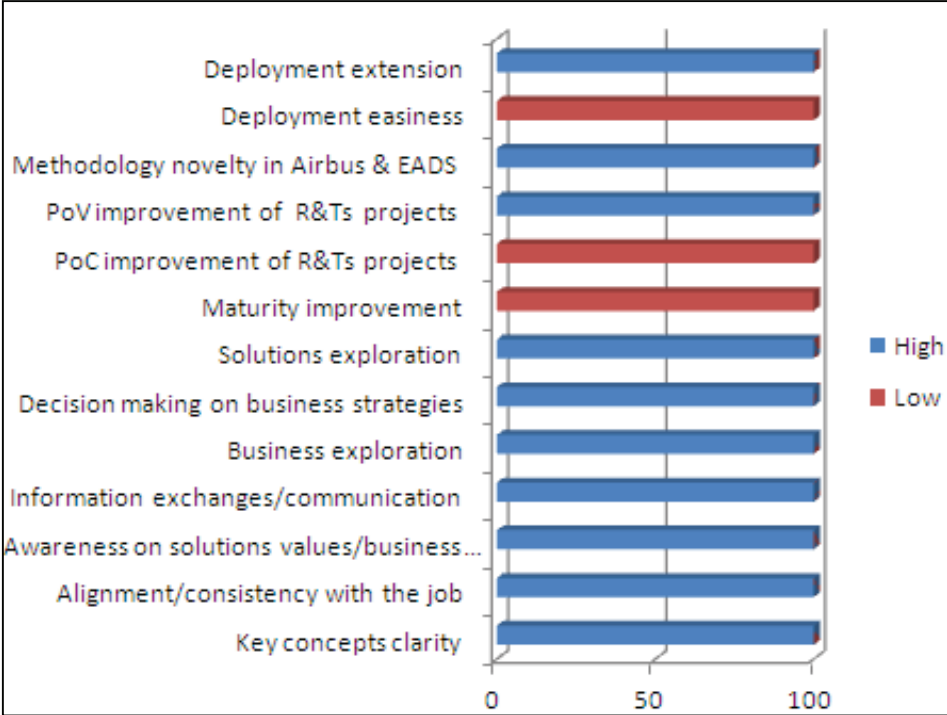


Figure 34: Distributions of participants answers on convergence characteristics (%)

Table 20: Convergence characteristics

Type	Characteristics of the Concept-to-Value methodology			
	Category 1: <i>Individual performances</i>	Category 2: <i>Collaborative teams performances</i>	Category 3: <i>Innovation projects performances</i>	Category 4: <i>Industrial deployment performances</i>
<i>Positive</i>	Key concepts clarity, alignment and consistency with the individual function	Awareness on solutions values & business adequacy, information exchanges/communication, business exploration, decision making on business strategies, solutions exploration	Proof of Value improvement of R&Ts projects	Methodology novelty in Airbus & EADS, systematic deployment in all forthcoming projects
<i>Negative</i>			Technological maturity improvement, Proof of Concept improvement of R&Ts projects	Deployment easiness

8.2.2 Trends characteristics

Another type of *results analysis* permits to raise *some trends* in the participants answers (see Figure 35 and Table 21). Indeed, even though there is no global convergence, *relevant highlights* can be extracted from the answers where the *majority of the participants* chose a given response level (i.e. “High”, “Medium”, “Low” or “Less”). There can be then a trend on *positive aspects* (i.e. majority of “High”), *negative aspects* (i.e. majority of “Low”), or on *mean aspects* (i.e. majority of “Medium”).

At first, there are some *trends*, which permit to define the following *positive aspects* of the CtV methodology about:

- The *individual performances*:

The related *mechanism and process* are clear. The *prototyped supporting tools* are easy to handle. There is a clear *added-value* by the methodology to the project, in which the participant is involved. This highlight confirms the *positive aspects* derived from the *convergence analysis*: the CtV methodology is quite *simple to understand*, as well as its *potential benefits* for a given *innovation project*.

- The *collaborative teams performances*:

The *trends analyses* reinforce the *positive aspects* deduced from the *convergence analyses*. Indeed, the CtV methodology allows the multidisciplinary teams being better aware of *potential business and solutions*, by sharing and acquiring *more useful knowledge*. Besides, it better supports *the decisions of the teams* on the technological solutions.

- The *innovation projects performances*:

In the same way, the *trends analyses* consolidate the fact that the CtV methodology improves significantly the *values* delivered by the innovation projects. It induces then the amelioration of the *projects profitability*. It also contributes to improve the hierarchy between the R&T projects on the basis of their *Proof of Value*.

- The *industrial deployment performances*:

The *trends analyses* confirm the *novelty of the methodology*. Most of the participants confirm also its *novelty* even in *the aeronautical industry*.

At second, there are some *trends*, which permit to define the following *negative aspects* of the CtV methodology about:

- The *collaborative teams performances*:

The CtV methodology is not really considered as a “*creativity*” tool. Indeed, most of the participants state that it is not dedicated to generate *new engineering solutions*, just like Triz methodology does for *design problems solving*. They mainly think that it is not the main objective of the methodology. They assume that the CtV methodology aims above all to analyze *value creation strategies*. Depending on the *Proof of Value* adding, such strategies may then lead or not to innovation and creativity. For the most promising strategies, *creativity activities* can be deployed to support their achievement. CtV methodology is then more considered as a way to define *the need of innovation*, and as a way to better position *the need of creativity* through the *value strategies*. The other methods of *cognitive, systematic* and *random creativity* can be implemented to support the identified *differentiating strategies*.

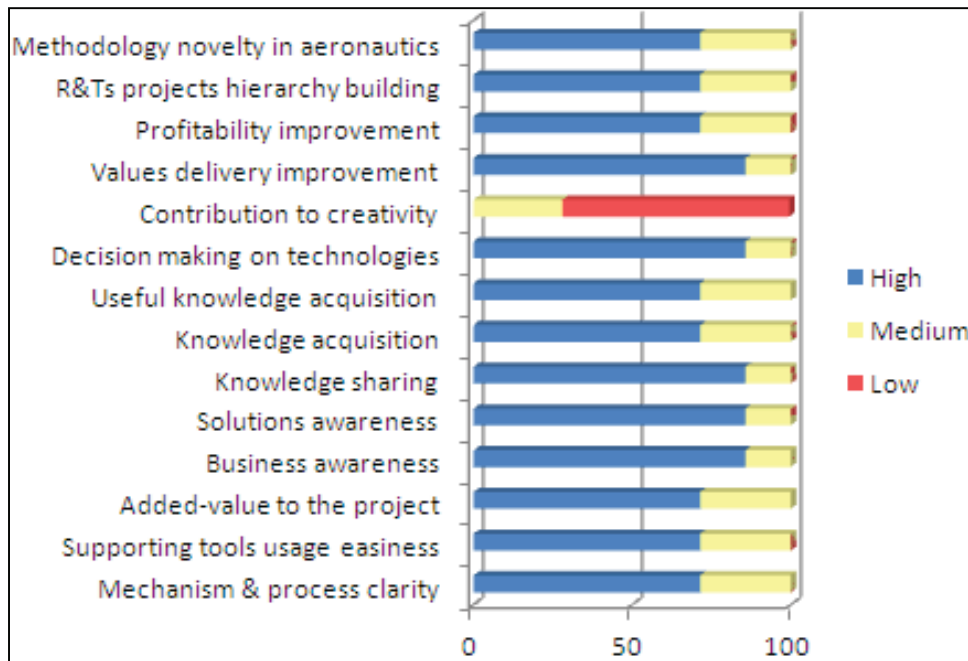


Figure 35: Distributions of participants answers on trends characteristics (%)

Table 21: Trends characteristics

Type	Characteristics of the Concept-to-Value methodology			
	Category 1: <i>Individual performances</i>	Category 2: <i>Collaborative teams performances</i>	Category 3: <i>Innovation projects performances</i>	Category 4: <i>Industrial deployment performances</i>
<i>Positive</i>	Mechanism & process clarity, easiness of supporting tools usage, added-value to the project	Business awareness, solutions awareness, knowledge sharing, useful knowledge acquisition, decision making on technologies	Values delivery improvement, profitability improvement, R&Ts projects hierarchy building	Novelty in the aeronautical industry
<i>Negative</i>		Contribution to creativity		

8.2.3 Medium characteristics

In addition to the *convergence* and *trends* analysis, another type of analysis can also be extracted from some of the participants answers. They correspond to an *equal partition* between the answers (i.e. “*High*”, “*Low*”, “*Medium*” or “*Less*”) on given characteristics (see Figure 36). Such characteristics are then qualified as *mean* for the methodology (see Table 22).

The *medium characteristics* of the CtV methodology concern:

- The *individual performances*:

The *level of individual effort* required for the methodology deployment seems to be significant. Indeed, assessed by the participants as “*High*” and “*Medium*”, this level must be considered because of the difficulty for the users to change their *mindsets*, their *ways of working*, and their *well established cultural practices*. The participants mention that the CtV methodology is radically different from their *usual individual and collaborative tasks*, and that they need some *additional effort* for its deployment. In a consequence, there is great challenge of convincing the *preliminary design actors* of the benefits from their *usual practices change*, in spite of the effort amount. Nevertheless, this challenge is much more difficult to achieve as the *added-values* perceived by the participants for *their personal works* and *expertise reinforcement* are also medium. This medium result is due to the fact that *the level of new knowledge acquisition* by the participants through the CtV methodology depends on their functions. The *engineering users* (i.e. the architects and researchers) seem to acquire *more useful knowledge* with the methodology than the *business users*. Indeed, since it is above all considered as a way to *steer innovation by value*, the engineers get more interests by being able to understand the *value creation strategies* of their *technological solutions*. They tend then to perceive “*High*” added-value for their personal works and expertise enhancement. In the contrary, the *business users*, especially the marketers, have already significant knowledge on *value creation strategies*, and are not very much interested in the definition of the *relevant technological solutions*. In a consequence, they tend to perceive “*Medium*” added-value for their personal works and expertise reinforcement.

- The *innovation projects performances*:

There is a medium appreciation on the contribution of the CtV methodology to the *development time and cost reduction*. Indeed, some of the participants do not consider these performances as primary objectives of the methodology: they are instead defined as *possible consequences*, and are not required. Interviewees explain that it can lead both to development cost and time decrease by eliminating *poor value*

strategies and solutions concepts, and also to development time and cost increase due to the profitable development of *differentiating strategies and concepts*. Moreover, the CtV methodology is not considered by all as a complete engine for *creativity, or for strategies and solutions generation*. Participants explain that it does not enhance their *individual creativity* (i.e. by helping to think beyond the “*innovation frontier*”), and that it is simply based on a *common framework* for better *sharing and integrating* multidisciplinary knowledge. In some cases, innovation has even to be interrupted when the strategies are not sufficiently promising. A possible interesting output of the methodology can be the absence of relevant differentiating strategies and solutions for a given scope. Thus, the successful deployment of the CtV methodology does not always lead to the definition of differentiating business models, technologies or new R&T projects. Participants state that it supports above all the *convergence of multidisciplinary views*, and the *conjoined exploration* of strategies and solutions. Finally, there is a medium appreciation on the contribution of the methodology to the *selection of R&T projects* for aircraft programs. The participants answers on this characteristic depend on their *respective functions or viewpoints*. Indeed, the *Engineers* tend to use the methodology to increase the number of selected *R&T technologies* in the new developed aircrafts, which is in some extent one of their main objectives. In opposition, the *Business managers* (i.e. the program managers) do not aim at increasing as much as possible the *rate of new R&T technologies* in the new aircrafts. Their objective consists namely in ensuring only that the relevant R&T technologies are selected for their programs. In some cases, the *Business managers* tend even to filter the list of *too numerous potential technologies* to be implemented. Their sole performances indicators are related to the programs profitability and values for the customers, whereas those of the engineers comprise the rate of selected R&T technologies.

- The *industrial deployment performances*:

There is also a medium appreciation on the *adequacy of the CtV methodology* to the continuous improvement policy of the organization. On the one hand, some participants state that this kind of value approach is *radically innovative* in EADS organization due to its support of multidisciplinary views integration. It corresponds then to a *methodological breakthrough* in the organization. On the other hand, other participants confirm that the CtV methodology is completely aligned with the continuous improvement of the organization process. Indeed, they assume that it permits to turn *usual value practices* made individually into *formal ones* enhancing multidisciplinary collaborations. It contributes in the formalization of the *process*, the *language* and the *collaborative tools*.

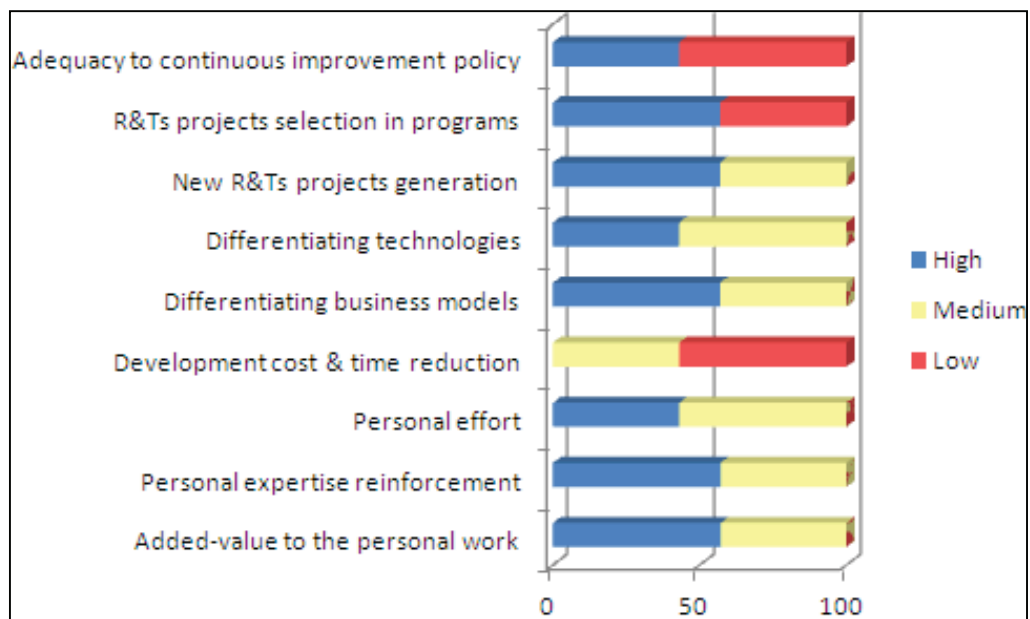


Figure 36: Distributions of participants answers on medium characteristics (%)

Table 22: Medium characteristics

Type	Characteristics of the Concept-to-Value methodology			
	Category 1: <i>Individual performances</i>	Category 2: <i>Collaborative teams performances</i>	Category 3: <i>Innovation projects performances</i>	Category 4: <i>Industrial deployment performances</i>
<i>Medium</i>	Personal effort, perception of added-value for the personal work, personal expertise reinforcement		Development cost & time reduction, contribution to differentiating business models, contribution to differentiating technologies, new R&Ts projects generation, improvement of R&Ts projects selection in programs	Adequacy to the continuous improvement policy of the organization

9 The Concept-to-Value methodology as a response to a benchmark of today expectations on innovation management

9.1 Description of the objectives and protocol of the industrial benchmark

Ecole Centrale Paris (ECP) and *Logica Business Consulting* (LBC) have conducted a benchmark on the practices and performances in *innovation management* of several leading French and European industrial companies. The research team consisted of 4 collaborators from LBC, of 4 professors and 3 PhD students from ECP. I have been one of these participants. The study lasted 10 months with 3 months of preparation, 4 months of industrial interviews, and 3 months of analysis and synthesis. It has resulted in the publication of a 130-page book [88].

The main objective of the benchmark is to describe, understand and build models of innovation management practices, and of their outcomes. A questionnaire is defined and applied in a 3 to 4-hour interview of executive managers or innovation directors of various industries. It is structured in 5 different axes:

- *1st axis*: it consists in describing and analyzing the *innovation strategies* that drive all the *innovation processes* (i.e. the type of new explored ideas, the level of customers needs investigation, the type of internal allocated resources...)
- *2nd axis*: it deals with the *organization of the R&D department* (i.e. structure in different knowledge area, separation of research process and new product development process, collaboration with external research centers...)
- *3rd axis*: it describes the *management of the innovation processes* from the new idea formulation to its introduction on the market, and through the management of advanced technologies and new family product planning.
- *4th axis*: it consists in defining the importance of the *innovation culture*, and the way it is promoted and transformed into innovation success.
- *5th axis*: it allows eliciting the different indicators used for the measurement of the innovation performances (i.e. number of patents, the return on investment, the market share increase...)

The questionnaire responses were analyzed in *qualitative* and *quantitative* ways. Some models of *innovation management practices* are then generated on the basis of two types of *variables*:

- *Explicative variables*: they are used to explain the *history* and the *external environment* of the innovative organization (i.e. the innovation context)
- *Descriptive variables*: they are used to describe the *behavior*, *decisions* and *structure* of the innovative organization (i.e. the internal environment)

9.2 Description of the main conclusions of the industrial benchmark

The benchmark leads to several conclusions on the way the industries manage the innovation, on the way they are more or less organized. A model of 5 different *levels of innovation management maturity* is proposed.

For the purpose of our research works, it is interesting to focus on the benchmark conclusions that deal with the management practices of innovation projects, and mostly the management of innovation in the preliminary phase. It is worth then building links between each of the relevant conclusions to our study and the interest of the CtV methodology deployment:

- 1st conclusion: *a consensus on innovation and value creation*

Most of the interviewed industries are aware of the importance of innovation. They converge all on the two sides of innovation: the *objective of creating value* through innovation, namely economical value for the industry and the customer; *innovation is multidimensional* and then can be related to the *product performances*, the *process* or the *business model*. The CtV methodology is well adapted to consider the different aspects of innovation and its impacts on a shared value model. It allows representing the value objectives of different stakeholder and customer profiles, and their links to various types of value drivers (i.e. technological performances, process, business model).

- 2nd conclusion: *the need for enlarged definition of radical innovation*

Nevertheless, a divergence between the industries exists on the efforts allocated to the different types of innovation. It corresponds to different types of innovation strategies. Most of the interviewed organizations associate the *radical innovation* only to the development of *breakthrough technologies*. It is above all shared by the organizations that benefit of an important R&D department. Some managers explain that the innovation is more likely linked to the definition of *new business model* or *strategies*, the *excitement of the customers* due to unexpected new product features, and the *covering of new markets* that do not still exist. From the CtV model, the *level of radical innovation* is not exclusively linked to *the level of radical technological innovation*. The CtV methodology promotes the *level of differentiation* or *high value creation* for the stakeholders, which can be generated by both types of radical innovation. Different types of metrics such as the

level of market contestation and the contribution to differentiation of Business and Engineering value drivers, and strategies are suggested. It can then be used both for steering the development of differentiating technologies, and the definition of differentiating business model. Moreover, a growing number of companies focus mainly on the innovation through *innovative services, and new revenue generation models*.

- 3rd conclusion: *the need for a multi-disciplinary and integrated approach*

In many organizations, with most often a *high technological innovation culture* and a well established *stage-and-gate product development process*, the *innovation process* is mainly a *convergence process* of selected *mature technologies* and *stable performances*, which ensures a *high level of feasibility, proof of concept* and a *very low development risk*. In such organization, the engineers play then the main role for the success of the innovation projects. The marketing department, as well as other departments of the organization (i.e. the financial department, the distribution centers, the customers support centers...), should take a larger part of the innovation process, and above all in the preliminary phase of *new concepts exploration*. The CtV methodology suggests a *common language* to be used by both Business and Engineering departments, so that they can efficiently share and integrate their *respective knowledge*. The main objective of the CtV process is to support a *win-win situation* where, from a *top-down approach*, the *Business strategies* are turned into *value creating Engineering strategies and architectures*, and where, from a *bottom-up approach*, the advanced technologies provide *unexpected, emergent and new Business values*.

- 4th conclusion: *the need for a systematic steering of innovation*

The last fundamental conclusion of the benchmark emphasizes the need and lack of *practical methodology* to steer the innovation process by taking into account all the *required players*, the *value enablers* and the objective of doing *more than just improvement of existing product*. Nevertheless, such a methodology must also consider the culture and history of the organization. Depending on this context, some efforts have to be put on the involvement, the formalization of the collaboration between all the organization actors, but also on the definition of a common language, process, and value model. The integration of all the contributors to the innovation success of an organization must be steered and supported through new organizational structure, new tasks and new tools. In a complete alignment with the principles of *Radical Innovation Design*, the CtV methodology is fully dedicated to the improvement and systematic steering of the strategic phase of new multidisciplinary concepts and ideas emergence, also called '*fuzzy front end stage*' of innovation process.

10 General conclusion

So far, the aeronautical innovation projects have been mainly led by *technological performances*. In the *preliminary design phase*, *aircraft concepts* have above all been defined from a *bottom-up* or *technology-push* approach. Although this approach is efficient to ensure sufficient *technological maturity* and *certification rules respect*, it is not adapted for the management of today *complex aeronautical projects*. Nowadays, a future aircraft to be developed has to bring *sufficient satisfaction* to several *stakeholders*, and to several *customer profiles*, which correspond to different *needs* and *aircraft operating ways*. Besides, there are several years occurring between the *first specifications* of an aircraft, and its *effective delivery* and *entry into service*. This long development cycle increases the risks of issuing on the future markets products that are not *differentiating* anymore, *inadequate* and *obsolete*. To tackle this problem, the *future aspirations* have to be already anticipated in the preliminary design phase. Thus, in order to lead the market becoming more and more *complex* and *competitive*, there is a necessity to adapt the aircraft manufacturing policy from *mass production* to *mass customization*. It permits to better take all the *stakeholders needs* into account, and to ensure them with optimal *value creation*. The innovation projects must then be steered by the *effective value perception*, and not only by the *technological performances*. To do so, the collaboration between the *Business* and *Engineering teams* must be reinforced in the preliminary design phase. Instead of collaborating through *punctual requests*, in *sequential mode*, or in *customer-supplier transactions*, the multidisciplinary teams must work in a more *integrated way*, with more *flexibility* to share more knowledge and common decisions. Such a collaboration must be well supported through *common models* of innovation *processes* and *objects*. Its final objectives consist in defining *aircraft concepts* with robust and high *Proof of Value* and *Concept*.

The analysis of the *scientific state of the art* permits to raise a significant *research issue* on the management of the *first step* of an innovation project, the *preliminary design phase*. This phase is described as the stage where *marketing plans*, *requirements*, *architectures*, and *technologies* are not frozen, and have to be defined and ever refined. In other words, the *Business* and *Engineering objects* are still fuzzy and uncertain. In the literature, two types of research works are identified for the management of this phase. On the one hand, some works describe *Product Planning* activities, which mainly support the definition of the *business* and *marketing strategies*. On the other hand, other works deal with the support of *Conceptual Design* activities, which are mainly related to *engineering requirements* and *solutions*. Despite existing models tending to merge the *Product Planning* and *Conceptual Design*, there is a lack of methodological approach allowing building *integrated collaboration* between *Business* and *Engineering domains*. The *research issue* for the development of a methodological proposal is formulated through *three questions*: *How to represent and integrate multidisciplinary objects?* *How to define common value metrics?* *How to define common and collaborative tasks?* Our goal has consisted then in contributing to provide better solutions to these issues than the existing ones.

The suggested *Concept-to-Value methodology*, named *CtV*, is to be used in support of the *preliminary design phase* of a complex innovation project. It allows defining and challenging both the *business strategies* and the *architectural solutions* from the perspective of *value creation* maximization for all the projects *stakeholders*, and different *customer profiles*. This methodology is based on a value model of *Knowledge, Problems and Solutions*, named value based *KPS model*, and on its implementation in a *four-step process*, to define relevant *product concepts*.

Through the *KPS model*, the developed *CtV* methodology permits to share a *common language* between the *Business and Engineering teams* involved in a preliminary design phase. Such a language helps them to build a *common understanding* of *multidisciplinary elements* that they must share. The *KPS model* describes and links, on the one hand, *stakeholders* to be satisfied, *value dimensions* or *high level value criteria*, *customer profiles*, and, on the other hand, *business and technological value drivers* or *enablers*, and *technological features*. It supports then the *capture and integration* of multidisciplinary *Knowledge*. Besides, it helps in defining common *Problems* to drive innovations for both *Business and Engineering*, through the definition of *value creation strategies*. The *KPS model* is also dedicated to the description of *architectural Solutions* as combinations of *technological features*, which contribute to *value drivers*, and consequently to *value creation strategies*.

The *KPS model* is completed with an associated *value model*, which describes practical value metrics to be used by both *Business and Engineering* teams. The value model permits to assess the *value contributions* of the represented *Knowledge, Problems and Solutions*. Different types of metrics are then specified such as: the level of *contributions to value dimensions*, the level of *completeness*, the level of *contributions to differentiation*, the level of *importance*, and the *gaps to strategies*. The explorations of *Knowledge, Problems and Solutions* are managed in a *collaborative and integrated* manner by multidisciplinary actors around common *value metrics* to be optimized.

A *CtV process* is defined to deploy the value-based *KPS model*. It supports the successful *collaboration and integration* between the *Business and Engineering* teams from the very beginning of an innovation project to the suggestion of *architectural concepts*. This process consists in implementing *four steps* in a collaborative way: *primary knowledge acquisition, stakeholders and value drivers analysis, value strategies analysis* and *architectural solutions steering*. At each of these steps, the elements of the *KPS model* are successively deployed with their value metrics. From the formulation of an innovation topic, the *Business and Engineering* teams collaborate through the *CtV* process to define at the end *differentiating marketing strategies*, relevant *technological requirements and solutions*. Therefore, the outputs of this process allow selecting or giving up some *technologies* from *R&T portfolio*, orientating *new research strategies*, and defining the *options packaging* for customers.

The *CtV* methodology aims at supporting a *practical and systematical steering* of the so called *fuzzy front end stage* of innovation projects. Its originality is based on the *better*

integration of multidisciplinary teams at this stage in comparison with existing more *sequential approaches* as suggested by *Systems Engineering* methodologies. For instance, it is different to the *Quality Functional Deployment*, which refines in a *rigid manner* some *business objectives* into *engineering characteristics*. Indeed, the CtV methodology allows exploring in a *conjoint manner* both *Business* and *Engineering value strategies*: it is then a more *flexible way* to converge to *relevant product concepts*. Besides, it provides a more *practical* and *systematical framework* for industrial organizations, in comparison with existing theoretical approaches like CK Theory. In opposition to methodologies based mainly on *individual creativity*, it puts the *integration of multidisciplinary knowledge* at the heart of the *conceptual innovation*. In addition, it contributes to the research works on *intermediate objects management*, by *integrating* them from *Business* and *Engineering* domains, and by steering them by *value*. The CtV methodology is well in alignment with the principles of *Radical Innovation Design* methodology [27, 35], to which it provides a *practical industrial guideline* for their application on complex innovation projects.

The industrial validation of the CtV methodology, through its *implementation on test cases*, and through *formal interviews*, has proven its *different benefits*. It better supports the steering of the *technological innovation by value*, the exploration of *value creation strategies*, the identification of *relevant innovation areas*, the *prioritization of the technologies*, and the improvement of their *Proof of Value*.

The further research axes to consider consist in improving *collaborative vote tools*, which are already experimented to support well the *CtV model* and *process*. Such *on line tools* usages have already shown that they really help the *Business* and *Engineering teams* to formalize and share their *knowledge*, and to *converge more efficiently* on the *innovation strategies* and *conceptual solutions*. Capabilities for *rapid value simulations* and *visualization* after any *votes updates* are to be enhanced. Finally, capabilities for *semi-quantitative votes* have also to be further developed within the collaborative tools to lead multidisciplinary actors to converge on *refined value assessments*.

The ongoing industrial challenge is to bring an *organizational change* in Airbus for the adequate deployment of the methodology. An *Airbus internal decision* has been made to officially build a *CtV team* for an *application* on at least four *innovation projects*. This team is dedicated to play the *mediation role* between the *Business* and *Engineering* teams, to help the *formalization of strategical business* and *technological orientations*, and to support the *requirements specification* for detailed design and more quantitative evaluation.

The CtV methodology is now deployed on several topics of the Airbus Future Programs, to challenge both business strategies and portfolios of technologies. It is the response to program managers requesting both aircraft mass production and “*haute couture*” production.

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13 Annex

Questionnaire for industrial validation of the Concept-to-Value methodology filled between December 2011 and March 2012 by 7 Airbus respondents familiar with CtV concepts and tools

Category 1: OPERATIONAL INDIVIDUAL COST & BENEFIT Objectives: to assess the personal effort and benefit of implementing the methodology		CHARACTERISTICS
QUESTION 1	Do you understand well the main key concepts of the methodology?	
	High - medium - low – null	level of key concepts clarity
		Comments
QUESTION 2	Do you understand well the mechanism & process of the methodology?	
	High - medium - low – null	level of mechanism & process clarity
		Comments
QUESTION 3	Do you think that the supporting tools are easy to handle?	
	High - medium - low – null	level of supporting tools usage difficulty
		Comments
QUESTION 4	Does it require you a significant effort to take part of the methodology deployment?	
	High - medium - low – null	level of personal effort
		Comments
QUESTION 5	Do you consider your participation to the methodology as being part of your job?	
	High - medium - low – null	level of alignment/consistency with the job
		Comments

QUESTION 6	Do you see an added-value of the methodology for your personal work?	
	High - medium - low – null	level of added-value to the personal work
		Comments
QUESTION 7	Do you see an added-value of the methodology for the project in which you are involved?	
	High - medium - low – null	level of added-value to the project
		Comments
QUESTION 8	Do you think the methodology permits to reinforce your expertise ?	
	High - medium - low – null	level of personal expertise reinforcement
		Comments

Category 2: OPERATIONAL TEAM COMMUNICATION, KNOWLEDGE & CREATIVITY objectives: to assess the benefit for a project team of implementing the methodology		CHARACTERISTICS
QUESTION 9	Does the methodology allow you to get more knowledge on potential Business strategies?	
	High - medium - low - null - less	level of contribution to business awareness
		Comments
QUESTION 10	Does the methodology allow you to get more knowledge on potential Engineering solutions?	
	High - medium - low - null - less	level of contribution to solutions awareness
		Comments
QUESTION 11	Does the methodology allow you to get more knowledge on the risks, values & adequacy of potential Engineering solutions to Businesses?	

	High - medium - low - null - less	level of contribution to the awareness on solutions values & business adequacy
		Comments
QUESTION 12	Does it allow you to share more of your expertise knowledge with the others?	
	High - medium - low - null - less	level of contribution to knowledge sharing
		Comments
QUESTION 13	Does it allow you to get more expertise knowledge from the others?	
	High - medium - low - null - less	level of contribution to knowledge acquisition
		Comments
QUESTION 14	Do you feel that the methodology improves the communication/information exchanges within a multidisciplinary team?	
	High - medium - low - null - less	level of contribution to information exchanges/communication
		Comments
QUESTION 15	Do you feel that the methodology brings you more useful knowledge?	
	High - medium - low - null - less	level of contribution to useful knowledge acquisition
		Comments
QUESTION 16	Do you feel that the methodology leads more to the exploration of new Business Strategies?	
	High - medium - low - null - less	level of contribution to business exploration
		Comments
QUESTION 17	Do you think the methodology can support better collaborative decision making on the Business Strategies choices for a new program ?	

	High - medium - low - null - less	level of contribution to decision making on business strategies
		Comments
QUESTION 18	Do you feel that the methodology leads more to the exploration of new Engineering Solutions?	
	High - medium - low - null - less	level of contribution to solutions exploration
		Comments
QUESTION 19	Do you think the methodology can support better collaborative decision making on the alternative technologies choices for a new program ?	
	High - medium - low - null - less	level of contribution to decision making on technologies
		Comments
QUESTION 20	Do you think the methodology better supports the creativity ?	
	High - medium - low - null - less	level of contribution to creativity
		Comments

Category 3: PROGRAM & RESEARCH PERFORMANCE Objectives: to assess the improvement by the methodology of Key Performances Indicators for new development programs and R&Ts projects steering		CHARACTERISTICS
QUESTION 21	Do you think the methodology contributes in issuing on the market more innovative/differentiating business models for a new program?	
	High - medium - low - null - less	level of contribution to differentiating business models
		Comments

QUESTION 22	Do you think the methodology contributes in issuing on the market more innovative/differentiating technological concepts for a new program?	
	High - medium - low - null - less	level of contribution to differentiating technologies
		Comments
QUESTION 23	Do you think the methodology can improve the values of the product & services of a new program to the customers?	
	high - medium - low - null - less	level of values delivery improvement
		Comments
QUESTION 24	Do you think the methodology can improve the maturity of the product & services of a new program?	
	high - medium - low - null - less	level of maturity improvement
		Comments
QUESTION 25	Do you think the methodology contributes in saving the cost & time development of a new program ?	
	high - medium - low - null - less	level of development cost & time reduction
		Comments
QUESTION 26	Do you think the methodology contributes in ensuring better profitability for a new program?	
	high - medium - low - null - less	Level of profitability improvement
		Comments
QUESTION 27	Do you think the methodology permits to enrich the R&Ts projects ?	
	high - medium - low - null - less	Level of contribution to new R&Ts projects generation
		Comments
QUESTION 28	Do you think the methodology permits to better build the hierarchy of the R&Ts projects ?	

	high - medium - low - null - less	Level of contribution to R&Ts projects hierarchy building
		Comments
QUESTION 29	Do you think the methodology permits to improve the PoC & PoV of R&Ts projects ?	
	high - medium - low - null - less	Level of PoC improvement of R&Ts projects
		Comments
	high - medium - low - null - less	Level of PoV improvement of R&Ts projects
		Comments
QUESTION 30	Do you think the methodology permits to improve the application of R&Ts projects in programs?	
	high - medium - low - null - less	Level of improvement of R&Ts projects selection in programs
		Comments

Category 4: METHOD & TOOLS DEPLOYMENT Objectives: to assess the degree of novelty, difficulty and importance of the methodology deployment in the organization		CHARACTERISTICS
QUESTION 31	Do you think the methodology is innovative in Airbus & EADS ?	
	high - medium - low – null	Level of methodology novelty
		Comments
QUESTION 32	Do you think the methodology is innovative in the aeronautical industry ?	
	high - medium - low – null	Level of methodology novelty

		Comments
QUESTION 33	Do you think it is aligned with Airbus & EADS process & tools continuous improvement strategy?	
	high - medium - low – null	Level of adequacy to the continuous improvement policy
		Comments
QUESTION 34	Do you think it is easy to adapt/change/improve the Airbus & EADS process & tool for the deployment of the methodology ?	
	high - medium - low – null	Level of deployment easiness
		Comments
QUESTION 35	Do you think that the methodology should be deployed in all forthcoming airplane development projects?	
	high - medium - low – null	Level of deployment extension
		Comments

SUMMARY

The *mass production* of aircrafts has been mainly led by the objective of both maximizing *technological performances* and minimizing the *manufacturing costs*. Within also the constraints of safety and security rules defined by certification organisms, the traditional innovation management has consisted above all in implementing a “*technology-push*” approach. New developed aircrafts have been then mostly driven by *Research and Technology* projects outputs. Nevertheless, current market *competitiveness* and *complexity* lead to change this approach. The *needs* of aeronautical customers evolve, change and become diversified, which raise multiple *specific profiles* to be taken into account as *early as possible* in today’s development programs. In order to ensure *high value* and *differentiation* perception by all the stakeholders, the innovation policy has to shift from *mass production* to *mass customization*, and to integrate both “*market-read*” and “*technology-push*” approaches in the preliminary phase of innovation. The goal of this PhD thesis is to provide the aircraft *program managers* with a methodological support, named *Concept-to-Value*, to steer by value the so called *Fuzzy Front End of Innovation* stage in the literature. At the bridge between the *Product Planning* and *Conceptual Design* research works, our contribution improves the existing methodologies on the *Business* and *Engineering* domains integration. *Concept-to-Value* brings a more *agile* and *integrated* collaboration of *multidisciplinary players*: a *common language* and *value model* represent their innovation *Knowledge, Problems* and *Solutions*. Finally, a *convergence process* is also defined to conduct the preliminary phase and to deliver *high value* aircraft concepts.

La *production de masse* dans l’industrie aéronautique a été surtout poussée par l’objectif de maximiser les *performances technologiques*, et de minimiser les *coûts de fabrication*. Dans le respect des règles de sûreté et de sécurité établies par les organismes de certification, le management traditionnel de l’innovation a consisté avant tout à mettre en œuvre une approche en « *technology-push* ». Le développement des avions a ainsi surtout été tiré par les résultats de projets de *recherche technologique*. Cependant, la *compétitivité* et la *complexité* du marché actuel tendent à modifier cette approche. Les besoins des clients évoluent, changent et se diversifient suivant de multiples *profils spécifiques*, qui doivent être pris en compte très tôt dans les nouveaux programmes. Afin d’assurer une *valeur* et *différentiation* importantes à toutes les parties prenantes, la politique d’innovation doit passer de la *production de masse* à une *production personnalisée*. Cela nécessite d’intégrer les approches en « *technology-push* » et « *market-read* » dès la phase préliminaire d’innovation. Pour piloter cette phase par la valeur, ce travail de thèse a permis de fournir aux managers de programmes un support méthodologique, appelé *Concept-to-Value*. A la croisée entre les travaux sur la *Planification Stratégique* et la *Conception Conceptuelle*, notre contribution porte sur l’amélioration des méthodologies existantes pour l’intégration du *Business* et de l’*Ingénierie*. *Concept-to-Value* permet une collaboration plus agile et intégrée entre des *acteurs multidisciplinaires*: un *langage* et un *modèle de valeur communs* représentent leurs *Connaissances, Problèmes* et *Solutions* d’innovation. Enfin, un *processus de convergence* est aussi défini pour amener la phase préliminaire à générer des concepts d’avions encore plus *créateurs de valeur*.