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INDUSTRIAL NEED TO IMPROVE COST INTEGRATION IN MULTI-CRITERIA DECISION DURING DESIGN - CASE STUDY AT AIRBUS AND EUROCOPTER

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1. Introduction

Methods such as Concurrent Engineering and Design for X have stressed the fact that parameters which are major stakes in terms of competitiveness (cost, weight, lead time) should be considered from early stages of new product design. This paper proposes to describe Design to Cost (DtC) method implemented to consider the cost parameter from early stages of design. In a first part, we study the positioning of DtC among other design methods. In the follow-up of the article, we focus on the case of Airbus' and Eurocopter's DtC teams. In section 3, we propose a way to characterise projects handled by DtC teams and a typology of tools needed for a good implementation of DtC. It allows us to study the converging and diverging points between the two practices. We also define the needs of the two teams to improve DtC implementation. In the last section, we propose to answer to some of their needs. First, we define a Process-To-Be adapted to the constraints handled by DtC teams. Secondly, we propose requirements for an information system that would allow design alternative management in a DtC context.

2. Design to Cost positioning

Around 1970, the earlier search of a maximum technical and mechanical performance in aircraft industry has turned into a new quest for balance between performance, life-cycle cost, reliability and maintainability [1]. Indeed, figures related to cost and new product development time in Aeronautics are critical. With a market facing an increasing competitiveness, efforts need to be achieved to improve the productivity [9]. Those statements have lead to challenging the design process. It was deemed important to take some parameters into account early in the design life cycle, even if their impacts occur at the end of the design lifecycle. This is referred to as Design for X.

In a Design for X context, Vliet [10] makes a distinction between the life-cycle *properties* and the lifecycle *aspects* of a product. The life-cycle *properties*, like costs, lead-time, quality, etc. can be determined for each phase. The life-cycle *aspects* however, are only dedicated to a given phase: e.g., the manufacture of a product (DFM), the assembly (DFA), etc. In this article, we focus on the life-cycle properties and more particularly on the Cost parameter.

To consider the cost parameter from early stages of design, several methods aiming at considering cost as an independent variable have been defined in industry. The basic principle is that cost targets are defined at the beginning of the product development and that those targets must be respected like any other requirements. The main methods are mentioned below:

- *Design to Cost* was defined by the Department of Defense (DoD) of the United States in 1971. Its implementation was compulsory for contracts with the army of an amount greater than 10 million dollars. The essence of Design to Cost is making design converge on cost instead of allowing cost to converge on design. Cost is elevated to the same level of concern as performance and schedule, from the moment the new product or service is conceived through its useful lifetime. Realistic cost goals are established from the beginning of the project. Trade-off analysis are performed to balance cost with other design parameters [7],[2].
- *Target costing* emerged in Japan in the 1960s, as a response to difficult market conditions. As explained by Lorino [6], "the future selling price for the product will be set by the market place. The profit to get from the product is set by the global strategic options adopted by the company. Cost must not therefore be regarded as a free objective, an action variable, but rather as an intrinsic constraint, a target which must be achieved for the company to meet strategic objectives".
- DoD of the United States defines *Cost As an Independent Variable* as a methodology used to acquire and operate affordable DoD systems by setting aggressive, achievable Life Cycle Cost objectives and managing achievement of these objectives by trading off performance and schedule.

Depending on the authors and on the methods, costs targeted in the quoted methods vary. In Design to cost, cost targets can concern many types of costs: research & development costs, production costs ("Design to unit production cost"), ownership costs ("Design to operation and support cost"), or maintenance cost ("Design to maintenance cost") [5]. By default, when talking about Design to Cost, we further mean Design to Production Cost.

A French standard (NF X50 156) defines the concept of Design to Objective, which is a generalisation of DtC. "The concept of Objective is extended beyond the economic scope by integrating on the same level technical, social, environmental and market issues into an organized set of objectives called specified objective" [8]. In our vision of Design to Cost, the aim is not to make the cost parameter the prior parameter, but to globally optimize the product. Cost parameter is emphasized because it requires the support of a specific method. A difficulty lies in the fact that there is a trend to create separate methods for each parameter; indeed, in some companies, there is Design to recurring cost, design to maintenance cost, design to time, design to weight. The fact that designers must concurrently use several methods doesn't help their acceptation. That is the reason why we broaden the term « Design to Cost » to « Design to X » where « X » can represent any parameter that needs to be stressed by the implementation of a target. It means that for each project, strategic parameters are identified. Those that are renowned hard to comply with are translated into targets; those targets are considered as inputs of the design process as well as technical requirements.

Gautier [5] reminds that Design to Cost can have two different meanings:

- In the case of a single company, Design to Cost is applied to the product development process, it consists in defining an economic target that prompts design players to consider the impact of their decisions on different costs.

– In the case of two companies (a client and its supplier), Design to Cost consists on finding a win-win partnership that leads to a product development respecting cost target fixed by the client at the beginning of the development.

In the follow-up, we focus on the first case described by Gautier: the case of DtC implementation in a single company (Airbus or Eurocopter).

3. Design to Cost study at Airbus and Eurocopter

Design to cost can be defined as a design management method that prompts designers to consider cost as an input of the design, at the same level as technical requirements. Cost targets are defined from the beginning of the project and are cascaded to lower levels. Designers use to propose *design alternatives* that let expect to reach targets during a DtC operation and that let expect technical improvements and/or cost savings during a ReDtC (Redesign to Cost) operation. As such, design alternatives must be managed during the design process, i.e. they must be recorded, classified, assessed regarding their advantages to partially fill the gap to the overall (cost/weight…) target. It allows to make a decision about their actual implementation in the project. One can easily figure out the importance of this stage of *design alternatives management*.

Airbus and Eurocopter are two aeronautic companies that belong to EADS group. Although they work in the Aeronautic field and share many skills and technologies, the firms are not subject to the same market constraints, and don't have the same characteristics. Indeed, the missions of an helicopter vary a lot depending on the customer. Eurocopter waits for possible financing from a contract or from a bid for tender to launch pre-project studies; as a consequence, pre-projects are much more constrained in time than at Airbus. However, the firms have in common the fact that *cost parameter* is not easily taken into account during new product development. Indeed, designers are used to take into account the weight parameter but not the cost. Facing this difficulty, each company has created a team responsible for *Design to Cost* implementation on projects. The role of the DtC team at Eurocopter consists in implementing Design to Recurring and Maintenance Cost on each project handled by Eurocopter. The role of the DtC team at Airbus consists in providing designers with a support to achieve recurring cost targets imposed by the project management. The teams don't cover the same perimeter of action, but they have the same goal: prompting designers to consider the cost parameter from the beginning of a new product development.

Since their creation (4 years ago), DtC teams have led numbers of DtC operations. In the follow-up, some of these operations are sketched to clarify the role of these teams. Table 1 characterizes those operations through the type of project and the stage of project at which DtC actions have taken place, the type of DtC action and the features of the organisation implemented for these DtC actions.

Table 1. Projects handled by DtC teams (A standing for Airbus and E for Eurocopter)

A: Airbus project E: Eurocopter project	Type of project			Stage of the project					Type of DtC actions			Organisation features			
	Research activities	Aircraft development	Cost reduction Campaign	None	Feasibility	concept	Definition	Development	Multidisciplinary evaluation	DtC process implementation	Cost reduction operations	Working Group organisation (by skills)	DtC Core team constitution	Multidisciplinary meetings	External consultants
A3		X					X			X				X	
E2		X					X			X					
E3		X					X			X					
E4		X			X					X		X			
E5		X			X					X		X		X	X
A2			X					X			X		X	X	
E1			X					X			X	X	X		
A1	X			X					X				X	X	
E6	X			X					X					X	

We have grouped projects that have similarities together. The first group of project is the Aircraft development (A3, E2, E3, E4, E5). A3 was an operation handled on a subsystem of an aircraft, this subsystem was identified as critical from the cost point of view. DtC team organized multidisciplinary meetings in order to identify cost reduction ideas. E2, E3 and E4 were handled at the very beginning of DtC activities at Eurocopter. Therefore, the activity has only consisted in target allocation. Finally, E5 is a very recent project; external consultants have been hired to organize multidisciplinary meetings during the feasibility stage. The aim of these meetings was to make the designer conscious of the cost issues and to find cost reduction ideas. It has only concerned the feasibility stage and time constraints were too strong to apply a complete DtC process.

The second group of projects is Cost reduction Campaign (A2, E1). These two projects have led to the creation of a core team that was in charge of managing design alternatives.

The last group of operations consists in research activities (A1, E6). A1 and E6 were not run in the context of a specific project, these two operations have led to the creation of a dossier gathering a multidisciplinary information concerning a technology.

Although the evoked DtC teams work in two different companies, and despite project constraints are not the same, many similarities can be observed in their activities. The conclusion of this first step of the study is that although the two teams don’t cover the same scope of action, because the types of project they deal with are the same, they are subjected to the same type of constraints and have several similarities in their activities.

The second step of our study is to compare the practices of the two teams in order to define how it would be interesting to share practices and where it would be interesting to support the DtC process with a new tool. We compare methods and tools developed in the two teams. We have identified 8 types of methods and tools that are useful in DtC implementation.

Table 2. DtC tools and associated needs

Tool/method type	Airbus		Eurocopter	
	Existing tool	Identified need	Existing tool	Identified need
1. Target cascading			1	Yes
2. Creativity method	1	Yes	0	No
3. Design alternative formalization	1	No	1	No
4. Design alternative management	2	Yes	1	Yes
5. Choice (DtC item selection)	1	Yes	0	No
6. Reporting on target achievement	1	No	1	Yes
7.Memorizing tool	0	Yes	0	Yes
8. Technology multidisciplinary evaluation	1	No	1	No

For each type of tool, we have defined what is available at Airbus and Eurocopter and what the identified needs are (see Table 2):

– **(T1)** *Target cascading methods*: Target cascading consists in allocating a target to sub-systems. This type of tool is a matter of concern to Eurocopter and not to Airbus. Indeed at Airbus, target allocation is decided at the project management level. This step is a strategic and hard point, as the DtC efficiency requires target acceptation by designers, and therefore the target allocation method needs to be accepted.

– **(T2)** *Creativity methods*: The goal of creativity methods is to support designers in finding design alternatives. Indeed, when designers are imposed a cost saving target, they need to find design alternatives that are the most likely to meet the target. A structured approach can be needed to focus on sub-systems parts that have cost reduction opportunities. At Airbus, a method has been developed that aims at identifying cost reduction opportunities during multidisciplinary meetings, based on a cost structure presentation and a functional analysis. The role of the cost structure is to identify the main contributors to the cost, and to focus on the identification and prioritization of cost drivers. According to Airbus, this latter task is a non-trivial task for which a methodology would be necessary.

– **(T3)** D*esign alternatives formalization*: it aims at gathering important data concerning design alternatives. At Airbus and Eurocopter, DtC sheets have been created; for each cost reduction idea, a sheet is filled for providing some extra (and contextual) information useful to be known for a possibly future choice.

– **(T4)** *Design alternatives management tool*: a DtC design alternative goes through different steps before its implementation on the aircraft. This type of tool allows updating the status of design alternatives. In the case of a large project, numerous design alternatives can be proposed; it is important to have a tool available to keep track of the evolution of design alternatives.

– **(T5)** *Decision making methods*: These tools or methods provide some indicators to help to make a decision concerning design alternative implementation. This decision often requires trade-off analysis: determination of the optimum balance between parameters (cost, schedule, weight, supportability, …). Indeed, a cost reduction idea often leads to a worsening of other parameters, therefore drawbacks and advantages have to be traded-off.

- **(T6)** *Reporting tool*: Reporting tools enable the status of design alternatives under study and an evaluation of the gap to target. This kind of tool is often associated to a design alternatives management tool. Some reporting tools have been developed at Airbus and Eurocopter.

- **(T7)** *Memorizing tool*: it allows memorizing design alternatives or the process of decision linked to a cost saving idea. Today there is no tool specifically created to enable memorizing activity, or reuse of experience from previous projects.

- **(T8)** *Technology multidisciplinary evaluation*: These methods allow gathering multidisciplinary data needed to make a decision concerning the implementation of a technology. In practice, these are files built on a technology; it is often done in a context of research activity.

To fulfil the identified needs, we propose a DtC Process-To-Be, and requirements of a tool allowing management of design alternatives that integrates memorizing aspects.

4. Propositions

4.1 Process-To-Be proposition

Our vision of Design to X is illustrated in Figure 1. It describes the way we believe the process should be implemented by the teams at Airbus and Eurocopter, i.e. the so-called Process-To-Be. It does not necessarily correspond to the way it stands today, namely the Process-As-Is. Nevertheless, this process is based on current practices and adapted to the constraints handled by DtC teams in Airbus and Eurocopter.

We describe the Process-To-Be between a system (level N) and its sub-systems (levels N-1) at any level judged relevant. For example, level N can be aircraft level and levels N-1 can be the wing, the engine and the fuselage level.

The following steps can be identified for the Design to Cost Process-To-Be:

- Level N receives a cost target for the system it is responsible of

- Level N allocates the targets to sub-systems constituting the considered system

- Level N-1 looks for design alternatives that enables the achievement of target (while respecting technical requirements)

- Level N-1 assesses promising concepts and proposes them to level N (with an associated decision file that contains the design alternative evaluation)

- Level N selects for each sub-system, the most promising concept that allows an optimization of the system

- Detailed definition is achieved by level N-1

Redesign to Cost is quite the same process; each level N-1 is allocated a cost saving target and must propose ideas that favors cost savings.

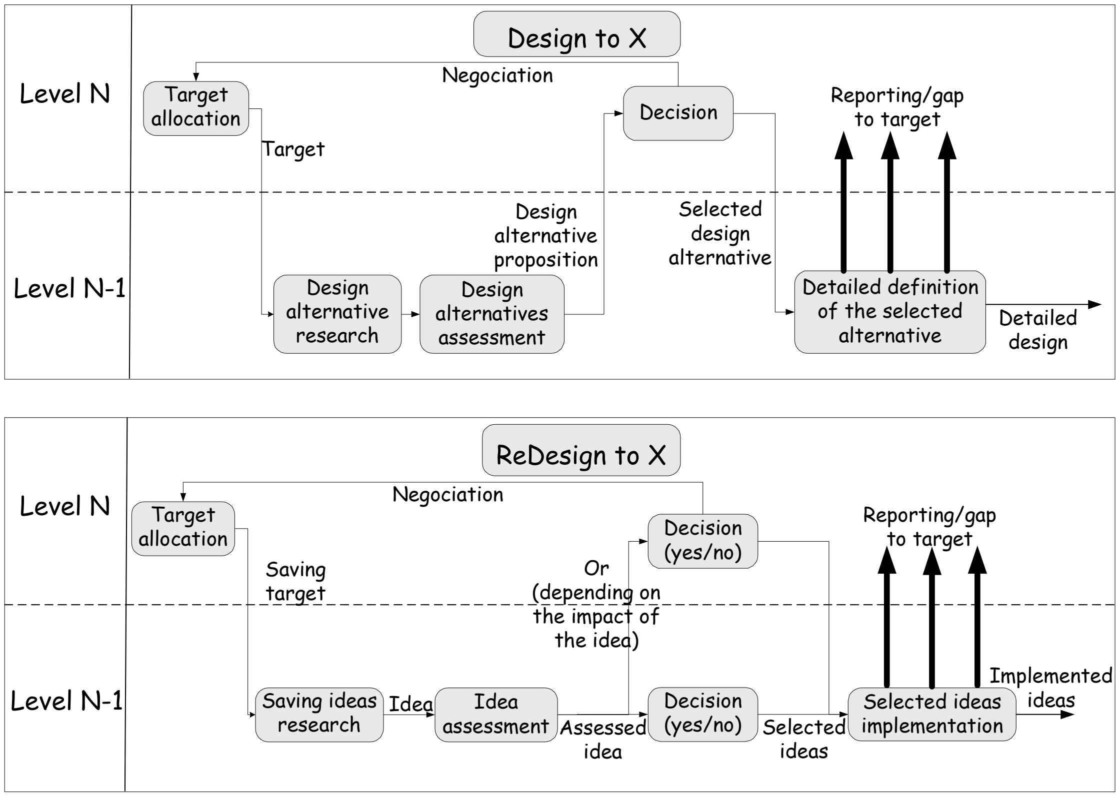

Figure 1: Design to X and ReDesign to X process

<u>Frontier between Design and Redesign:</u>

As explained in [3], one of the main difference between design and redesign lies in the fact that design process starts with a concept, whereas redesign process starts with an artifact. Therefore, from the moment a baseline solution (an artifact) has been defined, we consider we are in a redesign process. Frontier between Design and ReDesign within the lifecycle development of a new aircraft can vary depending on:

- the company: at Airbus, a baseline solution is defined as early as possible in the new product development process. Design propositions consist of weight or cost saving ideas. At Eurocopter this notion of baseline solution appears later.

- the type of project: two types of project exist at Airbus and Eurocopter: new aircraft development and evolution of an existing aircraft. In the case of evolution of an existing aircraft, a baseline solution can be defined from the beginning of the feasibility stage. For new aircraft development, a baseline solution intervenes later in the development lifecycle process.

In a Design to X context, design alternatives are merely design propositions whereas in a Redesign to X context, design alternatives are design improvement ideas.

It is important to notice that design and redesign may coexist on the same aircraft project. For example, let us mention a project consisting in an evolution of an existing aircraft: only the wings have been completely renewed. For the wings, design alternatives were wing design scenarios whereas for the rest of the aircraft, design alternatives were design improvement ideas.

In a DtC context, new design ideas are the drivers of technical requirement and cost target fulfillment; in a ReDtC context, cost reduction ideas are the drivers of design improvements.

4.2 Specification of a tool Design to Cost & Weight (DtC&W)

Design to Cost teams have emphasized the need for a tool that assists them in activities linked to design alternatives management. During DtC implementation, design alternatives are proposed, and the DtC teams recognize that it is important to memorize those alternatives and their associated decision process. We propose to define a tool that will correspond to these requirements: it is the Design to Cost & Weight tool.

The identified steps that can lead to a design alternative implementation are the following:

- Proposed
- Accepted for evaluation
- Technical assessment done
- Cost assessment done
- Accepted for implementation
- Implemented

Two types of context exist to create a design alternative:

1. Designers create themselves a design alternative; during reviews, the steering committee studies each created design alternative and accepts it for evaluation or not;
2. Multidisciplinary meetings are organised by the DtC team; these meetings aim at creating new design alternatives that are directly accepted for evaluation

The DtC&W tool may be linked to a reporting tool. Therefore, the tools have to be compliant, complementary but independent. We have conducted a requirement analysis based on the functional analysis principles. The results are shown in Figure 2.

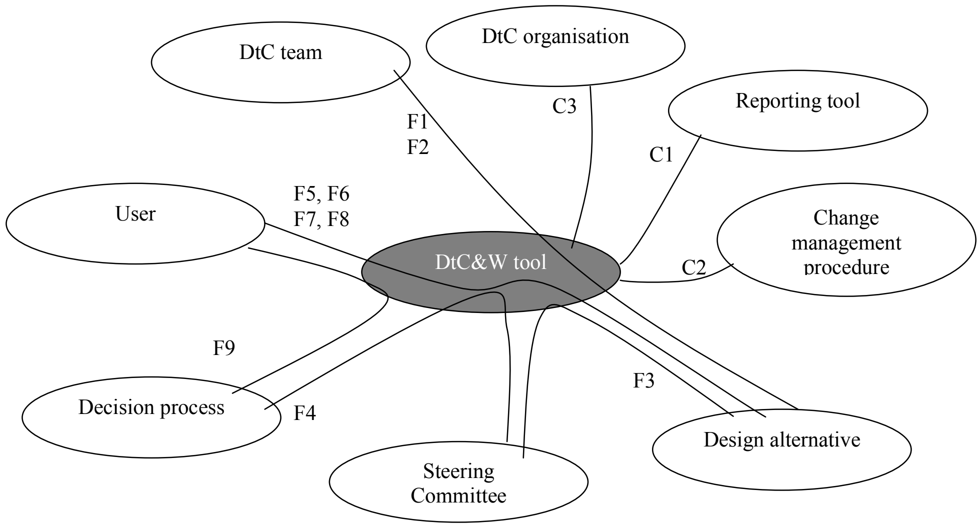

Figure 2: The environment interfaces of a DtC&W tool and its functions

– **F1**: the tool allows a DtC actor to create a design alternative (accepted for evaluation)

– **F2**: the tool allows a DtC actor to consult design alternatives from previous DtC operations

– **F3**: the tool allows steering committee actors to validate a design alternative

– **F4**: the tool supports steering committee to make a decision

– **F5**: The tool allows users to propose a design alternative

– **F6**: The tool allows users to describe a design alternative

– **F7**: The tool allows users to update information of a design alternative (technical and costing assessment)

– **F8**: The tool allows users to consult design alternatives from previous DtC operations

– **F9**: The tool allows users to consult decision process linked to a design alternative

– **C1**: the tool must be compliant with the reporting tool

– **C2**: the tool must be compliant with Airbus and Eurocopter procedures linked to change management

– **C3**: the tool must be consistant with the DtC organisation

The next step of the study will be to study design alternatives from previous projects: the aim is to identify which of their attributes have to be filed and memorized for experience capitalization.

5. Conclusion

Aeronautic market constraints evolution has stressed the need for a better consideration of parameters linked to the end of the product development process from the early stages of the design. At Airbus and Eurocopter, the goal is to consider cost parameter as early as possible in the design process thanks to Design to Cost implementation. Several difficulties linked to this new way of working have been raised. Indeed, constraints linked to projects are strong, and DtC process prompts project players to take cost parameter more systematically into account. DtC teams at Airbus and Eurocopter have developed methods and tools to make DtC implementation easier and to answer project players needs. We have conducted an analysis that allows a description of projects handled by DtC teams. The conclusion of this study is that the type of projects handled have the same characteristics and that the two teams can share some of their methods and tools. We propose a typology of tools needed to implement DtC; this allows us to define the needs in each firm and what can be shared. In the last section we try to fill some of the gap that none of the existing methods and tools can fill. We first propose a Process-To-Be adapted to the constraints handled by teams. Our second proposition concerns the creation of a tool DtC&W that supports the management of design alternatives, enables a memorizing of design alternatives and their use on future project [4].

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