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PhD Yearbook | 2021

Chair:
Prof. Marco Scaioni

DOCTORAL PROGRAM IN ARCHITECTURE, BUILT ENVIRONMENT AND CONSTRUCTION ENGINEERING

Vision

The Doctoral Program in Architecture, Built Environment and Construction Engineering (ABC) started in 2012 from the evolution of five older programs, active since the institution of the Italian Dottorato di Ricerca (PhD) in 1988. The aim of the ABC-PhD Program is to become a national reference point for training researchers and experts in the following fields:

- the sustainable transformation and management of the Built Environment, holistically viewed as an environmental, economic, cultural and social ecosystem, as well as time and space series of Architectures and cultural landscapes;
- the Engineering of buildings and components, structures and infrastructures, materials and service systems those architectures and landscapes are part of;
- the organization of the Industrial Systems that design, realize, manage and transform them and the Public Administration System that defines the rules for taking care of their value as social assets.

Program organization

The Program pursues the following ten pillars:

1) Selection through a transparent open process.
2) Candidates as independent, mentored and monitored, researchers.
3) Training plans tailored on Candidate's research topic and needs.
4) Training activities based on research practice.
5) Research practice hinged on the framework of Department activities.
6) Transparent tracking of Candidates' scientific production.
7) Systematic assessment and open and supportive peer review of Candidates' advancements.
8) Candidates as hot spots of international research institutions.
9) Systematic valorization of PhD holders and their products among stakeholders.
10) Candidates as active part of the Program's Quality Management System.

The award of ABC-PhD title requires that Candidates, under the control of their Supervisors:

- plan and carry out a three year, full-time, research activity;
- plan, attend and pass, with positive evaluation, a complementary series of Doctoral Courses, to complete her/his skills as researchers.
- develop a PhD thesis and defend it, in a Final Exam session certifying its original advancements on a specific topic.

For what concerns courseware, ABC-PhD Program boasts a wide (more than 20 titles/yr), diverse, educational assortment on cutting edge, specialized, research topics. It is an open list of courses that changes, year after year, following Candidates' needs as well as the opportunities offered by the Department. This list is further enriched with the transferrable skills courses offered by the PhD School and may be integrated by the offer of all the university Doctoral Programs.

Academic, industrial and social collaborations

Each Candidate is mentored by one main Supervisor and inherits Supervisor's Scientific Sector as reference. Due to the multidisciplinary nature of our wide research field, nevertheless, his/her activity may be supported by other co-Supervisors to make stronger, more sound and reliable his/her final research product. The main effort of the ABC-PhD Program Board is to keep Candidates research works constantly reviewed, involving every useful, available competency from the ABC Department, other Departments or other national and international Universities and Research Centers. Each Candidate is also assigned to a member of the Program Board, which serves as individual Tutor with the aim of constant independent monitoring of his/her activity.
Moreover, each Candidate is progressively encouraged to confront his/ her position, project, intermediate products and final results with any stakeholder that may acknowledge, enhance, valorize and exploit them through social or industrial collaborations. Our social and industrial collaboration starts often from the beginning: approximately 50% are thematic and the topic is defined (and the Candidate selected) together with an industry or an international research institution as funding – or co-funding – partner. Our mission is to train our PhD Candidates as self-sufficient and independent actors, able to gain – as scientist, as intellectuals, as professionals, as entrepreneurs – an outstanding position at an international level.
We are sure that our early stage openness toward stakeholders and the whole scientific world and networks is the best way to provide future PhD Holders with solid occupational opportunities for an academic career as well as for an employment in research centers and in any other enterprise, public body or private societies in need of highly qualified personnel, in particular of experts trained to innovate and to manage innovation processes.
The PhD-ABC Program deals with a wide variety of topics and related disciplines. It is not possible to list them in few rows (see our site, here: https://beep. metid.polimi.it/web/abcphd/milestones) and it is even useless, due to our fluid, adaptable nature: we look for new research questions (in the wide ABC sector) and for good ideas to give answers to them. A complex set of cutting edge, scientific and humanistic, disciplines and experts are at Candidates' service to support them to make their efforts three-time-winning (Researchers, Stakeholders, Academy) intellectual products.

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EVIDENCE-INFORMED HOSPITAL ASSESSMENT. IMPLEMENTATION, WEIGHT AND TEST OF A MULTIPLE CRITERIA TOOL FOR SOCIAL, ENVIRONMENTAL AND ORGANIZATIONAL QUALITY ASSESSMENT OF HOSPITAL BUILDINGS

Andrea Brambilla - Supervisor: Stefano Capolongo

Co-supervisor: Göran Lindahl - Tutor: Andrea Ciaramella

Introduction.
Healthcare facilities are complex infrastructures where different features from technological, social, clinical and architectural field interact. In modern healthcare systems there is the constant need of quality in terms of process, outcome and structure as defined by Donabedian model. Several tools already evaluate the quality in terms of process and outcome but very few are able to assess the built environment. Nevertheless, since 80s Evidence Based Design (EBD) researchers states that there is significant relationship between health, wellbeing, organizational outcomes and the built environment, few Building Performance Evaluation (BPE) certifications address environmental sustainability of hospital facilities and some Post Occupancy Evaluation (POE) protocols have been developed to investigate occupant satisfaction.

Research Objective.
Although several papers, literature reviews and empirical studies have been recently published on hospital assessment topics, there are not many instruments able to systematically measure the whole hospital qualities as built environment. Therefore, starting from an existing framework, the research objective is to implement, weight and test the tool with new indicators, methodologies and variables informed by the most recent available scientific evidence in terms of social, environmental and organizational quality and sustainability. The tool will act as a decision support instrument for hospital strategic management when dealing with operative facilities.

Methodology.
Firstly, a literature review has been conducted in order to understand the existing situation in terms of hospital quality evaluation. Several tools and regulations have been also included and analyzed to highlight the most important evaluation criteria and methods. Second, the existing framework has been implemented and a new structure has been set up. The different indicators have been validated through semi-structured interviews and the criteria and macro areas have been weighted with Simon Roy Figueras (SRF) multicriteria and Deck Card Method (DCM) during 1-to-1 workshops with international figures experienced in the field. Finally, the tool has been applied on a sample of Italian hospital and the results have been compared and discussed for further developments.

Findings.
Starting from literature and tools review considerations, the SWOT analysis of the first tool version, informed the implementation of a new multiple criteria tool named Sustainable High Quality Healthcare Environments version 2 (SustHealth v2) resulting in a hierarchical model composed by three macro areas: Social, Environmental and Organizational qualities. Each macro area has 5-6 criteria with 2-4 indicators each. Every indicator is measured with 2-9 operative variables.
After stakeholders' analysis and Decision Makers interaction, the SRF DCM procedure contributed to define the final weight assigned to the macro areas resulting in Organizational qualities accounting for 49%, Environmental qualities for 29% and Social qualities for 22%.
The application and test of the tool on two pilot Case Studies (CS1 and CS2) in Lombardy region, Italy highlighted transversal criticalities such as Sustainable Accessibility (CS1=0.04/0.16; CS2=0.11/0.16), Sensitization and Education (CS1=0.06/0.18; CS2=0.10/0.18) and well established issues such as Risk management (CS1, CS2 = 0.16/0.18) and Security (CS1, CS2=0.14/0.19). At the same time the private owned and managed case study (CS1) was able to achieve higher scores in energy (0.15/0.0.19), waste management (0.07/0.07), as well as future proofing characteristics (0.20/0.23) while the public owned and managed one (CS2) found more difficulties in achieving similar scores. Overall CS1 scored higher in all the macro areas reaching a total fulfillment of 72%, while CS2 scored 52%.

Conclusions and future developments.
SustHealth v2 is a weighted evidence-informed multiple criteria assessment tool able to i) evaluate the state of the art of a hospital building in operation, in terms of social, environmental and organizational qualities and ii) support hospital strategic management in highlighting area of improvement and investments. The application of the tool on two pilot case studies allowed to test its possibility of scaling up to a wider sample of hospital buildings and organizations at national and international level.

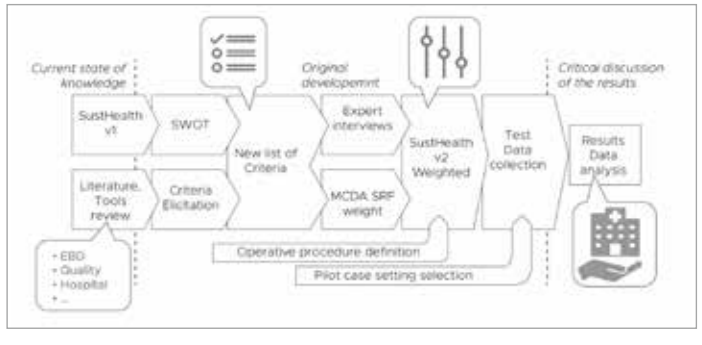

Fig. 1 - Flowchart of the methodological process adopted from literature review to data collection, analysis and discussion

Fig. 2 - Example of the evaluation checklist with criteria, indicators and variables for social, environmental and organizational quality assessment

Fig. 3 - Dashboard of the assessment tool SustHealth v2 with weighted macro area and criteria

BENDING AND FATIGUE BEHAVIOUR OF EXTERNALLY BONDED INORGANIC-MATRIX COMPOSITES

Angelo Savio Calabrese - Supervisor: Pierluigi Colombi

Co-supervisors: Tommaso D'Antino, Carlo Poggi - Tutor: Valter Carvelli

The thesis work reports on the results, procedures, methods and analyses of more than 200 experimental tests performed by the author in the three-year period 2018-2020, at the Materials Testing Laboratory of the Politecnico di Milano. The experimental investigation concerned the mechanical characterization of the adhesion-to-substrate mechanism of inorganic-matrix fiber reinforced composite materials. These materials, typically known as Fabric Reinforced Cementitious Matrix composites (FRCM), are now universally established as innovative externally bonded structural strengthening for reinforced concrete and masonry structures. Due to their low invasiveness, high structural efficiency, high strength-to-weight ratio and partial reversibility after application, they are particularly suitable for the reinforcement of masonry structures. Their execution is simple and quick, it requires adequate preparation of the substrate, on which the FRCM layer is subsequently applied, according to a continuous or discontinuous configuration (wrapping), for a thickness between 10 and 25 mm.

Although the application of these composites has proven to guarantee significant increases to the bearing capacity of the reinforced element, their structural efficiency is closely linked to the quality of their bond with the substrate: the premature triggering of a debonding mechanism from the support would, in fact, cause a sudden reduction of the bearing capacity of the reinforced element, and, sometimes, a fragile type failure of the structure. Therefore, over the years, various test set-ups have been developed for the laboratory study of the adhesion properties of FRCM materials, aimed at analyzing the effect of different parameters on their adherence capacity and the consequent debonding mode. In particular, this thesis work focused on the experimental and analytical investigation of the influence of out-of-plane bending and high-cycle fatigue load, on the bond behaviour of FRCM composites. A new test set-up was specifically designed to recreate laboratory conditions similar to those of a real inflected element (see Fig. 1). The campaign involved both direct-shear and modified-beam test, on different FRCM materials, including PBO and carbon textiles. The results of the experimental conducted on FRCM strengthened masonry and concrete substrates subjected to bending, showed that the application's bond capacity could be enhanced by the effect of a stress component normal to the matrix-fiber interface, attributed to the effect of substrate out-of-plane rotation.

The experimental campaign was supported by predictive analytical models, based on a fracture mechanics approach and calibrated on experimental results (see Fig. 2). The models proposed adopted a bi-linear rigid-softening cohesive material law, which allowed obtaining a simplified closed-form solution of the bond differential equation. Furthermore, to predict this extra bond capacity exhibited by modified beam test of FRCM strengthened specimens, a snubbing-friction coefficient may be included, calibrated on the specific fiber-matrix pairing.
The experimental results of FRCM strengthened concrete specimens subjected to fatigue, proved the effectiveness of those materials to withstand a considerable number of load cycles. This makes those materials eligible for the strengthening of bridges, viaducts and aqueducts, which, due to their intended use, are constantly subjected to oscillatory load over their entire service life. From the review of the concerning scientific literature, two main parameters appeared to affect the effectiveness of FRCM applications subjected to fatigue, namely the reinforcement ratio and the fatigue load amplitude. An important aspect emerged from the comparison between experimental results and corresponding analytical prevision, is the effect of fiber damaging and deterioration on the effectiveness of FRCM application. This aspect may assume a crucial relevance under specific circumstances, such as the presence of sharp corner at the fiber exit point of strengthened substrates subjected to out-of-plane rotation, or in the case of deflected RC beam subjected to cyclic action. Fabric deterioration dramatically reduced both the bond capacity and the fatigue life of quasi-static and fatigue tested MB test, respectively. The effect could be more evident if a brittle fiber textile was employed, such as carbon or glass.

The experimental procedures described and the corresponding results, alongside with the predictive analytical models, represents a valid database for the development of future works on those topics. Due to the poor capability of inorganic matrix to penetrate and impregnate the fiber layer, result of experimental test conducted on FRCM specimens are affected by high scatter, especially if compared to that of FRPs. This will require a wider number of test to validate hypothesis ad theses presented in this study.

Fig. 1 - Modified beam bond test setup

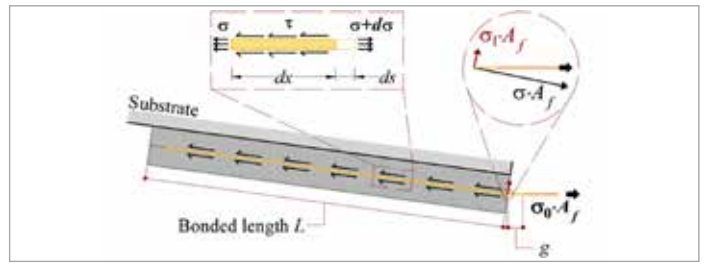

Fig. 2 - Analytical model

CO-EVOLVING SIGNIFICANCE. PROCESSES AND OUTLINES FOR THE VALORIZATION OF SPA TOWNS

Viola Fabi - Supervisor: Emilio Faroldi

Co-supervisor: Maria Pilar Vettori - Tutor: Stefano Capolongo

First tourist destination in the modern sense, spa town represents, at the turn of the XX Century, a point of reference for the international cultural and political panorama, as well as urban experimentations witnessing the evolution of tourism and health trends and the architectural culture of the last Century. Today, these places still suffer from a period of deep crisis that affected the thermal tourism sector at the beginning of the 1990s, whose repercussions on the local system —economic, social, cultural and environmental— are visible in the numerous episodes of degradation and abandonment of the public and private built cultural heritage. Whilst numerous policies have been undertaken to relaunch local tourism offers, the profound change in the socio-economic conditions that have determined the birth and development of these places suggests the need to reconsider the role that spa towns can play within territorial dynamics. With reference to the contemporary debate that advocates a renewed approach to the city and the territory, 'in search of new urbanities', the research argues that spa towns, as contexts of high urban and landscape quality, can be considered as privileged areas within territorial rebalancing and development dynamics: systems of latent opportunities able to concur to the innovation of territorial relations. By combining the state of the art with a critical reading of place-based research experiences, the research question is specified and declined in the Italian context. The question of local identity is combined with that of local development and opens up a reflection on the role of abandoned or underused built cultural heritage within urban transformation processes, as well as on the tools and processes that can accompany the management of change. While adopting a systemic and multidisciplinary approach, the research has a twofold objective: on the one hand, to generate awareness on the need to bring back the debate on the 'urban question', triggering a discussion on the intrinsic potential of these territories in the construction of the territorial capital; on the other hand, to identify tools and principles for the integrated valorisation of the Italian spa town and its abandoned built cultural heritage, highlighting the opportunities that strategic approaches to urban transformation can open — also considering the often limited financial resources available for public administrations—. These issues are addressed through two parallel levels of analysis. First, the research refers to theoretical features related to the role of cultural heritage as a driver for growth and territorial competitiveness. At the same time, the research provides a cross-reading of three international historic contexts which are renown for important processes of enhancement of their urban and architectural cultural heritage and that, today, are promoting urban and territorial development plans characterized by a strong strategic component (Bath, Vichy, Baden-Baden). The research highlights how, within logics of territorial rebalancing, the living environments of spa towns can represent an alternative to consolidated urban models, by reinterpreting and updating those very elements that historically characterized these places. While electing urban quality as a territorial asset, as a competitive advantage and as a lever for attracting resources and talents, the valorisation of the built cultural heritage plays the fundamental role of a catalyst of innovative synergies. From here, within a strategic vision for the city and the territory — able to combine local demands with regional specialization axes—, the spa town can be understood as a physical and cultural infrastructure able to contribute actively to territorial cohesion and growth: the strategic node of a network of proximity relations for the construction of a cohesive and inclusive territory. Finally, the research is carried out on an operational level through the systematisation of the themes, the tools and the processes that emerged. The research provides a collection of key principles and methodological outlines that define the verification of the research hypothesis and that, at the same time, constitute the basis for further studies and developments in the field.

Fig. 1 - European thermal heritage. In grey Moldoveanu (1992), in red Gillette (2009).

Fig. 2 - Overlook on the Italian context. On the left: Italian thermal municipalities, degraded urban areas and inner areas. On the right: Italian thermal structures and inner areas.

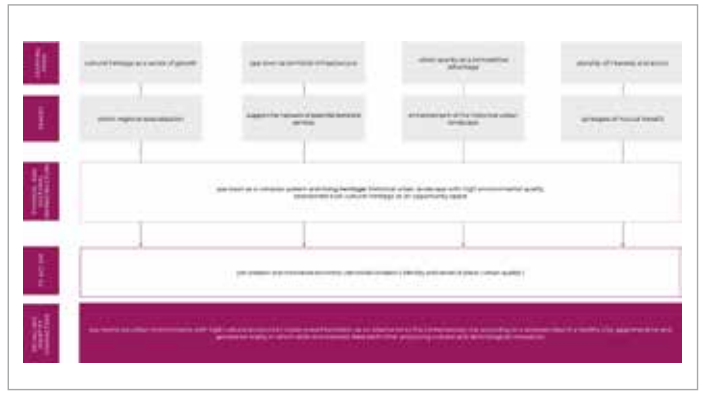

Fig. 3 - Synthesis scheme of the research project.

WALLED CENTER REGENERATION IN CHINA: DEVELOPING HISTORIC URBAN LANDSCAPE IN XI'AN WALLED CITY

Xu Lu - Supervisor: Laura Anna Pezzetti

Tutor: Daniele Fanzini

This research tries to develop a set of practical methodology to rehabilitate the walled historic centers in the frame of Historic Urban Landscape (HUL) approach to identify and reshape unique integrate urban landscape of Xi'an Walled City (XWC) in the residential rehabilitation process.

The city of Xi'an, (aka. Chang'an) is used to be the capital of ancient China for centuries. Xi'an Walled City of was built in Ming dynasty (1374) overlapping many layers from the glorious history. The great masterpiece itself is presenting city planning of China through its 3000 years history. XWC is sitting in the geometric center of metropolitan modern city, it without doubt has the potential to be a live monument and a record of China's urban history. However, starting the end of 20th century, due to the rapid and uncontrolled redevelopment, XWC has experienced extensive constructions and deconstructions, which leading to spatial and social fragmentation. Original physical urban fabric and social structure is heavily damaged, result in the characteristic historic urban landscape is fading away by the large scale of unrestrained demolition of "dilapidated building". As the regeneration of city occurring, urban heritages as monuments are recognized as the constitute key resources to enhance the livability and forester socio-economic conditions. The economic growth has alleviated poverty in Xi'an but at the same time has transformed essence of the historic areas specially in XWC. It's necessary for the core historic area of Xi'an to achieve the balance between the urban growth and quality of dwelling environment in a harmony and sustainable way. In the name of promoting deterioration of the quality of the urban built environment, the insertion of modern architecture leading degraded areas desertion in XWC that historic building typologies and organizational structure are disappearing rapidly on the major architectures apart from the heritages. local population as culture carrier are facing the replacement and XWC is losing its identity and characteristic as whole cultural milieu and magnet to a homogeneous urban landscape during this urban transformation process. The conventional conservation plan is either too general or only focus on the historic monuments. Majority buildings are renewing drastically under ambiguous guidance and regulations, no predominated and structural maintenance strategies are promoted. There is urgent need to propose a integrate approach in a sustainable development framework that can apply in a range of traditional and innovative tools adapted to local contexts. The Historic Urban Landscape approach (HUL) is adopted as an instrument to preserve the quality and historic, culture, socio-economic value of built environment. HUL as a definition, it's an urban area understood as the result of historic laying of culture and socio-economic values and attributes; HUL as an approach, it comprehensive and integrated approach to the identification, assessment, conservation and management of the historic urban landscape. Through the definition elements of XWC, including all built environment and historic assets, large amount of culture property, urban structure, residential typologies and inhabitants. Historic Urban Landscape (HUL) of Xi'an Walled City (XWC) promotes Xi'an with modern functions, as well as tourism, culture, education, intangible property, while makes XWC distinctive and creates sense of place and identity for the local communities.

Nonetheless, among the key traits to distinguish HUL, the state of residential buildings is often undermined, they are not treated as a component of urban landscape traits like the culture milieus in the conventional urban regeneration methods in Xi'an. As the majority architecture in XWC, a large portion of urban area that continuously regenerated by the homogeneous residentials with the same values, their attributes are impact the urban landscape of XWC decisively. This research implies explicit strategies that deals with the matter of integrating and organizing the quality resources that Xi'an inherits from history to produce living environment with wealthy, quality, and identity regarding the rehabilitation in XWC. Looking at the basic components of historic urban landscape by definitions, this research tries to apply a wide range of innovative approaches in local context in Chinese historic cities. Applied approaches include documentation, assessment, interpretation and mapping of historic and culture characteristics elements to support and facilitate decision making process into concrete scenarios and development framework to regenerate the historic city core in Xi'an.
Under the pre-condition of protecting the integrity and authenticity urban landscape in the walled city, this research is aiming to define the meaning of urban landscape in contemporary XWC, reinforce it by revitalizing residential architectures and urban living environment in variety urban units, to sew scattered urban landscape into a holistic historic walled city context.

Thus, the main process can be interpreted in 3 steps,
Step I Analyses and state of the art;
Step II Urban Landscape Units (ULU) delineation;
Step III Interpretation of Landscape Unit and engaging the treatments to the residential in ULU.

The contribution of this study has been confirmed two major questions:
First, state a clear HUL connotation of XWC as a definition, giving the precise definition of what is Historic landscape of Xi'an Walled City. Integrating the Historic Urban Landscape in XWC as a whole urban region, qualifying and enhancing the characteristic of unique historic center of Xi'an.
Second, with the integrated vision of Historic Urban Landscape, apply the residential regeneration operation guidance in XWC. Reinforce the HUL of XWC by revitalize the pilot area with corresponding set of goals and solutions. Explain how to engage a full regeneration process in specific communities in XWC, through which are expecting to improve and shape up the historic landscape of XWC.

By integrating the HUL approach in XWC, this research tries to identify, assess, conserve and manage the historic urban landscape in XWC, applying both the traditional and innovative tools into the contemporary city with the regeneration of residential in XWC. HUL framework plays a salient role on improving urban livability. By interpreting the urbanization and relating the specific strategy to the physical propose perceptible forms in polit area, there is high hope to implement into other ULU units with homogeneous qualities according to the HUL definitions and frameworks.

The study is expected to serve as a representative example to inspire following rehabilitation research of historic centers in China.

EVALUATING "DESIGN FOR ALL" IN HEALTHCARE ENVIRONMENTS. A NEW TOOL TO ASSESS PHYSICAL, SENSORY-COGNITIVE AND SOCIAL QUALITY: DESIGN FOR ALL A.U.D.I.T. (ASSESSMENT USABILITY DESIGN AND INCLUSION TOOL).

Erica Isa Mosca - Supervisor: Stefano Capolongo

Co-supervisor: Edward Steinfeld - Tutor: Laura Elisabetta Malighetti

INTRODUCTION.
People's needs are becoming increasingly complex, which represents a crucial issue in the design of buildings. Indeed, the physical environment can affect people's behavior and the way they perform activities. Currently, *Design for All* strategy, meant to design for human diversity, inclusion and equality, has been adopted in design practice to provide usable and inclusive solutions regardless of age, gender, cultural background, abilities or disabilities, overcoming the concept of architectural barriers. In a *hospital environment*, problems of accessibility, wayfinding and comfort can generate disabling situations and extra cost and time for adjustments, which impact users' health and the overall service quality. A lack of performance systems able to evaluate the integration of *physical, sensory* and *social* aspects of design projects was analyzed, particularly in relation to hospital environmental qualities.

RESEARCH OBJECTIVE.
Design for All strategy is becoming crucial to understanding the relation between space and users' needs. Therefore, how can the usability and inclusion of hospital environments be measured and projected, by means of a performance-based approach, so as to generate reliable evidence-based data? The purpose of the current research is to improve usability, inclusion and human experience by adopting Design for All strategy so as to enable the design of hospitals for all different users. The research aims to develop a tool able to evaluate the situation at existing hospitals, to define critical issues and to suggest design solutions for improving the environment in terms of users' health and well-being.

METHODOLOGY.
The research is set up around three different phases: Analysis, Elaboration, and Application-Validation. An in-depth literature review of the current state of knowledge in *Design for All* evaluation has been addressed to underline the most important theories, criteria, methods and tools. The following evaluation framework resulted from both theoretical and empirical methods: literature review, workshops and focus groups with both users and experts, and the analysis of four hospitals. Data have been gathered by following a multi-criteria analysis approach. The tool was applied in two hospital pilot case studies: the first version in an international context (United States) that allowed the testing and review of the tool, the second version in a national context (Milan) as validation. Finally, the results were discussed, together with research outlooks.

RESULTS.
The research led to a tool named "Design for All A.U.D.I.T. (Assessment Usability Design & Inclusion Tool)" to measure the Physical-spatial, Sensory-cognitive and Social quality of the hospital environments through a rating system based on performance. The tool's structure is based on a hierarchical framework composed by 3 Categories (Physical-Spatial quality; Sensory-cognitive quality and Social quality); 8 Criteria (Usability, Functionality, Safety and Security, Wayfinding, Understanding, Environmental factors, Well-Being and Social Inclusion); 20 Indicators and a plurality of requirements to compare quantitative and qualitative aspects of the same project. The tool is characterized by a flexible structure and is able to assess quality considering different areas of the hospital: Outdoor Spaces, Entrance, Interior Circulation, Support Spaces (waiting areas, bathrooms, food services), Workspaces (exam rooms, offices) and Overall Service. A questionnaire was developed and addressed in the first hospital pilot case study to compare the tool's analysis in relation to users' experience within the same hospital, which confirms the reliability of the tool's evaluation. The research defines both the way the tool should be accessed by the market, through an online prototype (website), and the integration of this instrument in a participatory process among stakeholders.

Fig. 1 - Stakeholders involved in the design and evaluation process to achieve an inclusive project

CONCLUSIONS.
Design for All A.U.D.I.T. is intended to be a service provided by an auditor to support the decision-making process regarding new buildings or the renovation of specific areas, highlighting weaknesses and improvements to promote the well-being of different healthcare users. Research outlooks aim to scale up the tool's application in both a wider sample of hospitals and different building typologies, seeking a patent of the tool as a consultancy service. On the whole, the study will contribute to filling the gap between theory and practice in *Design for All* project evaluation and to supporting the design of inclusive hospitals for as many users as possible.

Fig. 2 - The hierarchical evaluation framework of Design for All

Fig. 3 - Space settings of the hospital environment proposed for the evaluation.

A NURBS-BASED FORM-FINDING APPROACH FOR GLAZED GRIDSHELLS. MULTI-OBJECTIVE OPTIMISATION OF STRUCTURAL, GEOMETRICAL AND ENERGY-RELATED ASPECTS

Tommaso Pagnacco - Supervisor: Gabriele Masera

Tutor: Fulvio Re Cecconi

This work addresses the interest of Bollinger + Grohmann in exploring multidisciplinary optimisation of glazed gridshell under structural, geometrical and energy-related aspects. By exploiting the properties of Genetic algorithms, Non-Uniform B-Spline basis functions and an attentive design process understanding, we aim to develop a Vertical tool capable of helping designers in the early design stage. This choice leads to substantial improvements in the company outcome during competitions or initial project phases. The suggested framework aims to de-couple structural constraints from the form finding process to integrate multiple targets inside a unique work-flow. The particular choice of using Non-Uniform B-Splines inside a form-finding function allows to associate the gridshell mesh to a differentiable shape which can be controlled through a limited number of control points. Finally, the use of Genetic algorithms allows exploring non-differentiable functions that consider multiple design parameters offering a wide range of outcome alternatives. Considerations regarding the computational limitations of such a method are addressed in the final part of this thesis. The methods are illustrated by simple numerical tests on both theoretical and real case studies.

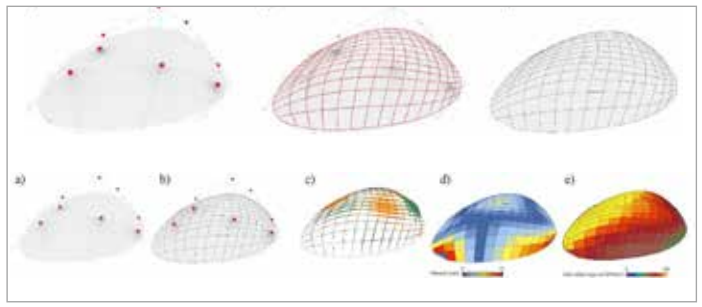

Fig. 1 - a) NURBS with Control points, b) Mesh from NURBS, c) Structural analysis of beams, d) Mesh Quads planarity, e) Direct Solar radiation on Quads

THE SOCIO-ECONOMIC IMPACT OF CULTURAL HERITAGE AND THE ROLE OF TERRITORIAL IDENTITY

Elisa Panzera - Supervisor: Roberta Capello

Tutor: Valeria Natalina Pracchi

Starting from the assumption that cultural heritage represents a valuable, unique and irreplaceable resource for European countries, the present thesis aims at identifying and quantitatively testing potential channels through which cultural heritage could influence local socio-economic development. As well as being able to generate positive influences on local culture, society and environment, cultural heritage plays a role in the processes of local economic growth. In fact, cultural heritage entertains tight and solid relations with the local environment in which it is located and with the related territorial elements and assets being them tangible or intangible, natural or artificial, socio-cultural in nature, cognitive, relational or economic. Despite considerable interest has been showed by the economic literature towards cultural heritage and its economic value and impact, it is still hard to find empirical evidence that explains and tests whether and how the endowment of cultural heritage could be able to benefit local socio-economic growth.

The thesis presents an original perspective according to which cultural heritage influences economic dynamics not only through pure and mainstream economic channels (e.g., tourism) but also through interactions with territorial socio-cultural and psychological characteristics that, in turn, affect local potentialities for development. In particular, the thesis focuses on the relationship and synergies between cultural heritage, territorial identity and local economic development.

Many economic activities are related to the presence of cultural heritage in a specific territory. Heritage institutions can be considered as economic subjects directly employing labor force and generating revenues from ticket sales (when required). Furthermore, various sectors are involved, influenced, and stimulated by the presence of heritage such as archaeology, architecture, museums, libraries, tourism, real estate, but also ICT and insurance. Even though attempts of measuring economic consequences of local endowment of cultural heritage have been carried out throughout the literature, the mainly national scope of the analyses and the focus on specific case-studies do not allow to generalize the results and to identify the existence of a valid and effective mechanism that works across national boundaries and typologies of heritage. More importantly, cultural heritage also presents synergies with non-economic aspects of communities and territories such as social capital, individuals' and communities' well-being, identity creation, shaping and enhancement, and sense of belonging. Even though it is reasonable to assume that these effects might result in some positive spillovers for local economies, the economic literature has rarely analyzed them.

Therefore, an innovative conceptual framework is proposed in which the concurrent existence of two diverse mechanisms of transmission between cultural heritage and local socio-economic development is recognized, conceptualized, and empirically tested. With the aim of better understand the cause-effect nexus between the endowment of cultural heritage and local development, two main channels are explored in the thesis, namely tourism and territorial identity. Whilst tourism represents a direct, purely economic channel, territorial identity is an intangible, soft and context-specific channel. By jointly investigating these two substantially different mechanisms in a single thesis the multi-faceted and multiple values of cultural heritage are acknowledged and valorized. In fact, heritage can determine consequences on local economies through its economic value in terms of sales, tourist consumption or related investments. Nonetheless, the socio-cultural values carried by cultural heritage influence its role in local development. Through, for instance, its historical, symbolic, and aesthetic values heritage represents an engine for curiosity, capability to doubt, sense of belonging, and cohesiveness resulting in a relevant driver of development in its broader sense involving cultural, social, and economic domains.

The first part of the research is dedicated at deepening and investigating one of the most studied and examined channels through which the endowment of cultural heritage could be able to influence economic dynamics, namely tourism. In fact, local cultural heritage and tourism attractiveness are inextricably related and, at the same time, tourism is a large, relevant and fast-growing economic sector. Empirical evidence investigating and proving the existence and validity of a link between cultural heritage and tourist flows is still uncertain and vague and the same is valid for the relationship between tourism and economic growth. The main novelties of this first part of the research are related to the proposal of an empirical model that jointly explores the relationship between material tangible forms of heritage, tourism and economic growth and to the extension of the scope of the analysis to all the regions belonging to the European Union allowing to affirm the existence of a mechanism that, on average, can be generalized. Furthermore, the risks of tourism being one of the predominant channels that allow cultural heritage to produce an impact on economic growth will be mentioned highlighting the need for implementation of cautious planning strategies able to control and limit the potential negative aspects of tourism assuring the right balance between conservation and usage of heritage sites and between economic benefits and socio-cultural dynamics.

The second part of the research is dedicated at examining the role of local endowment of cultural heritage as an economic engine through a socio-cultural type of channel, namely identity creation or enhancement. Being cultural heritage at once inherited from the past and a legacy for future generations, it is considered as a source of sense of belonging to a place and territorial identity. The association between cultural heritage and identity is commonly presented as socio-cultural in nature expressing its implications on - and being influenced by - society or culture in its broader sense. However, economic implications might result as well from this nexus. In fact, territorial identity and territorial identification give rise to varied feelings such as trust or togetherness but also disaffection or resentment. These elements, in turn, influence the way in which economic dynamics work leading to consequences on local economic growth. The main idea behind the present work is that the powerful interrelation between cultural heritage and identity does have an influence on local economic growth. In other words, cultural heritage plays an active role in the economic sphere through an indirect socio-cultural channel namely identity formation or identity enhancement. After the proposal of an original taxonomy of different ways of expressions of territorial identity, an empirical analysis will be performed on European regions to quantitatively test the existence of a link between the presence of tangible forms of cultural heritage and economic growth through synergies with identity and territorial sense of belonging. Different functioning of this mechanism according to different ways of expressions of territorial identity will be investigated.

The eventual purpose of this research regards the possibility to express some policy recommendations targeted to the importance of conservation and valorization activities assuring the right balance between cultural heritage usage and safeguarding. What is more, the thesis highlights the paramount relevance of cultural heritage and takes a step forward in the direction of considering heritage as a central, essential element for local development strategies.

CONDITION-BASED STRUCTURAL MAINTENANCE OF CULTURAL HERITAGE BUILDINGS. CONTINUOUS MONITORING STRATEGIES

Antonello Ruccolo - Supervisor: Carmelo Gentile

Tutor: Pierluigi Colombi

Cultural Heritage buildings preservation

The preservation and conservation of the invaluable historical Cultural Heritage (CH) buildings motivates vivid concern, since many ancient structures are characterized by uncertain and poor structural arrangement, crack patterns already triggered, and aging of materials.
Within the category of CH buildings, several typologies of structures are listed (e.g. vernacular architectures, bell-towers, cathedrals, and castles) that can be discriminated between three categories: “simple” squat structures, “simple” slender structures (towers, chimneys, minarets) and “complex” buildings (cathedrals, monumental buildings). Among them, the last two categories of CH structure are particularly vulnerable and prone to dynamic actions, such as bells swinging, strong wind, and earthquakes.
On the other hand, dynamic excitation can also be exploited as a diagnostic tool: in fact, the dynamic excitation produced by the surrounding environment (wind, traffic, human/industrial activities) induces a structural vibration that can be measured by few high-sensitivity accelerometers, leading to the evaluation of natural frequencies and their associated mode shape.
The knowledge of natural frequencies is very promising because, considering the tower as a mechanical system, natural frequencies are related to mechanical stiffness.
an effective damage-detection procedure can be established through continuous monitoring of the natural frequencies: any sudden structural damage will induce an abrupt shift of the natural frequencies.
Recent studies have acknowledged that vibration-based Structural Health Monitoring (SHM) can promptly detect the occurrence of structural anomalies in slender masonry towers, adopting only few high sensitivity accelerometers installed on top of the structure. Conversely, natural frequencies, being global features do not directly address the damage localization.
To perform an effective Condition-based structural Maintenance (CBM), the information gathered from the dynamic monitoring could be integrated within a network of heterogeneous sensors, capable to acquire both the environmental effects (temperature, humidity, wind speed) and the quasi-static structural response (i.e. inclination, rotation, local deformation, crack opening). The adoption of heterogeneous sensors might be useful to localize and classify the occurrence of damage combining the effectiveness of natural frequencies as damage-sensitive features, and the sensitivity of static mechanical parameters (inclination, crack opening…) to local alterations of the structural condition.
Finally, it should be remarked that static and dynamic signatures are not time-invariant, due to the environmental effects on the structure, therefore environmental factors are usually measured to establish a correlation with the static or dynamic signatures and discriminate between normal or anomalous variations. Damage-detection procedures usually require preliminary removal of environmental factors from the structural features and a subsequent novelty analysis.

Applications

The research project addresses a CBM framework aimed at the preservation of CH and historic buildings employing both static and vibration-based SHM. The procedures are initially exemplified on a masonry tower in Monza and then extended on the Milan Cathedral, a monumental building.
The first practical application of this methodology is devoted to the Santa Maria al Carrobiolo bell-tower in Monza. Such tower exhibits peculiar dynamic characteristics, conceivably due to the poor structural arrangement of the tower, and currently is under static monitoring (i.e. the opening of 8 cracks are continuously monitored) and under dynamic monitoring (by means of 4 accelerometers on top of the tower). Taking advantage of the lessons learned from this relatively “simple” structure, the research project has developed a strategy for CSM of complex CH buildings, applied on the monitoring system of the Milan Cathedral, one of the largest Gothic Cathedrals in the world. The overall monitoring system of the Cathedral and its main spire comprises: 27 seismometers are installed on the capitals of selected columns, 12 strain gauges are mounted on metallic tie-rods subjected to relatively high stress level and slight damages, and 9 seismometers are then installed at three levels of the main spire.
Furthermore, both humidity and indoor/outdoor temperatures are monitored by means of several sensors installed inside and outside the Cathedral.
Natural frequencies of the Cathedral and strain in the metallic tie-rods are affected by environmental effects. In turns, it seems that the great number of metallic-tie rods connecting the capitals of adjacent columns (i.e. 112 ties) plays an unexpected role in stiffening the Cathedral during the cold season. Therefore, the high correlation detected between strains in the ties and natural frequencies suggests to cleanse environmental effect out of natural frequencies and strain in the ties in a common framework, in the perspective to “fuse” the data collected from static monitoring systems and the dynamic one.
Moreover, the availability of seismometers distributed all over the Cathedral allows a simplified representation of its principal mode shapes: during the first months of monitoring, such mode shapes have proved to be quite unaffected by environmental conditions, thus might be adopted as damage-sensitive features. In turn, even modal displacements can be helpful to localize the onset of structural anomalies. The analysis of modal displacements has proven to timely detect the occurrence of sensors malfunctioning.

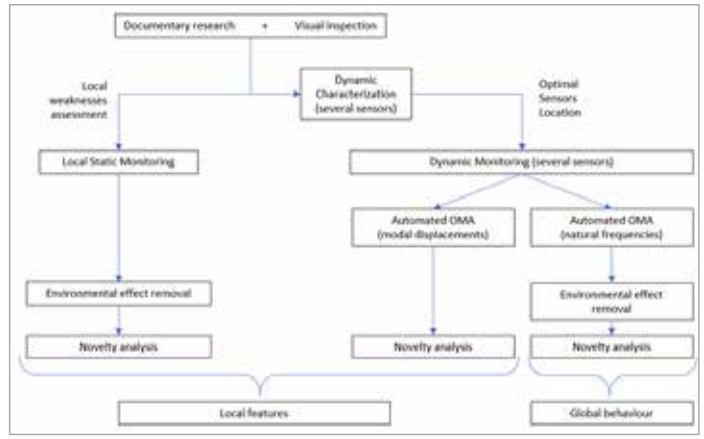

Fig. 1 - Framework for data-driven CSM of complex CH buildings

PAVEL JANÁK / A STUDY OF HIS FORMAL EXPRESSIONS AND DESIGN TECHNIQUES

Qi Wang - Supervisor: Domenico Giuseppe Chizzoniti

Tutor: Francesca Bonfante

The research is related to the Czech Architect Pavel Janák. As one of the protagonists of the avant-garde movement in Czechoslovakia of early 20th century, Janák had established the theoretical basis of cubist-style architecture and gradually developed it from a geometric formal language into a rational and spiritual expression with symbolic significance. Janák's architectural design concept was largely inspired by Cubist art, of which, the plasticity and abstract expression for him are as the key of translating the radical Slav architectural tradition to the glossy context of the "Modern". His early cubist-style works of formative years, had a strong plastic characteristic. They are in most cases composed of geometric shapes and representing complex and dynamic images. In order to decode this complexity, the research tracks the evolution of his design philosophy by tracing his works in different style-period and analyses the design techniques used. Therefore, the purpose of the whole research is to explore the evolutionary process of Janák's form expression and design techniques. And furthermore, the research is to look into the problem how Janák as the most "spiritual" architect at that time, struggled to reconcile between the ideal and the practical, seeking for a purity, free from influences of complex social factors, embraced as a response to "artistic will" with the technique separation. The research adopted a series of remodelling and diagramming approach to analyse Janák's practical works in different stages of creation. Referred to his theoretical works, we've carried out a close study of Janák's major works, from the initial sketches to the final achievements. In this process. the geometry archetypes were seen as a solid alphabet following a certain syntax of formal system. The design techniques were seen as the mediator that closely related to the architect's artistic intention, by which, the spirituality can be injected into the materialization of the building. More profoundly, by studying Pavel Janák's manuscript diary, the study tries to look into his self-reflection and deep thought behind each design activity, so as to interpret his intention from a height of aesthetics and link it to his design visions and life philosophy, and further, connect it to the cultural predicaments of his times.

The thesis is arranged in three parts: after a brief background narrative in the preface and introduction, it is unfolded firstly with Janák's formative years with Cubist influence; then expounded the way of his pursuing to the Modernism and analysing of the specific techniques; and finally, it is closed up with the long-term project Hotel Julis throughout his career, summarizing the enlightenments. So the following, as a summary of thesis content, also expands form these three aspects.

Cubist influence

Janák was born late enough to look back at the roots of Cubist art beyond dimensions through the haze of dynamic Baroque style. By reviewing Janák's important works of each stage, while analysing his design techniques as Oblique planes, Spatial Layering, and Grids, etc. it is not difficult to find out, that the formal language of his architectural work consists of an alphabet of geometry embedded in a systematic framework, it represents three characterestics - geometric, abstract, and systematic, which are all inherited from Cubist art. Under the influence of Cubism art, Janák devoted to relate the architectural perception from a two-dimension visual plane to the three-dimension volumetric reality by all means of abstract and empathy. As in the essay "From Modern Architecture to Architecture", he was motivated by his critical thinking against Otto Wagner's secessionist idea with the mood of rejecting the machine-like building of technical skeleton. In his essay "Prism and Pyramid", clearly, the space-generating capability of triangle was primarily emphasized. He set it as spatial laws to guide the design process. Thus, the new geometric language challenges the traditional right-angled shapes and advocating the sense of formal dynamic across dimensions. In the essay "About Furniture and Other Matters" Janák had fully linked the design process to the abstract method. and he called the method as "spiritual abstraction of matter" which referred to a spiritual arrangement, then was extended as "spatial expressions of emotion". In the essay "Renewal of the Façade", here he proposed to spiritualize architecture by means of sculptural surfaces expressively dramatizing the facade, for he pursued the idea that the inner three-dimension space of buildings should provide a place for something far more artistic and spiritual by a "spatial formulation of their surface".

The way to Modern

In the way of pursuing the modernity, the aesthetic urge, which Riegl saw as pivotal not only creatively possible but also artistically necessary, was always the creed of Janák's. He had always examined the architecture as an art. And Constructivism and Functionalism reflect the arrangement of the world and the program of social life rather than a new art. Although the influence of Cubism for Janák is overwhelming, throughout his 40-year architectural career, his works can hardly be summarized in one style as Cubist. That is because, at first, his design techniques were focus not on the solitary geometric and objects, but the pursuit of the relationship among them, as the rules of spatial composition and construction principles in design. Therefore, whenever a new criterion of the time appeared, he would attempt to achieve new forms. Thus Modern for Janák is meant for stylistic. In Janák's reconsideration of each discipline in architecture, form and style are related to each other, as his starting point and goal of design respectively. He emphasized that: "Purpose dies, not shape and faith, filling matter abstracted from the purpose". For Janák, the objective "form is the "starts point", and the subjective "stylistic figures" are the "goal of design".

Enlightens

Janák's emphasis on the spirituality of architectural form made him more visionary, foreseeing the value of symbolic meaning of architecture, which is placed over the pragmatic needs as presupposition. Obviously, "history" here is not just the classics or forms related to the authoritative polities, but in a neutral role, towards a "vernacular modernism", of which, Janák's experience provides successive precedents, no matter in the wave of nationalism arising in the great social changes, or spiritual pursuit in the restriction of economic development. And in the end, it is achieved a neutral symbolism with no obvious political stance in the period of the white functionalism. The lesson we can learn from Czech modern movement is that: modern Architecture is based on material, construction and efficiency, which should be natural, non-speculative, out of historical social life, receiving only the lifestyle of the contemporary world. It is in the principle to be directed toward inner expression; it is in the transformation of tradition into a functionality of a higher order that will fulfil more than just mechanical requirements, that will create an independent object with the complexity as a work of art.

TRANSACTIVE BUILDING TYPES FOR TERRITORIES IN TRANSITION. A PRAGMATIST ANALYSIS AND DESIGN METHODOLOGY APPLIED TO THE CASE OF DUTCH ARCHITECTURE BETWEEN WELFARE STATE AND NEOLIBERALISM

Andrea Zammataro - Supervisor: Antonella Contin

Co-supervisor: Andrej Radman - Tutor: Michele Giovanni Caja

Territorial transitions are uncertain phenomena which must be oriented through the definition of new settling forms. But how can architects design for inhabitants whose identity is uncertain as well?
The experience of the Netherlands facing both the investment programmes of the welfare state and the reforms of the neoliberal turn is exemplary with this respect.
In particular, the Dutch case demonstrates how territorial transitions require architects to disregard any logic of recognition between preordained building and user types and rather consider this relation as a transaction, i.e. a process of reciprocal determination between concrete environments and subjects based on a series of situated operations the latter perform with respect to the former. Even more, an initial operation of estrangement was sometimes adopted to let subjects suspend their assumptions and establish new dwelling practices on the basis of an original inquiry.
The objective of the thesis is to define a methodology which allows architects to consider the process of transaction in both the analysis of existing buildings and the design of new projects. To this end, the research draws upon pragmatist semiotics and applies it to the analysis of Dutch case studies in order to abstract a series of transactive building types which can help us manage the territorial transitions of the near future.
From a methodological point of view, the issue of subject formation requires the thesis to cross disciplinary limits and explore the philosophical domain. In particular, structuralism and pragmatism represent the main references because, due to their complementarity, they cover a wide range of positions about the topic.
Broadly speaking, structuralism interprets subjects as the discrete elements of a static structure while pragmatism conceives of subjects in more dynamic terms, i.e. as the result of transaction, which is a concept by the pragmatist philosopher John Dewey. In order to operatively model their theories, structuralism and pragmatism both elaborated their own semiotic systems. The former is mainly based on linguistic signs of which the conventionality mirrors the stability of the structure, while the latter also takes into account signs of an aesthetic kind of which the contingent value evolves into stabler and codified forms over time. Semiotics also represents the joining link between philosophy and architecture because it was interesting to post-war architects who wanted to understand how buildings could be significant to inhabitants.
Nevertheless, the structuralist and pragmatist versions were adopted in architecture in different periods, i.e. in the 1960s and the 2000s respectively. This is due to historical factors and in particular to the shift from the welfare state to neoliberalism, because the conventional character of structuralist signs better suited the centralized governance model of the former while the dynamic character of pragmatist signs better suited the self-regulatory post-Fordist system of the latter.
With respect to the geographical location of case studies, the focus is on Dutch architecture because the Netherlands offers a textbook

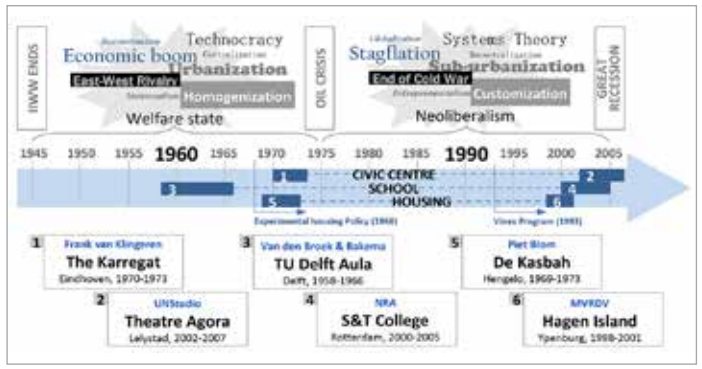

Fig. 1 - Timeline of case studies

implementation of both the agenda of welfare state and neoliberalism while, from a disciplinary point of view, it expressed the major representatives of structuralist and pragmatist architecture. Moreover, the traditionally strong bond between architects and public administration in the Netherlands makes the Dutch context particularly suitable to understand how architecture can accompany the transitions entailed by the implementation of socio-economic policies.
The outcome of the research is an analysis and design methodology which allows architects to take into account the significance of buildings to inhabitants and the role with respect to their formation, especially in the case of transitional subjectivities. In particular, given that the elements of the built environment can be understood as signs, the methodology draws upon the pragmatist semiotic theory by Charles Sanders Peirce, who formulated three different types of relation between subject and signs in order to represent all the possible gradations between aesthetic perception and codified interpretation. Moreover, Peirce's theory also explains the way these relations evolve over time. Indeed, an initial aesthetic type of relation can shift towards codified forms due to the fact that the interpretative process occurs by steps, each step starting from the provisional interpretation of the preceding in order to develop it into a more abstract version. The result is that the relation between subject and sign evolves from the extreme of an immediate interpretation, that is a simple sensation related to the way the sign materially affects the subject, to the opposite extreme of a final interpretation that is completely distinct from the sign so that it can be autonomously pointed at by convention, as in structuralist semiotics.
Due to the fact that structuralist semiotics is included in the pragmatist theory of signs as its final step, the methodology can be applied to both structuralist and pragmatist case studies, thus also allowing a comparative analysis. The result of the comparison is an original understanding of architectural structuralism and pragmatism which overcomes the oppositional confrontation proposed by architectural critics and rather recognizes how they both promoted a transactive relation between projects and inhabitants which was only differently intended with respect to the way it had to be negotiated among subjects because of the different underlying visions of society. The application of the methodology to case studies also allows the abstraction of typical combinations of design criteria. These combinations constitute transactive building types, i.e. building types which are inventively appropriated by communities in transition and also help architects and planners manage this transition.

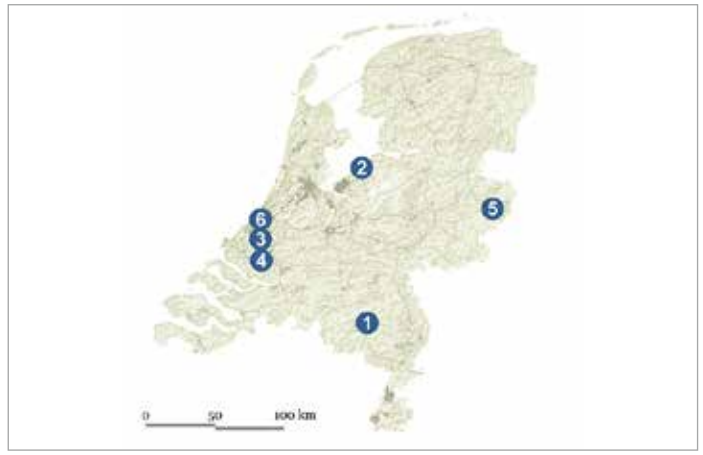

Fig. 2 - Location of case studies