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COMMUNICATION IN DESIGN. RESULTS OF A FIELD RESEARCH

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SUMMARY: *The paper reports the results of a doctoral research which analyses the communication processes in building design teams specialised in airport passenger terminal projects working in Italy. The analysis is focused on the communication processes requirements and it was conducted using a structured questionnaire based on reference to a technical standard. The aim of the analysis was to define the basic elements to build a User Profile finalised to plan communication processes in a networked design team. The problem to be solved, structurally affects the Construction Industry where it is necessary to face the complex relationship within the design team, which comprises different organisations, based in various sites or counties and using different languages but, most importantly, being culturally different. The results of the field research show many interesting features: for example we found that certified quality standard organisations often do not plan, carry out checks and properly implement the communication processes. In brief we show evidence about the non-awareness of critical importance of communication processes and their impact on design quality. The so-called Access Era does not allow behaviour such as a Win-Win Strategy. The research aims to face the Design Gap as an identified industrial problem defining a method to draw a User Profile tool and start communication processes based on it.*

KEYWORDS: *Building Design Gap, Design Communication processes, R-Tech in Building Design, Win-Win Strategy in Building Design*

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1. THE INDUSTRIAL PROBLEM TO SOLVE

The issue addressed in the research is about the contents and structure of communication processes in the building design process. The research compares the very synthetic vision which emerges in the current standard, where communication processes are only considered in their organizational aspect, with their effect on product realisation.

According to the organizational vision (UNI ISO 10006:2005) the defined processes are planning, management and control of communications, but the industrial problems arising from the structure and mode of transmission in the development of the project are not taken into account in this model.

These problems can be referred to the broader industrial issue of the Design Gap in construction as it has been identified in the ECTP (European Construction Technological Platform) documents and in the Egan Report in 1998 and its second update in 2008. The Design Gap is a concept that expresses the lack of target performances

achievement in the project within a product (the design output) which doesn't meet the Client/customer and/or the user requirements. Lastly the Design Gap concept is a way to represent the non-quality of the product in terms of customer and/or user expectation. Today's problems related to the Design Gap seem critical for quality achievement and these determine a real, negative economic impact.

In the UK it has been estimated that the quantitative, qualitative and economic impact of design errors amounted to around 87% between 1994 and 1999 (see ECTP).

Some examples of troubles arising from the industrial problem of the Design Gap in Italy are:

- Planning stage: underestimation of costs (process);
- Design brief: poor data entry (product);
- Schematic Design: underestimation of criticality (annual program, conference of services, lots, base of tender: process and product);
- Design Study: scarce time resources (formal validation process and product);
- Construction Documents: often developed together with the previous phase (process and product solution)
- Review of contract: no evidence of the underestimate the fall (QMS, process and product)
- Constructability / Site Work and Construction Design documents: often the only step in which drawings and specifications establishing the requirements for the construction of the project are realised (process and product).

The lack of studies to explore the causes of the Design Gap is principally shown if compared with two aspects that have been emphasised by the spread in the Supply side Technology Space of an increasing number of faster R-Technologies :

- a different organization of the supply chain, now potentially global;
- invisible barriers caused by different ways of understanding the project during design development (both disciplinary and cultural) within the design team, that appear with always greater frequency.

R-Technologies or Relational Technologies indicate those technologies which enable people to create and use digital networks. This term is better suited to describe the new technologies because these are technologies which don't create physical products, but only produce links and connections. The concept of technology changes and is then transformed from the concept of management of information to that of technology as a means of establishing relations.

The research seeks to address the question of what and how the project groups are able to embed and take advantage of the available R-Technologies in the planning, management and control of communication processes within the design team. We analyze in detail how communications are handled during the Construction Documents stage, trying to identify ways and means to improve efficiency and achieve the required performance targets. In this way we could also highlight the direct consequences that may result during the construction phase.

2. THE BUSINESS SCENARIO

The Construction Industry stakeholders are today facing a gap in the operational scenario: global challenges are reflected on the local operating levels, technological implementation is very fast, new trends occur in international markets. This scenario will probably deal with an acceleration in the changes of some features of the organizational processes that, even in Construction, will have to be re-oriented with timeliness.

Recent studies (Latham, 1994, Egan, 1998), conducted in the European countries and the U.S., show significant data about the quality in the construction sector over the past 10 years. In particular the data collected on behalf of the B Ministry show that 30% of construction processes are subject to rework (data collected in the U.S. and in Scandinavia and prove to be conservative estimates when compared with the amount of waste identified in industrial best practice);, labour is used at only 40-60% of potential efficiency, accidents can account for 3% to 6% the total cost of the project; at least 10% of materials are wasted. Construction as a whole is underachieving in the improvement of quality and efficiency: low capital profitability, research and development and training, a high proportion of clients unsatisfied with its overall performance, if compared to the best practices of mature but more sophisticated industrial sectors (such as those used in Japan byToyota). The slogan of the British report

"*eliminate waste from construction*" was coined to indicate the main strategic goal of a programmatic agenda for the sector based on the quality of processes in terms of reducing waste and therefore of achieving sustainability. Other studies show that 80% of inputs in the Construction Industry are iterative processes and 40% of the workforce on site is unemployed.

According to these sources the conventional process is sequential and it reflects the input of designers, constructors and key suppliers involved in a cascade process. Contractual documents provide a better definition of the chain on the contract side, but this system is often a barrier to the effective use of skills and knowledge of suppliers especially in the design and development process.

The previous cited studies show an integrated approach as the best one to improve the whole building design performance. This kind of approach is based upon interlocked elements:

1. product development;
2. project implementation;
3. partnering the supply chain;
4. production of components.

Point number 3 seems difficult to implement in the construction sector in some European countries, including Italy, because it clashes with current regulations in public sector bids. But this should be something that could be referred to the other elements: the integrated design, constructors and suppliers may work jointly in a series of projects, continuously developing the product within the supply chain, eliminating the waste in the interlocked processes of designing and building, innovating and acquiring knowledge from direct experience.

Adopting this kind of vision the Neeman Company (an engineering company, USA) has adopted the *Lean Construction* approach to reduce the time of preliminary design by 80% and the cost of the project by 30%. The practical approach, suggested by the CTF (*Construction Task Force*) to the British Ministry too, is an integrated process of design looking to build stable partnerships between the client, designer/s, manufacturer and suppliers, valid for more than one project of that kind.

The reorganization will mainly affect the processes of internal and external communication because of the *R-Tech* impact on all sectors. The main fact that we observed is that the supply Technology Space, a concept that expresses all the market offer options in a specific historical moment, it is characterized by very pervasive technologies. These technologies can enable a relational improvement, in terms of interoperability, speed and interconnection among the parties involved, which has to be taken into account with respect to organizational and decisional structures, both internal and external, in one industrial sector. Consequently, these elements, because of their nature, involve much more dynamic and rapid changes, with an immediate impact on the operational scenario in the Construction Industry, which consequently needs just as fast decisions by the parties involved.The technology acceleration seems at the moment even more pronounced and marked by several key factors that derive from it:

- increasingly fast information and access costs tending toward zero (decreasing the *digital divide*);
- efficiency of integrated project teams (designers and suppliers together to develop a product in a sort of partnership);
- call for customized quality of the product (the needs of the consumer/user as the target of the strategic project).

The new vision that we have in the European research, already taken as a guideline in Construction Industry policies in the most dynamic countries, is a 4th Industrial Revolution as in the *Relational Access Era* (Rifkin, 2000). The future scenario, therefore, should show a deep change in the design process, as it is the construction process that can benefit from the opportunities today offered by those characteristics of Technology, as long as designers are able to develop such computational and communicative thinking ability and to exploit the available technologies.

The project is, in fact, increasingly central in all industries, because it makes use of the production *information engine* Production is now globalized, even in the Construction Industry supply chain, but it shows that nature, especially as regards the professional knowledge and the skills, and thus particularly concerning the design responsibility. We must consequently pose the problem of whether the processes in which the design plan is articulated, in the various stages of progress, can correspond to such a vision or if rather it is possible to adapt methods and instruments to other features, and above all their informative contents, to conform to the speed and

to the required levels of quality.

3. KEY ENABLING AND EMERGING TECHNOLOGIES

In this scenario, the Design Technologies working in the organizational systems set (Quality Management Systems, Integrated Management Systems etc.), have to be considered critical success factors, because these have a direct impact on the quality of process and product, as the ECTP (European Construction Technological Platform) explicitly indicates in recent documents.

The current technological options help to support the organizational systems of the project and to improve communication processes of virtual teams. These are also classified as part of the Relational Technology (R-Tech) set.

These technologies are not only an expression of technical innovation, but are the result of scientific-computational thought, as S. Wolfram (2002) demonstrated with his mathematics theories. These can assist creativity and help to produce continuous technological innovations, which spread much more rapidly than in previous periods and have the capacity to reengineer knowledge, not only production chains, because of their pervasive nature and the very low cost of access (Rifkin, 2000).

4. RESULTS OF THE RESEARCH

4.1 Field research and case study selection criteria

The aim of the direct investigation phase was to collect data relating to communication processes which are used during the development of the construction documents, by members of different professional disciplines. The case studies method was applied in the research ,by submitting semi-structured questionnaires, created on the basis of UNI ISO guidelines 10006:2005 (Quality management systems - Guidelines for quality management in projects). The aim was to investigate the problems that lay among different members of the design team looking into the communication processes. All the members of the design team develop activities for the same project, although belonging to different companies and being geographically dispersed: the industrial problem concerns the resulting lack of collaboration and quality of the final result.

As we agree in the whole industry, the quality of the result in the construction sector means that the product performances meet the customer's expectations. Different interfaces, corresponding to different professional profiles, interact during the project development. The research looks into these, considering them as significant indicators for the industrial problem under review.

The chosen sector for the field research is the airport design (passenger terminal building), as representative of the following aspects of a generalised critical problem for quality:

- high standardization and international definition of expected levels of quality (International Air Transport Association , Federal Aviation Administration);
- project planning with a strategic view such as LCD (Life Cycle Design), that includes phases like maintenance, transformation, expansion, decommissioning, depending on the growth of passenger flow;
- presence in the team of different professionals figures with dissimilar background and expertise, which must interact actively for a coherent planning and design development of different specialist areas and subsystems;
- presence of a high level of complexity of the project, derived by a large set of specified performance levels for different requirements (security, environment, cost, management, etc..), defined according to the type of airport terminal, the technologies used, and so on.

Another significant aspect, as mentioned earlier, is the fact that airport design is one of the few governed by international regulations (International Air Transport Association , Federal Aviation Administration). This set of rules, while not explicitly declared as mandatory, is a common standard reference in design of such structures around the world. Since the criteria that influence the design of the passenger terminal form a common start-up point for all interventions in this area, we can assume that the results of the research will be valuable beyond the borders of Italy and of Europe too.

The airport sector is specific for the type of client too: the airport owner company has in its organization

technical offices able to control the different steps of design, implementation and management. The airport owner company is an "expert" client, which is able to express needs and requirements in a detailed and structured way. These requests, fixed during the design brief, must be satisfied first in the Airport Master Plan and then in the Terminal Concept, in the Design Studies, in the Construction Documents and so forth. This high level of technical knowledge of the project should permit designers to get all significant information in time, so that it can be used as an input for the start of the design process, also limiting the risk of misunderstanding in the relationships between the designers and the client.

The selection of representative case studies, at the basis of the inquiry, was a direct result of a brief investigation on all Italian airports, aimed at identifying the design projects considered significant for research. So starting from the identification of all the construction works involving airport passenger terminals recently completed or in progress, we gathered information about the type of design project carried out, the type of contract, the professionals involved in the design phase and their tasks. We also collected data regarding the number of movements, the characteristic flow of passengers and goods in the last three years.

Some preliminary observations were made:

- activities in recent years have mainly concerned the airport terminals in Southern Italy. Typical works are renovation, expansion, new terminal construction, etc., some have already been completed, others only partially, others are at the end of the contract tender;
- in almost all recent works there is a tendency to divide the design phase from the execution phase. First there's a design competition: participants are asked to develop the terminal concept. The winning design team will be in charge for the planning and development of the Design Study and of the Construction Documents, of the design coordination and of the management of the construction work. Then, once the design phase has ended, the airport owner company will launch a new tender for the construction contract;

The design team can be represented according to three macro-categories:

- technical offices of the airport owners company, responsible for all airside and landside interventions. These are large structures and they include all the specialist competences needed to manage very complex situations as airport projects are. They usually operate not only for the airport owner company of reference but for other airport companies or administrators;
- specialised engineering companies which have a vast experience in the sector of the infrastructures and transport;
- single planners or architects' offices, operating in various fields, which are in charge of solving the architectural part of the design project. They need to operate in agreement with structural designers, HVAC designers, etc. for the definition of the final project.

Case studies were critically selected on the basis of the findings from this first reconnaissance. The aim was to form a sufficiently representative group of samples to investigate the current design practice. The selection criteria were these:

- recent project, use of planned communication processes and IT connected to them;
- geographical distribution, useful for a national representation of reality, in order not to fall only on the choice of interventions located in the same region;
- significance of the project in relation to the number of annual movements and passenger flows, excluding operations involving airport size, limited or subject to strong seasonal variations (international and regional airports, excluding major hubs);
- occurrence of different categories of designers, as listed above, to highlight differences and points of contact between various organizations.

Given the criteria listed above, initiatives involving the following airports were selected:

- Torino-Caselle;
- Brindisi-Casale;
- Catania-Fontanarossa;
- Napoli-Capodichino.

4.2 Features of the passenger terminal design project

The passenger terminal is the cornerstone of the airport system and it defines its architectural image; combined with the quantity and quality of offered services, it is the most crucial aspect in the design of this type of structure. The project's compliance with the expressed requirements is evaluated in terms of the structure's compliance with the implicit and explicit customer, airline companies, owner company and, obviously, passengers' requirements. It was established that a terminal full of services and with attention to customers, which is both a pleasant and a human-scale environment for the passenger, increases the earnings of the whole airport system, that is anyway a "money machine". A poor level of services (if compared with standard classes there are insufficient or poorly equipped spaces) is very negative for the efficient functioning of the terminal and thus decreases the competitiveness and earnings of the infrastructure.

The number of passengers travelling by plane for business or vacations is constantly growing and this determines for airport owner companies the need to plan actions and investments with a long-term strategy based on estimated passenger traffic. However, given the rapid technological trends (for example development of aircraft design) and growth in the number of annual movements of aircraft and, consequently, the number of passengers, these investments are needed to adapt the terminal and to maintain the functioning of the structure according to acceptable standards. It may happen in a relatively quickly time range compared to almost all other types of works. Often these initiatives, which include the maintenance, the renovation and the construction of the new passenger terminal, take place with time intervals significantly shorter than the average duration of the natural life of the part which is the object of the work. This means that the input for the start of a new design and development process is not given by the obsolescence of an item, being it technical or due tolack of performance, or by the achievement of the period fixed for its disposal in the defined end of its life cycle . The start of the design process moves from commercial, operational and management needs or basically from new requirements, often imposed by legislation. The BAA (British Airports Authority) has estimated that the average duration of airport facilities shall be:

- 100 years, for runways, taxiways and aircraft parking;
- 50 years, for transport networks, interconnection of roads and the terminal building (as a whole and evaluated for its functionality);
- 20 years, for equipment and passenger transport systems;
- from 5 to 20 years for installations;
- from 5 to 10 years, for offices;
- from 3 to 5 years for shops, bars and restaurants.

These requirements include, for the terminal designer, the creation and development of flexible architectural concepts which can be developed even in later years, and the design and choice of compatible technological solutions. Airport owner companies need to build the terminal with subsequent upgrading without affecting the terminal's operation and good functionality.

In order to meet this complex set of needs it is necessary to conceive the terminal with a different logic from that commonly adopted in most categories, and based not only on flexibility but also on the adaptability and "replaceability" (Edwards, 1998), typical of temporary constructions. To address these needs it is essential to think of the airport terminal as a set of fixed and stable elements (for example structure, installations, etc.) and of parts which are subject to change in a shorter time frame, such as internal partitions, equipment and furnishings.

4.3 The envelope of the airport passenger terminal in the Construction Documents stage

The envelope system of the passenger terminal is, in some respects, the watershed between a system made of fixed and stable elements and a system composed of temporary elements. The envelope, despite an average life cycle similar to the structure life cycle, is clearly distinguishable from it, because of the criteria that guide the design, which are primarily aimed at ensuring enough flexibility to the system, to meet the needs of subsequent upgrading and expansion of the terminal functions. This requirement is not primary for the structural system as it is, for example, for the interior fixtures and equipment.

The technological evolution has transformed the envelope systems from simple protective barriers into dynamic and intelligent integrated systems able to satisfy a systemic performance set from thermal and acoustic comfort, to the reduction of energy consumption and to functional integration and flexibility. The flexibility, in particular, has great importance in the design of the passenger terminal envelope, because the airport terminal is a building that by nature must be extremely flexible and able to easily adapt and grow in relation to changed needs. We

must remember that if the life cycle of structures can be considered to be between 30 and 50 years, the envelope has a relatively shorter life for various reasons (architectural image, changes in the functional layout and in the distribution systems, technological obsolescence, integration with other systems, and so on). For these reasons we are more often seeing in the envelope and in the structure a separate design concept, and also we observe an increasing use of dry assembly technologies, less used in other types of building.

In this topic and according to the development of the project design, the research investigated the Construction Documents stage, limiting the issue to the envelope design of selected airport passenger terminals. The Construction Documents stage is the most detailed phase of the project design, which must be conformed to the specified requirements and suitable for the next step of construction. All the technological components and elements are designed and defined starting from the identification of the modular system, to the development of the structure fittings, to the study of solutions integrated with the technical utilities, the control of energy, noise and fire performance and finally the establishment of procedures for assembly/dismantling and maintenance of the system's parts. At this design development stage, critical issues such as the interoperability and the different communication systems adopted by the design team are tangible too.

4.4 The semi-structured questionnaire with a focus on the project manager

The innovative nature of this research is already determined by the ways in which the data were collected. The method used to obtain the information was the case study method, through the creation and use of a specific questionnaire. The questionnaire consisting of both open-ended and closed questions was given to project managers to collect at the same time quantitative and qualitative data. The questions were composed to investigate the following aspects:

- the conditions and the peculiarities of the project, in relation to the context, with particular reference to the client (expressed requirements) and the structure of the process, the actors involved and their responsibilities;
- the arrangements for coordination and collaboration among the professionals involved in relation to different project phases;
- the different points of view of every design team member and the information requirements of each one;
- the arrangements for planning, management and control of both communications and information;
- the representation of objects through the use of ITC, the link between the various representations and the mode of updating the information;
- the ability to quickly share information between all the participants in the planning process through the use of new technologies;
- the interoperability of the applications used.

The questionnaire was structured in its form and content according to both UNI EN ISO 9001 and the UNI ISO 10006. The reference to international quality management standards has been adopted to facilitate the framework and understanding of the issues investigated, which however are poorly explored and quite unknown to the actors in the construction sector. Referring to the process approach, we identified, through the questionnaire, the processes and the main stages of the design process for each case study. We recognized issues related to the organization of the design group, to the project management interface, to the communication (content, formats, technologies), to quality management communication (planning, management and control) and to the evaluation of the product's performance (performance specifications).

For the acquisition of the necessary information, we identified the different processes and the activities that characterize the design development in this area, highlighting for each one the supply relationships between upstream and downstream stages. In this way we tried to emphasize the supply chain that emerges for each development step and each phase of the planning and design of the project, identifying users who create or acquire the early data, users who receive and/or manipulate the information, and then studying the formats of input and output data. More information was obtained through the examination of the documents exchanged and the communication flows , for both of which content and tools were evaluated according to the needs expressed by the users themselves.

4.5 Data analysis

The data collected through the questionnaire answers were analyzed by double data processing. During the first step the information obtained was analyzed in a qualitative way, then a quantitative analysis of the same data set was conducted. The qualitative analysis of the information was made through a SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis of the responses contained in the questionnaires collected. In detail, four SWOT matrixes were built for every case study: each matrix corresponded to different topics addressed in the research. The four matrixes, each one illustrating strengths, weaknesses, opportunities and threats, have been built based on the same criteria that guided the construction of the questionnaire. The four areas are the following:

- Design and communication planning;
- Design development and communication management;
- Design verification and communication control;
- Purchasing processes.

In the second step the same data sets were analyzed using a quantitative method. The number of answers compared with the total number of questions has been measured. This information was significant because the project managers who completed the questionnaire, were asked to answer only the questions related to the tasks performed during the Construction Documents development. Therefore, for any other task not performed by them or for any issues that were not considered in the project, they were asked not to answer.

The answers were then evaluated with a score ranging from 1 to 6 (corresponding to an evaluation scale from very poor to poor, to partly poor, to partly good, to good and to very good). The score was attributed to every answer of each case study considering both the level of the corresponding answers which emerged from questionnaires and the effectiveness of the response according to requirements outlined in UNI EN ISO 9001 and in UNI EN ISO 10006, and also compared with best practices in communications identified in construction sector literature (Emmit and Gorse, 2003, Dainty et al, 2006).

4.6 New facts: qualitative analysis

Four SWOT matrixes were built to sum up the emerged evidences from the detailed case study analysis. Matrixes were created on the basis of criteria relating to the four main areas mentioned above, which are:

- Design and communication planning (Fig. 1);
- Design development and communication management (Fig. 2);
- Design verification and communication control (Fig. 3);
- Purchasing processes (Fig. 4).

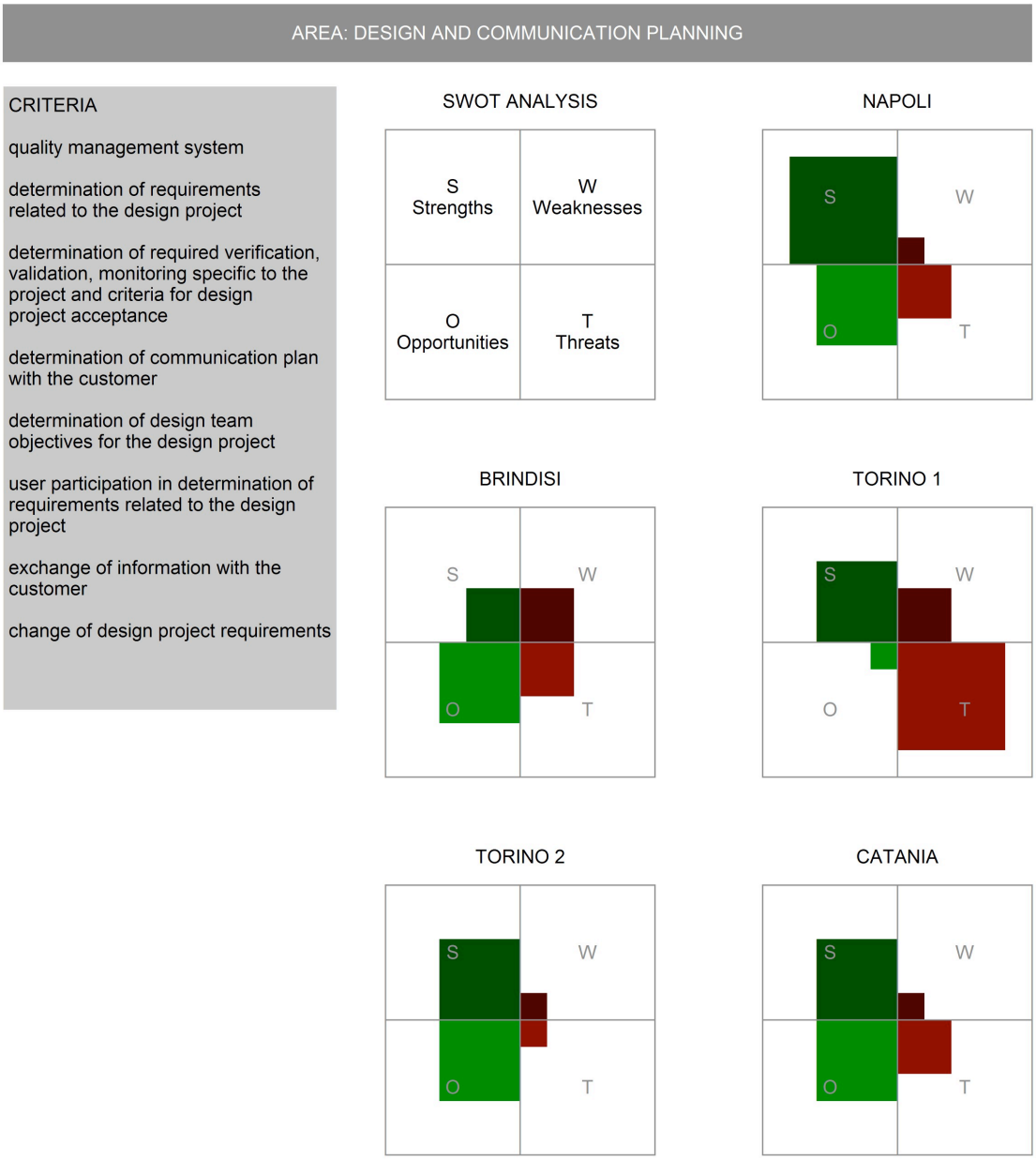

FIG. 1: Case Study SWOT analysis referring to design and communication planning.

On the basis of the answers related to the first area analysis (Design and Communication Planning) some significant information emerges. The first evidence is that the organizations already ISO 9001 certified face difficulties in applying the quality management system in the planning and development of the design project. Many activities, such as project verification, validation and monitoring, are not carefully identified and planned. These activities are not properly planned either;, basically this happens only in the following cases: when the airport owner company requests them at the end of the design brief, or they are mandatory because the Quality Assessor responsible for the project validation asks explicitly for them. The airport owner company is often the one which is in charge of defining the requirements of the design project through the design contract. The design team does not review the contract requirements and doesn't include any additional goals, sharing them with other members, who are concerned only to the contents with the assigned tasks and price. The design requirements reflect the concerns of the owner company, which requests to be assured with regard to any future development of the passenger terminal and first and foremost asks for fixed times and costs. Environmental aspects, such as those relating to sustainability and energy savings, are not taken into proper consideration: the design project is limited to observing the law.

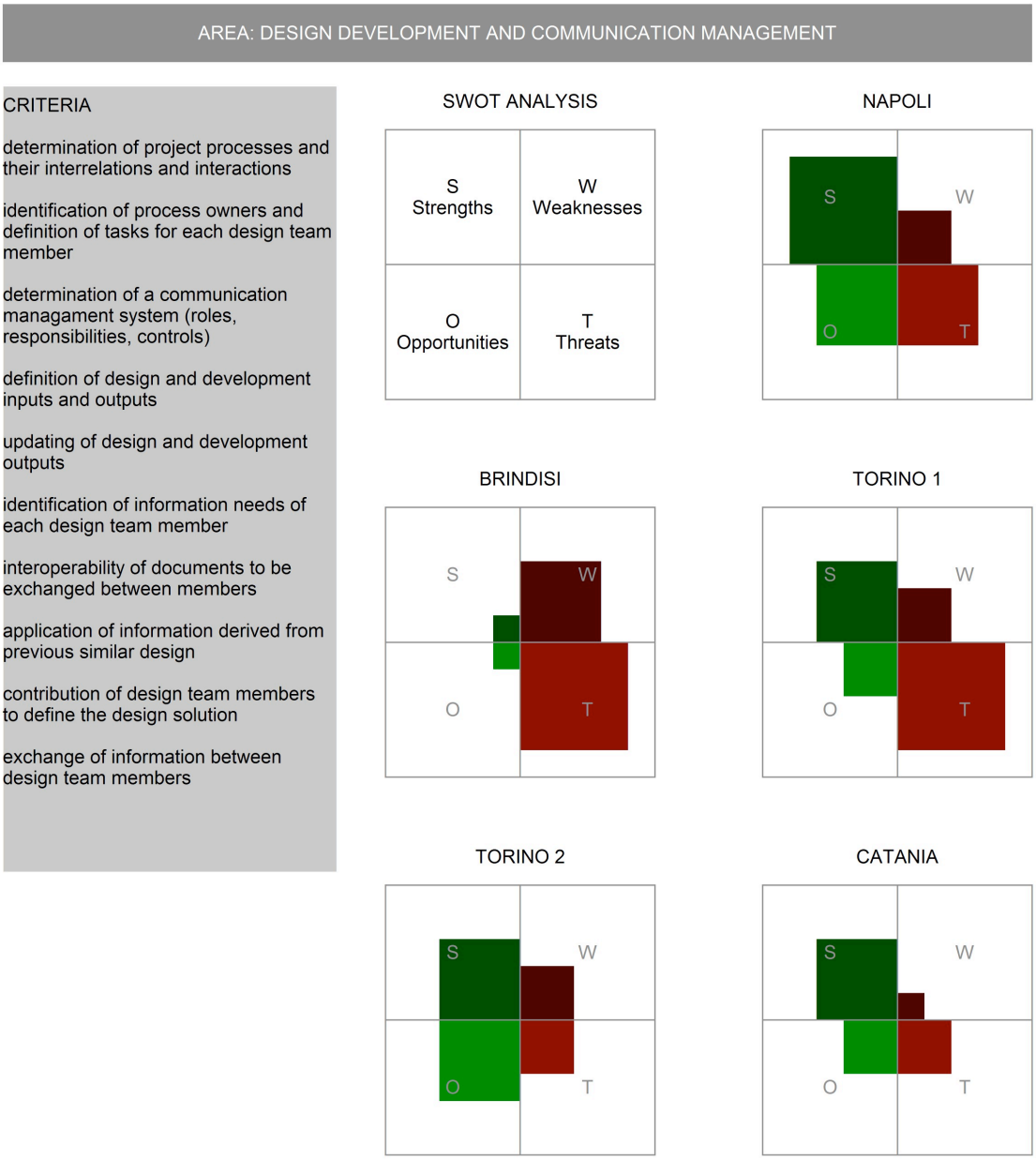

FIG. 2: Case Study SWOT analysis referring to design development and communication management.

In current practice the project manager, who may play also the role of the architectural designer, negotiates with the owner company during the briefing, while the other team members are involved only in the next steps of the design project (in the earliest case after the end of the briefing or at the start up of the preliminary study). The late notification of the design requirements to the other interested parties, especially during the preparation of the Construction Documents, has often led to necessary design changes to avoid affecting the efficiency and functionality of the airport during operation. Even the communication plan (if done) shows it as inadequate as regards several aspects. It often provides generic indications regarding the design documentation sending mode, using certain media, without setting down in detail, for example, the owner, the format, the content and the frequency of communications. Team members, therefore, habitually communicate through informal channels and there is no tracking, check and recording or conservation of the majority of these interactions.

The answers related to the second area (Design development and Communication management) show the difficulties of using the quality management system in practice and its ineffective application in the design process. The planning process in most cases is organized in accordance with sub-processes which are only partly related to each other and which are identified just according to the architectural designer's needs. They figure a model of a traditional cascade design approach in which the architectural designer shall find all the architectural and technology solutions, and only at a later stage takes advantage of the contributions of specialists (structural,

plant, energy, etc..). In the context of airport projects, even if in some of these there's the participation of European partners, the interaction among team members has not yet been transformed into a more advanced, networked organisation. Consequently, the communication management system, although planned, is not able to respond correctly at the some time to the information needs of participants, as a result it is shared with difficulty by the interested parties. Even the exchange of information and contents among team members is poorly planned. This happens because there isn't at the early stages of the design process a precise identification of information needs of all the participants, who therefore have to adopt different standards from those normally in use, with resulting difficulties in the implementation and interoperability performances.

The planning of the design review and verification of the outputs of each sub-process are compulsory steps in the majority of the case studies. The field of application of the planned measures, however, seems not to be very effective, especially regarding two key issues. First, we observe that the procedures for (documentary) validation are quite poor; second, it is evident that the results of the controls are not carefully documented, registered or conserved in a proper way for their further use in subsequent design projects. There is also a gap in the way of keeping under control the design changes between the programming phase and the executive development step. Even if a detailed definition of design changes control procedures already exists (such as ISO), the project team has difficulty in applying the established measures to properly provide information to all interested parties. The problem particularly is refers to documents and the means of transmission to be used. Even the results of customer and user satisfaction surveys once the finished building is in use (Post Occupancy Evaluation), even if they may represent a useful feedback that could be used as an input for subsequent interventions, they are rarely recorded or stored in an useful manner.

In general any qualification, beyond professional registration, is required for suppliers, defined as an organization or person providing a product according to EN ISO 9000:2000, and thus interpreted in the organizational scheme as members of the virtual design team. This means that the majority of the main organizations, which are ISO 9001 certified, have to collaborate with other professionals who, probably, are organized in a significantly different manner. The preparation of plans and the consequent activity ofcheck ing the information received from suppliers, is only partially carried out due to the ineffective control measures applied to the verification of that information itself. The weaknesses that have already emerged in the procedures of recording the results are evident even in this area. While taking care to define specific requirements for the acquisition of the information, the organization observes in practice that these are widely disregarded by the suppliers. The definition of operative instructions for the creation and the exchange of information by the organization is never the result of planning shared among participants, but on the contrary it is the expression of the information needs of the main organization only. In a single case study an advanced mode of working and sharing information has been activated: the project team has exploited the corporate network and has used a web-based system for information sharing. In other cases the design documents are still transmitted and exchanged substantially with traditional means, even if in the design team there are international partners.

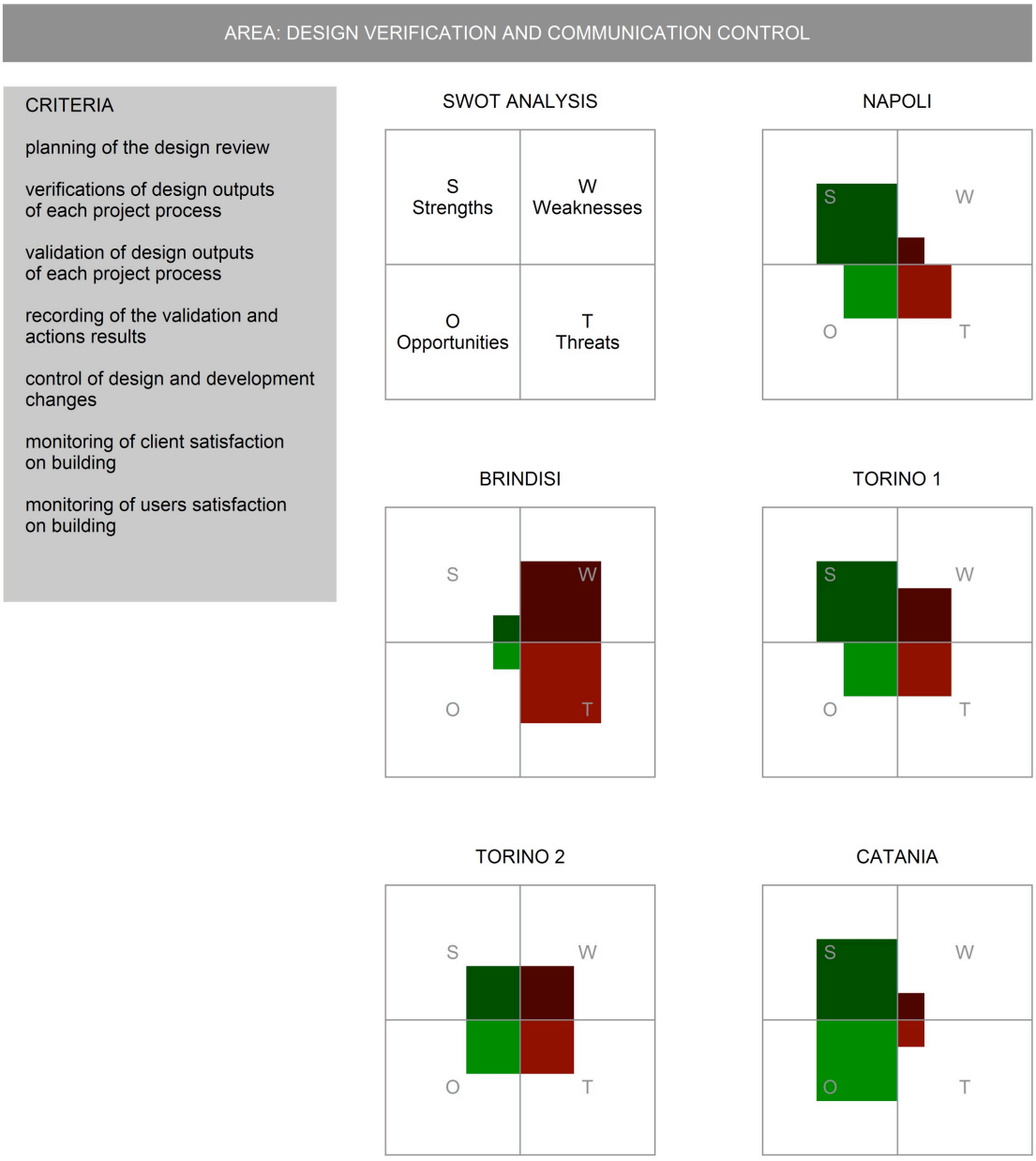

FIG. 3:Case study SWOT analysis referring to design verification and communication control.

The overall use of R-Technologies is extremely limited in these projects. Although the market is mature and is able to offer advanced IT support tools, it is clear from the responses received that organizations continue to use IT technology and traditional means of communication (telephone, email, web). Collaborative and advanced sharing tools have not been used in the development of the project for economic and timing related reasons. This is due to the fact that the design team is a temporary team, that those involved have limited communication and coordination skills in interpersonal relationships, and new instruments are unable to resolve such failures; they even tend to augment them.

The problem of familiarity with these instruments is substantial: a user often prefers to use some technologies, even though obsolete but of common use between the parties, rather than use new ones, which perhaps are potentially more effective but which involve changes in cultural approaches and the use of time for 'learning. This means that for launching new technologies it is necessary to change work patterns. It's necessary to have the approval, motivation and participation of all the actors involved and interested in change. It is also essential to ensure the flexibility of structural support for the design project and its development. Therefore, the adaptability and the ability to customize the tools have to be strengthened. Finally, since the human factor is the most critical, it needs more attention towards the client and toward the user regarding the information circulating within the network. In this sense the project of the interface between user and media will become increasingly

crucial in the future. ITC technologies and, in particular, systems based on the concept of social networking show that the main interest is in the user, who can directly customize the use of certain tools in terms of both content and interface, rather than in the technology itself.

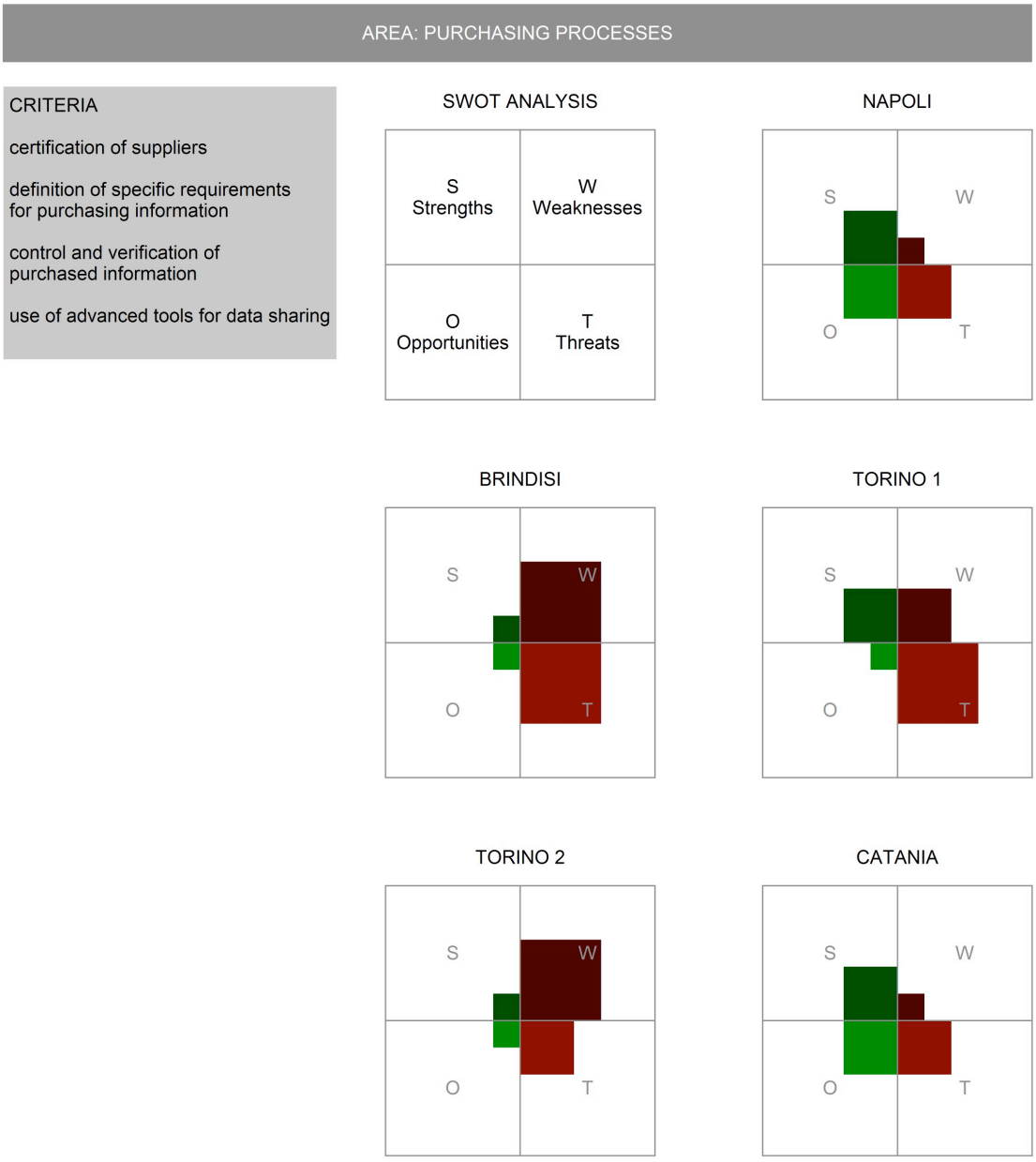

FIG. 4: SWOT analysis of the five case study referring to purchasing processes.

4.7 New evidence: quantitative analysis

The quantitative analysis of responses was conducted in two steps:

- STEP 1: identification of the number of positive responses referring to the minimum requirements (ISO);
- STEP 2: assignment of scores, from 1 to 6 according to the level of satisfaction of the requirements related to communication processes.

Based on the assignment of scores in scale from 1 to 6 to the answers given in the questionnaires, some graphs were prepared to compare the scores given in the five case studies in relation to the four areas mentioned above. The score is 0 for answers not given. Considering the classification stated in the draft of the 9004:2009 standard in which there are five new maturity levels in an organization, we've chosen to categorize design team

organizations through the analysis of communication processes, taking as a reference the results obtained and by creating a match with that classification:

- Beginner organization: score 1-2
- Proactive organization: score 2-3
- Flexible organization: score 3-4
- Progressive organization: score 4-5
- Successful organization: score 5-6

The area of greatest risk was identified in the research as the area located under the medium score 4.5 (which was assigned the threshold value: DGRT - Design Gap Risk Threshold). It has been observed that above this threshold, organizations will have more ability and opportunity to succeed and to achieve a significant improvement compared to the risk of design errors through collaborative design strategies. The value of 4.5 corresponds to the attainment of the minimum requirements expressed by ISO 10006 standard in relation to communication processes. By going beyond this threshold the design team is enabled to reach an area of strategic value defined Win-Win Strategy Area, which is defined as the place where you can develop strategies for collaborative design.

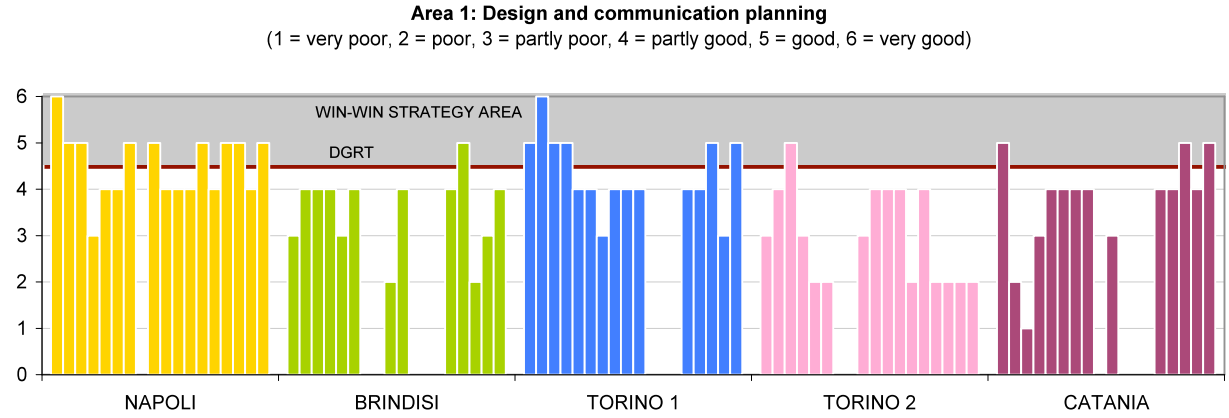

FIG. 5: Scores of the answers grouped by case study according to the area of design and communication planning.

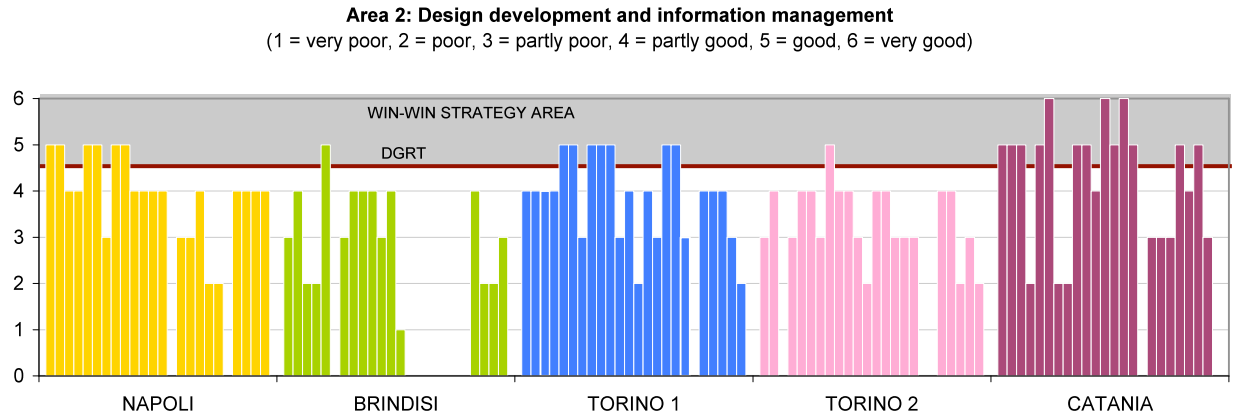

FIG. 6: Scores of the answers grouped by case study according to the area of design development and information management.

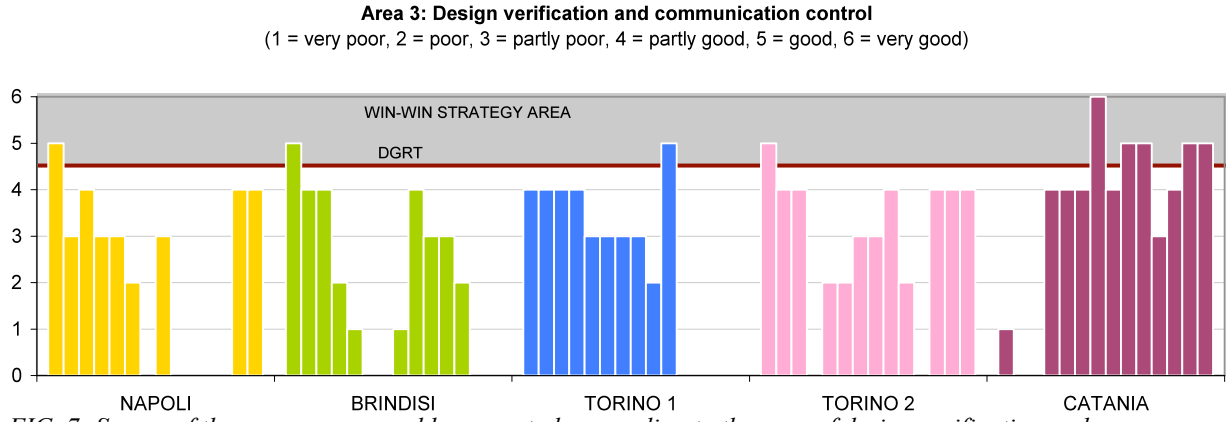

FIG. 7: Scores of the answers grouped by case study according to the area of design verification and communication control.

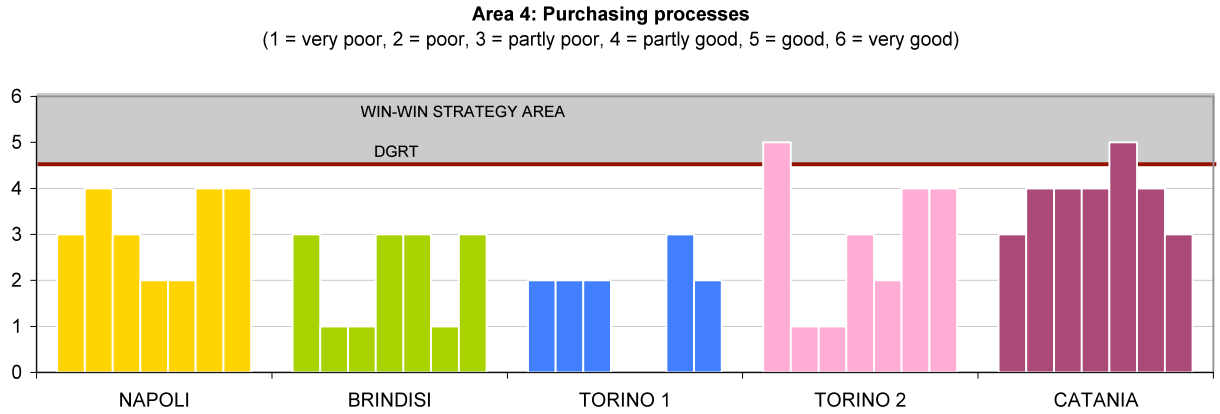

FIG. 8: Scores of the answers grouped by case study according to the area of the purchasing processes.

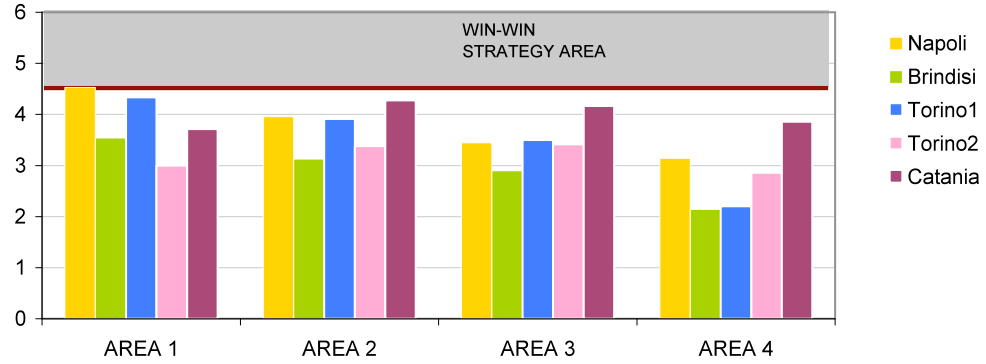

FIG. 9: Average scores of the answers grouped by area and coloured according to the case study.

The charts illustrate briefly the results in terms of DGRT evaluation with a score attributed to individual answers grouped by area are compared . The differences are noticeable in both the comparison between the different case studies and in relation to the different areas. The last graph shows the average values of answers in the different case studies, grouped according to the area of reference. The case study in Naples Airport is the only one that exceeds the minimum threshold of 4.5 points for the area of project planning and communication, thus indicating a trend towards the WWS (Win-Win Strategy). This chart shows clearly that even if the organizations are facing up to their responsibilities in the area of design and communication planning, the goals reached in the further areas of design development and verification, and especially in the one of purchasing processes are really unsatisfactory. The fact that the area whose average value is the lowest, is the last one, clearly denotes that the procedures and measures applied in the organizations to interface with other members of the design team are still one of the key issues to be resolved in order to achieve the WWS goals.

The analysis of the answers through the attribution of the score reveals that some aspects, whether positive or negative, are common facts for the whole case study. So it's possible to operate by reading these data. We observe, for example, that there are some occurrences in the answers (which are on average 16% of the total).

Referring to the first area (design and communication planning) and according to the definition of the requirements of the design project, there are basically two noticeable aspects:

- the members of the design team do not care to define requirements, additional to those expressed by the client (airport owner company);
- the requirements for the design which are established in the initial phase have almost never been subject to change.

This means that the client, being an expert, is able to precisely translate his needs into clear requirements for the design project, so there's no need for negotiation with members of the design team. The other aspect is related to the frequent changes during the design development: if the initial design requirements are not changed, the reasons that lie behind the request for changes are of a different nature. These are mainly related to the development of the design project and to the (poor) coordination of expertise between the various members of the team. This caused the negative deviations from the line of DGRT.

The answers given in the second area related to design development and communication management show that each team set up the figure of reference and identified those responsible for the development, verification and approval of each activity sub-process. The team demonstrates the awareness that each participant has specific information needs and therefore they try to define them, in particular during the project meeting. Apart from recognizing this problem, however, it is evident that the measures taken are not sufficient to ensure an efficient and effective communication among stakeholders. It is difficult for the design team to define precise information to be formally submitted to the other team members, to define the means used to transmit and the frequency of communications. Even the definition of the format and the structure of documents is generic: the problem of interoperability is apparently resolved through the use and exchange of documents whose output logic formats are commonly used among the partners (for example .doc for texts, .dwg for the drawings, .jpeg for images, etc..) but there is no common object description structure.

The difficulty in collaborating and sharing information with other members of the design team is remarked in some answers: the architectural designer is responsible for the architectural solutions and the technological choices regarding the envelope. The contribution of other specialists involved in the project usually happens at a later step and they often merely offer a form of "consulting". There isn't a real collaboration in identifying and defining the design solution. Specialists are simply asked to guarantee that the chosen solution will be able to meet the requirements established in the briefing.

This kind of approach, poorly coordinated and less collaborative among the partners, reveals its limitations in airport design, in which the compliance of many performance standards and goals (related to timing, cost, environment, management, etc.) can't be left to a second phase.

Referring to the area of design verification and communication control, it is clear that the verifications and the validation measures for the outputs of sub-processes are inadequate. The results of the validation phase, of the verifications steps and of any corrective action are rarely planned, documented and maintained. These data confirm the above-mentioned difficulty in the application of quality management by the design team regarding several operational aspects.

The answers collected in the last area about purchasing processes, confirm the widespread communication problems between the members of the design team. The summary chart clearly shows that the average value of the responses gathered in this area is, for each of the case studies analyzed, the lowest score referring to the total of four examined areas. This result demonstrates that the difficulty in reaching the value beyond the threshold over which WWS targets are set, is characterized by the risk of performance failure for the project (under the DGRT threshold). The importance of defining specific requirements for the acquisition of data and information from suppliers is underestimated by teams. For the companies this issue may be considered to have been solved if they provide to the partners the information just to ensure the correct interpretation of documents for the purposes of planning decisions. This attitude jeopardizes the final results, as indirectly confirmed by subsequent answers. The project managers say that although specific requirements for the acquisition of data and information have been defined, the received documents rarely showed comply with the established parameters.

The perception of communication problems is evident even in the final assessments of the project managers' opinions. The majority complain about the difficulties of collaboration within the design team, especially in the

case in which some partners are foreigners and are not aware of Italian design project culture and regulation. Other project managers reported that a lack of communication among team members has sometimes led to failure to address the problems, which then emerged during the following step in the project design and during the construction phase too. In one case the interface with other partners who do not operate according to a quality management system, was reported as a problem.

4.8 Critical data analysis in relation to the business scenario

The first results of our research indicate some forms of innovation in different areas in which we should experiment new approaches with operational speed, according to the speed of construction at least to that expressed in other industry sectors to address the dynamics now in place., both technological and of the market.

Design supports the entire Construction Industry, in particular the communication processes in the project can be considered critical to the final quality of the product. In the last 10 years, Europe seems to have been very backward in terms of methods and tools in its organization and plagued by a formal and epidermal quality. For example the technical specifications are inadequate in their structure: they cannot express the changed expectations in the user's requirements/performance framework and therefore cannot ensure the expected quality levels for the final product (in terms of product customization). Furthermore, the approaches do not encourage innovations in any direction: either procedural or content design (for example with regard to functional and use aspects, performances, technologies or materials). The study of the results of the collected data clearly demonstrates that the problems to be solved arise mainly from procedural deficiencies during the project development.

Moreover, the environmental problems, which could be treated in an integrated and harmonious way with the quality management of the project, instead of becoming an incentive to improvement, seem to stop it. For example, methods promoted in Europe and generally referred to the concept of Life Cycle Thinking (see Life Cycle Assessment analysis) and the Life Cycle Design, although available, have not spread much in construction neither among designers nor manufacturers or clients.

Tools identified in research, to improve on the communication processes in design, concern:

- vision of the design project as a communication network equipped with standardized multiple interfaces (IFC, Industry Foundation Classes, vs aecXML, engineering architect construction technology for web communication, etc..), and interpersonal and group relationships (cooperative tools);
- adoption of a process approach such as PDCA (Plan Do Check Act) type, but with the character of a network and the adaptation of lean construction logics;
- definition of the Communication Plan of the design project and relative operational and relational procedures defined by the content information necessary for the user (User Profile);
- introduction of advanced methods in the process of planning, management and verification of technical information;
- adoption of a system of requirements/performances that incorporates specific knowledge (for example tools for LCA, LCD);
- adoption of integrated design teams with producers referring to our knowledge base (home, school, hospital, infrastructure, etc..), the need for personalization of the final product (specific intervention), the possibility of association in the supply chain (local and/or global), the production of components (pre-assembly) and disposal at the end of the useful life of the product (disposal, recycling).

Recent experiments in the English-speaking countries have shown that these types of combined approach lead to improving the above- mentioned situation of serious inefficiency in the construction sector. According to these studies we should ultimately aim to design a model that rather responds to the profile of an instrument of supply chain management and of agreement between partners to ensure the achievement of operational goals (quality).

In particular, the "Product Development" approach implies a new vision in the Construction Industry based on an alternative set of priorities, but largely related to the increased relational capacity of the design planning, to:

- incorporate the expectations of the end user;

- develop a product that exceeds the expectations of the end user;
- translate expectations into a consistent and measurable set of requirements/performances (aims of the project);
- define how this framework influences the outcome by the specific systems and components;
- develop projects that are able to provide an adequate product in specific circumstances of intervention and give clear objectives to the integrated group of design-supply-construction;
- continually and objectively check the satisfaction of users, accumulating knowledge from the received feedback to be used in subsequent planning;
- develop innovation with suppliers to improve the product without losing reliability.

5. KEY ENABLERS AND BARRIERS

The forms of organization and aggregation are rapidly evolving. We observe the gradual disappearance of the traditional design team as a part of a unique organization that brought together all the skills necessary to the planning and development of the design or that figured as mandatory in a joint venture, and the progressive spread of new aggregates, such as virtual teams, as an indirect confirmation of the phenomena. Unlike traditional teams, the virtual teams work, going beyond spatial, temporal and organizational borders; the links generated are much more similar to those typical of the industrial supply chain. These links are much more stable and are strengthened through the help offered by information and communication networks. Although the participants do not share the same space or are not part of the same organization, there's the real perception that spatial-temporal distances are cancelled and that it is possible to use differences in time zones to create continuous processes of design development. The birth of the virtual team, thanks to R- Technologies, poses new demands to be satisfied for communication in the design.

The development of sophisticated software, intended only as hyper-technological islands of automation, has not produced in practice the expected benefits in terms of increased efficiency of communication processes. The reasons for this lack of results is clearly demonstrated in the research and these are mostly related to the lack of a communication culture in building design. The applications have been excessively designed and oriented toward greater specificity, looking only at speciality subjects, based on the idea that this could match and represent the increasing complexity of the design process (Wolfram, 2002). The design process, instead, introduces new demands, mainly as a dynamic relationship network among the partners. These approaches have proved to be decisive, especially as regards the quality of information that has been produced in the highly specialized, local islands of automation, marked by extremely specialised languages (Pollalis, 1997), but they do not provide equally effective for the information sent to other members of the team. The lackingor only partial consideration of the user of that information within the involved parties, according to the requirements expressed and the information produced, edited and exchanged, has not yet allowed new technologies to fully express their potential in strengthening communication processes in the Construction Industry. The communication issues, rather than facilitate those processes, have often caused other problems such as overproduction of uncontrollable and redundant information, poor interoperability among different software and tools in different disciplines, with the result that we have missed the opportunity to communicate frequently and effectively as the project plan intended.

There is still a lot of resistance and there are barriers to be overcome in order to ensure an efficient and effective communication in Construction. Such resistance encountered in research is due to the "invisible barriers in the communication processes" and leads to dysfunctions and errors in the activities. Among these we detected on one hand technical barriers due to low standards and therefore to the ability of exchanging data and interfaces between different software applications. On the other hand there are real cultural barriers due to the different cultures of the project and to multi-cultural aspects. Other barriers are procedural and are due to a lack of integration in the organization systems, or rather to the separation of the planning and development phase of the project.

The scenario of the Construction Industry has a temporary basis because of the lack of the collaboration among the members of the design team, who often work together once only. In most cases the participants involved in the process to work with other professionals in different combinations and without continuity in their relations. Each project, therefore, faces unique characteristics in the context, in the set of design requirements expressed by users and in reference to the type of relationships that are determined between the players involved, that unlike

what is happening in the automotive sector for example, have never met in stable organizations, although formed by third parties. Because of their highly differentiated technical culture, as already mentioned, the design team members express themselves in specialised ways and languages, not fully communicating and they therefore tend to act independently in their own category, producing a poor product data integration.

6. RESULTS

The research seeks to demonstrate the ability to obtain an effective improvement in these processes by bringing the user back to the centre of the communication process. The goal is to reduce the Design Gap. It's not only a problem of the speed of the exchange of information, but rather of informative integration of different software applications, which are able to communicate with each other in a dynamic and interoperable way. In these new environments, innovative ways of viewing, modelling, simulation, etc. can be developed and customized according to the user's requirements.

The research tries to define method and tools for effective planning and management of communication in the design and development project in situations of temporary and multidisciplinary collaboration among different experts having a different cultural backgrounds, focusing on data integration for product development. For the definition of this method the research uses methods and innovative tools for the Construction Industry, already applied in other sectors, operating a technology transfer and re-engineering communication in the design project. The research has set as its goals the identification and tagging of information needs of different stakeholders/users involved in the design process and the corresponding performance specifications in connection with various design activities, so as to foreshadow a performance-based approach in the management of design communication.

The research, by applying the process approach, consolidated in quality management and in systems integrated in the project , specifically looking at the improvement in communication, has defined the criteria for the rapid establishment of the information requirements of each participant (User Profile) involved in the design process. It is set up in order to rapidly build an efficient and customized model of team communication, calibrated according to the specific design (project requirements, project phases, ways of organizing and contract, professionals and skills involved, etc..). The definition of these elements in designing the User Profile, is expressed in the form of requirements that must be met for the proper configuration of the profile itself. Referring to the four areas of investigation outlined above, we have well-defined strengths to be developed, weaknesses that must be eliminated, opportunities to exploit and threats to avoid in the design and development of the User Profile (Table 1, Table 2, Table 3, Table 4).

TABLE 1: Elements of User Profile design for design and communication planning.

AREA 1: DESIGN AND COMMUNICATION PLANNING	
STRENGTHS • quality management system ISO 9001 • careful determination of requirements related to the design project and specified by airport owner company and users • determination of required verification, validation, monitoring specific to the project and criteria for design project acceptance • determination of communication plan with the airport owner company	**WEAKNESSES** • lack of application of quality management system in the planning and development of the design project • determination of requirements, especially for sustainability and energy saving, limited to respect of the lowest level established by law • no planning of verification, validation, monitoring specific to the project, if not specifically requested by the airport owner company • no detailed data regarding the information to be communicated, the media to be used or the frequency of communication
OPPORTUNITIES • design team agreement upon roles and responsibilities of each member, determination of standard to be used in the planning • involvement and participation of different types of users in defining the requirements for project • formal and informal exchange of information with the airport owner company	**THREATS** • no determination by the design team of common additional requirements (in addition to the ones specified by the airport owner company and the users) related to the design project • limited involvement of the passenger in the determination of the requirements for the project • changes in the requirements for the design project during the development of Construction Documents, with subsequent review of Design Study phase, by request of team members not involved in the briefing • no conservation or tracking of sent and received communications

TABLE 2: Elements of User Profile design for the design development and the communication management.

AREA 2: DESIGN DEVELOPMENT AND COMMUNICATION MANAGEMENT	
STRENGTHS • structuring of the design process in interrelated design sub-processes, , with description of the inputs and outputs of each documented sub-process • identification of process owners and definition of tasks for each design team member • creation of a communication management system • updating of sub-process outputs at defined times or according to a defined plan of controls	**WEAKNESSES** • partial application of the process approach model; sub-processes defined according to architectural designer's requirements • deficiencies in the identification of process owners and in the definition of information to be communicated to the other team members • poor capacity to share the defined communication management system with the other team members • lack of control procedures for information preparation, collection, classification and storage
OPPORTUNITIES • satisfaction of the information requirements of the team members through project meeting and review meeting • adoption of already experienced and documented design solutions to save time and money • involvement of all team members in the design and development of the envelope • identification of the formats, language and structure of exchanged documents to ensure interoperability	**THREATS** • low involvement of design specialists in the briefing; they often come only after the selection of the architectural image and the technological solutions • identification of the formats, language and structure of exchanged documents according only to the requirements of the main organization, with subsequent low application of defined standards • exchange of (especially graphic) information, poorly planned, with flow mainly directed from architectural designer to the other team members

TABLE 3: Elements of User Profile design for design verification and communication control.

AREA 3: DESIGN VERIFICATION AND COMMUNICATION CONTROL	
STRENGTHS • planning of the design review of Construction Documents • planning of the verification of design outputs of each design sub-process • validation of design outputs of each design sub-process by the defined owners according to precise control levels and recording of the action results	**WEAKNESSES** • recording of results of verifications through minutes with little attention to the conservation of records for using them in futuredesign projects • deficiencies in the identification of correct validation procedures according to the defined requirements and the sub-processes of the design project
OPPORTUNITIES • control of design changes through evaluation of the effects on the project, approval by the design manager after comparisonation with other team members, conservation and sharing of the related documents • measurement of airport owner company and users' satisfaction at the end of construction phase (post occupancy evaluation)	**THREATS** • deficiencies in the identification of efficient means of transmission for communicating changes to the other team members • deficiencies in the recording of the results collected by the measurement of airport owner company and users' satisfaction • invisible barriers to understanding

TABLE 4: Elements of User Profile design for the purchasing processes.

AREA 4: PURCHASING PROCESSES	
STRENGTHS • design team partner required to have specific qualifications • identification of check list sets for the verification of the design documents received	**WEAKNESSES** • design team partner's lack of qualification • deficiencies in the identification of efficient measures of control of the information exchanged and limited application of planned procedures • deficiencies in the recording of controls and action results
OPPORTUNITIES • definition of operative instructions for the creation and the exchange of design documents • creation and use of advanced tools for data acquisition, structuring, visualization, modelling, sharing, storage, etc. • creation and use of advanced tools for virtual team management (user profile)	**THREATS** • lack of consideration of the requirements of the other team members in the definition and application of the instructions • poor compliance of the information sent by other team members to the fixed design standards • use of traditional systems of information exchange, with low effectiveness for information sharing, especially for international design teams

The User Profile (UP) collects and organizes the needs of different stakeholders/users involved in the design process on the basis of the results of the direct search. The UP is configured according to the recent methodologies of software engineering: the information requirements of participants in the design team are organized as a set of metadata.

Metadata are literally "data about data", or information, set up in predefined sections, according to appropriately defined classes and attributes. Metadata describe, in greater or lesser detail, format and content, the object to which they relate. In our case the User Profile can be technically represented as a collection of metadata about the processes of communication, customized according to the user. The information collected concerns characteristics, technical standards, preferences that describe the user and his environment /work context. The purpose of metadata is to allow (or facilitate) the achievement of a series of targets set in relation to communication processes: development, research, tracking, storage, distribution, etc. of design project information.

The metadata of the User Profile were developed by referring to the ISO standard about metadata in geographic information systems. The geographic information sector is one of the most advanced in the process of standardization, which has been launched for many years. The ISO 19115 - Geographic information - Metadata were analyzed with particular interest because, while setting up a default set of information, the structure of this

standard is essentially open. The adoption of UML (Unified Modelling Language) as a language (standard) for the modelling allows to configure the system of relations that are determined between the different levels of metadata (packages, sets, classes, attributes). By transferring this model in the construction sector and by applying it to the communication processes, the research has come to define the User Profile (UP) in its conceptual and in its logical structure, creating a collection of metadata.

The information requirements of the development process of software engineering have been structured in conceptual terms by identifying classes of data and attributes, described with four main packages of metadata. The four packages were defined as follows:

- MD_Context, which contains information about the background of the design project (design requirements, standards to be met for the creation, exchange, and update of design documentation);
- MD_Users, which contains information about the actors involved in the project (identification of actors, contact details, role in the project, information needs);
- MD_Processes, which contains information about the various processes and sub-processes of design development activated in the specific design project (responsibility, activities, input and output of each sub-process);
- MD_Products, which contains information identifying the products of the design process and their logical structure and formats, the receivers, the methods of distribution and the registration procedures for updating and deleting information.

Each identified package groups some sets of objects (clusters) characterized by the attributes necessary for identification. Objects can be freely linked according to the related logical rules of the Entity-Relationship model. This association may be called directly by users in a dynamic way. The thus- defined User Profile responds better to the needs of organizations to plan communications, to manage information and keep it under control in accordance with what is indicated by the UNI ISO 10006 standard, section 7.6. The relationships system that is determined in the model can be an easily implemented and updated. Consequently, it may decrease the incidence of Design Gap risks generated in the processes of communication, at the same time producing an improvement in the quality management of the organization.

7. FORESEEN INDUSTRIAL IMPACTS

Ten years after the "Rethinking Construction" (Egan, 1998) ambition to improve the Project Process, the enabling success factors allow the possibility of real achievements. Although the recent policy assessment report (10 Years since Egan - G4C brainstorming evening, 2008) it is pessimistic and registers several target failures., our research pointed out invisible barriers, still pushing the operational scenario and which should be removed.

To allow an innovative impact of an integrated design approach in the Construction Industry it also necessary to create a new scenario: firstly by simplifying the procurement process (particularly Public Works) to enable the streamlining of the supply chain and encourage long term partnering arrangements among stakeholders.

It is important to create a culture of trust between the Client, the design team and the manufacturers: this should lead to improved collaboration (Win-Win Strategy). This target must still face the tender regulations in the EU: the Construction Industry needs to replace competitive tendering with some kind of long term relationship able to sustain organizational investment and to improve quality and efficiency.

This kind of experimental regulation and resulting new organization should be tested by pilot products (Housing, Health facilities, School buildings, Transport construction) and finance projects for specific products also with the aim of defining measurement of performance to be compared with tendering results as competitive as they are today.

It should be possible to modernize the Construction Industry in order to tackle the problem today facing it: lack of investments, work accidents, energy costs, environment impact, design gap and Client dissatisfaction (the competitive architectural design tender is based on the price), a continuing lack of communication culture in skills requirements, to get full value from new methodologies and R-Technologies.

Modernizing Construction means creating the industrial conditions to allow to plan, measure, and improve all process performances.

In brief the research pointed out some important "new abilities" to be created for this purpose:

- Ability to prevent the threats of the Design Gap, including: determination of common requirements, early involvement of all the team members and their participation in the planning and development of the design solution, technical and cultural interoperability, use of customized advanced tools to support the virtual team;
- Ability to plan the required "just in time delivery" design information and ensure its accuracy: accurate performance information is necessary, for example form and technologies of the building envelope, with particular regard to façade orientation and solar shading, glass and balancing of the main walls, heating, cooling and ventilation systems has to be continually evaluated during the project process and not only at a later stage;
- Ability to pre-check design conformity to requirements: re-engineering the validation process: the later design stage should also allow evidence of design compliance to building and air side regulation. A faster validation step may be achieved using integrated data models, managed and controlled in a structured manner;
- Enabling flexibility: there is the possibility to carry out the project organisation to adapt the design process to a modified scenario using approaches like LCD (Life Cycle Design). The way to standardise work has also to be flexible because of the peculiarity of each building (i.e. the airport terminal),to be able to manage a wide range of design and performance issues involved in any kind of project.

8. THE MAIN BENEFICIARIES OF THE RESULTS

The direct beneficiaries of the results of this research in the construction are the designers. But as the project is the driving force, even industrial manufacturers and construction companies can implement innovative organizational approaches for the project by using the results. The approaches can be more oriented towards the development of a product with closer cooperation and a strategy of mutual benefit (Win-Win Strategy), by eliminating waste and not quality (*eliminate waste from Construction*). The end-users can indirectly benefit from the same results through the elimination of certain performance deficiencies caused by the Design Gap.

The research brings in an innovative method to define communication processes in design development by taking into account the potential of relational technologies (R-Tech).

The method used for defining strategic objectives of this kind gives business operators the tool of the User Profile that improves the performance of the communication process, by avoiding the risk associated with a *lack of information* in the exchange of data and information during the development, the construction and then the management of the lifecycle of the product until its decommissioning and demolition.

9. CONCLUSIONS

The results of the research show the possibility to fully exploit the potential of communication processes in the design project with effective methodologies, customized for the individual project. The research offers a real customized methodology for planning and management of communication processes in project teams, divided into three steps:

1 - Analysis and Evaluation Phase:

- Analysis of communication processes, through customized questionnaires;
- Evaluation of processes;
- Identification of the DGRT (Design Gap Risk Threshold) and evaluation of the positioning of the organization against the threshold set, through qualitative and quantitative analysis of responses.

2 - Planning Phase:

- Modelling of customized support tools (UP User Profile, metadata);
- Structure of communication processes;

- Planning and development of processes.

3 - Management Improvement Phase:

- Definition of the customized operative strategy;
- Implementation of the strategy.

The methodology developed in the research is in fact a Tool Box for the planning, management and control of the communication in the design project.

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