Optimizing competence management processes: a case study in the aerospace industry

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Abstract

Purpose – The purpose of this paper is to describe the case of a leading Italian aerospace company which developed an integrated system aimed to optimize the management of engineering competencies within the Chief Technical Office function.

Design/methodology/approach – The paper was based on a set of interviews to company referents and a one-year period of researcher's observation at the company site to analyze competence management processes and the application on the field of the methodology and the tool. The approach adopted is to present a real practice following a pragmatic and illustrative approach.

Findings – The integrated system provides an objective method to support critical evaluations related to the management of competencies and actors. The benefits achieved derive from a more effective and efficient monitoring of competencies available to perform given activities, and from the analysis of gaps, actor allocation, and job-rotation issues.

Research limitations/implications – The application of the method and the tool is still quite "dependent" from the skills of their developers. Besides, the activities and competencies of those units which support new product development processes should be also integrated in the system.

Practical implications – The case described can be a useful benchmark for organizations working in complex industries in the effort of improving the performance of engineering activities through an enhanced management of knowledge about people potential and expertise.

Originality/value – The value of the paper may stay in a twofold process/project and people management perspective in the monitoring, development, and scouting of technical competencies.

Keywords Aerospace industry, Competences, Knowledge management, Knowledge management systems, Resource allocation, Italy

Paper type Case study

1. Introduction and problem statement

The dawn of the new millennium is characterized by a rapid advancement in technologies and disruptive changes in global markets, with opportunities to add value through e-transformation, web-based tools, product development, innovations, and management of global supply chains (Chang, 2005). However, the complexity which characterizes some industries asks organizations to manage at best a mix of heterogeneous competencies located both internally and in their external environment. For instance, the design and manufacture of complex products such as aircrafts and automobiles is based on the integration of specialized management and engineering competencies which are distributed among many actors within an extended supply chain. An inter-organizational

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and value-network perspective is thus needed in which the continuous monitoring of resources and competence gaps, and the definition of actions aimed to fill them, become fundamental organizational capabilities. Especially, in dynamic and innovation-driven contexts, this is likely to impact significantly on the overall product quality, and thus on customer satisfaction.

A particularly interesting industry in this sense is the aerospace, a very complex sector characterized by high levels of costs and risks, many actors participating in the supply chain, and a multifaceted and multidisciplinary knowledge base which determine the need for firms acting as system integrators to hold very broad knowledge bases to co-ordinate design and production (Brusoni *et al.*, 2007). Aerospace organizations are thus particularly concerned with the continuous assessment of design and manufacturing competencies, and the appropriate allocation of human resources for the execution of engineering processes.

Several studies focused on the topic of competence management (Baets and van der Linden, 2003; Berio and Harzallah, 2007; Cheetam and Chivers, 2005; Houtzagers, 1999; Hustad and Munkvold, 2005; Lewis, 1997; Lindgren *et al.*, 2004) but no one is specifically focused on the process of competence management in engineering activities such as the design and development of aircrafts.

This paper is thus aimed to investigate the main issues related to the management and optimization of engineering competencies in the aerospace sector. At this purpose, the paper shows the case of a leading Italian aerospace company in which a purposeful methodology and a software have been design and implemented with the ultimate objective to support the identification, development, and scouting of competencies required in design, manufacturing, and testing activities.

The rest of the paper is organized as follows: next section presents the theoretical background investigated; Section 3 introduces the research question, method, and field; Section 4 describes the company case in terms of the approach, the methodology, and the tool developed; Section 5 provides a classification and a preliminary qualitative evaluation of benefits achieved; the main conclusions and limitations of the study, and some avenues for further research, are finally drawn in Section 6.

2. Theoretical background

The theoretical background of this paper can be found in the area of competence management and the adoption of information/knowledge management systems to managing competencies within organizations.

The optimization of individual and organizational competencies is particular relevant for companies operating in knowledge and technology-intensive industries. For a company, a distinctive competence is typically defined as an enduring firm-specific ability that leads to above-average economic performance (Makadok and Walker, 2000). A relevant example is represented by the development of new complex products (Henderson and Clark, 1990). In particular, engineering organizations are increasingly under pressure to perform more efficiently with fewer people and need therefore to understand what skills, knowledge, and behaviours they need from engineers (Allan and Chisholm, 2008). Competence models are thus at the heart of organizational performance as they drive training and learning strategies and processes, content development, and performance assessment.

Effective management of human resource requires large amounts of information on people and their and knowledge needed at all job levels. In this perspective, a key transformation in the field of human resources management consists in redefining the key concept of the job into a set of individual competencies and organizational units into core competencies architectures (Godbout, 2000). The analysis of organizational competencies as a potential source of competitive advantage allows also to re-examine the basic competitive assumptions. A study in this sense has been conducted in the Aerospace Composite Technologies that has analyzed the sources of competitive advantage coming from its competences. The case shows how the successful application of a method based on the definition of competencies, resources, processes and learning model can be valid, reliable and useful for the company internal assessment (Lewis, 1997). The focus is thus on evaluating the strategic position, weaknesses and strengths of the company whereas the main purpose in the case presented here is to discuss the optimization of engineering processes based on the evaluation of individual competencies involved. The integration of these two strategic and organizational perspectives can provide a comprehensive framework to support the development of the organization.

It is important for a company to enable the emergence of competences. This emergence can be sustained by the comprehension and deftness in catch the knowledge and perform a set of process. Comprehension is perhaps the determinant of deftness and the deftness impact on the competence enlarge or not them. The competences express the degree to which a firm can satisfy or not their objectives. The comprehension brings to understand the competence in the team working and their deftness in the task execution. Analyses based on measure of comprehension and deftness in the competence area are feasible to evaluate the competence impact on the firm objectives (McGrath *et al.*, 1995).

If competencies represent a key concept, a preliminary definition is here needed. A competence can be defined as a set of intrinsic attributes correlated with the performance in executing one or more defined tasks (Spencer and Spencer, 1992; Boyatzis, 1982). A competence is thus a standardized requirement to properly perform a specific job and it typically encompasses a combination of knowledge, skills and behaviour utilized to improve performance.

Competencies of individual actors have also a strong organizational relevancy, being the overall performance of the actor strongly related to his/her behaviour, work or understanding skills (Baets and van der Linden, 2003). The human competencies have to be specified considering a strong connection with the tasks performed and thus, the competence diagnosis and competence gap analysis have to be lead by the normal working tasks (Ley *et al.*, 2008). An individual possesses different types of competencies, resulting in different possible patterns of evolution as well as changes in organizational systems (Grandori, 1999). For a company, the identification of the ownership of specific competences is necessary to understand the kind of "behavioural language" effectively impacting on fast changing situations and scenarios (Civelli, 1998).

Individual competencies have been classified in different ways in literature and by practitioners, as well. Leveraging on Bloom's studies on the taxonomy of education objectives, a generic distinction used is that between "knowledge" (understanding gained through experience or study, the base information required to operate), "skills" (ability acquired and developed through practice and repeated application of knowledge), and "attitude" (individual qualities, characteristics, or behaviour) possessed by people. A three-level classification among "generic" competencies (reflecting the managerial mindset and existing in different organizations, like the ability to listen), "organic" competencies (job-related and context-specific, like technical leadership and project management), and "changing" competencies (oriented to the competence lifecycle and the ability to recombine resources and technologies, like business development) has been also proposed (Baets and van der Linden, 2003).

A given activity requires the presence of specific competencies to optimize performance and the application of these competencies in other activities does not ensure the same level of performance. The same thing might happen if a competence is about a particular relation with a determined actor. At this proposal, competence has been also defined in literature as "effective performance within a domain/context at different levels of proficiency" (Cheetam and Chivers, 2005). Another relevant aspect is the level of specialization of a given competence, based on the qualification, experience, and focalization of the actor in executing an activity. The actor possessing a more specialized competence is able to execute an activity in which the competence is required in a faster and more performing way (Grandori, 1999). In this perspective, skills and competence management systems (CMSs) can help organizations improve the effectiveness of their training (Homer, 2001) and become a key trigger to ensure that the individual and organization development plans are linked to business goals. A method has been also suggested in literature (Houtzagers, 1999) to set up skills and competence management in order to map the desired actors' skills and competences, and improve the empowerment process. Studies show also the importance to determine the causal link between antecedents and consequences to the development of a specific competence inside the firm (Makadok and Walker, 2000).

Competence management involves several processes that can be categorized in four classes:

(1) competence identification;

(2) competence assessment;

(3) competence acquisition; and

(4) competence usage.

Being the management of knowledge about competence, competence management can take advantage from the knowledge engineering techniques to support the mentioned processes (Berio and Harzallah, 2007). Studies of effects and challenges related to computer-aided competence management are also present in literature (Zülch and Becker, 2007). As part of a human resource management system, information technology (IT)-supported strategic competence management can be a driver of relevant benefits such as experts and talents location and optimized knowledge sharing. At this proposal, a case study has been described in literature showing how this kind of system supports the company in the placement of skilled employees and stimulates the creation of internal "communities of knowing" (Hustad and Munkvold, 2005). In a study of six Swedish organizations (Lindgren *et al.*, 2004), a model has been developed to describe the interactions among organizational and individual competences and the role of technology, in particular CMSs, in this process. Three types of individual competences are identified such as competence-in-stock (previously acquired), competence-in-use (currently put in practice), and competence-in-making (target competencies). Two design challenges emerge in the development of CMS: the trade-off between competence transparency and user's privacy and the trade-off between data accuracy and system flexibility. The idea of competence-in-making and the issue of user's privacy were particularly useful for the analysis of the Alenia case.

A CMS can be seen as an evolution of a learning management system, i.e. a system which integrates an extensive family of learning-related functionalities such as learner services, training workflow, on-line learning and assessment, and learning resource management. More than a learning supporting system, a CMS is characterized by a multidimensional and comprehensive approach since it includes features such as skills-gap analysis, succession planning, competence analysis, and profiling. CMSs are aimed to identify those processes or tasks that are critical to achieving results, design task knowledge and supervisor observation, inventory training resources and align the right resources to the right task, group processes into job families, align jobs with organization units. All these features are strongly linked to the optimization of key performance indicators of a company. In the implementation of a CMS, a critical aspect is represented by the framework according which to classify competencies. At this purpose, a top-down approach (definition and classification competencies made by top management or project managers) can allow to reduce design and implementation time. However, acceptance problem may emerge and represent a very critical issue to solve. As a solution, the potential of bottom-up ontology can be evaluated to increase the value of each single contribution, resulting in a comprehensive structure based on a common and shared language (Corallo *et al.*, 2005).

The problem of managing technical competencies is a very pressing issues in engineering processes aimed to produce complex products and systems, where a large number of elements interact dynamically both in physical aspects and in the transfer of information. Each interaction is rich and influences all the others elements (Cilliers, 1998). In the aerospace industry, companies are involved in the production of aircrafts, aircraft engines, aircraft parts, guided missiles, space vehicles, and their propulsion units (National Technical Information Service, 2000). An aerospace product is composed by many parts and the production process is shared among several companies with the aim to better manage costs, risks, and complexity. Around the realization of a complete product (e.g. aircraft and space vehicles), few big companies manage the agreement with the final customer (e.g. airline company and space agency), and assemble the whole product whereas several companies work along the different supply chain levels in order to produce components and sub-components (Esposito and Raffa, 2007).

The aerospace context is thus a particularly interesting case for studying the role of technical competencies given the sophisticated technologies, innovative materials, knowledge-intensive processes, and the need for large and accurate data exchange. The process of managing competencies involved in the design and development of complex products such aircrafts has not been specifically addressed in literature. This paper aims to contribute in this sense with the analysis and discussion of the experience of a leading Italian company involved in the design and manufacturing of aircraft components.

3. Research question, method, and field

The major focus of this paper is on the monitoring and optimization of people competencies in complex engineering processes, such as the design and manufacturing of aircrafts. One core research question has been formulated:

RQ. How to design and support competence management processes in order to improve resource allocation, scouting, and development?

To answer this question, the study of a specific industrial setting and organizational context was identified as research strategy. In particular, a qualitative investigation approach has been chosen which is suitable to address the needs of a specific context (Stake, 1995; Yin, 2003). In particular, a case study is particularly appropriate to study contemporary events and non-controllable units of analysis (Yin, 2003). The study is not aimed to build new theory but rather to discuss and share a real practice of particular relevance given the characteristics of the industry and the features of the subject company, being a leading organization also in the management of technical competencies. The case is thus guided by the pragmatism knowledge claim. It is problem-centric and the attention is therefore placed on the problem and how to solve it in a real organizational setting (Creswell, 2003).

Multiple sources of evidence, such as interviews with managers and direct researcher's observations, were used to increase the case study's construct validity (Yin, 2003). The most of the information was collected through a set of interviews to key company referents selected through a non-probability "snowball" approach (Bryman and Bell, 2007). The researchers firstly contacted the person within the company who leads the competence management project. This key informant provided an extensive overview of topics and helped the research team to identify two other persons to interview. Interviews were held through the use of semi-structured and open-ended questions, with the objective to better stimulate perspectives, views, and opinions sharing (Creswell, 2003). In detail, seven interviews were done with the project manager and two engineers in three distinct moments: a "preliminary" interview before the researcher's observation with the project manager and one project engineer (to capture a first understanding of the context and key organizational issues), a "middle" interview after six months of observation with the same persons (to analyze the evolution and discuss findings obtained), and a "final" interview at the end of the year with the project manager and two project engineers (to consolidate and validate findings achieved from the observation and the previous interviews).

The researcher's observation was carried on a week per month at the company site with the objective to read technical reports, analyze key processes in the management of engineering competencies, and study on-the-field the application of the methodology and the tool described in this paper. The phases of data collection are shown in Figure 1.

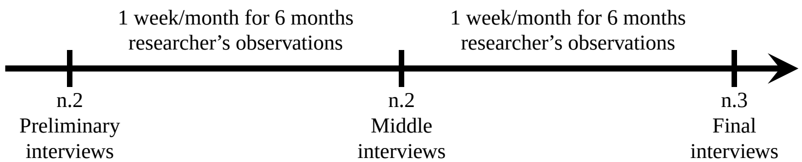

Figure 1.
Data collection steps

To assess the validity of findings, the research team adopted a twofold strategy: the presence at the study field for an extended period (about one year) and the use of member checking (Creswell, 2003). The time spent in the company was fundamental to understand in deep the methodology and the tool developed whereas member checking provided an important support through discussion groups and brainstorming. The data collected were analyzed and discussed by a team of three researchers to compare opinions, eliminate biases, and achieve consistency. A key informant reviewed the case study report and validated the main findings and conclusions. The main focus of analysis was represented by the identification of key engineering activities and their complexity, the assessment of people expertise, and the identification of competence gap and related issues.

The organization analyzed is Alenia Aeronautica, the biggest Italian aerospace company. Alenia is part of the Finmeccanica group which operates in the aerospace sector and is involved in several programs (e.g. "C27J," "ATR," "Eurofighter Typhoon," and "Boeing 787 Dreamliner") with different levels of responsibilities and risks covering with its business portfolio the main levels of the aerospace supply chain. Alenia Aeronautica has a capital of about €2 billions with solid financial results and about 12,000 employees distributed in several subsidiaries around the world. The company operates in scenarios like:

- full integration capability through design, manufacture, and support (overhaul, maintenance, and modification) of military and civil aircrafts (e.g. C27J and ATR line) as prime contractor;
- partnership of advanced aerospace projects worldwide (e.g. Eurofighter Typhoon and Boeing 787) as project partner; and
- design and manufacture supply for aerostructures (e.g. F-35 JSF, a multi-function fighter) as supplier.

The large dimension of turnover, activities, and workforce requires an accurate monitoring of company projects and processes to ensure increasing levels of performance. At this proposal, Alenia is introduce innovations at both technological and organizational level ld and trying to optimize the company's processes increasing the quality and safety for the customers and enriching the performance of the final products.

The company unit which was specifically involved in the research is the Chief Technical Office (CTO), an area involving 1,700 employees and responsible for the engineering of design activities (from the initial concept to manufacturing support) as well as for the research and innovation activities related to engineering processes. In order to consolidate its industry leadership, Alenia and its CTO are asked to face different challenges in the very next years, such as:

- develop/improve technical excellence in the design and manufacture of composite aerostructures for civil products (e.g. Airbus A350);
- enhance its capability of full aircraft integrator (e.g. C27J JCA and ATR MP – ASW) also by managing a global network of partners and suppliers; and
- be a leader in the most advanced research fields of the market, like unmanned aerial vehicles (e.g. Sky X and Sky Y).

The competitive pressures and the high quality/safety requirements which characterize the industry ask the highest levels of engineering performance. This is also based on the optimal allocation of people in different design, manufacture, and testing activities. It is thus a primary concern for the company to identify, in the whole CTO function, the competencies which are considered highly strategic, and to develop plans and actions for the continuous monitoring, scouting, and development of those competencies.

4. The approach of Alenia to competence management

4.1 The competence development project scenario

To sustain the company's growth and address the strategic challenges described in the previous sections, Alenia has defined a competence management process whose key parts are represented by the identification of strategic competencies, the definition of development scenarios, and the definition and monitoring of development plans. In each of these areas, a family of actions is identified to support the classification of core and non-core design and development competencies, and consequently to identify improvement plans and a set of changes necessary at organization and process level. The management of technical competencies is based on the evaluation of potential gaps and the use of scenarios to mitigate or eliminate them. The identification of key activities also allows to identify as owners of competencies some external actors working in the company either as consultants or suppliers. This aspect is particularly relevant since, if the realization of an activity is mostly based on "external" competencies, a change in the company/actor relationships (e.g. actor leaving the organization) can cause serious issues because of critical (and often tacit) know-how being lost.

In this frame, a project called competence development was internally launched by the CTO function of Alenia with the aim to design and implement an integrated system, composed by a methodology and a software tool, supporting the identification of the portfolio of competencies available within the organization, the activities and related actors, and the definition of plans for developing most strategic competencies. A relevant goal of the system is also to increase the "objectivity" of decisions in human resource allocation, activities sharing and mitigation of gaps in areas like research and development, technological innovation, product, and process development. The overall timeframe needed to design the methodology, develop and test the tool was about one year (from May 2006 to July 2007). In the next sections, the seven steps of the methodology and the software tool are described in details, also through the use of illustrative examples.

4.2 Competence development roadmap

The essence of the competence development project within Alenia is a seven-step roadmap, which has been developed with the support of a leading consulting firm. The roadmap was conceived in a way to be robust by a methodological perspective as well as commonly accepted and easily applied throughout the organization. The application and ongoing improvement of the roadmap is founded on a continuous interaction among its developers and the unit managers involved in the definition of competence areas, activities and actors. The competence development roadmap is aimed to provide a shared procedure and the basis for a reliable source of evidence about the current state of a company department or unit. In this perspective, the interaction among methodology developers and unit managers is able to provide a complete picture of the company and, more important, to avoid too much specific definitions of competencies or activities (to enlarge definition of areas and facilitate the actors exchange). The following seven steps build up the roadmap:

(1) competence area definition;
(2) activities definition and actors allocation;
(3) activities' technical complexity matrix creation;
(4) actors evaluation;
(5) experience index calculation;
(6) activities state evaluation; and
(7) "as is" competence area matrix creation.

Figure 1 shows the flows and the input/output links among the different steps. Besides, a set of intermediate outputs, a final result is obtained which is represented by the "As is" competence area matrix.

The seven steps are described in the following paragraphs with the use of illustrative examples.

4.2.1 Competence area definition. The first step is represented by an in-depth observation through which the developers' group defines a set of macro competence areas present in a specific company unit or department. The areas are defined in a way to obtain groups which are very homogenous and easy to communicate but, at the same time, which actually reflect the vision and understanding of the persons actually involved in daily activities. This first step is a very challenging one since it should come up with a punctual, consistent, and not ambiguous definition of competence areas which characterize a part of the CTO department. Some examples of competence areas are represented by the "Product Data Management," "Airworthiness," "Research Technologies and Innovation," and "Aero-Navigability and System Efficiency."

4.2.2 Activities definition and actors allocation. After the identification of macro competence areas, the manager of each unit is asked to identify the activities performed in the unit and the persons involved, and to associate them to competence areas. As for competencies, also the definition of activities should be not excessively specialized, and their categorization in competence areas should be consistent. The association of actors to the single activities is easier since there are no specific restrictions and a single actor can perform different activities. As an example, some activities related to the area "Airworthiness" are the following: "Organizing the First Flight Readiness Review," "Defining Initial Limitations for the Flight," and "Defining Airworthiness Rules for a Product." For each of these activities, the various actors allocated are then identified, such as the "Civil Airworthiness Engineer" and the "Software Qualifier Engineer."

4.2.3 Activities' technical complexity matrix creation. In order to better describe the activities executed within the CTO department and to allow a set of useful analysis, each activity is represented in a matrix whose dimensions are the "technical content" and the "level of interaction" with internal discipline boards and external boards (Figure 2). The technical content (y-axis) can assume values of "very complex," "complex," "medium," and "easy" according to the amount and complexity of specialized knowledge required to execute the activity. The interaction level (x-axis) can assume

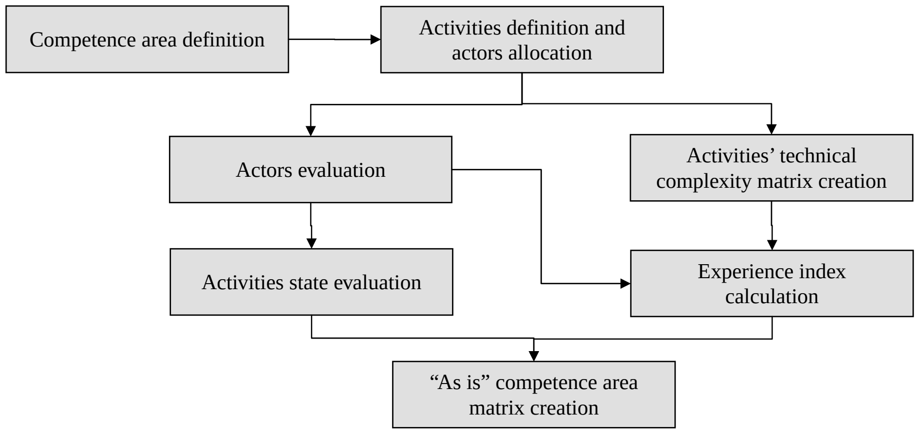

Figure 2.
Methodology steps

values of "very strong," "strong," "medium," or "weak" according to the density of interactions/relationships needed for the execution (Figure 3).

The association of technical content and interaction level values to a given activity allows to position the activity in a specific area of "technical complexity" which can be "very high," "high," "medium," "low/medium," or "low." The use of (five) different colours provides an immediate perception of the average level of complexity for an area. For instance, the activity "Defining Initial Limitations for the Flight" mentioned in 5.2 is characterized by a very complex level of technical content and a medium interaction level. This determines the positioning of the activity in the "high" area of technical complexity.

4.2.4 Actors evaluation. The description of activities and their complexity is followed by the evaluation, made by each unit manager, of actors involved in terms of their ability in performing those activities (included in a specific competence area). The idea of competence is thus mostly of competence-in-stock and competence-in-use (Lindgren *et al.*, 2004). The manager is asked to indicate if an actor is able or not and to provide an evaluation, ranging from 1 to 4, of the quality of results achieved in the

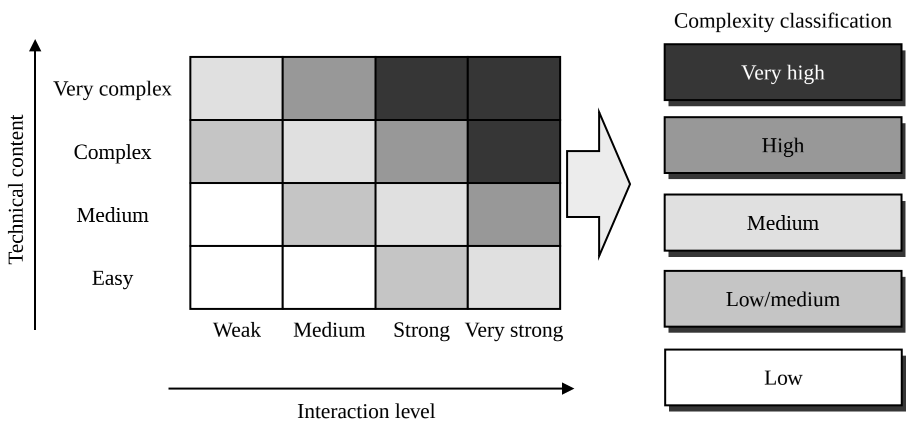

Figure 3.
Activities' technical complexity matrix

execution of the activity (1 – not always good; 2 – almost good, 3 – good; 4 – excellent).

Besides indicating if the actor is able to perform a task or not, the manager is also required to indicate the "status" of the actor with reference to the activity, i.e. if he/she actually performs it (yes – Y) or not (no – N) and, if not, if he/she could be potentially able to do that (potentially – P). Actors are evaluated based on activities actually executed since this criterion, respect to other more subjective indicators, is more easily known by the evaluator (the unit manager in this case).

Thus, at the end of the evaluation process, all the actors involved in each activity belonging to every competence area, are associated to a twofold evaluation represented by a letter for the performance status (Y, N, P) and a number for the quality of execution (one to four).

The unit manager could decide to make an exchange of actors with the objective to optimize resource allocation and consequently the activity performance. An example could be that two actors in the same activity have one an evaluation of "3P" (i.e. means that the activity can be potentially performed with good results) and the other one an evaluation of 1Y (i.e. means that the activity is performed by not always with good results), changes in the allocation of the two actors could be considered.

4.2.5 Activities state evaluation. Looking to each activity and to the related situation in terms of performance and number of actors involved and actually operating (i.e. the actors' evaluation results), an evaluation is obtained of the "risk" status of the activity in terms of competence gaps currently existing (or likely to emerge).

This evaluation, together with the assessment of technical complexity, allows to identify in details which are the gaps existing in the execution of a given activity. A purposeful chart (Figure 4) can be created to show the competence gap for each activity and for each level of technical complexity. A traffic light metaphor is used to indicate the activity results: a green traffic lights correspond to excellent results, a yellow one to good results and a red one to indicate an activity with poor performance. Naturally, for a similar amount of "reds," competence gap issues increase with the increase of technical complexity.

4.2.6 Experience index calculation. An "experience index" is calculated for each actor in order to obtain a clear characterization of the workforce available in a given company area. To calculate this index, three steps are performed:

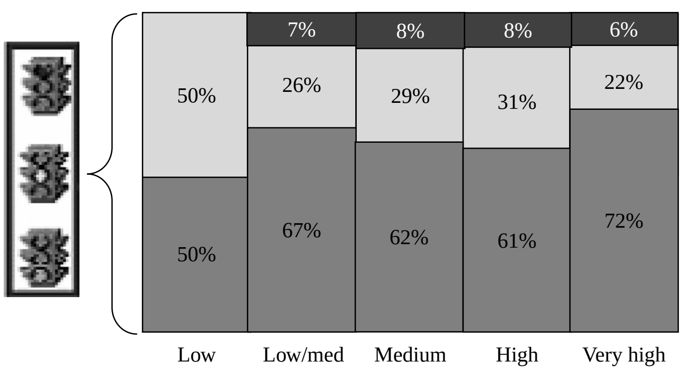

Figure 4.
State chart by activity: synthesis

(1) The levels of activity performance of each actor are summed for each degree of activity complexity (i.e. summing the votes in the "very high" complexity activities, votes in the "high" complexity activities, etc.).
(2) Each sum is then multiplied per a coefficient/weight (ranging from 0.5 to 4) which expresses the degree of complexity.
(3) The sum of all these multiplications is then normalized using a value (ranging from 1 to 10) which is associated to an expertise scale of "discipline advisor," "very expert specialist," "expert specialist," "senior specialist" and "basic specialist" (Figure 5).

To allow this normalization process, each unit manager defines what a "discipline advisor" should be and which specific competencies he/she should possess. This "best" profile is thus associated to a value of "ten" and represents the benchmark according to which all the others actors are evaluated.

4.2.7 "As is" competence area matrix creation. All the evaluations described in the previous steps provide an overall picture of the as-is situation in terms of competence gaps and actors' experience related to an entire department, a single unit or a specific competence area. In particular, it is possible to create a matrix (Figure 6) which shows the overall "competence level" of an area (ratio "activities with good performance/total activities") on the *y*-axis and the "experience level" of the area (ratio "number of expert resources/total resources available") on the *x*-axis. A given competence area is thus positioned in one of the four quadrants of the matrix according to the level of competencies and expertise which characterize it.

In the first quadrant, it is possible to position those competence areas whose activities are well covered in terms of competence level but many inexpert actors are involved. In this case, the support of more expert actors would help young resources. In the second quadrant, the best situation is depicted since both competence and expertise levels are high. In this case, it would be only necessary to evaluate if the turnover of resources can be easily managed/sustained in the future. The third quadrant shows a very delicate status in which both competence and expertise levels are low. This requires urgent actions, also according to the level of strategic importance of activities, based on reallocation, training, turnover, off-loads, etc. Finally, in the fourth quadrant, there are competence areas with a reliable expertise but focused only on a subset of activities required.

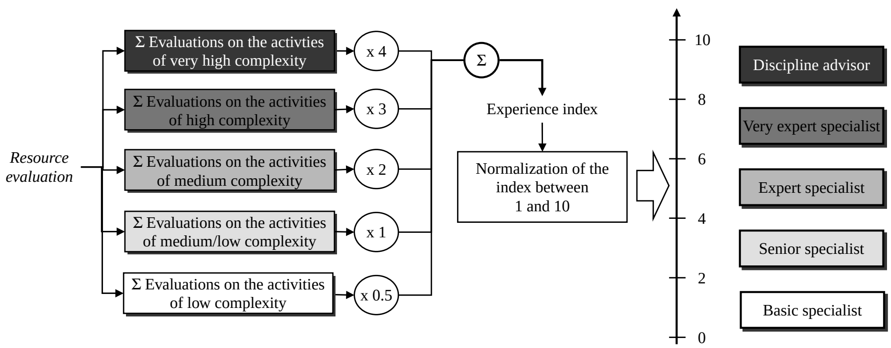

Figure 5.
Experience index calculation

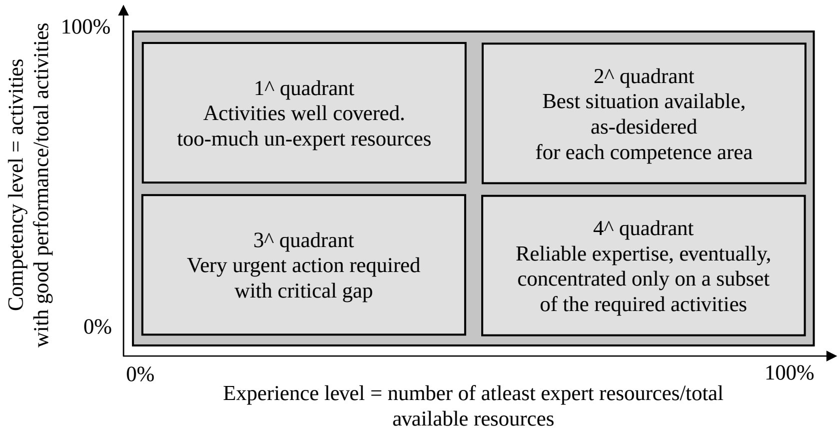

Figure 6.
"As-is" competence matrix

4.3 The tool

To support the implementation of the roadmap, a software tool was also developed inside the CTO of Alenia to allow the collection and analysis of relevant data about competence areas, activities to be performed for each area, actors available, and activity evaluation.

The tool is a web-based java application that collects data through a relational database present inside a unique server. The web interface was developed in a server-side language which allows to manage, view and modify user permissions. All the data is managed by a hybrid architecture, consisting of a client distributed encrypted XML database for storing sensitive data related to the actors, and a server-side relational database for all the other data. In the tool, the identification data is anonymous for each user. A unit manager can log-in securely from a web browser and he/she is allowed to view and edit only the data related to his/her department. Only the director of a department has full access to all data.

The tool provides the following functions related to competencies, activities, and resource management (some snapshots are shown):

- Assignment of a "capability score" (yes, no, potentially) and a "performance score" (from 1 to 4) to each actor and for each activity (as for the methodology steps), also preventing inconsistencies in data entry (i.e. the assignment of a performance score to an activity which is not performed by that actor).
- Visualization of different outputs such as tables with data about actors/activities and their evaluations, traffic light/technical complexity matrix per activity, experience index per person, overall unit/department status based on experience index and competence matrix.
- Elaborations shown by actor, unit, activity, or competence area.
- Search and chart creation based on given parameters (for instance the manager can analyze the composition of his/her unit in terms of age, firm seniority or degree for each level of expertise in order to plan interventions to stimulate interaction, cross-seniority collaboration, and knowledge sharing).
- "Warnings" deriving from competence gaps, work amount gaps for a given activity, limited presence of available actors.

- Simulations that support management decisions and pre-evaluation/scenario forecasting (i.e. hypothesis of an actor moved to another unit with a resulting competence gap, or exchange of two actors belonging to different units), as shown in Figure 7.
- Competence scouting based on personal reports showing the level of performance of an actor in the activity, the specific competencies possessed and the number of other actors performing the same activity in the same area (this is to optimize the fit between activity gap/actor without determining drawbacks in other activities).
- Cross-references and evaluation of how different actors are linked together and in which competence area.
- Competencies, activities ad actors monitoring to support dedicated initiatives of training, resource allocation, and company development plans.

The tool is an important asset for the CTO function and this is also proved by the extent of use for evaluating and scouting competencies, as well as by the ongoing improvements which are brought to the system. Historical data analyzed through the tool are stored in a dedicated section of the database for future analysis and design of trends.

The competencies are defined in collaboration by system developers and unit managers and the evaluation of each user can be verified only by the unit manager and by the director of the department. The challenge of managing the trade-off between data accuracy and system flexibility (Lindgren *et al.*, 2004) needs further design and development effort to allow each actor to access the system and describe directly his/her profile. Of course, this "self-evaluation" should then be compared with the evaluation provided by the manager.

5. First findings and benefits achieved

The application of the roadmap, supported by the tool, allowed the CTO of Alenia to achieve three major categories of benefits in terms of mitigating competence gaps, actors' allocations, and overall performance improvement.

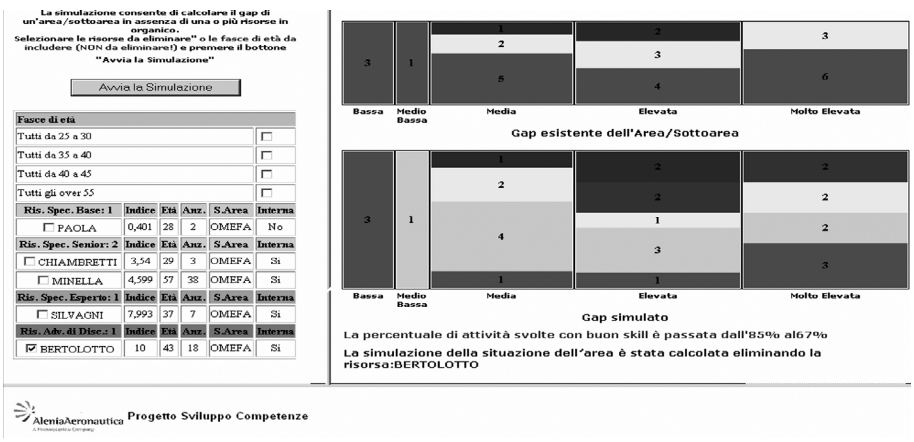

Figure 7.
Example of simulation

In the gap mitigation, the integrated approach allow to have a more efficient monitoring system; more objective and real-time analysis of activities with the possibility to visualize gaps; and to realize punctual analysis to evaluate the competence area performance and identify gaps and fields of improvements.

In terms of actors' allocation, the key benefits achieved are easily visible in a streamlined job rotation with the evaluation of pros and cons of resource transfer; in more objective allocation of resources to activities; in the possibility to monitoring competencies not "used" or not used at their full potential; and in availability of a detailed evaluation of people competencies.

Furthermore, the integrated web-application and the roadmap permits to reach benefits in the performance sustaining the improvements of product quality; reducing the lead time of activities, the errors, and process costs; sharing in a better way the critical know-how; supporting the decisional process of the central function of the organization (the CTO); and reducing costs for mitigating gaps, also due to reduced cost for external training.

Competence gap mitigation and better resource allocation are strictly related and represent "direct benefits" of the competence management project in Alenia. In turn, they have an impact on performance improvement, which can be thus considered as being an "indirect" advantage achieved. These benefits represented for Alenia a relevant proof-of-concept of the potentialities of the integrated approach developed. This encourages also managers to promote and champion further developments and a steady use of the roadmap and the tool throughout different company areas. The evaluation of advantages achieved, mostly qualitative so far, is now the object of a more systematic and quantitative analysis.

6. Conclusions, limitations, and future research

The continuous monitoring, development, and scouting of technical competencies is particularly relevant to improve engineering activities in organizations working in complex industries. This paper described the case of Alenia Aeronautica, a leading Italian aerospace company which developed a purposeful seven-step roadmap and a web-based software tool with the ultimate purpose to optimize the management of engineering competencies within the CTO function.

The methodology and the tool represent a powerful system to support critical management decisions related to the monitoring of actors and competencies available to perform given activities. Furthermore, the methodology provided the company with an objective method for competence-based evaluations that were previously based on subjective criteria. The benefits achieved through the integrated application of the roadmap and the tool can be classified in three major classes:

(1) more efficient competence monitoring and problem identification;

(2) more effective actors' allocation; and

(3) enhanced process and organizational performance.

The output of the competence management project, including the methodology and the tool, could be appropriately customized to be applied in other aerospace companies and, in general, in companies working in the realization of complex products, such as automotive and naval ones. In this sense, the case can be a useful benchmark for organizations working in complex industries in the effort of improving the performance of engineering activities through an enhanced management of knowledge about people. However, to maximize benefits, the application of the methodology and the tool within another organization requires a customization based on a deep analysis of the context.

The analysis should be focused on aspects such as organizational structure, managerial culture, resources available, privacy issues, and others. Even if companies working in complex industries have like structure, differences in the organizational "shape" can have a relevant impact in the endeavour of managing competencies of people. Managerial culture also matters in that the potential of competence optimization as a trigger of organizational development can be perceived differently from one company to another. Resources available are important constraints since the implementation time could vary sensibly based on the volume of resources which can be dedicated. Another issue to consider is the employee perception and support. Individuals could be indeed concerned about a project aimed to disclose their professional "status" inside the organization. Also, project managers could adverse a system showing the performance of their unit or team. Privacy is thus a central issue and should be managed with appropriate disclosure policies and enabling technologies.

A possible limitation of the integrated system stays in the fact that the use of the tool is still quite dependent from (the skills of) its developers and this could be a risk if these people leave the company or change their mansions within Alenia. A second limit is that the activities and the competencies of actors working in departments which "support" new product development processes (e.g. finance or human resource) are not evaluated by the methodology/tool, also if those activities and actors could have a strong impact on the final product design and manufacturing performance.

Next research will be dedicated to better formalize the competence management methodology and apply it to other organizational contexts within Alenia and in other companies as well. At this proposal, it would be interesting to evaluate an extension of the system to other departments through the creation of a bottom-up ontology of competencies where each manager is asked to define instances based on his/her preferences, opinions, conceptual structures, or mental models. In fact, the top-down approach allows to reduce design and implementation time but it can also cause acceptance problems, whereas a bottom-up ontology can increase the value of each single contribution, resulting in a comprehensive structure based on a common and shared language. Finally, other improvements will be aimed to enhance the involvement of employees in the evaluation process as well as in the definition of their personal development plan (target competencies, gaps to fill, etc.).

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