A Methodology for Engineering Competencies Definition in the Aerospace Industry

Laura FORTUNATO, Serena LETTERA, Mariangela LAZOI, Angelo CORALLO
Center for Business Innovation (CBI), University of Salento,
Lecce, 73100, Italy

and

Giovanni Pietro GUIDONE
Gestione Processi & Design Assurance, Ingegneria, Alenia Aeronautica SpA,
Viale dell'Aeronautica, Pomigliano D'Arco (NA), 80038, Italy

ABSTRACT

The need to cut off lead times, to increase the products innovation, to respond to changing customer requirements and to integrate new technologies into business process pushes companies to increase the collaboration.
In particular, collaboration, knowledge sharing and information exchange in the Aerospace Value Network, need to a clear definition and identification of competencies of several actors. Main contractors, stakeholders, customers, suppliers, partners, have different expertise and backgrounds and in this collaborative working environment are called to work together in projects, programs and process.
To improve collaboration and support the knowledge sharing, a competencies definition methodology and the related dictionary result useful tools among actors within an extended supply chain. They can use the same terminology and be informed on the competencies available. It becomes easy to specify who knows to do required activities stimulating collaboration and improving communication.
Based on an action research developed in the context of the iDesign Foundation project, the paper outlines a competency definition methodology and it presents examples from the implementation in Alenia Aeronautica company.
A new definition of competency is suggested supporting by a new method to specify the structural relationship between competencies and activities of aeronautical processes.

Keywords: Aerospace industry, Technical activities, Human competencies, Competency management, Competency dictionary.

1. INTRODUCTION

In a value network [1], many actors are called to work together in projects, programs and processes sharing resources, knowledge and expertise.
This interaction requires to several actors with different expertise and backgrounds to discuss about the requirements of products and decide about technologies, innovation, time, budget by which develop the product that best satisfy the potential customers.
The organizational activities aimed to continuous monitoring of resources and their expertise, become fundamental to identify the gaps in the skills and to define the actions to fill them [2] improving the creation of value for the whole network of companies.
In business environments, characterized by extended structural dimensions and by organizational complexity, often it is very difficult to objectively define and identify competencies of people involved in business activities. Also, it is complex to express these competencies with a common language shared by all the companies belonging to the network.
Each competency must be associable and linkable to specific activities performed into a company and to individuals, who are the owners of these competencies. Having a skills portfolio, companies can define a competency development plan consistent with future objectives and strategic positioning of the company.
In fact, the competency management has an important impact on improving the overall quality of the final product, and then on customer satisfaction.
These effects are clearly visible in a very complex enterprise network, like Aerospace Value Network, where the design and manufacture of complex products such as aircraft are based on the integration of specialized management and engineering competencies [3, 4, 5] available in different companies.
In aerospace industry, often the effort of improving the performance of engineering activities is translated into an enhanced knowledge management of people about sophisticated technology, innovative materials and knowledge-intensive processes and into an appropriate allocation of human resources in complex engineering processes, such as the design and manufacturing of aircrafts.
Therefore, competencies sharing between these companies necessitates of a clear definition and identification of competencies within the aeronautical network. However, studies explore the competencies management topic in aerospace industry [6, 7] but none is focalized on the description of a methodology that allows competencies definition in one company and in the whole network.
In this industrial context, the scientific research has the role to define general reference models, to indentify the basic pillars and the future troubles. The research project Innovative Design Foundation (iDF) is being carried out by a partnership among the Center for Business Innovation, a laboratory of University of Salento (Lecce, Italy), and two Italian firm: Avio, an aero-engine company, and Alenia Aeronautica, an airframe one. It aims to define an innovative model of a collaborative New Product Development, NPD, into the aeronautical value network, building a framework able to permit an intra-firm

collaboration, with high levels of standards of security and protection of knowledge assets.

The development of a complete competencies definition methodology and of a system supporting it is one of main objectives of the iDF project. A competencies definition methodology means a set of rules to specify and, thus, define all the available competencies creating a dictionary. The proposed iDF methodology is based on a competencies dictionary that contains and structures all the competencies available in the network in order to homogenize and generalize similar competencies and to define and identify critical competencies into a specific area. The system is actually under development and it will be able to evaluate the competencies set existing into each aeronautical company areas and to measure the impact of different allocation of individual and their competencies in other areas or firms in order to support collaboration and creation of relationships for NPD. This paper aims to describe the developed methodology and the related dictionary focused on a competencies identification process based on technical activities of design and development of complex products such aircrafts that is characterized by many competencies that need to be analyzed.

The paper is structured as follows. In the next section some theoretical definitions and previous studies are briefly reviewed in order to outline the background of the proposed methodology. Section 3 contains the description of the research approach highlighting the followed phases. In section 4, the paper results are treated: firstly the definition of a competency dictionary methodology is done and secondly there is a practical case study of the methodology application. Finally, section 5 draws conclusions, limitations, and future research.

2. BACKGROUND

In literature, several definitions of competency are available. The term competency has became popular with the study of McClelland and his collaborators, especially Richard Boyatzis [8, 9]. In its book "The Competent Manager", Boyatzis defines a competency as an intrinsic characteristic of an individual casually related to an effective or high level performance (e.g. motivations, skills, own image, knowledge) in executing one or more defined task [10]. Klein [11] has, instead, provided a definition that looks the competency as a set of observable behaviours or behavioural indicators that can be grouped around a central topic and became a competency.

From the definitions available in literature, it is possible to conclude that competencies are the knowledge, ability and behavior to execute an effective work task. These features are observable and measureable and looking to them is possible to improve and differentiate the results of the related activities [12, 13].

Several studies are focused on the classification of competencies. In competency model of Harzallah [14] the competencies are shared in three categories:

a) *Knowledge*. It concerns to everything that can be learned from educational/formative system, training course and everything which involves cognitive processes (i.e. perception, learning, communication, association and reasoning). It represents the theoretical understanding of something such as a new method or procedure, an updating of them, etc.…
b) *Know-how*. It is related to personal experiences and working conditions. It is learned by doing, by practice, by experience. It is the practical knowledge consisting in "how to get something done".
c) *Behavior*. It is referred to individual characters, talents, human traits, or qualities that 'drive, direct or select' someone to act or react in a certain way under certain circumstances.

Furthermore, an individual has several competencies impacting on the organizational activities and on patterns of organizational evolution and change [15]. An activity needs specific competencies to be executed and to optimize its performance. The application of the same competencies in two different activities can lead to different level of results. In this perspective, competencies are defined in literature as "effective performance within a domain/context at different levels of proficiency" [16]. In addition, the level of specialization in a given competency, based on the qualification, experience and focalization of the actor in executing an activity is also an important aspect. A more specialized competency allows to execute an activity, in which it is required, in a faster and more effective way [15].

Competency management involves several processes that can be categorized in four classes [17]:

- *competency identification*. Starting from an analysis of business processes, business areas, operating procedures, values and corporate culture, and using the definition of competency on the business context, for each business area/process, the competencies of the human resources are identified. These are the skills that must have employees to make (in the short and medium term) the expected performance and business objectives. This phase brings to a competency dictionary creation. In order to be an effective tool, this catalogue of competencies should be regularly updated and adapted to any changing needs of business and corporate strategy.
- *competency assessment*. In this process, a valid method to measure the effective knowledge of human resources that performs a specific activity, is identified. To calculate a competency gap, the real competency level of each employee is compared with the level of competency considered optimal.
- *competency acquisition*. In this phase, a company have to plan and decide about how and when to acquire some competencies. There are different acquisition competency tools that allow several types of analysis.
- *competency utilization*. This process uses information about the competencies produced and transformed by the identification and assessment processes.

The assessments obtained allow to perform analysis such as [6]:

- identifying the gap between the competencies needed by activities and competencies possessed by personnel and corporate entities;
- placing all available resources in the right roles with positive organizational effects;
- identifying critical resources that need training and/or improvement actions to develop their potential;
- assessing the change impact of movements of certain individuals in other companies or areas.

Looking to the literature, it is perhaps missed a definition of competency able to collect all the evidences needed to represent the complexity of high technological sectors such as the aerospace one.

3. RESEARCH DESIGN

Based on an action research, the paper outlines a competency definition methodology and it presents findings from the implementation in Alenia Aeronautica company. An action research [18] has been realized moving from the objectives of the iDF project and from the needs of the members companies.
In Corallo [6] is described a methodology used by Alenia Aeronautica to improve and monitor the own competencies looking to the internal company activities. This methodology needs more customization and theoretical justification that have lead the company to explore a new methodology able to catch all the available competencies and structured them in a sounder way. Furthermore, technological systems are available inside the company to support the employees allocation in the work activities based on their competencies [6] and new technological solution more powerful are actually under development [19].
The aim of the study is to suggest a new competency definition methodology representing the complexity of the aerospace industry that can be diffused in networks of companies in order to share common definitions about the competencies needed to perform an activity favoring the allocation of employees and the scouting among companies. The methodology is, thus, created and used to define a competencies dictionary for the aerospace sector. To develop the methodology four main phases have been followed:

- literature analysis;
- companies exploration;
- methodology definition;
- methodology test.

The literature analysis has investigated competency definitions and methodologies available in scientific papers in order to highlight and compare different scholars and specify existing gap. The second phase has, instead, explored how companies manage their competencies and which methodology they apply. In this phase, the methodology used in the iDF partner companies and in other companies have been explored in order to find best practices and criticalities. The first two phases have been useful to design the "as is" in the competencies field and to guide the development of a new methodology. In the third phase, a new methodology has been proposed to reflect the complexity of the aerospace sector and the network perspective. In the final phase, the methodology has been tested in the Alenia Aeronautica by a set of interviews to company key persons in order to validate the findings.
In the following section, the methodology is described and some practical examples are reported.

4. COMPETENCY DICTIONARY

The research activities in the Research Project I-Design Foundation have allowed to develop a methodology for drafting a competency dictionary for aeronautical network.
The competency concept definition is focused on the structural relationship between technical activities of an aeronautical process and its required skills .
Starting from the competency subdivision in *knowledge*, *know-how* and *behavior* ([14]; see section 2), this study leaves out the behavior category. Because for its multifaceted feature it's difficult to define and classify. Only the concept of knowledge and know-how related to a competency have been considered. The introduction of behavior in the competency dictionary methodology will be evaluated in a future extension.

Concepts and proposed methodology

The analysis of Alenia Aeronautica's technical activities and the study of competencies classification (knowledge, know-how, behavior) reported in the literature have been necessary to obtain a competency definition valid in a technical context. This definition provides guidelines for the creation of a competency dictionary.
In order to get the competency/ies necessary to realize/implement a technical activity it is necessary to ask: *"What is it need to know?", "What are the main aspects of the tasks you need to know to perform them?"*. By analyzing the activities and how they are described, it is possible to identify three main features that characterize them: method, technology and product.
Method represents procedures, company policies, methodological standards, implementing rules and calculation methods. Method's knowledge allows the human resource to operate and carry out activities in accordance with default procedures.
Technology is the tool or technological knowledge used for the activity. It may be broadly defined as everything, both material and immaterial, created by a mental and physical effort to solve real world problems. In this sense, technology can refer to both simple and complex tools/machines and technological knowledge necessary to carry out the activities. The virtual technology as a software falls under this definition of technology [20].
Product refers to the good or service (with all its components and sub-components) that the company produces. For manufacturing activities, it could coincide with the output of an activity. In general, the product is defined on the basis of its physical characteristics (size, shape, etc..) and its complexity (detail or assembly).
Given a task, a human resource has the competency to carry out this task if he knows these three aspects.
In conclusion, the competency to perform a given activity is defined as the knowledge that the human resource must have about the three main features characterizing the activity: method, technology and product.
The activities description will be the starting point of this study: only after understanding in detail their content it is possible to identify the related three competencies features.
To correctly identify the competencies all the activities must be described with the same level of detail.
However, the list of activities considered often presents both macro activities described in a very general way and simple activities described in great detail.
In these cases, to obtain an homogeneous and detailed definition of competencies of each activity, it could take into consideration the output of the activity.
A macro activity produces several outputs while a simple activity produces a single output.
Starting from the analysis of the information about the output, the competencies features about method, technology and product required to perform an activity, can be specified. Usually, an activity generates an output that typically can be a document, a design model, a single product or assembly, etc. The output description contains all the information about the three aspects of competencies that people must have to execute the task. (Fig. 1)
Considering a simple activity that produces a single output, the three aspects of competency required by activity can easily be deduced from the analysis of the only output.

Considering a macro activity that produces several output, the list of competencies required is given by the set of competencies needed to get every output.
The output of the activities can also be considered in the competency assessment phase within the competency management model.
Indeed, an objective competency evaluation of human resources is focused on the assessment of the output produced by the resources in their activities.
Therefore, the output is a fundamental element both to identify and to evaluate business competencies.

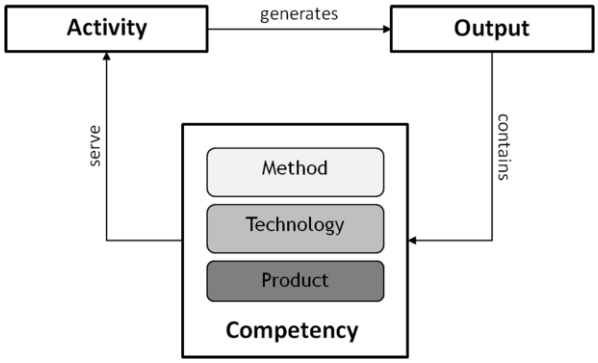

Fig. 1: Competency identification.

Competencies indentified in this phase are used to populate the competency dictionary. This dictionary will be composed by three chapters: the first containing the competencies related to the products made in the activity, the second comprising those related to the methods, practices and procedures adopted and the last including those related to technological tools and technologies that the activity uses.
In this study the term "competency" is intended only as *knowledge*, i.e. the theoretical knowledge about the three features but not as *know-how* or practical knowledge.
The dictionary should be used to understand which competency of a person must be assessed. In the competency assessment phase, only the knowledge aspects that find expression in tasks and become know-how, are evaluated. To allocate its resources on the business activities, a company needs to evaluate what a person can effectively do, that is the "know-how" derived by his experience in present or past programs or projects useful to perform the activities. When the available knowledge is not converted in know-how, improvement initiatives, such as training courses, must be provided to the resources in order to fill the identified gaps.

Practical Examples
The case study presented aims to be an example of the application and, consequently, validation of the methodology illustrated in the paper. It is focused in the Alenia's Interiors Area, specialized in the development of all aircraft's inside arrangement.
The competency dictionary methodology is applied to all the activities of the Interiors Area in order to obtain a complete competency dictionary related to this area.
In this section, it is reported a part of this competency dictionary obtained from the application of the methodology to the technical activity "Drawings and production detail models issue" belonging to Alenia's Interiors Area. This is a generic task which produces different types of outputs, related to different products.

Consequently, a detailed definition of competencies of method, technology and product of this activity, cannot occur without the analysis of its outputs. As an example, two of the several activities outputs are treated ("Design model of Lining of the passengers cabin"; "Design model of aircraft's secondary structure") and some competencies of method, technology and product are identified.
The realization of the output "Design model of Lining of the passengers cabin" requires the competencies listed in figure 2. In order to carry out the activity "Drawings and production detail models issue" that produces such design models is necessary to know:
- the products Lining;
- the materials forming the product (such as Aluminum);
- the manufacturing technologies (such as folding process) related to the product material;
- the software tools as the CATIA V5 modeling tool and the product lifecycle management (PLM) software, Engineering Team Center;
- some company procedures (Drafting Manual, Practice and Procedure Design, Civil Regulations).

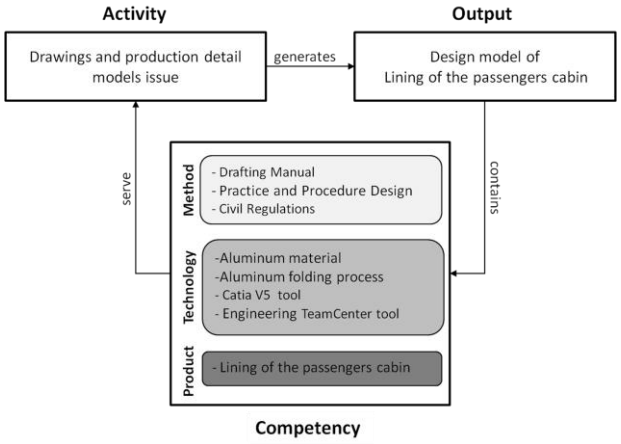

Fig. 2: Competency identification starting from the output "Design model of Lining of the passengers cabin".

Different competencies will be associated with the same activity for each output it produces. The activity taken in example, "Drawings and production detail models issue", realizes the output "Design model of Lining of the passengers cabin" described before and the output "Design model of aircraft's secondary structure". For this last one, a competency characterized by a specific combination of Method, Technology and Product is required (Fig. 3) and it differs from the previous one described (Fig. 2). In fact, the realization of this output, requires the knowledge of:
- the aircraft's Secondary Structure;
- the materials which form the product (such as Steel);
- the manufacturing technologies (such as forming process) related to the product material;
- the software tools as the CATIA V5 modeling tool and the product lifecycle management (PLM) software, Engineering Team Center;
- some company procedures (Drafting Manual, Practice and Procedure Design, Civil Regulations).

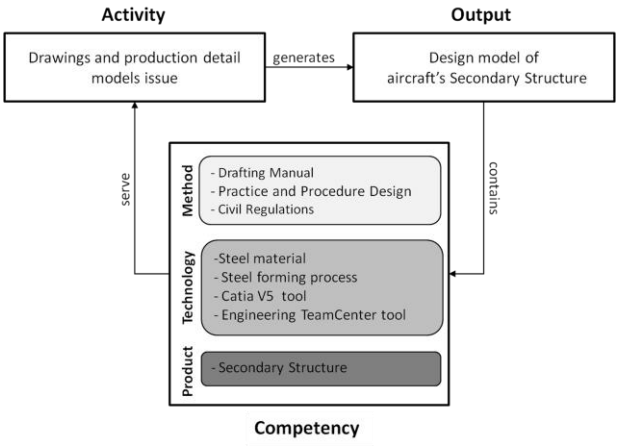

Fig. 3: Competency identification starting from the output "Design model of aircraft's Secondary Structure".

The similarity of the competencies of methods and of technologies (related to the tools) between the previous examples was expected since both competencies are related to different outputs which belong to the same activity. Therefore, among competencies of the same activities there could be some similarities.
Looking to a whole activity it is possible to summarize all the related competencies and thus, to present the activity as a set of competencies. Looking to the analyzed activity "Drawings and production detail models issue", the identified competencies respect to the two outputs, are summarized in the following table.

Activity	**Competency aspect**	**Competency: Knowledge of…**
Drawings and production detail models issue	**Method**	Drafting Manuals
		Practice and Procedure Design
		Civil Regulations
	Technology	Aluminum material
		Steel material
		Aluminum folding process
		Steel forming process
		Catia V5 tool
		Engineering TeamCenter tool
	Product	Lining of the passengers cabin
		Aircraft's Secondary Structure

Tab. 1: Example of Competencies dictionary related to the activity "Drawings and production detail models issue".

Continuing the analysis of all the different outputs, the complete competencies dictionary associated with this activity can be obtained.
The same method has been applied to all the activities belonging to Alenia's Interiors Area in order to achieve a complete competency dictionary.

5. CONCLUSIONS, LIMITATIONS AND FUTURE RESEARCH

Starting from the definition of the "competency" concept reported in literature and by the analysis of competency definition methodology in literature and in the firms practices, a new methodology to define the engineering competencies has been defined and tested on a real process of Alenia Aeronautica using a set of interviews to company key persons. The main goal of this approach is to obtain a competency dictionary common to the actors working into a collaborative environment. The competencies available in each company will be defined with the same criteria and using the same terminology that will support the collaboration, the search and exchange of resources.
A competency related to an activity, it is characterized by three main aspects: method, technology and product. Consequently, the competency dictionary mapping the knowledge required for the activities is divided in three sections, the competencies related to the methods, the competencies related to the technologies and the competencies related to the product. The methodology has been tested on the activities of a specific technical area of Alenia Aeronautica but the study will be enlarged with the implementation of the proposed methodology to the whole enterprise including also other areas and activities (such as logistics activities, manufacturing activities, administrative activities, etc…).
The approach described and validated in this study may be and should be extended also in other companies of the aeronautical sector in order to obtain a common and sharable competency dictionary.
Furthermore, in a future research the methodology could be tested and verified into company of others complex sectors (such as naval, medical, ecc…)

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