

The role of conceptual structural design in the Architectural Education

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Abstract: Modern architectural design requires a strong multidisciplinary component. This paper deals with the subject of teaching Conceptual Structural Design at the School of Civil Architecture of the "Politecnico di Milano" and the "Université catholique de Louvain". In particular, the course, from which the final example was taken, was held at the Politecnico di Milano, in the second semester of a first-year Civil Architecture Master in 2014. The course, characterised by a strong multidisciplinary, aims to deal with the project of architecture not only from the architectural composition point of view, but also from the point of view of the other disciplines that are involved in the design process. The didactic activity carried out has allowed to make some considerations on the classical design strategies (Top-Down, Bottom-Up) and to search a multidisciplinary approach with more emphasis on the collaboration among various disciplines.

The theme developed seems to be of great interest for the teaching methodologies as well as for developers' tools supporting the design process.

Keywords: Education in design; Conceptual structural design; Design strategies; Didactic activity; Architectural design.

1. INTRODUCTION

In recent years Structural design, whether it refers to new buildings or to the recovery of existing buildings, has assumed an ever more complexity. New design principles have been introduced, in order to minimise the cost of the structure for the society and improve the safety of buildings, thus reaching an aware design not only of the structural problems, but of all the main disciplines which are involved in the design phase and the realisation of the building.

Moreover, many exponents of contemporary architecture conceive their projects by exploiting all the possibilities that modern science and technology offer. Just think of the Portuguese Pavilion Expo '98 of Alvaro Siza (1998), of the Olympic Stadium of Beijing of Herzog and de Meuron (2008),

of the Sendai Mediatheque (2001) and of the Taichung Metropolitan Opera House (2014) of Toyo Ito.

Nowadays it seems clear how structural themes must intervene in the design process just from its early phases of development, that is during the so-called Conceptual Design phase. The Conceptual Design is by now universally recognised as one of the early design stages, in which reasoning involves designs and solid models (Austin 2001, Rehman and Yan 2007). In this stage, the designers provide a description of the final product in terms of ideas and concepts in order to envisage how the final user can use their product and most part of the strategic choices are carried out and important decisions are taken. Even though a great amount of information must be handled in a relatively short time, the Conceptual Design is the part of the design process less supported by dedicated tools. This lack is probably due to the difficulty in translating the insights that arise in the early stages of a design into a numerical mathematical language when nothing has yet been defined, and to the remarkable difficulty of interaction among the different disciplines which intervene to define a project, and which often require different professional figures (Garavaglia et al., 2020).

In the last years many authors have been involved in integrating the Conceptual Design in the designs tools that computer science makes available to designers. In Malekly (2010) a fuzzy methodology is proposed to be suitable to assist the project manager in the decision-making phase of a bridge. Such methodology, which uses fuzzy mathematics to take into account linguistic assessments, evaluates different design requirements, among which even aesthetics, the complexity of construction and durability. Always in the ambit of linguistic information and of qualitative assessments of choices, Akay (2011) proposes a fuzzy methodology for the decision-making phase of problem solving. In Arnout et al. (2012), instead, a tool of structural optimisation is proposed able to work within the early stages of the design, when choices are not yet well

defined. Remaining in the theme of development of tools useful for the design, in Hofmeyer and Davila Delgado (2013) a virtual toolbox is presented (under development) able to turn a space design into a structural design.

The concept of multidisciplinary design is fundamental in the design of modern engineering constructions, however it is a relatively recent research field (Hirt and Luescher 2007, Geyer 2009, Lefèvre et al. 2014). The main difficulty, in integrating the concept of multidisciplinary within the tools of support to design, is undoubtedly the organisation and the sharing of information. In the last decades, various authors have studied the way to decompose problems and procedures (Liikkanen and Perttula 2009, Sarkar et al. 2009, Arangio and Bontempi 2010), organise information (Austin et al. 2001, Chakrabarti and Bligh, 2001) and provide tools of development which may allow designers to work in a team (Fuyama et al. 1997, Wang et al. 2002). The use of web technologies has finally provided new opportunities of exchange, above all for tools which develop multidisciplinary approaches (Lee et al. 2009). Despite the substantial effort made in recent years, the author concludes that at least two questions remain substantially open:

- The tools developed and present in the literature, are mostly related to monodisciplinary problems. A remarkable effort should be made to extend the concepts and the tools developed for the phase of the Conceptual Design to the various disciplines which are involved in the design process and which have different organisation, language and calculation requirements.
- A no less remarkable effort must be carried out in design schools (engineering and architecture) to educate the future designers to focus on the phase of Conceptual Design, currently recognised as the most important phase in the development of a project, and to make it multidisciplinary.

In this paper an abstract space will be proposed, where the design path of a designer can be visualised and the design experience of a student of the M.Sc. Architecture of Building of the “Politecnico di Milano” will be analysed (Sgambi et al. 2019, Garavaglia et al. 2020). Using the example proposed we will demonstrate how a mono-disciplinary approach to the project (where different disciplines intervene in sequence) is not the most efficient way to proceed. Finally, how a multidisciplinary approach to the Conceptual Design phase can significantly reduce the divergence phases in the conception process will be shown.

2. THE DESIGN ACTIVITY IN THE ARCHITECTURAL DESIGN

The design process is a highly non-linear creative and strongly multidisciplinary activity (Blockley, 1980). Particularly in the architectural design, a very large number of disciplines are involved: urban planning, architectural composition, structural calculation, energy, technology, landscape architecture, construction cost estimating, acoustics, brightness study and others. In this paper, only the following disciplines will be considered: architectural composition, structural engineering, architectural technology and energy engineering. In fact, these four disciplines have the leading role in multidisciplinary design studios in which the author has had the opportunity to teach. However, the developed considerations may be applied to a wider context.

2.1 The visualisation of the design process

Several authors tried to visualise the design process (Cross 2000, Singh et al. 2012, Claeys 2013). In particular Cross (Cross, 2000) describes the design process as a succession of convergent and divergent phases which, from an initial concept lead to a final solution (Figure 1). The model is a “dynamic” model, as it tries to highlight the iterative features of the design, even if the space in which the design path is visualised, remains essentially indefinite.

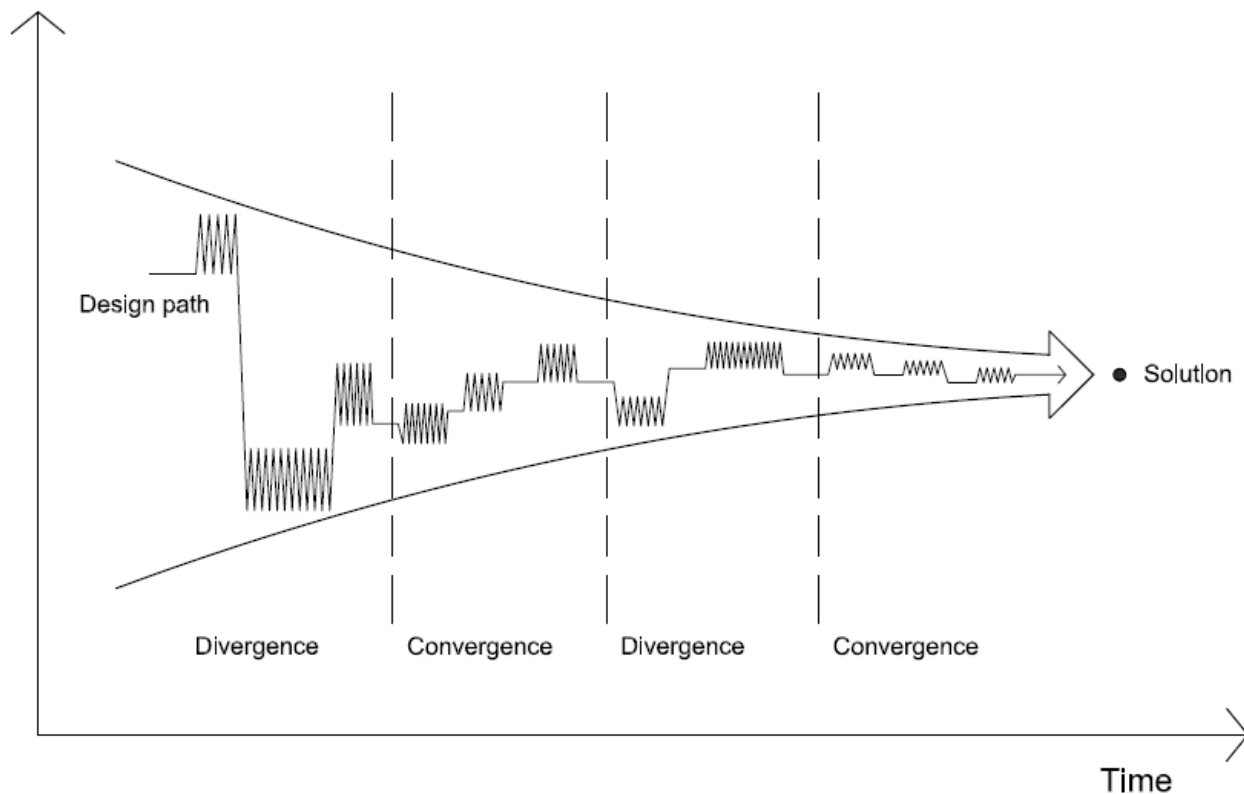


Figure 1. Convergent and divergent phases in the Cross's diagram.

In Arielli (2003), instead, the characteristics of the space of representations are investigated. A single object can be represented in different ways, depending on the level of completeness or of detail of the representation. Arielli shows how the different representations of an object can be related to each other on a Cartesian plane having as axes the completeness and concreteness of the representation itself.

The Cartesian space proposed by Arielli is a "static" space useful to connect the different representations of an object. If we aim to have a dynamic visualisation of the design process in a well-defined Cartesian space, we can combine the definition of space of the representations created by Arielli with the concept of design path used by Cross. However, the application of this

space to a process of conception of an architectural design is not immediate; we must define the meaning of completeness and of concreteness of the various design disciplines within an architectural project (Sgambi et al., 2013).

If such definition results in being quite obvious for the representation of an object, when it is applied to the different design disciplines (meant as part of a single project experience) their meaning results in being less clear. We could say that a design examined in depth only in terms of architectural composition is a design with a high degree of completeness but with a low degree of concreteness (the project is considerably more detailed in architectural and functional terms, but it is not clear if and how it can be carried out). On the contrary, the structural design of a structure (or the detail design of a façade) represents a project with a high degree of concreteness but with a low degree of completeness (it seems to be clear how the structure can be realised, but not its function inside of the design). Based on this kind of considerations, we can attribute to the various design disciplines different degrees of completeness and concreteness.

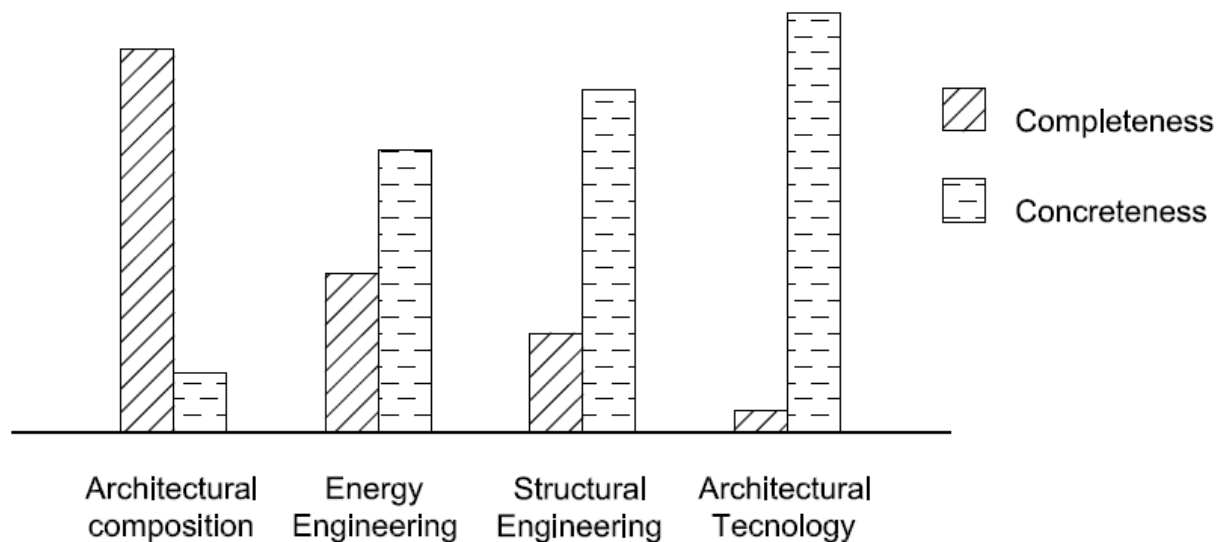


Figure 2. Qualitative evaluation of completeness and concreteness suggested by the author for the four disciplines considered in this paper.

It is obvious that a design process will only be completed when the dimensions of both the completeness and the concreteness are examined in-depth.

In the following paragraph (2.2), this abstract space will be used to visualise some of the most diffused design strategies (top down, bottom up, collaborative design). In section 3 the conception process of an architectural design will be analysed with the same procedure, by highlighting the phases of divergence linked to the multidisciplinary aspect of the process in the conceptual design phase. Finally, we will suggest how the most serious divergent phases can be avoided through an appropriate study of the conceptual design.

2.2 Approaches to the design

Using the abstract space previously defined, it is possible to graphically visualise the design path followed during the creation and the in-depth analysis of a project. In this paper, the author does not want to provide an exhaustive overview of the reasoning and decision paths involved in a design process, but only report some didactic experiences. In this context, we will examine the following approaches to design: top-Down, bottom-Up, and collaborative Design.

The top-down approach is a classic approach, examined in detail and applied by many authors (Simon 1969, Chen et al. 2012). From the didactic point of view, it is the approach used in many multidisciplinary design studios. In these courses, even though there are different disciplines, the organisation of the laboratories is determined so that the technical disciplines intervene only when the architectural design has reached an elevated degree of completeness. Since the problems of the engineer are often different from those of the architect, the introduction of engineering themes (structural and energy) can lead to greater changes in the original architectural concept. The result is often the failure of the design idea (see Figure 1) and the need to opt for a variant of the design.

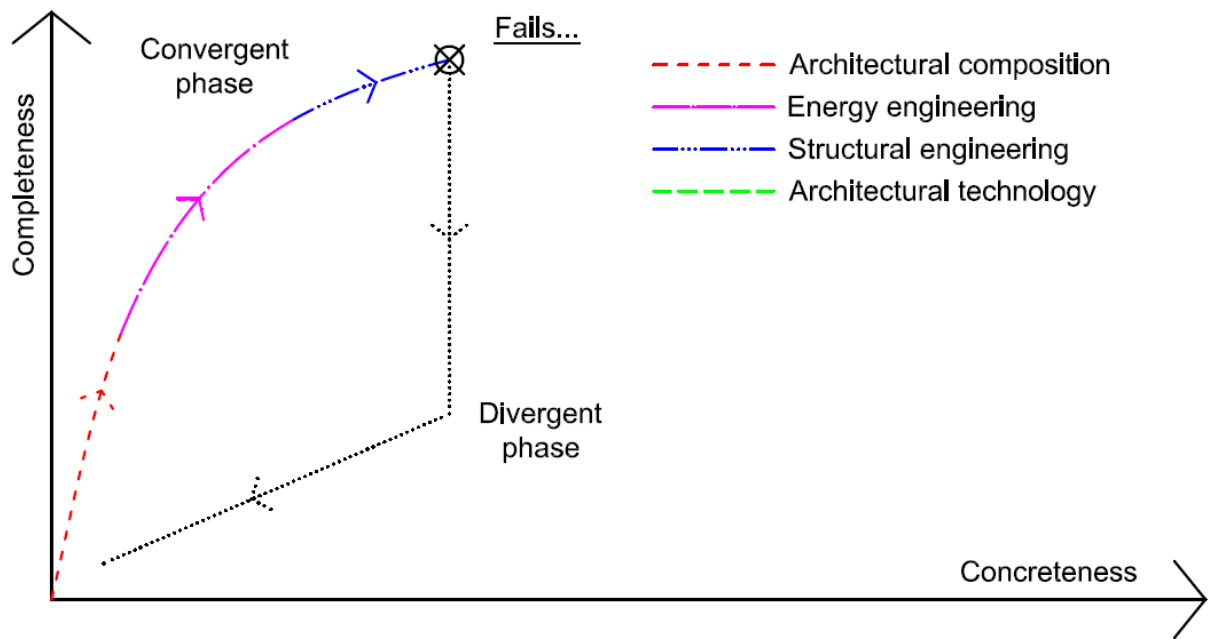


Figure 3. Top-Down approach to design.

Students often feel frustrated, when they have to completely or partially abandon a design idea in which they had started to believe and on which they had started to work seriously. Inside of the conceptual path studied by various authors (Blockley 1980, Cross 2000, Claeys 2013, Shuming et al. 2013) this situation is represented by a series of cycles or by very complex interacting networks (Dias et al. 2003). Having a wide availability of time and of resources, an approach of this kind certainly leads to an effective solution, even in a multidisciplinary field. Yet, since university courses last only a few months, often technical disciplines must opt for solutions which are not realistic or not examined in detail so as to allow the student to pass the exam. This way of working, which clearly neither meets the requirements of good design nor of good didactics, unfortunately finds its bases in the culture and work traditions of the building industry. In fact, the design of a building is at first developed by an architecture office and then it passes to a structural engineering office and finally it is examined by a specialist of energy engineering and a specialist of architectural technology. The top-Down approach, which seems to be suitable in

some industrial sectors, is not a desirable approach for building industry. In fact, the complexity of the multidisciplinary design is such that it involves a remarkable number of designers. These designers (architects and engineers) often work on different levels of completeness and concreteness. In which case, if the conception of the project is carried out serially (e.g. if the engineer intervenes on the project after the architect), the work of a designer can lead to profound changes on what has already been defined by his colleagues.

An approach with a completely opposed philosophy is the bottom-up approach, which is also an approach examined in-depth by many authors (Simon 1969, Russell 2010). From the didactic point of view, it is the approach used in the traditional design studios with monothematic theme (interior design studio, structural design studio, etc.). A structural design studio, not having at its inside the skills to develop a valid architectural design and having to focus on structural design, will choose a simple and clear structure around which to develop the building. It should be noted that also this way of proceeding validates the idea of a serial design, where the single discipline intervenes only when the task of the previous ones is exhausted. A design modification, carried out within a discipline, leads, as in the Top-Down design, to non-linear cycles in the design path.

It has been highlighted that even some students inside of the multidisciplinary studios prefer this kind of approach. They are usually students who “fear” the technical aspect of engineering (calculation), so they prefer to be sure, from the beginning, that they will encounter no difficulties. In this case, the students base the architectural design on simple and regular geometric grids (often of $5\text{ m} \times 5\text{ m}$) so as to define easily realisable modules. This choice can be appropriate when, for example, the designer pursues the modularity of the design as architectural composition requirement, but the same choice is not justifiable on the basis of an only simplification of the engineering calculation.

In the abstract design space, the bottom-up approach is substantially the opposite of the top-down one (Figure 4), in which technical problems are considered (concreteness) first and then the architectural composition of the design is created (completeness).

The bottom-up approach leads to observations similar to the top-down one. Even in this case, within a design team there cannot be a real collaboration. In multidisciplinary studios, this approach is generally blocked and the student has to use a top-down approach, which has a greater freedom of expression. Having a wide availability of time and resources, even this second approach converges to an efficient multidisciplinary solution. In the professional field of buildings, this approach is used for small buildings or economically-built constructions where the figure of the architectural designer is often missing and the entire project is assigned to an engineering studio.

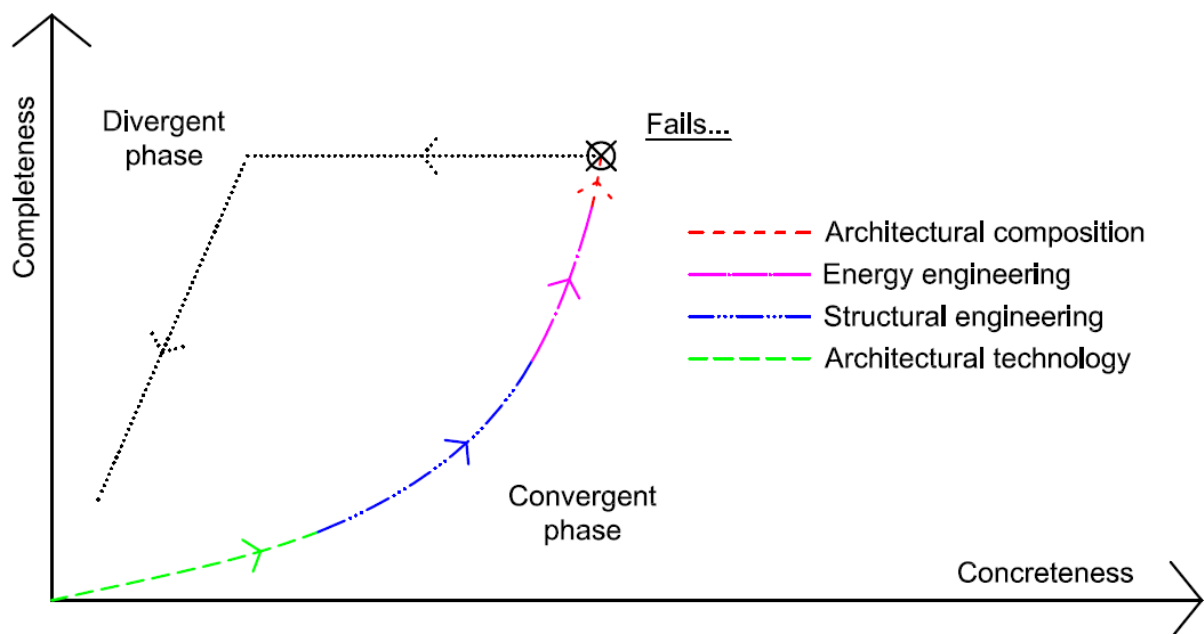


Figure 4. Bottom-up approach to design.

Top-down and bottom-up approaches are based on serial paths. In practice, designers reach the definition of the project by solving a certain amount of mono-disciplinary issues in series. If during such conception path, a discipline has to deal with a problem that cannot be solved, the process

enters into a non-linear cycle where choices previously made in other disciplines have to be revised or changed completely. Whenever a designer enters into a non-linear cycle, he finds a loss of energy and an accumulation of frustration.

The multidisciplinary aspect of the design must enter into the brainstorming stage so that different designers can discuss different design solutions (collaborative design) in a phase in which completeness and concreteness of the design are still not at an advanced level (Wang et al. 2002, Goel et al. 2012, Stefan et al. 2013). The most effective proposals must be examined in detail and compared with one another until the definitive design solution is reached (Figure 5).

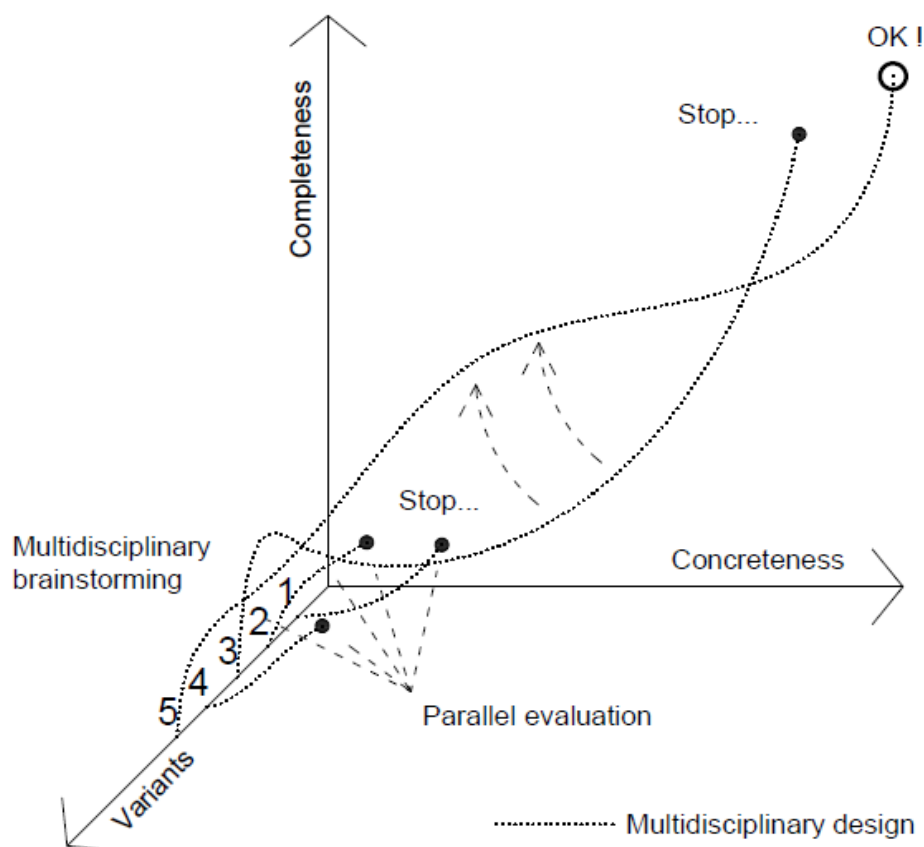


Figure 5. A collaborative design approach (emerging design).

In this third type of approach, the mind is certainly more open to alternatives of design and the design path is overtly non-linear. Unlike the two previous approaches, where variants are examined in detail one at a time, in this case a number of design variants are examined in depth at

the same time. Thus, a wide range of competing solutions open up, where the best ones “emerge” from the whole picture (Emerging Design). This kind of approach to design can be seen in Darwin’s theory of the evolution of the species, where among the existing species, only the most suitable to the environment survives over time. Considering an initial high number of design variants, selected following a multi-disciplinary and brainstorming, weak proposals are gradually rejected, leaving room only to the most appropriate solutions. Moreover, even if the weakest proposals are rejected, some of their design characteristics might still be included in the final solution. Formally, this step is similar to a modification in the individual’s genome during the evolution of species.

From the didactic point of view, the process described is very useful, because it forces the student to formalise many lines of reasoning which are not usually expressed. The student is obliged to define a set of design requirements (what and how one wants to design), to assess a degree of importance to each requirement (requirement of great, average and low importance) and to assess the design solution in an objective way. In this last phase, the student can realise what the best choices are and pursue them.

3. APPLICATION AT A COURSE OF MULTIDISCIPLINARY DESIGN STUDIO

In this section, the design experience of a student of the “Politecnico di Milano” will be described. This experience will be visualised in the abstract space proposed and defined in Section 2. It will be shown how the interaction among different disciplines may increase the number of divergent phases in the process of conception and how the application of a collaborative design can greatly improve the pedagogical experience.

3.1 Design considerations

The design theme of the studio (coordinated by Professor Giulio Barazzetta) that the students have had to deal with in the academic year is the design of a new station in San Cristoforo, a quarter situated within the city of Milan (Italy).

From the beginning of its recent story, the station has always looked like a public and industrial building, linked to both the architecture of the urban monument and to the technological world of the machine. Based on such considerations the design for the new station was realised consisting of: the railway station, the metro station, the tram station, the interchange car parking for public means and small means for the Navigli crossing (a network of artificial canals built in the year 1152 and still in part navigable). If, on the one hand such intervention aims at becoming a new pole and "symbol" of urban renovation and improvement, on the other hand it aims at establishing a relationship with the technical world, which has always characterised the history of the "station" building. Unlike nineteenth century stations, such dialogue between architecture and engineering is not solved by juxtaposing two different volumes (that of classical façades and the one of large vaults in steel and glass), but looks for a solution in the same composition of the machine-station. The dimensions give the building a strong element of urban identity and in the interior metal body, strong connections are established between the structural and architectural elements. Being an infrastructure hub, deriving from the intersections of different flows, the student chooses not to create the architectural object from the influence of the urban area, but rather to include it into the context as an object "fallen" from above. A shell devoid of hierarchical orientations will have to protect different levels, which will develop from the bottom up and which will connect infrastructures, while the central hole and its pure shape will guarantee speed and clarity of internal connections. The design of the building will not have to favour any hierarchical principle: the student will not draw a main axis, typical of terminuses, but define a spatial continuity among different infrastructures.

3.2 The students' subjective experience

The students' design experience begins by defining an open plan building, without the overall dimensions of pillars, whose floors are supported by a mesh of structural steel elements, which recalls the structure of the Milanese gasometers (structures conceived in the nineteenth century to store gas, now become monuments of industrial archeology) present in that area.

Variant 1. The students begin to develop the building plan, satisfied with the possibilities that an open plan building may provide to its architectural design. In their minds, the image of the reference (gasometer) remains strong: an almost transparent building with a very light structural mesh. Soon after the architectural plans have been realised, the students ask the structural expert to start thinking about the dimensions of the structure. Some simple structural assessments lead to define the height of the floor between 1.0 and 1.5 m and the structural-technological section of steel façade elements between 40 and 50 cm. However, such considerations contrast the idea of lightness and transparency. The easiest structural solution would be to insert pillars to support floors but this solution would contradict the will to keep a plan as freely as possible.

Variant 2. Thus, the students decide to take advantage of the presence of 3 stairwells, using reinforced concrete which can also support the floors. In this case, the plan is kept sufficiently free and the height of floors may be reduced. A central hole in the floors is also planned in order to create a light well in the building. The student recreates the architectural plans from the beginning and once more, consults the expert on the structure. The structure teacher instructs the student how to carry out an FEM modelling of the floors, in order to better evaluate the overall dimensions of the same. The height of the floors is, in this case, identified between 60 and 80 cm. However, it will be necessary to add to this thickness the overall dimensions of the air conditioning

plants which once more, lead to a rather important thickness in contrast to the lightness and transparency desired in the façade .

Variant 3. The students are therefore convinced of the need to use multiple vertical structures to minimize the height of the floors and consequently, their impact on the façade. A solution is proposed with a circular network of reinforced concrete pillars, inserted inside the building to avoid having other important structures on the façade, thus being able to choose a lightweight and transparent technology solution. The students recreate the architectural design of the spaces, but they find it difficult to design the interior spaces which become too constrained by the design of the structure.

Variant 4. At this point, a fourth structural idea springs up and it will turn out to be the final choice. The three reinforced concrete stairwells and the central light well are maintained, prestressed reinforced concrete beams were placed at the top of the building and steel hangars were inserted along the two façades (external and internal) to suspend the floors. This solution allows to have a: much more reduced structural thickness of floors (40 – 50 cm), plans relatively free from the structures (the students can return to the design of spaces already carried out for option 2), minimal overall dimensions of steel hanger in the façade (15 – 20 cm) and the possibility to have a ground floor free.

Figure 6 shows the phases of convergence and divergence towards the final solution. It must be noted how the students applied a top-down approach in their first approach to the project, thus preferring to solve aspects of architectural composition initially. In the second approach, the students always use a top-down approach, with the introduction of some structural constraints. In the third, frustrated by the first two failures, he tries to set up the design process with a bottom-

up approach. Finally, he finds the solution in the fourth proposal, where the structure chosen appears well integrated with the desired architecture.

In this experience, it is evident how the process of conception followed by the students looks more like a “trial and error” method rather than a multidisciplinary reasoning. To achieve this goal, it is crucial to introduce multidisciplinary aspects from the initial stages of the conceptual design (brainstorming), to identify multiple design variants and to finally evaluate the same in search of a compromise valid for all disciplines involved.

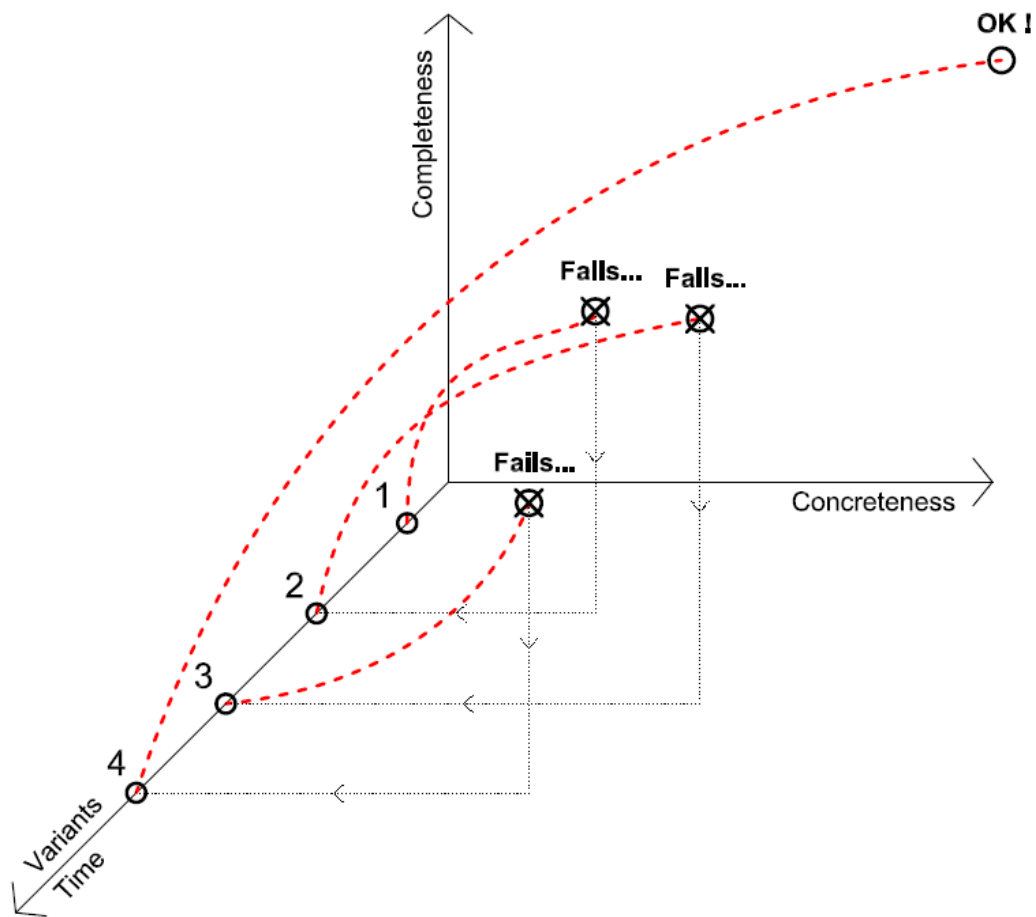


Figure 6. Representation of the students’ experience in the design space proposed.

3.3 Towards a multidisciplinary conceptual design of structures

Based on the design considerations, described in the previous paragraph (3.1), the students should identify a series of design requirements which the structure will have to meet. Given the multi-disciplinary aspect of the design, each choice made inside a discipline influences the themes of all disciplines involved. Therefore, the design requirements must not concern only the structural field, but consider all the disciplines involved (in this practical task: architectural composition, structural engineering, architectural technology, energy engineering). By way of example, some issues that should be evaluated are reported, for the design application described in this section.

Architectural composition:

Is the structure analysed capable of ensuring a good spatial continuity at the level of the ground?

(1)

... to enhance the design and make it a reference point for the territory? (2)

... to guarantee an easy composition of interior spaces? (3)

... to allow the building to be a joint point among various systems of transport? (4)

Structural engineering:

Can the structure be considered to be built in a simple way? (5)

... to limit the vibrations produced by means of transport? (6)

... to guarantee an easy maintenance process? (7)

... to guarantee a good structural robustness? (8)

Architectural technology:

Is the structure considered suitable to provide adequate supports for external coating? (9)

... to be built with a prefabrication technology? (10)

... to limit displacements among levels, so as to reduce break risks in the façade panels? (11)

Energy engineering:

Is the structure considered suitable to help the building to have a good thermal insulation capacity? (12)

... to allow an easy distribution of the thermal distribution systems in vertical direction? (13)

... to allow an easy distribution of the thermal distribution systems in horizontal direction? (14)

The structural choice will have to respond to each of the questions previously listed. It is clear that a structural solution can hardly fully meet the requirements needed, and it is also clear that a choice of a structural solution has an influence on the entire design.

3.4 Definition of the design variants

Before elaborating a design solution, the students have to examine more variants (together with experts of different disciplines) in the light of the topics outlined in section 3.3. Each variant of the design should be evaluated as objectively as possible to avoid being influenced by prejudices.

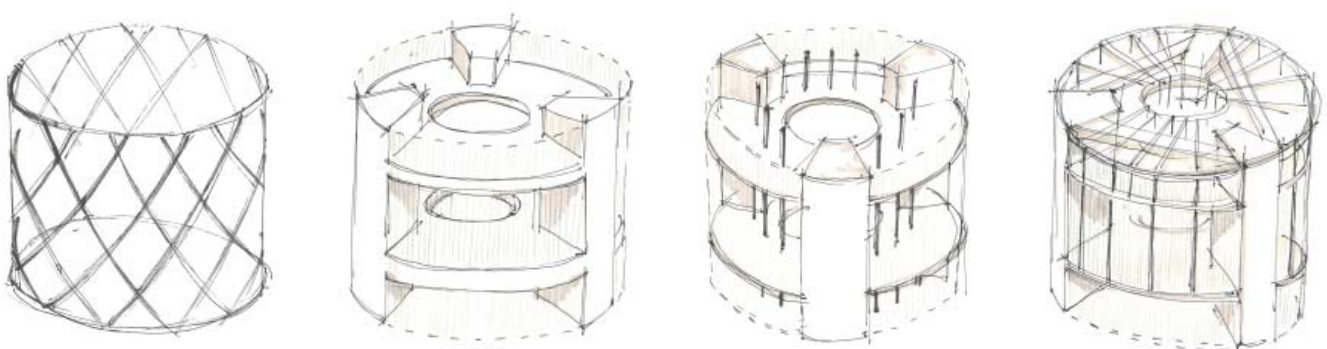


Figure 7. Four variants of structural design for the new station in San Cristoforo.

It is not always easy for the students to complete this first step objectively. In fact, questions come to mind and evaluations are pondered even before the freehand sketch has been completed. Therefore, it often happens that one or more sketches are less detailed when compared to others, which means that the students have already decided unconsciously to reject those design solutions. It can be noted, for example, how the sketch to the left of Figure 7 results in a much more reduced amount of information when compared to the other 3 (floors, staircase blocks and pillars are not marked). In the students' minds, even before moving to the following step, a prejudgement that solution 1 is not the ideal choice, is formed. However, faced with the question "why did you reject solution 1?" the students are often unable to answer, if not vaguely and superficially. The teacher should encourage the students not to allow themselves to be influenced by prejudices and to postpone the step of evaluation and of choice using an assessment criteria which is well-formed and objective.

For each identified design alternative (Figure 6), the students must make an assessment on the basis of the requirements identified during the discussion of the design guidelines (paragraph 3.3). In Table 1 we show an example of assessment in terms of high (H), average (M) or low (B) evaluation. It is worth noting that even to each question, a factor of importance can be associated (H, M, or B) depending on how much that specific aspect is considered to be important inside of the design.

	architectural composition					structural engineering			architectural technology			energy engineering		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	H	H	L	M	M	H	M	H	M	H	M	M	H	H
1	L	H	M	L	H	M	M	H	M	M	H	M	M	M
2	H	M	H	H	L	L	M	M	L	L	L	H	M	M
3	M	M	L	M	H	M	H	H	H	L	H	M	H	H
4	H	H	H	M	M	H	H	M	M	H	M	H	H	H

Table 1. Table of assessments.

The students can choose algebraic methods (giving a score to each linguistic assessment and to each importance factor) or other to find the best solution of compromise among the proposed variants. For example, by entering a score proportional to the grades of judgment present in Table 1, it is found that solution 4 is the most appropriate one, since it answers the 84% of the requirements demanded. The procedure proposed is an application of the collaborative design and it turns out to be useful in reducing the amplitudes of the divergence phases of the design process as well as giving a more scientific aspect to the pedagogical activity.

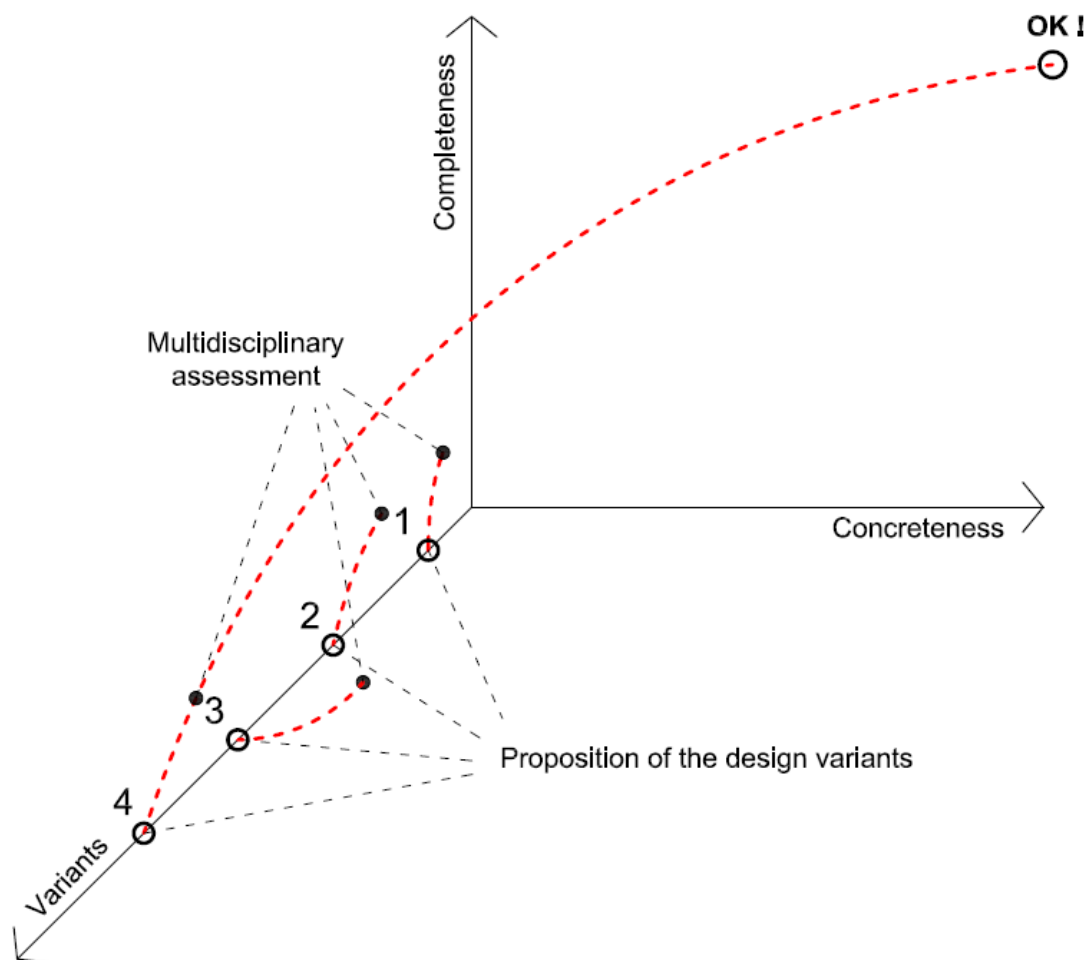


Figure 8. Application of a multidisciplinary conceptual design to a student's experience.

It must be observed that during the evaluation process of design solutions, some quantitative assessments may be necessary to allow a proper evaluation of an alternative design. For example, for the solutions 3 and 4 an analysis has been performed with a finite element software (ADINA900) which has allowed to obtain more reliable assessments of the structures concerned. Figure 9 shows a volumetric representation of the final design solution.



Figure 9. Volumetric representation of the design of the station of San Cristoforo.

From a didactic point of view, it has been found that proceeding with this method raises the awareness of the students in the design choices made. While arriving at the same result of a serial approach, the collaborative design seems to be a more robust and more scientific approach.

4 CONCLUSIONS

The present paper summarises the studies related to the multidisciplinary conceptual structural design developed inside of the course of Architecture and Construction Design Studio of the

“Politecnico di Milano” and the course of Conceptual Structural Design of the “Université catholique de Louvain”.

In this paper an abstract project space is proposed, a combination of the abstract diagram proposed by Cross (2000) and of the space of representations proposed by Arielli (2003). In this space, it is possible to visualise the divergent – convergent activity typical of the design processes. After having visualised typical top-down and bottom-up design strategies in this space, the process of a real design conception has been examined. It has been highlighted, in this context, as to how a pedagogy to the project based on the succession of design disciplines leads to an amplification of divergence-convergence cycles and to an approach to the project based more on a “trial and error” process rather than on an effective scientific strategy. The introduction of a collaborative design approach, where the different disciplines already have their importance in brainstorming and conceptual design activities, allows to reduce the phases of divergence and gives a scientific characteristic to the entire design process.

Moreover, the following conclusions, which are more general, are also to be emphasised:

- The design of a building is highly multidisciplinary. The schools of architecture, as well as the engineering schools should acknowledge this characteristic endeavouring to include some multidisciplinary design studios in their course of studies. Single topic studios are undoubtedly less costly, in terms of organizational resources; however they contribute very little to the general view of the design problem. Professionals, engineers or architects, working in the building industry must be used from the outset to consider the multidisciplinary of the problem. This leads, in the workplace, to reduce the waste of resources and of time to follow the non-linearity of the design path, thus achieving a more efficient and effective design result.

- The tools of development to support building designers, must improve the character of multidisciplinary, of communication and of exchange of information even at the expense of providing less powerful tools in terms of calculation and monodisciplinary optimisation. The most important and delicate design phase is that of conceptual design, where advanced calculation algorithms appear to be powerless. It is instead, essential to exchange sketches, ideas, experiences and qualitative assessments.
- Research in didactic field is fundamental. The classroom represents the place where a teacher can test new teaching methodologies, in order to improve the comprehension of mental processes linked to the design activity and to increase the creativity of future professionals.

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