Architectural and Environmental Compositional Aspects ... Technological Innovation in the Built Environment.

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Abstract

This paper focuses on the complex relationship between historical consolidated building design projects, both from compositional and environmental points of view. In spite contradictions in their nature, their integration is essential from the very both to improve and efficiently preserve the environmental and architectural qu this work is to define a number of guidelines to support and inform the des and eventually ensuring the quality of the built environment, both aesthetically and environme end, the paper explores the use of climatic and microclimatic analysis as a and sustainability performance of future buildings. In particular, the work microclimatic matrix, as support to the climatic considerations about differe and cooling systems; and to the architectural/compositional approach defin

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1. Introduction

The building sector, excluding industrial buildings, represents almost 40% of total pr consumption in developed countries [1]. This percentage includes energy demand for space heatin cooling, hot water production, lighting, cooking and appliances. In addition, considering the warming effects of the current trend of greenhouse gas emission, the energy consumption for space in several countries [2,3]. Within this framework, a passive approach to building des taking envelop rather than HVAC system as the main technology for environmental c reducing energy consumption in the building sector. This approach can contribute to curb trend related to carbon emission-dependent on space air conditioning systems. technologies able to increase the energy efficiency of buildings are considered and incentivized legislation, standards, and codes of practice. In addition, passive solar gain and hybr and mitigating internal gains, summer solutions for increasing solar gain in winter are well known even if, especially for cooling, more widespread could decrease drastically the used energy for heating and cooling a building. However, to reach much more stringent goals near-zero-energy buildings (NZEB), as EPBD 2010/31/EU by 2020, or, even more, th positive-energy building (NPEB), a much stronger effort than currently done to i impact technologies to a sustainable architectural design approach needs t In spite the scientific progresses achieved in the studies of environmental debate about the aesthetic of sustainability seems to have fallen behind the professionals and academics. The projects categorized as sustainable are often defined either according to th type of environmental systems and technologies utilised, as well as the architectural design approach. The contemporary examples of sustainable best different aesthetic approaches that designers seem to have undertaken. T more literal design solution of environmentally aware buildings, in which t was conceived as a design tool; more technology oriented approaches, where environmental artificial systems became expressions of the architectural aesthetic. Examp these approach can be considered: 1) the Jacob House 2 built by Frank Lloyd Wright in Wisconsin, United States, built between 1944-1948, in which the incidence of the solar light was lit... the building and the floor plan; to the 2) the environmental houses larg... technological features were heavily applied to the buildings without much design i... more sophisticated example of high tech buildings such as the Centre du Po... France, built between 1971-1977. The architectural goal of sustainability seems therefore t... the mimetic tendencies of relating to the environment in a literal manne... sustainability by expressing the efficiency of the technological features. The path of p... integration seems not to be explored or discussed as much. This happens... software and tools that can assist the design process, by integrating microc... systems and technologies. This paper will explain in the next sections how s... 1) offer support to the design process; 2) enhance the integration betw... technological systems; and 3) contribute to the debate on the definition of sustainabilit...

2. The preliminary design process

According to Nigro and Mattei [4], the delivery process of building projects can be subd... theoretical areas such as: building opportunity generation; building sco... production; building erection; building functioning and control. Each of these pha... from conception to construction, is characterised by a number of instances in which the... design choices and technological systems can be critical to enhance the ... performance of projects. Specifically, this paper will deal with the area of p... design process, as critical moment to explore the integration between a... technological features. Several researchers [5] explained that the earliest involvement of ... awareness in the design process, the more cost, time, and quality effec... Moreover, Gibbs [6&7] together with Cherry [8] pointed out a number of critical considerations during the phases of building design programming and building preliminary design... clients need, the building scope and the building characteristics, through the program another important part of the preliminary design, the site analysis, represents a critical aspect of in... between environmental awareness and architectural design approach. The s... wind, light, ground, water, surrounding buildings, and the urban has the potential to drama... building orientation, dimensions, interrelation, and localization, as well ... approach. During the preliminary building design, technical and environmental... informing geometry, volumes, colours, construction systems selection, and ... As the flow chart in Figure 1 shows, the building design program phase ... compatibility and performance assessment related to the definition of virtual spa... result of fulfilment of both functional and environmental requirements. Thes... determining design objectives, activities to be performed and the user needs as well as laws, standards, and regulation at various scales. On the side, but not less... not considered part of the building programming represents an essential operational for the ... compatibility assessment of building design choices.

3. Environmental aspects of the preliminary design

The environmental aspects of the preliminary design process are related to... affecting the impacts of the building on the physical context at various spatial scales, ca... global, regional, local, and indoor/outdoor as well as temporal, during the running of... the building and its entire life cycle.

Environmental assessment implies different approaches and methods at di... preliminary design phase two types of main analysis are, generally, considered: envi... programming and site analysis. After a brief description of the former, this paper will focus on ... particular attention to site climate evaluation.

3.1 Environmental building programming

Environmental building programming follows a performance-based approach and it is a process of analysis and assessment from user needs and activities to requirements, a... definition, according to the compatibility (environmental) loop above descri... During this process various tools such as diagrams, checklists and matrices can be a... Examples of these applications are numerous, but generally they do not deal with environmenta... [9, 10 & 11].

Fig. 1. Flow-chart of the preliminary design process based on a performance-driven approach (image modified from [6]).

The main actions to be carried out in the environmental building programmi

- reception of the client brief including building design objectives and users needs;
- reception of laws, standards and regulations related to the building type t
- list and classification of activities and relevant environmental requirements;
- analysis of input/output flows related to the activities and affecting both outdoor and indo
- list and classification of functions related to the activities;
- definition of virtual spaces as spatial representation of aggregated functions;
- definition of dimensional (order of magnitude) and environmental requirements of virtual space unit

- aggregation of virtual space units according to their reciprocal linkage characteristics ... compliance to the defined environmental requirements;
- alternative configurations of virtual space layout.

A virtual space does not have physical boundaries but just potential links within and with the external context. These potential links are related to various aspects: geometry, communication, physical phenomena (airflow, daylight, solar radiation). The environmental building programming focuses on some of these aspects, the ones which have an imp... as mentioned above.

3.2 Site-climate analysis

The site analysis phase of a preliminary design process concerns various ... transportation, landscape, socio-cultural issues, town planning tools, land use, economic value, ... impacts. Within the latter, the climate analysis is aimed at evaluating the potential vocatio... site to locate an activity, a virtual space or a building, with regard to thermal comfort as a funct... factors such as solar radiation and wind flow [7, 8, 12]. The site-climate analysis uses a site microclimate matrix (SMM) as a tool allowing for optimising the location of outdoor activities, space units, i.e., buildings, in relation to thermal comfort. The elaboration method was introduced by two American scientists [2] and modified by G. Gross [7]. It allows designers to locate properl... to a sustainable and bioclimatic approach, the outdoor activities/space units defined in the building programming phase as described above. SMM can also be used to study the optimal layout of buildings ... urban design by evaluating the influence on potential exposure/protection related to solar radiation and win... either for new assets or in a specific existing context.

An SMM is elaborated as a graphic overlay output from the analyses of shading and airflow dynamics on a lot resulting on a four variable zoning derived from the combination sun/shade and windy/sheltered zones (Fig. 2). This zoning is called matrix because it is discretized by a norm... cells are characterized by one of the four variables. Each cell is then associated to a pote... level (see Table 1) in order to assess its vocation as a recipient of activities.

The SMM is built on a virtual plane, which is generally at the ground level, but it is possible to ... different matrixes by changing height or to create a three-dimensional matrix of the project site. ... depends on the specific needs, however, three-dimensional analyses require a higher investment in terms of time, costs and computer memory, in case of three-dimensional CFD software for airflow studies. It is advisable to proceed with vertical analysis of facades of the building under design, or retro... in order to evaluate the mutual influences between facades of different buildings

Fig. 2. Example of wind wake core analysis in winter and summer (point 4) for a construction lot in ... The airflow analyses were conducted by using the software KARALIT CFD.

Theoretically, SMM changes over time following yearly, daily, and hourly path of the sky sun and the seasonal (or monthly, daily, hourly) prevailing wind directions on the considered site. However, SMM, being used as a design parameter, refers to extreme climate conditions a during solstices, in the morning and afternoon, and relevant seasonal prevailing. As example, the reference dates for Boreal hemisphere are 21 December at 10:00 and 14:00 and 21 June at 8:00 and 16:00. It is possible to choose different times, like the hottest and coldest day of the year, estimated by using the typical meteorological year (TMY) of the locality or general reference July 21st and January 21st at 9:00, 12:00 and 15:00 [5]. When the calculation of shadi conducted by using specific software, it is important to pay attention to the correct time definition (local Meridian, reference Meridian, solar hours).

The following steps shall be performed to elaborate a SMM:

1. definition of the site context and constructions surrounding buildings and natural obstacles;
2. discretization of the analysed lot by a normal grid with cells dimensi (for example, 5x5 m);
3. analysis of solar paths and relevant shading dynamics in different reference days and hours;
4. seasonal analysis of wind wake core (see Figure 2) for different temporal analysis, for example day-night breezes);
5. overlapping of the results from the analyses (steps 3 and 4) on the grid defined in step 2 in order to classify each cell by a 2x2 matrix of climate conditions (sun-wind; sun-calm; shaded-wind; shaded-calm); this process is repeated for considered hours and days (see Figure 3);
6. assigning a score to the four classes considering the activities to be hosted for each matrix developed in step 5 (Table 1);
7. construction of a four time-reference SMM for each type of activities/functions/space u

In Figure 2 wind wake core seasonal analysis is carried out in a specific lot of Melbourne port, Australia. The prevalent wind directions are North in winter (from hills to sea) and South in summer (from sea to land), and a change in directions occurs during a daily breeze regime. These analyses were carried out using the CFD software Exa Cradle [13]. Existent building context redu wind velocity at the ground floor in the East side of the construction lot, c natural ventilation. At the same time, on the same side, Venturi effect is evident, consequent increases in the wind velocities. The barrier disposition could represent an effective solution for this potential discomfort situation.
Wind analyses could be done in different ways: CFD using software, which needs specific aerodynamic knowledge and is time-consuming and costly; wind tunnel simulation, which re physical model, specific knowledge and laboratory facility; simplified method based on statistical correlation of wind tunnel test data on modular solid models with varyi incidence angle, such as the one elaborated by Gross [7] on the basis of a previous research [1 The score assigned to each cell of an SMM, as in step 6, is based on classification of potential outdoor comfort conditions related to types of activities and their metabolic rate, that can be assess on a qualitative scale (Table 1) or using quantitative values

Activities		Season	Relation between site microclimate m conditions			
			shaded calm	shaded wind	sun-calm	sun-wind
Low metaboli rate	Stay; wal around	Winter (cold win	Unfavoura Good	Worst Worst	Optimal Optimal	Good Unfavoura
		Summer (high RH)	Optimal Unfavoura	Good Optimal	Worst Worst	Unfavoura Good
Medium metaboli rate	Walking slow runni	Winter (cold win	Unfavoura Good	Worst Worst	Good Optimal	Optimal Unfavoura
		Summer (high RH)	Good Unfavoura	Optimal Optimal	Worst Worst	Unfavoura Good
High metaboli rate	Run fast; activities	Winter (cold win	Worst Good	Unfavoura Worst	Good Optimal	Optimal Unfavoura
		Summer (high RH)	Good Unfavoura	Optimal Optimal	Worst Worst	Unfavoura Good

Tab1: A classification of outdoor thermal comfort conditions in relation to the microclimate matrix variable types of activities.

As an example of a quantitative assessment, a score could be, for a high m running: in winter, 1 for calm, 2 for shaded-windy, 4 for sun-calm, 5 for sunny-windy; in summer, 1 for sun-calm, 2 for sunny-windy, 4 for shaded-calm, 5 for shaded-windy.

3.3 Architectural/compositional implications

The SMM presented above was used as a base for a design research conducted in the Master of Architecture for Sustainability of the Polytechnic University of Turin. The call of the atelier was to de design proposal for a new university building in Melbourne, following the ex Building and Planning faculty at The Melbourne University.
In this atelier, the microclimatic analysis was applied to the early stages of the design process, to infor the decision-making process on a compositional level.
As showed in figure 3 and 4, the microclimatic analysis produced a reading of the site that sh of calm (wind and sun) over different time of the year. By analyzing the sit was defined optimizing the volumetric definition of the buildings, shape of th volumes; define the internal spatial layout allocation of functions; and determine characteristics of each façade (figure 4). This latter allowed the design of a which pattern, shading systems, and glazing features where equally balance and surfaces exposures (figure 6).

Fig 3: Example of calculation of a matrix as basis for a volume (study by Maryam P.Tootkabo Danial Mohabat Doost, and Xiaochen Song).

The definition of the volumetric organization allowed the definition and the the design proposed. Figure 5 shows an example of solar exposure analysis in whic mapped according to incidence of the sun on each its part. This analysis decisions on the shading devices design as well as the definition of the façade pattern (fig 6).

Further analysis was also utilised to determine the performance and spe components defined in the project proposal. Specifically, glazing charac ventilated façade and curtain screen were selected for each façade, according the exp characteristics, elaborated in the climatic analysis.

Fig4: Example of design process in which the volumetric organization was defined to the characteristics of the site, previously explored by the microclimatic analysis (study by Mamak P. Tootkaboni, Danial Mohabat Doost, and Xiaochen Song).

Fig5: Example of solar exposure analysis on the design proposal for the site (study by Mamak P. Tootkaboni, Danial Mohabat Doost, and Xiaochen Song).

Fig6: Example of design process to establish modules, patterns and shading devic
according to the solar analysis on the façade, climatic case study by Mamak P.Tootkaboni, D
Mohabat Doost, and Xiaochen Song).

4. Discussion

The use of SMM showed a number of aspects that can enrich the design process
providing design alternatives; 2) the assistance in the definition of technologies and specifications; 3) the
contribution to the selection of the construction systems; 4) ensuring quality thr

1. The ability of providing design alternatives could be referred to the ab of volumetric configuration and location within the site; the definition relation to the building orientation; the use(s) of the land; the inclusion (o natural elements found on site as architectural features; and the characteristics as main concept for the overall design approach. Moreo can also inform elements of façade design such as the relation betwe shading configuration and location; colours and patterns diffusion, elements; orientation and type of façade elements.
2. The use of SMM can also assist in the definition of technologies and speci the relation between performance required and positions within the b

specific technical requirements and therefore of required elements; highlighting the opportunity of innovative design elements or details.

3. The awareness of the microclimatic configuration of a site could assi appropriate construction systems, by an accurate analysis of areas of the futur could be design or treated with the use of different construction sys contribute in saving in cost and time by applying the use of eco-constructi Moreover, the results of a microclimatic analysis could as well info construction systems.
4. The ability of designing buildings that embed the site specific conditions can also contribute better conditions throughout the Life span of the building itself. Not only architec more effective choices in terms of construction systems, and technolo of sustainability over time.

Fig 7: The image shows the design parameters that can be informed by the use of microcl of the design process and delivery. Above the blue band the design process is characteristics. Below the blue band the parameters that can be enrich/integrated by the use of micro-climatic analysis are listed for each phase of the design process.

Figure 7 summarizes a number of parameters that can be modified and informed by the use o analysis throughout the design process and delivery. In the image the design process is descr phases and related to all the design parameters that can be. The ability of relating the use of a site-climate analysis, design phases and design parameters represents a methodology that can be applied through all the phases of projects delivery. This me considering technical parameters, and optimizing design solutions, without impinging on the design process, which instead informed on a number of potential. Moreover, this des methodology could assist the development of specific requirements/rules for each technical elemen support the testing of the quality of design and their optimization.

5. Conclusions

Environmental building programming and site-climate analysis can provide designers and ar ability of open an informed discussion on the role of design within the sust Having a number of design alternatives directly informed by the environment a new architectural language that can gather the approaches that have been taken so fa architecture until now, and implementing them toward an integrated languag This language could potentially produce a variety of buildings that not only limit energy consumption, resources depletion, but that are able to express the identity of those environmental and technological approach to design, driven by an approach since the preliminary design phase, is essential for considering these issues in the design compositional solutions and suggesting possible optimization procedures.

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