

CHANGE MANAGEMENT AND NEW EXPERTISE IN AEC FIRMS: IMPROVEMENT IN ENVIRONMENTAL COMPETENCE

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Abstract *The aim of the paper is to provide an overview of the change management inherent Architecture, Engineering and Construction firms, focusing the attention on the transformation made by environmental issues and their related drivers.*

Over the last years, building sector has become increasingly complex, due to the heavy demand of a wide range of requirements and to the globalization of the market. This leads on one side the innovation of digital tools, as a result of the development of Information and Communication Technology – ICT, and on the other the division of labour in AEC firms, that is socially spread with an even more highly specialization. The fragmentation can take place in two directions: along what is conventionally defined as the vertical dimension of the process (i.e. the sequence of operations that proceed from inception to implementation phase) as well as along the horizontal dimension (i.e. operations occurring at any given stage). The paper shows the results of the analysis carried out on some of the AEC firms established at international level, highlighting the inner structure, organization, competences and tools used in practice. The configuration of the process structure and the consequent division of labour turn out to be established by a set of internal conditions, generated by the project itself as well as the available technology. Furthermore, the decision to structure internal firm hierarchies or to have external equipment (both experts and tools) depends on the cost that the firms should undertake in order to acquire knowledge, services or products that are external to their sphere of governance. The overview gives an evidence that the explosion of product/service options and the connected specialized systems for the whole building, from exterior cladding to computer-controlled HVAC, require even more a highly amount of knowledge and skills and the demand of new competences and expertise. In particular, the study shows the increasingly request in AEC firms of experts and tools, to deal with the challenging environmental topics. Firms themselves are taking advantage by the integration of environmental topics and goals, as proven by the fact that in the top ten global AEC firms seven of them are considered environmentally friendly (source: ENR). The paper highlights that many drivers are pushing effort in that direction: on one hand, policy and legislation at international and national level, incentive programs and also voluntary certification such as Green Building Rating System; and on the other hand design firms themselves, stimulated by competitiveness or, in few case, by their philosophy.

1. INTRODUCTION

Over the recent decades, building sector has expanded and become increasingly complex, as direct consequence of the globalization of market and the demand of a wide range of requirements. These factors have a great impact on both the design and the physical realization of buildings and so on the change management of Architecture, Engineering and Construction (AEC) firms. On one side the advances in transportation and in telecommunications infrastructure, such as the new digital media and internet, generate further interdependence of economic activities across the world through a rapid increase in cross-border movement of materials, goods, service, technology and capital and above all an easiest way of communication allowing a high potential of information flow. On the other side, building sector have to meet a set of requirements even more specific and demanding, in line with the “modernist obsession” with control, optimization, efficiency and performance of their product/service [1]. In particular, the concept of quality and sustainability is spread worldwide and share at different level, introducing an even more broad spectrum of design requirements with the related constraints.

Faced with these pressures, the construction field is changing step by step in that direction, even if AEC industry is still now considered resistant to change [2]. The firm’s transformation is involving all the inner resources and so the physical, social, financial, technological and organizational factors that allow a company to create value for its customers. This resources can be divided into two type: the tangible and the intangible one. Tangible resources are all the physical items visible to everyone, such as materials, buildings, plant, equipment, tools and money, while intangible resources are nonphysical and invisible entities, such as knowledge, organization and intelligence of people [3]. Both tangible and intangible assets are involved in the AEC transformation process: the first ones with the increasingly innovation of digital tools, as a results of the development of Information and Communication Technology – ICT, and the second ones with the division of labour, socially spread with a highly specialization within the design process.

Regarding tangible resources, technology is always more relevant in AEC practice: design activity is used to take advantage of different software, but in recent times the set of tools available on the market are significantly increased, providing specific digital tools to meet any design issues [4]. New technologies are touted as an opportunity to expand the designer’s ability to solve technical problems and to deliver accurate and exhaustive projects but, on the contrary, they can be seen as a de-skilling process where plans are calculated rather than drawn. The so-called digital revolution as manifest in the AEC industry started in the early 1990s [5] with digital technology being used for computerized technical image (CAD 2D), then for virtual image (CAD 3D) and finally for information’s flow management (BIM 2D-3D-4D-5D-6D). The passage from drawing with pencils and drafting instruments to computer-aided drafting, felt momentous at the time it occurred, it was actually a mere translation of hand drawing to computerized drawing. Formally it did not change the process of design but improved the process of developing and managing drawings: the end results are identical even if more precise and little change of process resulted. The transition is now moving from drawing-based methods to model-based methods, from Computer-Aided Drafting (CAD) to Building Information Modelling

(BIM). According to Schumpeter, we can call it as “creative destruction”, since BIM completely replaces CAD as a tool and builds new markets in the process: shifting from representation to simulation, from loosely connected, orthographic abstraction of designs to behaviourally accurate, 3-D digital prototypes of designs that include extensive metadata and information [5]. In this way, it is reductive and unfitting define BIM as a new digital technology and tool, it is a new method, a new process, a new way of coordination and communication: a flow of information between different actors [6]. It puts the process of design closer to the production of building, merging production, design, construction and management into a common and shared language of digital information, involving designers, engineers, contractor, suppliers, owners and all the experts of the process. For each project its implementation is strategically modelled on a multiple-source software approach in which the software tools and plugs-in are chosen to suit the particular needs of the project. But we have to bear in mind that technology alone cannot force process change, also it has the potential to enable it.

The current scenario pushes more and more toward the understanding that in a highly competitive context the real added value lies in intangible resources [7]. As mentioned above, they stand for the set of knowledge and skills that each actor owns and uses in order to best exploit the ever changing market needs: knowledge and know-how became the basis for sustainable and competitive advantage. Indeed, to meet the heavy demand of requirements, AEC firms require even more the division of labour, which is today socially spread and always more specialized. Design process is shown as an integrated practice where autonomous units of work provide particular services to turn into systems. Architects, engineers, fabricators, contractors, construction manager, technical consultants and several specialists collaborate, make different artefacts, bring their specific knowledge to design process and increase the technical content of the production effort. In a partialized environment, the specialization of competences is even more sector-based, covering all the topics of major interest within AEC practice, such as security, energy, acoustics, structure, systems, quality and environment, followed by the connected professional specialization. The fragmentation of work takes place in two directions: along what is conventionally defined as the vertical dimension of the process (i.e. the sequence of operations that proceed from inception to the various stages of implementation) as well as along the horizontal dimension (i.e. operations occurring at any given stage). The configuration of design process structure and the consequent division of labour turn out to be established by a set of internal conditions, generated by the product/service itself as well as the potential availability of technology. Moreover, for both the employment of particular forms of labour and the adoption and application of technology and tools, a key role is played by the economic analyses and decisions of the specific firm, particularly in relation with two factors: the presence of external economies, due by scale of production and organizational scope, and the minimization of production risk [8]. Moreover, the efficiencies of internal firm hierarchies versus external equipment (both experts and tools) depend on the cost that firms must undertake in order to acquire knowledge, services or products that are external to their sphere of governance. This cost, of course, cannot be sustain by all the AEC industries and it is connected to the financial means of the firms and so on their dimensions.

Actually, the problem is that there is no pre-determined relationship between the resources of a firm and its capabilities. The types, the amounts and the qualities of the resources, both tangible and intangible, available to a firm have an important bearing on what the firm can do since they place constraints upon the range of organisational routines that can be performed. A key ingredient in the relationship between resources and capabilities is the ability of an organisation to achieve collaboration, cooperation and coordination between teams, where communication and the flow of information is considered a turning point [9]. Tools, like BIM, can be used for capturing and building collective competencies, but this is not enough and also intangible assets must be taken into consideration. AEC firms often look to technology to improve productivity, but the introduction of new tools and procedures requires the change management in the inner structure and organization and therefore a transformation in contracts, rules and responsibility of the actors engaged in design-to-construction process.

The global economic competition and the growing awareness of the importance of sustainable resource consumption are applying new pressure and demanding even more change across AEC firms. Architects, engineers, builders and all the experts involved in the process are exploiting the advancement in technology and in digital tools, redefining step by step their contracts and the organizational structure. Now more than ever practice is in the paradoxical position of being invested in the production of real, concrete matter yet working with tools of abstract representation, such as digital drawings, models and computer simulations [10]. The matter is that real world does not change and grow together with the virtual one, but rather remains behind, requiring long time of reaction to comply with technological innovations. At the same time firms and their related process need to adapt themselves to this rapid change, if they do not want to be exceeded by development in the own sector and by the competitors.

2. OVERVIEW OF AEC FIRMS IN PRACTICE

In light of what we have shown up to this point, it is important to go deep into the current practice of AEC firms to see how actually they are changing to face the over mentioned issues. What is the inner structure of the firms? What are the competencies required? What are the tools used?

To understand how design firms are organizing and equipping themselves, a questionnaire with open questions was developed and submitted to some AEC firms established at international and national level. Since there are different types of firms that today operate worldwide and that their selection can affect the outcomes of the study, it was adopted an as unbiased as possible criterion for choosing. Before starting, it's right to underline that the transformation's processes get involved especially the big and medium-sized firms rather than small ones where the inner changes are limited and less visible. In this context, the big and medium-sized firms have been identified and afterwards contacted following the ranking "Top 150 global design firms", developed by ENR according to revenue for design services performed in 2015 [11], while for the smaller firms it has been taken into account the Italian ranking "Top 100 national design firms", developed by Edilizia e territorio in 2013 [12]. Both classifications include architectural firms, engineer firms and

construction companies. Right now, another aspect to point out is that seven of the ten global design firms are considered environmentally friendly in accordance with ENR, leading us to assume that firm themselves are taking advantage by the integration of environmental topics and goals.

During the study, AEC firms are analysed as groups rather than as individuals, trying to identify and summarized the current practices and tendencies (companies cannot be named due to privacy concerns). The following analysis is structured in three sections. The first section gives a general overview about the size and the competencies required inside the firms. The second section deals with the structure and the organization of the firms, depicting the operational units and sub-specialized units, the potential support of external partners, the different ways to manage and tackle the design process, the potential use of BIM tools and the information's flow between the different actors involved. The third and last section is related to environmental issues where are pointed out the main drivers of such topics, the main goals addressed, the main experts who handle them, the main environmental consultants if any, the possible evaluation of the environmental impact of materials/products and the use of Life Cycle Assessment as support in decision making for projects/services development.

2.1. General info of AEC practice

The questionnaire was filled mainly by architecture and engineering firms, since the contacted construction companies have not yet replied. Moreover, AEC firms in question are often integrated structure and thus involve both architecture team and engineering team in order to work jointly and all at once on the different projects. It is a design approach which brings together design experts usually considered separately, for example combining architecture, structural engineering and HVAC, typically to achieve the share goal to produce sustainable building. Indeed, integration appears like a prerequisite to respond to the increasingly complexity of the building sector and to get to sustainable design that ensures the control of costs, time and quality of the project.

As previously mentioned, this study keeps out the smaller firms since they have not seen meaningful changes over time, not making a significant contribution to the research. The involved practices are defined as big and medium-size firms, encompassing on one side structures made up of 200 offices and 10,000 employees and on the other smaller structures made up of 10 offices and 80 employees. The sprawl of many branches all over the world is for the firm's perspective a key factor to be in close contact with the traditional culture and the local reference standards, being very different from country to country. The AEC firms' head office is usually placed in North America or in Europe with branches positioned especially in the Middle East and in Asia, but also in South America, Oceania and Africa.

As regard the competencies embedded, two are the main features of every design practice: the multidisciplinary of actors, since multiple players are essential to make up a project of any size, and the relationship of interdependence between experts, since no one reaches the goal alone but being part of a team. Within AEC firms the areas of expertise are several in order to address all the issues of the projects arising from the different

disciplines and to be able to meet the wide range of requirements. The main expertise for architects involve: architects, interior designers, landscape designer, industrial designer, urban planner and lighting designer; while for engineers they involve: mechanical engineers, structural engineers, plumbing engineers, electrical engineers, transportation engineers, environmental engineers, water quality engineers. In addition to the traditional design subjects mentioned above, there are also other professionals within AEC firms, such as project managers, economists, fire prevention specialist, technical and administrative specialists, acoustic specialist, environmental specialist, security specialist, quality specialist, climate scientists, biologists and so on. Of course not all of the listed skills co-exist inside all design firms and their presence depends on the size of the company, the prevalent kind of projects/tasks and the main type of clients and final users. However, it is right to underline that at the end all members are mutually responsible for the project's outcome and that each activity is fundamental to the overall output of the system. Indeed, the multidisciplinary approach and, at a lower rate, also the multicultural one have become over time increasingly important within the design practice, representing a key role especially in the firms with an integrated approach.

2.2. Structure and organization of AEC practice

The inner structure of the firms interviewed is always split in an administrative area, in a commercial area and in a technical-operational area. In the big and medium-size firms, the technical-operational area is in turn divided in sub-specialized units to meet the emerging issues such as energy, system, ICT, quality and safety, just to mentioned a few. Every unit is made up of specific teams, while in the smaller firms they turn out to be individual experts. Also in this case not all the specific units, with the related experts and specialists, are embedded in all the analysed design structures. However, their existence shows the growing interest to the performed issues and their strengthening over time, to the point that a specialized area was established in response to that matters. When for economic and/or organizational reasons not all the required different skills are present internally, AEC firms rely on external partners to meet the specific design requirements. For smaller company this happens quite often, especially if they deal only with architecture or engineering, but also for the integrated design firms, where this need arises in particular for special equipment. Nevertheless, even big firms, also if they technically can handle all the aspects of a project, prefer when necessary to have external partners that know local requirements and have better skills set in certain areas.

Due to the increasing specialization of competences and skills, the traditional linear process, where activities were performed sequentially to address the different project phases, turns out to be unsuitable to AEC current needs. Building process is changing from linear to circular: all professional experts are present starting from the early stage of the project, adding value and make improvements in the decision-making process. In this perspective, especially with regard to complex projects, coordination, collaboration and communication are necessary conditions to ideate and realize a project according to time, cost and quality. Indeed, the totality of the AEC firms confirm the synergic presence of the different experts starting from the early design stages, even if they outline that every

project is unique and characterized by different scopes and set-up. On the whole, design practices share a holistic approach which includes key steps and milestones, to ensure the conformity to the initial goals through project's reviews, checks and approvals. In this context, they usually set all sustainable targets and vet all strategies in the concept or schematic design phase, for example including energy modelling with payback analysis. Then, when the design stages become more extensive, all teams detail the content of their work to generate a coherent and comprehensive information package. This practice is strengthened in big and medium-size firms, while in smaller firms it is still limited or otherwise restricted to specific projects.

All the AEC firms interviewed claim to be BIM-oriented even if it is not clear, also with regard to their size, at what stage of development they are. Indeed, in literature there are three different stages to implement BIM in a company: the first is the object-based modelling, the second is the model-based collaboration and the third is the network-based integration [13]. In practice, Revit is the most widely used BIM software, especially for architectural design, while for particular project of engineering design is still employed CAD, although there are exceptions. BIM models are used as support for exchanging design data, but also to make verifications by other software, for example through the use of many energy analysis plug-ins for Revit but also stand-alone modelling software. Moreover, to facilitate the flow of information every AEC firms interviewed have an intranet site that contains all project's tools and resources, accessible for simultaneous work from any office/staff. This is usually attended by a quality control leader which ensure that each project is going in the right direction through the specific tools provided by the company.

2.3. Environmental issues in AEC practice

Environmental issues are generally addressed by AEC firms within the design process, even if there are substantial differences with reference to their structural dimensions. Inside big firms, environmental issues are constantly subject to review, in some cases only due to the need to meet regulatory requirements, but in the most virtuous cases because they share the principles and the philosophy behind. Moreover, many of them have signed international and national policies, such as happens in USA with AIA 2030 Commitment, which requires that firms strive towards a 70% energy reduction from the average in all projects, regardless of the scope or project requirements. For the smaller firms, even if environmental issues are an integrated part of design practice, it is not always possible to apply certain types of solutions since they are often not recognized as an added value by the public or private clients. Indeed, there is a large gap in the awareness of environmental matters, which could be contrasting in the different countries of the world. Nevertheless, the main drivers that pushing in that direction are generally the growing consciousness that market have on the subject and the consequent regulatory requirements and/or voluntary certifications, such as Green Building Rating System. In addition, the same companies underline that nowadays a lot of private clients have adopted sustainable targets as part of their base design standards, encouraging the firms to seek new and better solutions for the built environment and to minimize the impact of the projects.

AEC firms usually stress environmental issues according to the type of project but generally, as is shown by questionnaire's feedback, energy and water have been the focus for the past 5 years, while health and wellness are emerging as a hot topic for 2016 and beyond. Big and medium-size company usually try to comply with all the aspects of environmental and human impacts, while smaller company mainly deal with energy issues, since it is the subject that raises more interest in clients and customers. As already mentioned, the experts who handle this issues are single experts for smaller structures and working groups for big and medium-size firms. These teams exist in the structures both at local and global levels and are specialized in delivering high performance projects thanks to specialists in energy modelling, water, materials, health and wellness. They have the task of lead the design team to sustainable thinking, where at the end it is expected from everybody the awareness of these issues and problems. Occasionally AEC firms bring on external environmental consultants and, despite what we usually think, this happens not just in smaller structures but also in the bigger ones. Indeed, some of the most important companies, although embedded all the expertise in house, sometime prefer to be supported by a third-party contractor, if there is a strategic partner that can enhance the project.

Concerning the tools commonly used to meet environmental issues, we can assert that firms are spoiled for choice. In fact, an infinite number of tools are available on the market for energy simulation, as Equest, Energy Plus, Pro Energy and CFD, for lighting simulation, such as Radiance, Daysim and Revit Solar, for the impact assessment, as Sefaira, Trane Trace and IES, and many others. In this way, interoperability is seen as a crucial and decisive factor to eliminate duplicate effort and to speed information flows. Indeed, it allows to make different systems and software talk to one another: at a technical level, it refers to the process of streamlining information exchange between two or more model platforms, while at an organizational level, it refers to the ability for different stakeholders to work together towards a common goal. Poor interoperability sets limitations on team's ability to be flexible with their tools and often force them to restrict the range of tools even if there are clear benefits from their possible use. However, AEC firms are used to take advantage of different software available on the market and/or in-house software, developed mainly by big firms to suit their own needs.

Actually, the minority of the firms interviewed and above all the ones with a large size, use to attach in the BIM model the environmental information of the products. In these cases, they seldom include personal data but utilize application with internal database, like Tally (with GaBi database) that lets you calculate the environmental impacts of your building material selections directly into Revit model. With this information they aim to perform the Life Cycle Assessment of the project, developed typically starting with the first large impact, such as concrete, steel and façade, and then work down to the smaller installation items. However, in most AEC firms today is not carried out an LCA study of the projects/services, even if begin to feel the need since the method has been included in some criteria of Green Building Rating Systems. There are also instances of companies that rely on external environmental consultants focused on life cycle services to develop LCA analysis.

3. CONCLUSIONS

The overview displayed of Architecture, Engineering and Construction firms' practices emphasizes the increasingly complexity of the building sector and the resulting need for change management. Involving both tangible and intangible resources, it is little by little establishing itself and taking part in the current practices, leading to many changes in the inner structure and organization, demanding even more new competencies and expertise. Moreover, the use of innovative technological tools, such as BIM, and the involvement of a growing number of actors engaged in the design process bring up the need to review contracts, rules and responsibility, since that they have not yet been defined.

The interview and analysis of the current practices inside AEC firms have been developed with the aim to understand not only how the real world in a sense is chasing the virtual one, but above all to understand how the wide range of requirements are addressed taking an internal perspective. Environmental topics and goals are surely very challenging, bringing out new pressures and more radical transformations inside design companies. Indeed, contrary to other sectors where different issues can be managed in a more or less autonomous way from team or specific experts, environmental issues involve all the actors engaged with significant repercussions in the decision-making process. In this context more than ever, collaboration, coordination and communication play a key role in making sure that firms' resources turn out to be first "capabilities", or in other words minimum ability, and later "maturity", that means quality achieved by good practice. This inclination to combine different fields to meet design complexity is confirmed by the growing number of integrated design practice, where usually the sustainable targets are set and developed from the early stages of the project.

AEC firms deal in different ways with the design process that is commonly established by a set of internal conditions, generated by the product itself as well as the potential availability of technology and expertise, the type of clients and so on. Concerning to this, the dimension of the company is extremely important, both for the economic and organizational possibilities and for the network embedded. The choice within the explanation to consider the AEC firms interviewed as groups rather than standalone entities is deriving from the wishes of identify common trends rather than individual peculiarities. In fact, being aware of the many factors that may affect the choice, it is not possible to define a best practice in this field. Certainly bigger firms are more advanced than the smaller ones and represent a practice's reference models, although difficult to apply and be reduced in lowered contexts.

In conclusion, it is sure that the global economic competition and the growing awareness of the importance of sustainable resource consumption are applying new pressure and demanding even more change across AEC firms. The challenge is to be able to integrate environmental issues in all practices, regardless of their size. For this purpose, further analysis are required to understand the current AEC practices, where the examination of real case studies could become a turning point for understanding the real interaction between tools, experts, requirements and targets, but also the flow of information between the several actors involved in the different phase of design process. Technology has

undoubtedly a great potential that, if exploited skilfully, can be implemented in the smallest structures in order to spread environmental issues in a broader number of projects and thus to reduce the environmental impact of the building sector. The problem is to understand where, when and how it makes sense to take action, since with little and precise solutions could be achieved remarkable results. In any case the question has to be addressed as soon as possible to bring benefit to all of us as well as to the environment.

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