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Development of a process mapping for glass façade renovations

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ABSTRACT: The design and construction process of glass façades intended for renovations involves complexities, which integrate different issues such as load-bearing structure, building services, building physics and, not least, architecture. There is a multitude of developments and requirements that demand new strategies for the future application of glass envelopes in renovation contexts. The presented work has planned to carry out a literature research and a series of interviews with designers and experts in the field of glass façades and renovation projects. The aim of the investigation was to learn directly what are the main strategies that can be adopted and what are the main problematic aspects. The paper presents a map of the design and construction process for glass façade renovations and an overview of the findings of the interviews as a basis for the development of support tools, to help the efficient storage, access and transfer of design information.

1 INTRODUCTION

For centuries, the main functionality of glass elements in façades has been to meet three principal requirements: to let in daylight, to grant a direct view of the immediate surroundings and, at the same time, to provide protection against wind and rain. The use of glass in architectural applications, especially in façades, has spread recently, in order to meet the current trends of lightness, robustness and energy efficiency.

The quest for performing façades towards extreme transparency is required also in renovation projects, in case of routine maintenance, change of use or ownership and to comply with new codes. Nowadays, the energy-efficient renovation of existing glass façades or using new façades to "wrap" existing buildings is a central issue to qualify and reuse our architectural heritage.

In addition, the study and the use of glass façades develops into a regulatory framework that is still poorly defined and constantly evolving, regarding both design issues (i.e. lack of detailed standards and guidelines for glass structures; enactment of EPBD, Energy Performance of Buildings Directive of the EU, which involves the envelope performance), and requirements for building materials and systems (i.e. enactment of CPR, Construction Product Regulation, with the mandatory application of CE marking from 1 July 2013).

Due to the current technical improvements, the design issues and the standard requirements, dealing with glass façades is taking on a fundamental role during the design and construction process, both in case of new construction and in renovation projects (retrofitting and/or upgrading). Such trend suggests to study and carefully define the entire design process of glass façade renovations, to analyse the main issues related to the design, the engineering challenges and the possible future developments. The aim of the project was to collect data and information on existing design approach towards renovation projects with glass façades, in order to provide an overview on the design process, the related main issues and the best practices.

2 RESEARCH DEVELOPMENT

2.1 *Methodology*

The present work has developed a map of the design and construction process for glass façade renovations. The map uses BuildingSMART's adaptation of Business Process Map Notation and extends a map already developed for the construction of new façades (Voss & Overend, 2012). Basically, the development of a simplified version of the map was based on state-of-art and literature research.

Then, the map has been verified by 10 interviews with experts in UK (6) and in Italy (4). The interviewees were selected among architects, engineers, industry professionals, all of them with a strong experience of designing glass structures and/or of dealing with renovations projects. The interviews were carried out in person and consisted of a 1-hour meeting. The interviewees were asked to comment on the map, step by step, in order to correct and eventually integrate it, talking freely of the topics they consider to be most relevant with respect to the subject matter. The first version of the map has been then reviewed and validated.

The interviewer had prepared a series of questions to discuss with the stakeholders in order to deal with some specific issues during the meetings. The questions were related to:

1. *What are the main features of glass façade design and construction process, especially for renovations?*
2. *What are the differences between new construction and renovation projects in glass design?*
3. *What is your experience with different types of glass façade renovations? Which do you find more challenging?*
4. *What are the differences between new construction and renovation projects in glass design?*
5. *How has the process been evolving?*
6. *What are the process steps, and how are they linked?*
7. *What are the weaknesses and the challenges for glass façade engineering?*

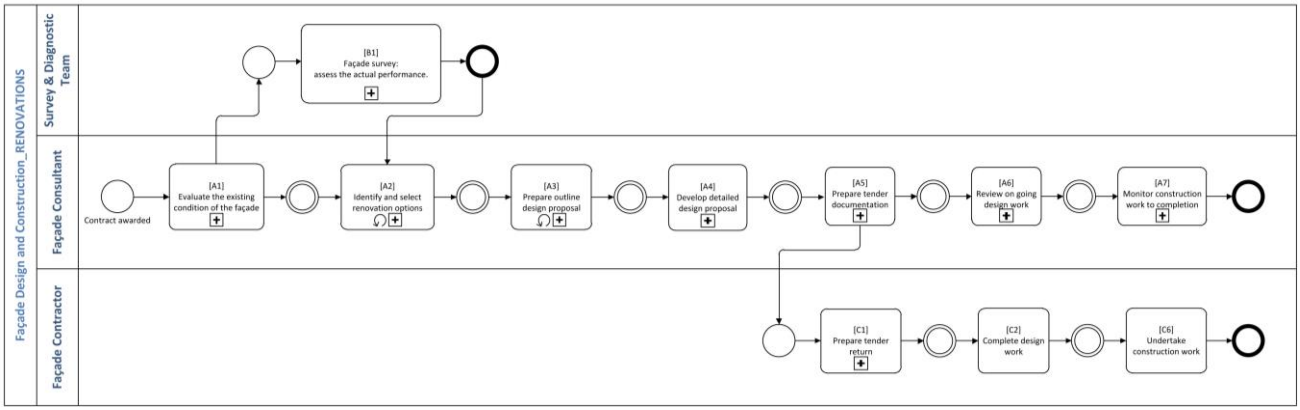

Figure 1. The final map.

The main task was to enhance a process mapping for glass façades renovations; the development of the process mapping has showed that one of the main issue when dealing with an existing envelope is to assess how it is actually performing now. The evaluation of existing performances shall be deduced by monitoring and in-situ tests, concerning thermal and structural behaviour. The number and the types of monitoring shall be defined in the early steps of design, to undertake useful surveys and obtain the information for the baseline benchmark: this is the basis to develop technical solutions and to compare different options.

Three stages of the entire process map are analysed in further detail, namely (a) the assessment of the actual performance and (b) the selection of renovation option and (c) the preliminary project. The work presents an overview of the findings of the interviews and is the basis for the development of support tools, to help the efficient storage, access and transfer of design information. An extensive explanation of the method of preparation of the map and the list of questions is not reported in this paper due to lack of space, but they are included within the PhD thesis of the author (Marradi, 2013).

ACTIVITY A1. EVALUATE THE EXISTING CONDITION OF THE FAÇADE (FAÇADE CONSULTANT).
ACTIVITY B1. FAÇADE SURVEY: ASSESS THE ACTUAL PERFORMANCE (SURVEY AND DIAGNOSTIC TEAM).

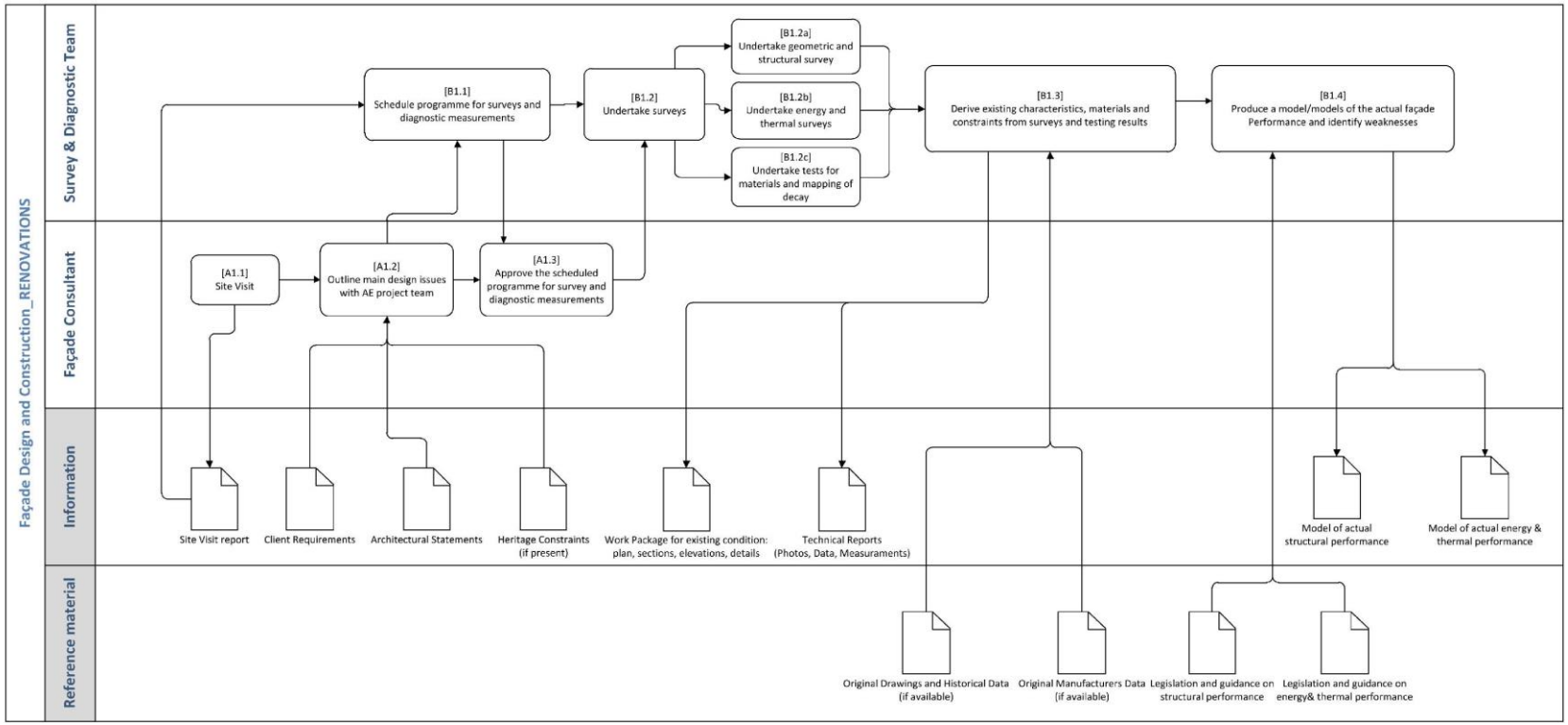

Figure 2. Activities A1 and B1.

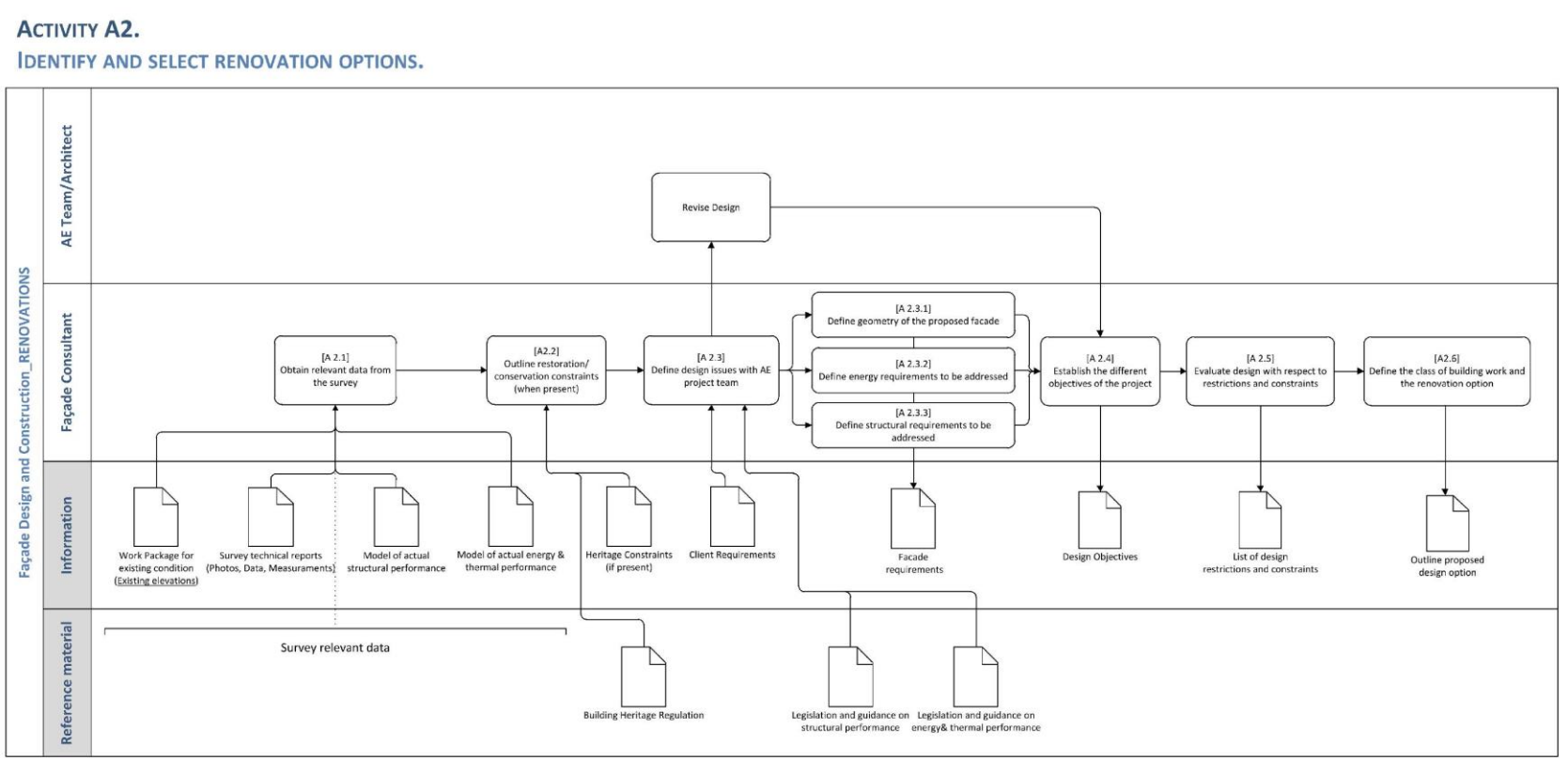

Figure 3. Activity A2.

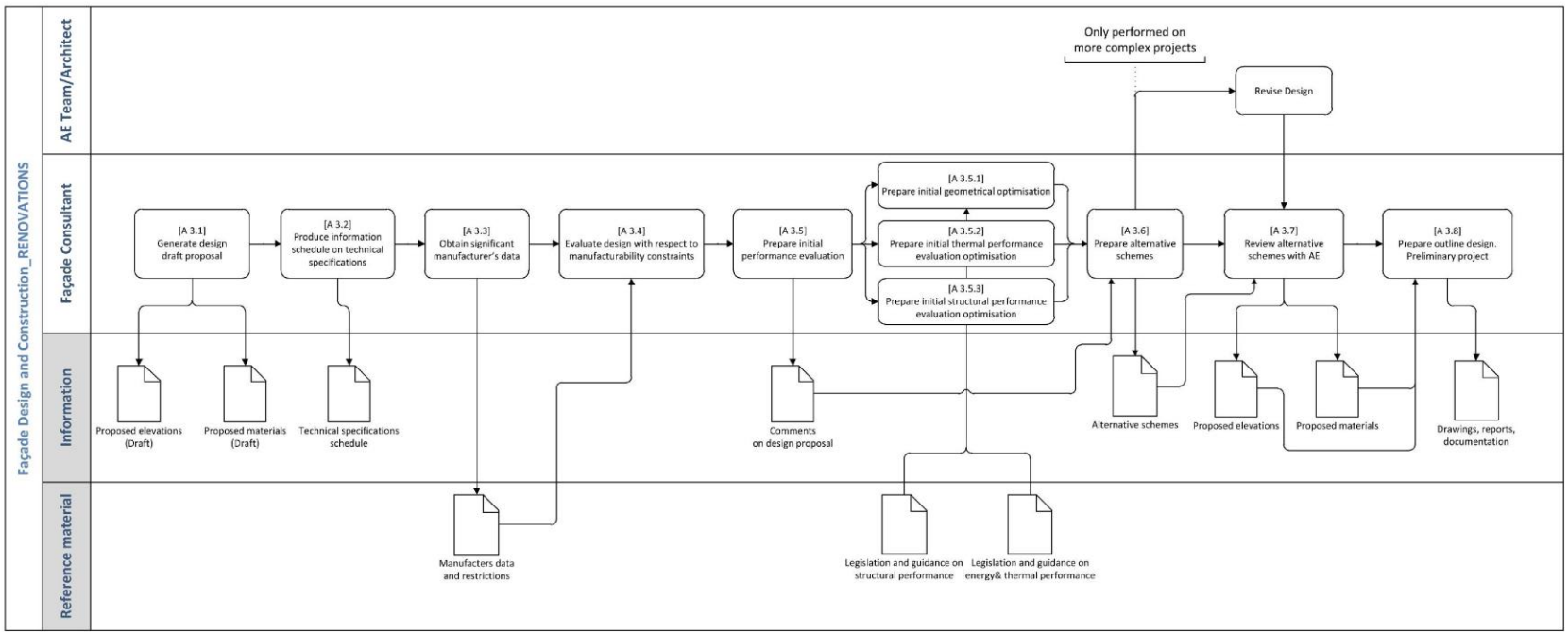

Figure 4. Activity A3.

2.2 *Why modernising a glass façade or using a glass façade for renovations?*

All the respondents confirmed that an increasing interest in glass façades in case of upgrading and retrofitting is detectable, since glass envelopes can be used in different building types, finding application in public buildings, banks, museums, commercial and residential buildings, and even in archaeological/historical sites.

The examples of renovation and reuse of abandoned buildings through a wide use of glass highlight how it allows the historical readability of a place. Nevertheless, glass construction, if used without understanding, can destroy space and architecture.

Modernizing buildings with new envelopes improves the value of a property. Thereby the operating costs are reduced. There is a wide range of improvements, mainly regarding:

- Energy efficiency,
- Functionality,
- Comfort,
- Appearance.

Two of the respondents, who work in both the UK and the USA have shown that sometimes the projects and upgrading / retrofitting are imposed by local laws or by the insurance companies who have the management of commercial buildings in the City. Some American city councils require periodic inspections on the facades of skyscrapers: the New York City Department of Buildings has instituted Amendments to Local Law 11/98, the law that requires buildings taller than six stories to have their facades inspected every five years. Façade inspections must be conducted, witnessed, or supervised by "Qualified Exterior Wall Inspectors".

Such interventions involve structural and performance improvements both for the opaque and the transparent envelope, which is often the weak point of the system. In addition, it should be noted that the major part of tall buildings is nowadays made with glass façades, using different technologies and finishes: therefore the retrofitting of glass elements in existing buildings is becoming more and more relevant.

This strategy, which involves monitoring, inspections and checks on the building envelope, it is not yet widely used in Europe, but all the interviewees agreed that the trend in the coming years will be directed to this approach.

2.3 *Classes of existing buildings*

On the basis of the data collected during the interviews, it is possible to make a division of the main categories of buildings that can be involved in retrofitting/upgrading operations using glass façades: architectural monuments, listed buildings, existing buildings with "minor" historical value (no listed buildings).

Figure 5, 6. Bauhaus in Dessau, after renovation.

Architectural monuments play a significant role for the identity and the history of a society; their energy performance is usually poor. Typically the categories of intervention allowed on this kind of buildings are only repair, restoration and replacement with elements of the same material and the same sized, both as regards the glazing and the frame. Thereby, the energetic

renovation will be taken behind the heritage protection. The energetic improvement shall be always compared to the baseline case, i.e. the existing performance.

Some of the most important interventions in this context, which have treated glass façades as real monumental elements, concerned iconic buildings for modern and contemporary architecture, such as Faguswerk in Alfeld, Bauhaus building in Dessau, Schillerpark in Berlin: all of them are listed in UNESCO World Cultural Heritage.

Existing building with "minor" historical value usually belong to a large part of real estate in Europe, that is not monumental, but old and aesthetically appreciated, too expensive to demolish or to adapt to the new regulations.

Thereby, in order to reduce energy consumption and CO_2 emissions, a large part of buildings from the 1950s and 1970s are being now refurbished. They usually do not comply with the stricter standard building regulations introduced in recent decades and therefore they often need to be renovated not only in terms of energy efficiency, but also to improve serviceability and robustness.

More than half of the respondents had to deal with an intervention of this type of buildings, both residential and commercial facilities. They all confirmed that the renewal of an existing building has a creative potential and allows to present a new modern appearance to the façade and, at the same time, to optimise the building's energy efficiency.

In some cases, especially in retail department, commercial and office buildings, the interviewees have been requested by the client to use a glass façade for aesthetic purpose only, in order to give new expression to their corporate image, improve communication and facilitate the rental of the building.

Work on buildings that are listed by the Architectural Heritage, but not considered as monuments, represent an intermediate category as the constraints do not affect the integrity of the façade as a whole. Regarding this category, there are several design approaches, which vary case-by-case, but generally it is possible to replace the glass elements and frames with new materials and façade systems.

2.4 *Categories of work*

The analysis of the different case-studies proposed by the respondents allow us to identify three main classes of intervention on glass façades, which can vary as a function of the building category. These classes consist of selective reconstruction, recladding and over cladding.

In a *selective reconstruction* only those members of the glass façade that are defective would be removed and replaced with elements that are identical or similar. Examples would be the selective replacement of corroded portion of steel frames, reglazing of existing frames or the local repair of sealants and gaskets.

Recladding is the removal of an existing exterior system and replacing it with a new system. Typical reasons for recladding include water/moisture damage, general upgrade or replacement of improperly installed systems. The overall recladding of a glass façade can imply the use of high-performance glasses, that can significantly improve the comfort inside the building and the performance of the envelope. The recladding option has become quite popular with the 1950-s skyscrapers because it allows the owner to complete update the image of the building as well as install a state-of-the-art curtain wall that will perform in a superior manner if compared with the original curtain walls. This option, however, is bound to become more controversial as a building becomes listed or landmarked.

The concept of *over cladding* is now well established as a means of regenerating older buildings. With the over cladding the original wall system is left in place and is clad with a new curtain wall system: nowadays glass façade systems are used widely to over clad, because of their versatility, the ability to integrate in any context and to fit in with different architectural styles and materials. New over cladding can serve to restrain and protect the existing façade such that the regenerated buildings life expectancy is comparable to that of a new building.

Experts confirmed during interviews that warranties are available to cover both the existing structure/facade and the new over cladding as they are mutually dependent upon one another for performance and longevity. A wide variety of cladding solutions exist that offer an equally wide variety of life expectancies, performance and aesthetic properties. To refurbish, meeting only minimum standards, extending the buildings life short term for say 20 years is to pass our

inherited problem to the next generation. Quality, long term, 60 year life systems exist that can readily surpass current standards by 50% for additional capital expenditure of circa 15% over the cheapest solution. An example of over cladding is the renovation of "Bergognone 53" complex in Milan, Italy, as a result of an international competition by real estate developers, Hines.

The former Postal Service building is located in a former industrial area and complete urban block, four building with an inner court built in the 1960's and 70's. Renovation preserved the existing internal space, whilst updating the design of the building for new functions. The before and after renovation images of this building are shown in figures below.

Figure 7, 8. Hines Office building in Milan before (left) and after (right) over cladding.

The new transparent outer skin follows the modular structural frame of the block. The more exposed south-west side has a "second skin" projecting 600 mm that acts as a large sun blind or passive filter. This second layer reduces solar radiation, thereby lowering air-conditioning energy requirements. "Chilled" ceiling beams, partly behind perforated suspended ceilings, are connected to the ventilation system and to part of the lighting circuit. The internal courtyard was completely refurbished using a structure of suspended steel and glass.

The architectural model's overall energy consumption requirement has been calculated at 145 kW/m^2, which represents up to 50% energy reduction. A similar façade in a standard cladding material would lead to 280 kW/m^2 energy consumption.

Feasibility assessment must be accurate and comprehensive to allow the informed decision-making process to work effectively. The interviewees stated that past project examples of most cladding and window options are available up to 20 years old: they can be examined and reported upon such that the industry learns and progresses, improving efficiency. Over cladding will normally have an impact on the appearance of the building.

During the interviews, it was found that one of the main issue related to the process of redesigning existing glazed façades is the connection of the new façade supporting elements to the existing structure of the building: most of the interviewees (80%) underlined that the assessment of the characteristics of existing structures and materials is crucial to design joints and anchors able to resist to additional loads.

The renovation of a façade can also be wired entirely from the outside, whilst the building is still in use. Manufactures has developed systems and high-efficient components that can be installed keeping the building in operation; this means that the underperforming existing windows on the inside can be removed efficiently and to a precise deadline.

3 DESIGN AND CONSTRUCTION PROCESS FOR GLASS FAÇADE RENOVATIONS

The different steps of the design construction process for glass façades in renovation projects has been deeply discussed during the 12 interviews. The focus was mainly on the early stages of design, since they seem to be, according to the interviewees, the fundamental and crucial moment for the future development of the project.

The interviews with the general designers (architects, engineers) have shown that often they lack of the basic knowledge to understand, in the early stages of project design, what are the technological solutions and the products available, and what could be, in broad terms, the impact of such choices on the performance the façade. On the other hand, the façade consultants highlight that their role "engineering" becomes extremely complicated if there is an initial inconsistency, for example, on the structural level. The problem is that the use of glass systems intended for renovations involves complexities, such as geometry, aesthetics, technology, structural and thermal issues, that are often difficult to manage during the whole development of a project. The information collected during the interviews leads us to reflect that one of the key-criteria for the success of lies in the organizational structure of the design process and the related construction phase.

The increased complexity in general of curtain walls and of glass façades caused a development from craftsmen structures, as happened in the '50s, to sophisticated building systems, without however excluding the contribution of manual skills in some specific stages of the assembly process. Fully industrialised façade construction is still far off.

The main difference between the façade sector and other building disciplines is the strong relationship with architecture and aesthetic meaning: the building "skin" is always related to a specific context, creates a language with the surroundings and communicates (or even deny!) the building task.

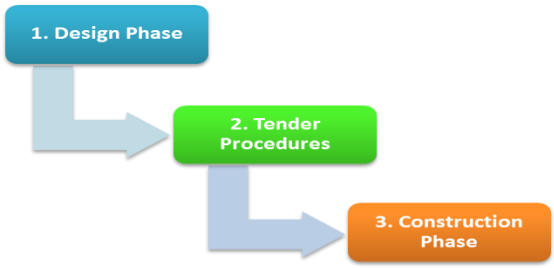

Figure 9. The design and construction process

Therefore, from a management point of view architecture must be primarily project-oriented: this differs from other industry sectors which work product-oriented. This is particularly true in the design phase, but it also affects the development of tender procedures and, not last, it becomes a fundamental approach in order to transform architectural design into built construction.

The design and construction process describes in which way different stakeholders interact to create a façade: the stakeholders include sponsors, designers, consultants, system providers, general contractors, users and anyone that is involved in the decision-making process. The process starts with the design of systems prior to the actual building project and ends with the end of life phase of a façade construction.

The main feature of the traditional design process, that has developed over thousands of years, is the scanning of possibilities, striving for the optimum-specific solution. Specific disciplines and craft skills have developed with a defined focus, with the purpose of providing quality assurance of a specific task. Basically, the originally "linear" project structure and its division into different disciplines have been the basis for the development of tender procedures and of the construction structure.

This organisational structure is sustainable only as long as the complexity of the process is not very high and specialized skills can be managed and resolved directly. In this scheme, it is accepted that the level of project definition and detailing are not very accurate, since many of the conflicts can be resolved in the realization phase, case-by-case, thanks to the experience of the architect or team work that manages and coordinates the construction process.

The increasing complexity of modern construction requires that the conventional and linear process needs to be complemented by additional, more-in-depth skills since the early phases of design. This is mainly true in complex building sector, such as façade design and construction for renovation projects.

The objectives, the constraints, and the milestones that characterize the work, should be clear already at early stage. In addition, the designers needs reliable statements about the performance of systems and products. At the same time, product flexibility needs to be maintained in order to manage possible changes during the design process. This leads to a modular construction method in which the design process and its phases are dealt with an iterative approach to improve the deliverables for each work package. Such way of dealing with the problems that arise during the development of a project can be easily compared with quality control methods for management.

4 CONCLUSIONS

The investigation demonstrated that the design and construction process to renovate/upgrade glass façades is a complex operation and requires a fundamental knowledge of the physical properties of the material, the different available products and façade systems, and the accessories (shading devices, elements of completion etc.), that can ensure a proper functioning within the building. Dealing with existing facilities means that many unknowns and variables emerge within the project, case-by-case, and they must be recognized and managed.

The project-oriented and iterative design process has a crucial impact on the way glass façades are constructed but sometimes the fragmentation between the stakeholders is relevant and it is time-consuming and leads to increased costs and low performances.

There are still many problems regarding glass applications, and therefore new challenges for designers and researchers can be exploited. The lack of detailed standards and guidelines leads to a confusing design process and often designers are not entirely aware of the advantages and disadvantages of dealing with glass. In the future, we will see an increase of interventions on the existing building in particular on the transparent envelope. The "use" phase and the "end of life" phase in the process of design and construction will rapidly gain importance. This means that new approaches that consider all these different aspects will be required in order to deal with the rising performance demands, the growing complexity of interventions on existing buildings and the fundamental role that the glass envelope plays for the building as a whole.

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