ALTA SCUOLA
POLITECNICA
POLITECNICO DI MILANO | POLITECNICO DI TORINO

PROJECT / 11TH

Preface

This book marks the completion of the course of studies for the Alta Scuola Politecnica's 11th student cycle.
Created in 2004, the Alta Scuola Politecnica programme draws inspiration from the Politecnico di Milano and the Politecnico di Torino's experiences, which both share the common goal of offering a highly-innovative academic curriculum to talented students with a passion for multi-disciplinarity. From the very outset, this ambitious project aimed to create a so-called "Learning Route" between Torino and Milano. Thanks to the tight economic and social bonds between the two cities that are two pillars of the Italian economy, we are increasingly confident that we took the right decision, a decision which, over time, has evolved and transformed.
The world is experiencing a rapid economic and social development through the widespread application of technological innovations that are providing new creative solutions to emerging societal challenges. This is leading to the emergence of new economic paradigms that are coming forth to meet existing and new social needs affecting society, such as poverty, aging, climate change, migration and many others.
As a result, future professionals and researchers should master different knowledge domains, competences and capabilities to be transferred into future innovative products and services. At the same time, the Alta Scuola Politecnica is gifted with an extraordinary asset: the talent of its international students. This places us in a role that goes well beyond awarding degrees. It entails preparing students to become future responsible leaders in a changing planet. At Alta Scuola Politecnica, responsibility is not a soft commitment but a serious challenge, based on the intuition that understanding the complexity and structure of problems is the only consistent way to social responsibility.
Alta Scuola Politecnica's mission is centred on the concepts of multi-disciplinarity, complexity and responsibility, where high-profile graduates are combining domain-specific disciplinary knowledge with the interdisciplinary skills needed to succeed and contribute in the new playing field. ASP students are given the opportunity to continuously benefit and profit from one another, from the interdisciplinary and cross-cultural courses offered by the ASP programme and from projects proposed by companies and institutions that are at the cutting edge of technology, architecture and design. Through this unique blend of learning experiences, they develop leadership skills and competences that employers are increasingly seeking in top graduates from technical schools. Students have the opportunity to work in teams and to manage complex projects which require multi-disciplinary contributions, as illustrated in this book, and to attend residential courses, as well as enjoying a stimulating social and learning experience and being exposed to top scientists and the world's intellectual leaders. The significant presence of industrial sponsors in the thirteen ASP cycles is the proof that the mix of specialized skills coming from the Master's programs, and interdisciplinary skills provided by the Alta Scuola Politecnica, are highly valued.
This important achievement confirms that the path we chose to follow in 2004 was the right one, and it encourages us to pursue this goal with, at least, the same enthusiasm that is shown daily by our ASP students.

Prof. Marco Gilli, Rector, Politecnico di Torino
Prof. Ferruccio Resta, Rector, Politecnico di Milano

ALTA SCUOLA
POLITECNICA
POLITECNICO DI MILANO I POLITECNICO DI TORINO

Alta Scuola Politecnica (ASP) is a school for exceptionally talented students who wish to develop their capabilities for leading and promoting innovation in a multi-disciplinary environment.
Founded in 2004 by Politecnico di Milano and Politecnico di Torino, ASP is attended by students who at the same time pursue a Master of Science programme (Laurea Magistrale) in Engineering, Architecture and Design offered by the two Universities. Therefore, ASP is characterized by a multidisciplinary and multicultural community of students, and by an equally diverse Faculty.

The ASP cultural program complements the disciplinary knowledge achieved in the Master of Science programme with multidisciplinary knowledge that aims to provide methods and conceptual tools for designing solutions to complex problems and to enhance cognitive capacities, aptitude to learning, and talent for interpersonal relations.

This book presents the results of the multidisciplinary projects of the eleventh ASP cycle. These projects are developed by teams of students coming from very different disciplinary backgrounds, in cooperation with professors and with external institutions such as companies and governmental bodies. The book provides a snapshot that illustrates the variety and creativity of ASP contributors, as well as an inside view of the work and life of this unique community.

The illustration of project results is preceded by a short presentation describing the ASP program at its thirteenth birthday, complemented by testimonials from ASP Sponsors and Alumni.

ASP Sponsor

ASP is partially financially supported by external institutions which share our vision of educating talented students and promoting interdisciplinary innovation.
Following a three-year initial financial support from the Italian Ministry of University Education and Research, the main supporters of ASP are currently Compagnia di San Paolo and UBS.
Other institutions, both private and public, have joined in by providing financial support as well as a relation aimed at developing projects and opportunities for the career development of our students.
The logo of our sponsor are presented below and their valuable support is hereby gratefully acknowledged.

Compagnia di San Paolo

UBS

The Compagnia di San Paolo, founded in 1563 as a charitable brotherhood, is today one of the largest private-law foundations in Europe.
It pursues aims of public interest and social use, in order to foster the civil, cultural and economic development of the community in which it operates. The Compagnia is active in the sectors of Research and Health, Art, Cultural Heritage and Activities, Cultural Innovation, Social Policies, and Philanthropy.
In 2016 the Compagnia awarded 1044 grants in its areas of activity, amounting to 175 million euros.
The Compagnia pays great attention to advanced research and the development of scientific and technological centres of excellence, seen both as catalysts and multipliers of research and higher education initiatives. It supports the strengthening of Torino's university system, especially through the promotion of excellence at Torino University and Politecnico.
The commitment of the Compagnia in the field of Research is focused on university and postgraduate education, starting from the growth of human capital, internationalization and the provision of infrastructures, with special attention to the conditions that assure equal access for students. The Compagnia's relations with the universities in Piedmont (Università di Torino, Politecnico di Torino, Università del Piemonte orientale "Amedeo Avogadro") are regulated by strategic agreements covering infrastructure, research and postgraduate education.
In this context, the ASP's focus on excellence and innovation – besides characterizing it as a valuable initiative per se – allows this programme to enhance the global attractiveness of the Universities involved and promotes, within the leaders of the future, a specific attention to the interdisciplinary and international dimension of contemporary society. The programme, which has been supported by the Compagnia since 2007, also represents an interesting and successful example of cooperation between educational institutions based in the north-western region of Italy, such as the Torino and Milano Politecnici.

www.compagniadisanpaolo.it

www.compagniadisanpaolo.it

UBS is committed to providing wealthy, institutional and corporate clients worldwide, as well as private clients in Switzerland, with superior financial advice and solutions while generating attractive and sustainable returns for shareholders.

Its strategy centers on its Wealth Management and Wealth Management Americas businesses and its leading universal bank in Switzerland, complemented by its Asset Management business and its Investment Bank.

These businesses share three key characteristics: they benefit from a strong competitive position in their targeted markets, are capital-efficient, and offer a superior structural growth and profitability outlook.

UBS's strategy builds on the strengths of all of its businesses and focuses its efforts on areas in which it excels, while seeking to capitalize on the compelling growth prospects in the businesses and regions in which it operates. Capital strength is the foundation of its success.

Headquartered in Zurich, Switzerland, UBS has offices in more than 50 countries, including all major financial centers, and approximately 60,000 employees.

UBS Group AG is the holding company of the UBS Group. Under Swiss company law, UBS Group AG is organized as an Aktiengesellschaft, a corporation that has issued shares of common stock to investors.

The operational structure of the Group comprises the Corporate Center and five business divisions: Wealth Management, Wealth Management Americas, Personal & Corporate Banking, Asset Management.

www.ubs.com/italia

Summary

ASP Alumni

Association – Overview

The ASP Alumni Association was founded on June 28th, 2007, the day of the 1st cycle ASP students' graduation ceremony, with the aim of promoting opportunities for personal and professional growth and becoming a frame of reference for all future Alumni.
ASP Alumni operates with the purpose of growing the professional value of the Alumni and their network, acting in accordance with the common values of competence, innovation, and attention to sustainability and social responsibility.
The Association is a global network of highly qualified professionals who wish to share experiences and growth opportunities. Indeed, the association has grown rapidly during its first 9 years, and now boasts a community recognized both in the academic and business worlds, with a network of over 1000 members located across 20 countries and operating in the most widely recognized international companies and research organizations.
The Association, led by the passion of many young professionals alumni, offers a wide-ranging agenda of events. All of them - conferences, workshops, parties or outdoor events – contribute to strengthen the unique community spirit of ASP and foster the professional career of the associates.
A brand new official website has been released at the beginning of February 2015 and is going to be the main internal and external communication channel and organization platform of the Association, jointly with the groups and pages on the main social networks (LinkedIn discussion group, Twitter page and Facebook group, which at present hosts more than 800 members). ASP Alumni members, but also ASPers who have not completed their ASP path yet and followers of the Association can keep themselves updated about all the Association activities and events through the above mentioned social media. Moreover, interactions and sharing opportunities within the Alumni community are fostered by these communication media, as their users continuously post comments, pictures, articles, opinions and professional opportunities.
A brief review of the main recent activities organized by the Association is presented in the following paragraphs.

THE OPEN INNOVATION WAY | Conference on Open Innovation

On March 5th, 2016 the first conference jointly organized by ASP Alumni and SPE Young Professionals Italy took place at Politecnico di Milano, as a result of a partnership established between the two associations at the end of 2015.
The conference provided a full overview on the Open Innovation development and on its impact on companies' strategies through the experience of renowned speakers like Federico Frattini (Politecnico di Milano, Italy), Lucia Chierchia (Electrolux, Italy), Mario Chiaramonte (Geolog International), Carlo Napoli (Enel, Italy) and Danny Bar Zohar (Novartis Farma, Italy). The second part of the event hosted a panel discussion about the Open Innovation Environment, involving the representatives of different players in the field: a bank (Intesa San Paolo), two networks of excellence (ASP, SPE), an open innovation facilitator (BlueThink) and an incubator (PoliHub).

IOT: STORY OF THE FUTURE | Conference on Internet of Things

In consistency with the strong focus of Alta Scuola Politecnica on innovation and technology, ASP Alumni decided to base the 9th edition of its traditional Fall Event on the connected world characterizing everyday life, made of objects continuously beaming data to the internet, and on the increasingly

growing phenomenon of Internet of Things (IoT).
The best players in the field were gathered, in order to share different ex-

periences and points of view about the whole IoT revolution: from the very beginning - back to the 80's when the only connected object was a coke vending machine in a university department - to the unpredictable future. Marco Taisch (Politecnico di Milano, Italy), Danilo Pau (STMicroelectronics, Italy) and Giuliano Busetto (Siemens Italia, Italy) described the world of connected Machines and Industry 4.0 from the point of view of academy, research and big companies, explaining how small sensors can help saving human lives and live better, and proving that a sensor can fit in the most unimaginable places.
A series of IoT applications, in fields ranging from smart cities to the future horizons of open source, were then illustrated by Stefano Sarasso (Ubiquicom), Domenico Indolfi (Everis), Giuseppe Giordano (Enerbrain) and Francesco Meneghetti (Fabbricadigitale).

Sliding Session 2016 | Winter leisure event

Born in 2012 as a collaboration between students and Alumni, the fifth edition of ASP Alumni Sliding Session took place in March 2016, with a growing success among ASP Alumni members and ASP students. The event took place in Clavière, renowned alpine resort close to the French border and to the equally renowned ski area of Montgenèvre, hosting Alumni and students for a weekend and engaging them with a number of different activities including alpine skiing and relaxing hours at the thermal baths of Grands Bains du Monêtier. Accommodation for all participants was arranged in a chalet exclusively dedicated to ASP Alumni.

Carton Rapid Race 2016 | Summer leisure event

As 2016 Summer Event, based on the success of the previous years, ASP Alumni joined for the third time the famous Carton Rapid Race in Oulx (TO). The event, usually followed by more than 15000 people, engaged the participants in a crazy rafting race, for which all registered teams had to build their own boat only using some self-retrieved paperboard. All participants enjoyed a sunny weekend in the camping settled by ASP Alumni on the Dora River.

ASP Alumni Mentoring | Building the cooperation bridge

60 Mentors, 60 Mentees, the Education Team of our Alumni Association and the desire to create a project of excellence! These were the ingredients of the Mentoring Project launched by ASP Alumni in December 2012 and that is up and running for its fifth edition. Moreover, the Education Team is currently working at the sixth one. The aim is to build the cooperation bridge between ASP Alumni and Students to help them enter the job market, because talented students deserve promising opportunities.
The Project has started with two simple questions: "Have you completed your time at university without any idea of what comes next? Is it worth getting support from the network of ASP Alumni in the steps towards the first job?" After experiencing these needs as students some years ago, the ASP Alumni Association has decided to take care of current ASP Students.

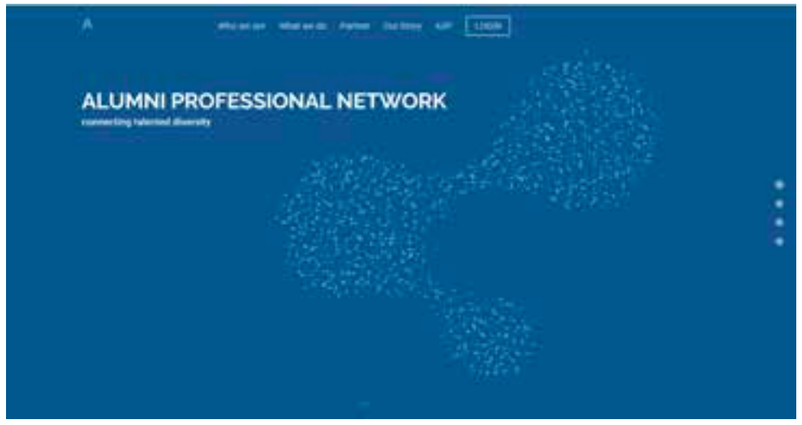
The key players are the Mentors, Alumni with several years of working experience in all areas, such as research, marketing, finance, consulting, design, etc. together with the Mentees, selected ASP Students. Mentors and Mentees are paired according to their background and the professional preferences stated by each Mentee.
The enrollment for the Project starts every year in the ASP Summer School. After that, Mentees are entitled to a minimum of five meetings with their Mentor, both face-to-face or by videoconference, to address topics such as the choice of the sector or geographical area, how to write a CV and a cover letter, how to get ready for a job interview and much more. From the second meeting onwards the Mentee is able to meet additional Mentors who can offer experience in other job fields.
The Network of Mentors is truly global; widespread in five continents, they can give a live perspective about their own function, business segment and country. Along the way, the Education Team helps Mentors by means of a guideline, to be used as a reference in their encounters with the Mentees. Moreover, the Team created a Linked-in group to put together all the Mentors, so that they can help each other with some Mentee's tough questions or special needs. All participants are enrolled in the project only after signing an Ethical Code. The Code seeks to ensure that Mentors will honor their commitment and provide the service free of charge, as a token of gratitude, with the idea that Mentors give back something they had received.

Coming Soon

Impact on Society. A new Business Mindset | 1 April 2017 | Milano
ASP Alumni 10th Anniversary | 24-25 June 2017 | Stresa
A Window Into Your Future | September 2017
Fall Event 2017 | October 2017

ASP Alumni in Internet

Website www.aspalumni.com
Mail board@aspalumni.com
Twitter @AlumniASP
LinkedIn www.linkedin.com/groups/Alta-Scuola-Politecnica-4297244
Facebook group www.facebook.com/groups/AlumniASP/
Facebook page www.facebook.com/AlumniASP/



ARE

The Adaptive
Remediation & Reuse

Project

Santa Marta

ARE

The Adaptive Remediation & Reuse

Principal Academic Tutor
Matteo Robiglio
DAD, Politecnico di Torino

Academic Tutors
Elena Sezenna
DICA, Politecnico di Milano
Isabella Lami
DIST, Politecnico di Torino
Sabrina Saponaro
DICA, Politecnico di Milano
Roberta Ingaramo
DAD, Politecnico di Torino

External Tutors
Edoardo Zanchini
Director, Legambiente
Jean-Pierre Davit
Director, Golder Associates
Marina Dragotto
AUDIS

Team Members
Bianca Fagetti [Team Controller and Communication Coordinator]
Management of Built Environment, Politecnico di Milano
Philip Adedokun Adewale
Petroleum Engineering, Politecnico di Torino
Samuele Fanetti
Management of Built Environment, Politecnico di Milano
Federica Gucciardi
Ecodesign, Politecnico di Torino
Gabriele Lo Torto
Management Engineering, Politecnico di Milano
Luisa Ximena López Tamayo
Environmental and Land Planning Engineering, Politecnico di Milano
Ana Gabriela Maldonado Barragán
Urban Planning and Policy Design
Olushola Olapade
Petroleum Engineering, Politecnico di Torino
Radoslav Marinov Valkov
Building Architecture, Politecnico di Milano
Xu Xin
Architecture, Politecnico di Milano

Project description
Industrial sites reuse is a crucial issue for sustainable land and urban development. Adaptive reuse is the most sustainable form of reuse, as it is based on maximal conservation of built assets, minimizing time, materials

and embodied energy waste and preserving industrial heritage and identity.
Reuse of industrial assets is subjected to previous remediation and/or risk assessment. This activity is usually designed, carried out and assessed before and independently from urban design, planning and real estate strategies. This independence leads to higher remediation costs and often implies demolition of built industrial infrastructure, preventing any potential adaptive reuse. Italian legal framework for remediation is particularly strict and unfit to adaptive reuse scenarios.
The current real estate crisis has heavily reduced expected economic outputs of dismissed industrial assets redevelopment. Uncertainty and high remediation costs (in current approaches) lead large-scale projects to failure or stall, leaving local communities exposed to a permanent risk.
ARE – the adaptive reuse & remediation project has defined an holistic approach to the regeneration of dismissed industrial sites, based on the multidisciplinary integration of knowledge and skills during the whole design, risk assessment, remediation and construction process.
The approach has been tested and tuned on the real case study of the ITALGAS historic industrial plants of Santa Marta in Venice. The selected case study represents a highly challenging situation of relevant chemical pollution in a highly sensitive and delicate historical contest. Reconstruction of the urban and industrial history of the site led to a complete understanding of the complex overlay of materials and processes leading to the current situation. This was the basis for the definition of a complete, incremental and holistic urban Masterplan that approaches progressively the transformation of the site, harmonizes clean up processes and settlement phases in order to minimize costs, preserves and reuses heritage buildings and infrastructures, inserts new architectures in the existing urban tissue. Economic evaluation proved that this approach leads to a relevant reduction of site reclamation and construction costs, thus enhancing the feasibility of urban regeneration already in early process phases.
ARE project findings will be tested in further case studies and developed in research, in order to generate concrete proposals of legal, policy and technical framework improvement for more sustainable and feasible reuse procedures.

Tasks and skills

Urban and architectural design
Ana Gabriela Maldonado Barragán: Analysis of urban context, concept development, definition of intervention proposal and policymaking.
Radoslav Marinov Valkov: Structural diagnosis, 3D visualization and graphical representation and masterplan development.
Xu Xin: Analysis of the architecture in the plot and surrounding morphology and typology; conceptual architectural interventions.

Economic Evaluation and Business Plan
Bianca Fagetti: Team Controller, Analysis of market, definition of intervention proposal and analysis of cost and revenues for development project.
Samuele Fanetti: Analysis of the market and of the stakeholder, studying in deep their needs and requirements for the project.
Gabriele Lo Torto: Analysis of the state of the art, analysis of the market and proposal of the actors to be involved, definition of intervention proposal and analysis of business plan.

Environment and Remediation
Luisa Ximena López Tamayo: Analysis of the remediation aspects: site characterization, risk analysis, description of techniques for pollutants removal and proposal of final remediation techniques.
Olushola Olapade: Analysis of the environmental aspects, site characterization, pollutants description and effects on health and suggestion of remediation methods.
Philip Adedokun Adewale: Analysis of remediation techniques.

Communication strategy
Federica Gucciardi: Design of the communication strategy.

Abstract

The importance of reactivating abandoned industrial areas is becoming important nowadays due to the fact that these kind of sites can impose a risk to people but also can be a restrain to urban development. The issues that makes requalification of this kind of areas difficult is because its intrinsic complexity: there is a polluted site with old abandoned settlements which is located in an area that is not connected to the nearby context. These kind of problems leads to the lack of attractiveness of the area for future investors.
In order to requalify this kind of areas, the present project uses an approach that integrates the technique of adaptive reuse with remediation methods in order to reuse the former settlements, remove the present pollutants and develop the area providing green areas, infrastructure, services and leisure spaces.
Specifically, the area in which this approach was applied is the Ex-Italgas Santa Marta (Venice) area in which several projects had been proposed in the past without succeeding due to the lack of real understanding of its complexity.
The final proposal is a step-based approach which assesses all the needs of the stakeholders involved with Santa Marta site but at the same time meets the necessities of the inhabitants.
Finally, calculating the costs of the environmental activities and summing them up to the costs regarding to the reuse and construction of new spaces, it can be seen that in a holistic view the project is feasible comparing it to the projected earnings related with each step. This is possible due to the creation of different sequential steps, each of which provides a new piece of the regeneration.

Understanding the problem

Nowadays it is common to find urban voids in cities due to the presence of pollutants and due to the difficulties related to their remediation and reuse. Difficulties regarding the intervention of these sites are related to the high and unsustainable cost but also it is often associated to large surfaces that entails a large number of developers and stakeholders. Taking this into account, it became necessary to create a strategy to deal with this problem, merging different perspective as the environmental, infrastructural, architectonic and economic one. This new strategy is called “adaptive remediation and reuse” and needs a deep and careful analysis of current conditions of the studied site in order to minimize the new construction activities.
In particular, the present project aims to use the strategy of adaptive remediation and reuse in the Ex-Italgas Santa Marta located in Venice a site which is polluted due to a former industrial process that presents abandoned settlements. Then, the main objective is to find a feasible project which foresees the removal of the polluted soil and the creation and requalification of the area leading to the reactivation of the site that will consequently attract the attention of investors.

Santa Marta wharf

Localization of Ex Italgas Santa Marta area

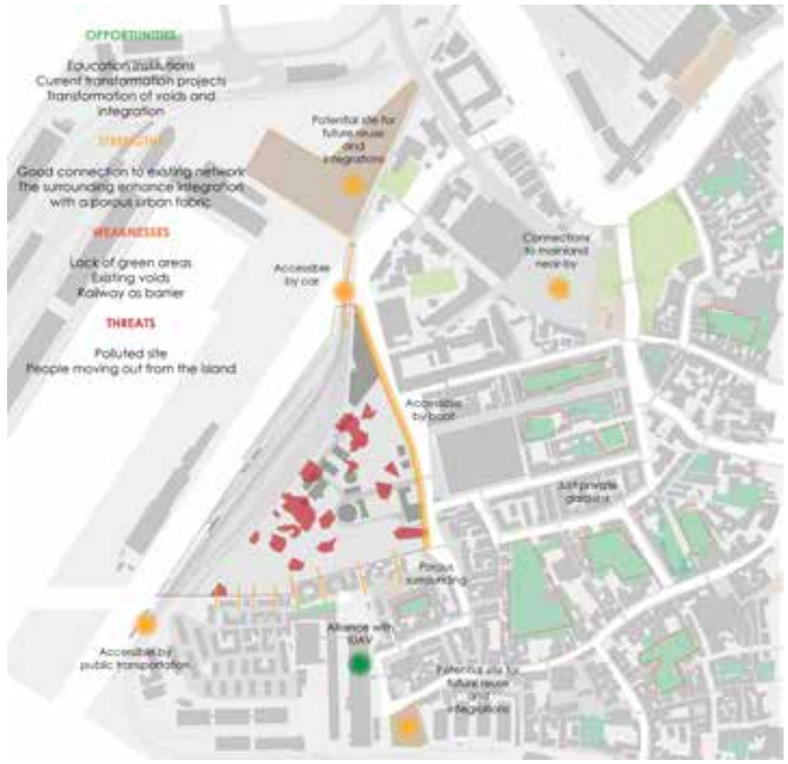
Santa Marta Gasometer

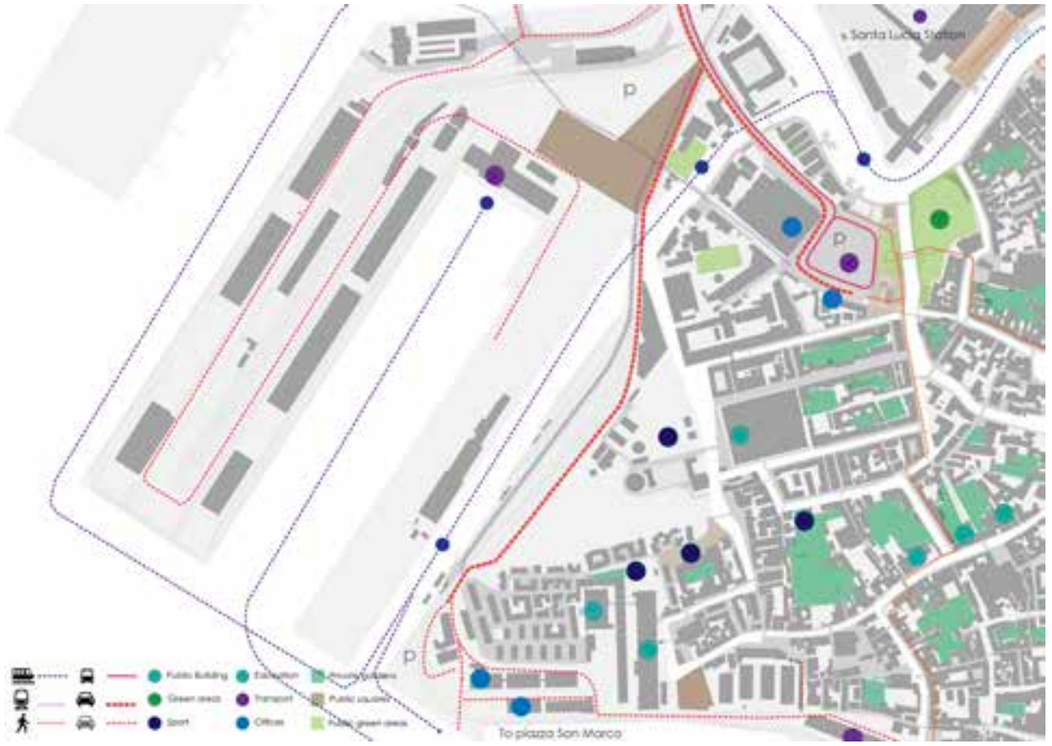
Santa Marta Railway

Exploring the opportunities

The main challenge the team had to face was bringing the different perspectives of the project in a coherent, feasible and efficient way. Different interests were identified: environmental concerns were a priority and required a deep understanding but also urban and social analysis had to deal with precise stakeholders' requirements. This mix of interests delivered to a complex framework where economic and financial return acted as a constraint for the feasibility of the project.
Before reaching to a feasible solution for the area it was necessary to identify the main aspects to improve on the site in order to develop the drivers that could deliver to a final proposal. In one hand, for the adaptive reuse it was necessary to identify the weaknesses of the area which were the lack of connectivity of the site with its surroundings, the lack of green spaces in that area of the city, existing barriers, shrinking phenomena and so on. On the other hand, for the remediation aspect, the group was dealing with a site which presented pollution in the saturated and unsaturated soil which was required, as a preliminary measure, to be removed completely.
At the same time, the site presented several stakeholders (Italgas, Municipality, Cooperative of citizen, IUAV and Port Authority) each of them with their own requirements. Finally, the ultimate goal was to gather the information of the environmental, urban and economic perspectives and to give in return a project which contemplates the creation of an intervention that tackles all of the site's issues in a feasible approach. Thus the idea was to minimize the costs finding a balance between remediation costs, construction of new infrastructure and requalification of old settlements to obtain an area attractive for investors and possible users.
The solution was reached gathering the different skills within the group. About the remediation of the area, it has been chosen to actively work on the pollutants which the risk analysis showed an actual hazard of exposure and the specific solution for the needed remediation was chosen to minimize costs. At the same time, a jointly work, according also to stakeholder's needs, was conducted on the urban side that aimed to foster urban integration by a porous layout, accessibility through new connections, the creation of green cores and corridors and livable and inclusive places by mixed uses. Among the different alternatives, the best tradeoff was the requalification of the area through different uses and activities such as affordable housing complex, lofts and luxury apartments but also workshops, commercial and touristic activities a plenty of public spaces, parks and gardens. Moreover, the choice of what and when to overlap was conducted consistently with economic consideration about the return of the investment and the increase of the intrinsic value of the land.

Potentialities of the area





Urban analysis of the area

Generating a solution

After identifying the drawbacks of the site and understanding which could be the drivers for its requalification, it was decided to proceed by steps. This was decided because working in a sequential mode, it was possible to requalify small subareas, removing the pollution but at the same time providing new spaces, in which the investor could introduce his money in a modular way. In other words, the investor would not need to make the total investment at year 0 but progressively on time depending the activities related to each step. In that case the cost is sparse on time in the benefit of the investor.

Given the results for the risk analysis done in the site, the results delivered necessary the removal of heavy hydrocarbons and arsenic in the saturated soil in order to avoid the exposure of inhalation, contact and ingestion. Taking this into consideration the remediation technique chosen was excavation given its effectiveness in the removal of pollutants and its relative low costs but also a combination of eventual excavation and capping in case for pollutants under the new infrastructure. Taking this into consideration during all the steps the removal of pollutants present in the subarea developed in each step was made. The activities which were selected to develop were affordable housing, lofts, luxury apartments, workshops, commercial activities, parks and gardens.

Consequently, the subareas for each step were divided depending on the presence of pollution. For each subarea was chosen the best combination of remediation technique and new use, for instance capping and workshops in the existing buildings or excavation and public park in the south side of the area. Finally, each combination was organized within a chronological schedule along 10 years. The order of the steps so obtained were conceived considering a trade-of between the remediation costs, the construction costs and the related economic and social benefits.

Pollutant that impose the risk inside the area

The first step (year 0 to year 4) includes the construction of affordable housing and luxury apartments in the south east section and of a temporary commercial site in the railway area on the west side. The second step (year 1 to 5) involves the requalification of the existing buildings introducing workshops, exposition spaces and botanic garden. The main components of the third step (year 5 to 8), are the creation of a loft complex in the top right corner and commercial gallery and public space above the existing buildings. The last step (year 9 to year10) is a bet on the future: the requalified area is ready to host a hotel activity together with a public park. The overall solution has two advantages. On one hand, a social return

Masterplan of the area

in terms of requalification of an abandoned area through uses and destinations that are highly useful to the specific community of Venice. On the other hand, an economic and financial return of the investment along 20 years represented by an Internal Rate of Return of 14%.
Finally, a communication strategy is developed and implemented in an advertising campaign based on three main aspects: the innovative elements of the site, the possibility to easily reach the area by both car and boat and the presence of commercial and public spaces fostering social integration.

Phase 1/2

Phase 3/4

Render of workshop area

Render Affordable Housing

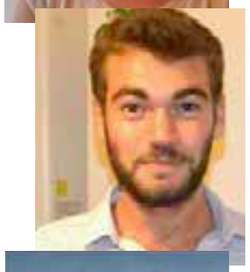
EVEH

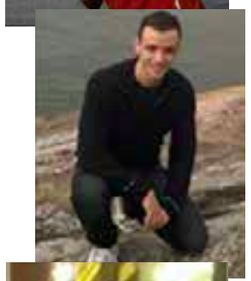
Enhancing Vibrational
Energy Harvesting

Project

2

EVEH
Enhancing Vibrational Energy Harvesting





Principal academic Tutor
Michele Bonnin
Department of Electronics and Telecommunications, Politecnico di Torino

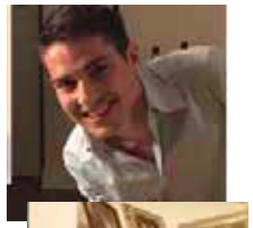
Academic Tutor
Raffaele Ardito
Department of Civil and Environmental Engineering, Politecnico di Milano
Paolo Maffezzoni
Department of Electronics, Information and Bioengineering, Politecnico di Milano

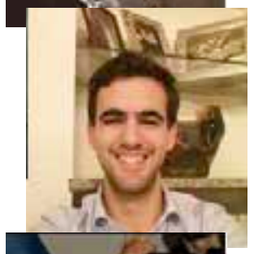
External Institution
CNR-IMM

External tutor
Sabina Spiga
MDM laboratory, CNR-IMM

Team members
Fabio Capogreco [Communication Coordinator]
Mechanical Engineering, Politecnico di Torino
Barbara Cappello [Team Controller]
Electronic Engineering, Politecnico di Torino
Luca Corinzia
Physics of complex systems, Politecnico di Torino
Alessandro Gallo
Automotive Engineering, Politecnico di Torino
Simone Ghio
Energy Engineering, Politecnico di Torino
Francesco Regazzoni
Mathematical Engineering, Politecnico di Milano
Alessio Russo
Automation and Control Engineering, Politecnico di Milano
Tommaso Vanzan
Mathematical Engineering, Politecnico di Torino

Task and Skills
Barbara Cappello: analysed the advantages of different energy conversion schemes and the storage of harvested power.
Fabio Capogreco: designed a 3D prototype and carried out FEM analysis in Ansys environment.
Luca Corinzia dealt with the user's requirements and design issues.
Alessandro Gallo: studied the state of the art of EH analysing strong and weak points of every application and participated to the design phase.
Simone Ghio modelled deterministic and stochastic vibrations and provided theoretical understanding of Duffing equation.
Francesco Regazzoni: implemented numerical schemes for Montecarlo sampling while studying stochastic resonance and Melnikov method.
Alessio Russo: provided help regarding the stability analysis of the system, made use of the DF method to find limit cycles, exploited optimal control theory to enhance the power harvested, and developed the EVEH toolbox.
Tommaso Vanzan wrote numerical codes to simulate Fokker Planck PDE equation and investigated stochastic resonance.





Project description
Small scale electronic devices, both portable and not portable, are becoming more and more pervasive. Examples can be found in healthcare, quality control, structure health monitoring, security and military purposes. Although the power requirements of electronic devices has significantly dropped over the years, the powering of small wireless devices is still an open problem, since batteries are not always a feasible solution. An alternative solution could be the use of a system able to gather energy where and when available. The main objective of the EVEH project is to evaluate the potential of novel principles for the development of innovative devices capable of harvesting energy from the environment and transforming it into electrical energy, available for powering the next generation of autonomous information and communication technology devices.
Fluctuation-dissipation theorems establish that, in an open system, energy flows from macroscopic to microscopic (thermal) degrees of freedom due to dissipation. The flow in the opposite direction manifests itself as fluctuations of the macroscopic variables. In nonlinear systems, fluctuations are not symmetric. As a consequence of the nonlinearity, preferred directions exist along which fluctuations are amplified, while in other directions they are reduced. The result is a not null contribution to the expected values of macroscopic variables. The far reaching consequence is the conceptual possibility to realize a "Maxwell demon", capable to extract energy from the environmental noise and convert it into usable power. The influence of noise on the behaviour of dynamical systems has been investigated. Some physical mechanisms of macro-to-micro and of micro-to-macro energy conversion in electronic and mechanical devices have been assumed as a case study. Comprehensive mathematical models have been developed to capture the interplay between the characteristics of a device and the noise properties. Software tools for the simulation (like the Monte Carlo methods) have been developed to test the validity of the models. In the second part the team has addressed the problem of energy extraction from noise and its conversion into electrical power. The problem has been analysed with the help of the mathematical models and simulation tools previously developed.
Different mechanisms of energy conversion have been considered, above all stochastic resonance: this is an effect consisting in a random switches of the system's state between two stable operating points. The last part of the project has been devoted to the design problem. Using the models and simulation tools developed in the first part, and having identified a promising conversion mechanism, the team developed a procedure to optimize the response of the system to the noise influence.

Abstract
Our world and our lives are led by innovation. New brilliant solutions and break-through ideas dawn as answers to go further everyday obstacles or just to force mind set barrels. Among these novel projects, energy harvesting, which is the study of all those technologies capable of realizing the direct conversion of reduced amount of energy coming from the environment into electricity, represents a promising tool in the near future, thanks to their ability of making small devices as sensors self-sufficient, much

reliable and efficient. Consider for a while a world in which it would be possible to recover energy from all those phenomena in which it would have otherwise gone lost: the vibrations caused by cars travelling on a bridge, the heat dispersed in our house when we are cooking, the motion provided by our muscles during a walk and consider how common these phenomena are. The widespread introduction of a new technology designed specifically to cover the leap between random, wasted vibrations or heat and useful power could have a deep impact for an extremely broad range of users. EVEH's goal is not just to approach energy harvesting following methods and simplification purposed by the literature, but also to make a real step beyond studying and simulating the systems under other hypothesis and working conditions, purposing optimized solutions. In short, we had offered our engineering service and expertise to help vibration energy harvesting design and developing. Starting from an economical and user-oriented analysis, we have explored all the possible multidisciplinary sides of the subject such as the mathematical modelling of noisy systems and their simulation, the power management, that is the regulation of the harvested power to make it suitable for external load and battery, the energy conversion mechanisms, such as piezoelectric effect and electromagnetic induction, and the mechanical stresses to which the components are subjected to.

Understanding the problem

The EVEH project stands as a deep, broad and interdisciplinary analysis of Energy Harvesting, which is the study of all those technologies, tools or systems capable of realizing the direct conversion of reduced amount of energy coming from the environment into electricity.
It is very likely that such a technology will undergo a significant development in the forthcoming future, when the Internet of Things and pervasive sensors nets are part of our everyday life and experience.
Hence, our analysis has taken into account not only the conditions required for the product to be functional and to extract energy from the environment, but also the constraints that the harvester has to fulfil in order to be embedded in the IoT.
Therefore, the requirements that have to be spotted regard the best sources from which the energy can be extracted, the precise amount of energy to be scavenged, and the typical working conditions and cycles to which the devices are subjected.
The set of stakeholders involved in the system engineering is both large and broad, due to the many applications in which harvesters could have a main role.
Some example could be low power sensor networks, industrial monitoring, precision agriculture, building automation and security and health care.
One of the basic target of the project is the feasibility analysis conducted upon energy harvesting, in order to determine whether or not this technology can have a practical application.
The first goal to achieve is to understand the power consumption of the sensor directly connected to the harvester. Considering that every node communicates for approximately 1 percent of its deployed life and during the remaining 99 percent, the only activities occurring in a node are background, it is possible to provide a rough estimate of a reasonable power requirement of few milliwatts.
In order to asses a market breakthrough as an IoT enabling technology, EH system has to guarantee longer lifespan than state-of-art battery technology. This request is particularly restrictive for some applications e.g. health care applications (pacemakers, implanted sensors etc.) and industrial monitoring systems (sensors distributed over unattainable and inaccessible places). For these applications, a life-span baseline is 10 years.

Fig. 1: Energy harvesting applications

Exploring the opportunities

Different alternative sources have been identified during the years in order to harvest energy from where it would be otherwise dissipated: thermoelectric from heat, mechanical from vibrational sources, electric from light. Even though the potentialities of such technologies and strategies are well known, the development of energy harvesters is relatively new, though in the last years the potentialities of using these systems have increased their interest dramatically and energy harvesting has been turned out of the incubation phase into the diffusion phase.

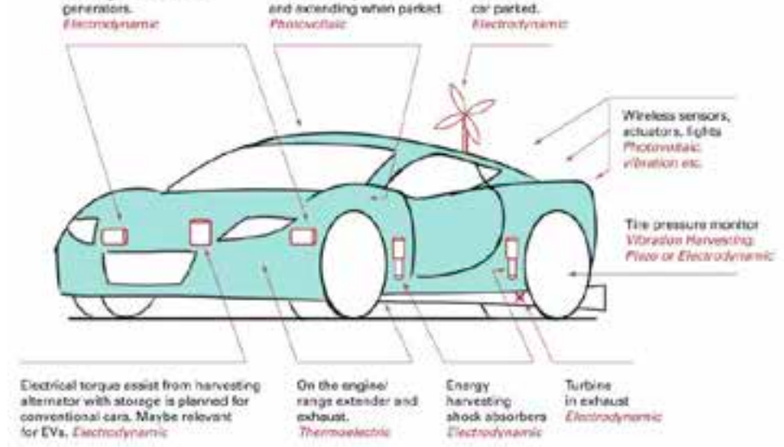


Fig. 2: Different energy harvesting sources merged into a single system

Perhaps the most common form of energy harvesting is the photovoltaic one that is able to recover power both from indoor and outdoor light.
Another possible way to extract energy from the ambient is by exploiting dispersed heat fluxes through a thermoelectric generator, which is a device capable to generate electric energy when a heat flux travels through it.
A less known method is the acoustic energy harvesting which is the process of converting high and continuous acoustic waves from the environment into electrical energy.
One of the first tasks achieved by the team was the selection, amongst

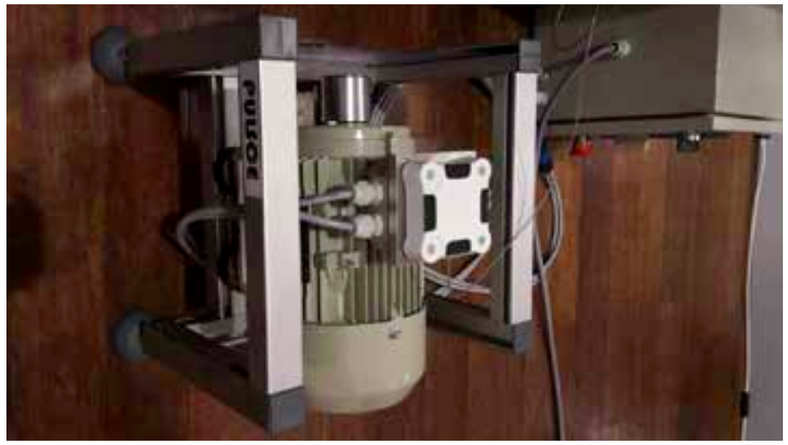


Fig. 3/3bis: Examples of real energy harvesters

the many shades of energy harvesting, of an appropriate application to focus on. The basic requirement of the targeted field relies in its multidisciplinary nature: the selected topic had to be well suited to be analysed from a variety of viewpoints, from the theoretical to the most pragmatic ones. Secondly, this application must be adapted to be practically implemented, i.e. the source of energy on which the harvesters rely must be as common and diffused as possible, in order to be easily adopted in a broad diversity of contexts and situations.

Noticing how widespread and common the vibration motions are, and how complex to analyses oscillatory phenomena can be, the team decided to centre the project on vibrational energy harvesting.

After a detailed analysis of the possible energy source for an energy harvesting system, the team understood very soon the nature of the vibrations that are dispersed in the environment surrounding us: not a deterministic motion, easily described by a limited amount of parameters, but an extremely broad and diversified spectrum of random vibrations, whose proper definition can be completed only resorting to statistical quantities. [fig.4] Such properties lead to inevitable complications in the preliminary analysis and design stages. One of the most important challenge faced by the team was to develop new mathematical methods and tools in order to study and simulate the behaviour of random vibrations.

Generating a solution

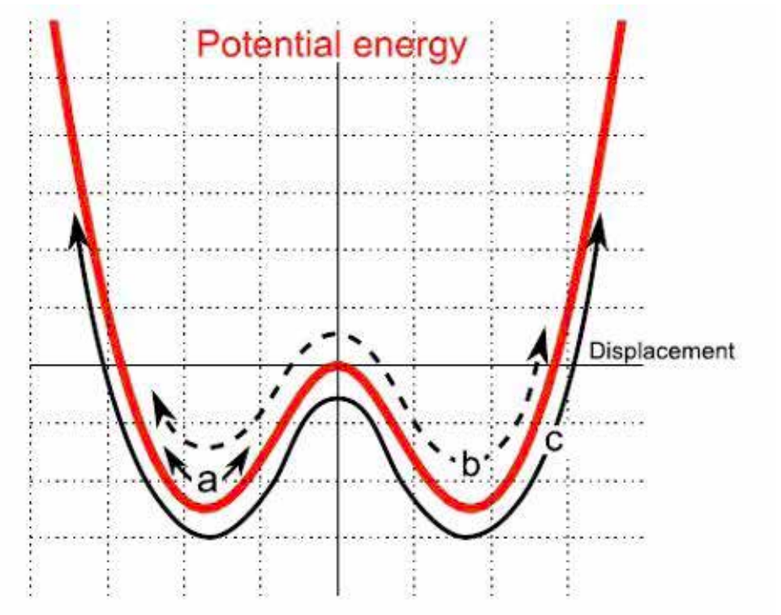
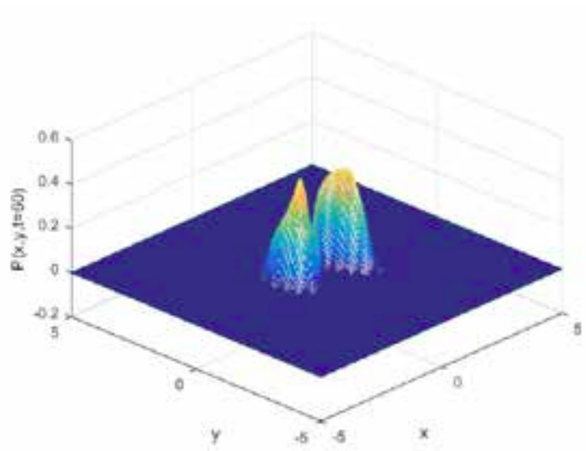


Fig. 4: Double well potential

In the previous paragraphs we have exposed the meticulous analysis of the state of the art that represented the very first stage of our work, and secondly the reasons and constraints that induced us to focus the attention on the vibrational energy harvesting (essentially because of the wide range of possible applications). We therefore started studying non linear systems getting deep insights on the possible working regimes. Furthermore, the step by step characterization of the electromagnetic device gives a clear and robust methodology to go backward to the real system starting from the simulated simplified one. In fact, we needed to reduce the number of parameters in order to study our system and make it as much general as possible and valid in every circumstance. In particular, exploiting the powerful Melnikov Method we identified the parameters range to reach the chaotic behaviour, which leads the system over high-energy trajectories, improving the available power. Moreover, thanks to the use of Optimal Control, we managed to follow a reference trajectory and make the harvester more efficient. We subsequently addressed methods to perform numerical simulations of the system, exploiting both a Monte Carlo and a Fokker Plank approach. We developed and implemented non standard numerical schemes to meet the requirements of our investigation. Thanks to the numerical results we gained a deeper understanding and we managed to increase significantly the accuracy of our inferences respect to an only theoretical approach. Besides, numerical results pointed out that stochastic resonance can improve up to a factor three the available power. Eventually we have developed the so called EVEH Toolbox which, with a user friendly interface, can help and guide the future engineers

Mathematical results of the simulations



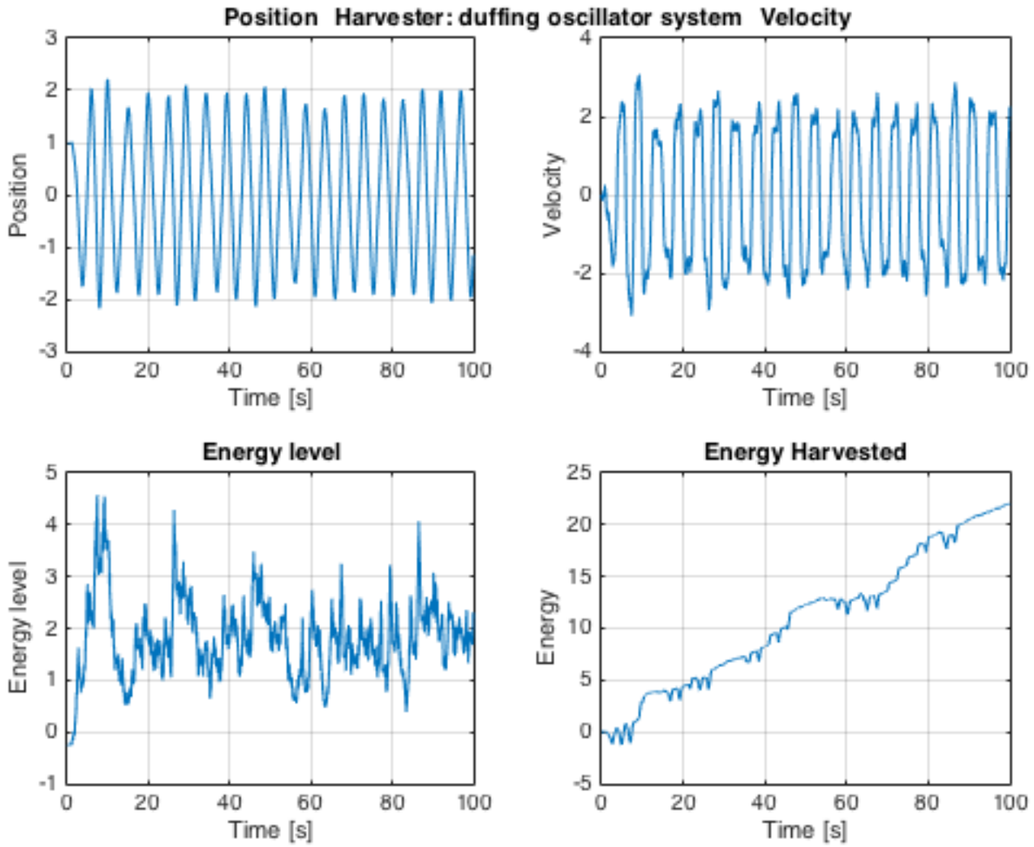


Fig. 5/5bis: Mathematical results of the simulations

Fig. 6: EVEH Toolbox

and possibly the researcher of CNR in the design/tuning phase [fig.6] [fig.6bis]. Another goal reached by the team Enhances is the design of a prototype destined to be practically developed and optimized [fig.7]. These are the reasons why we truly believed that the Asp project EVEH has undoubtedly pushed a little further the current knowledge in the energy harvesting field, especially in the vibrational harvesting area.

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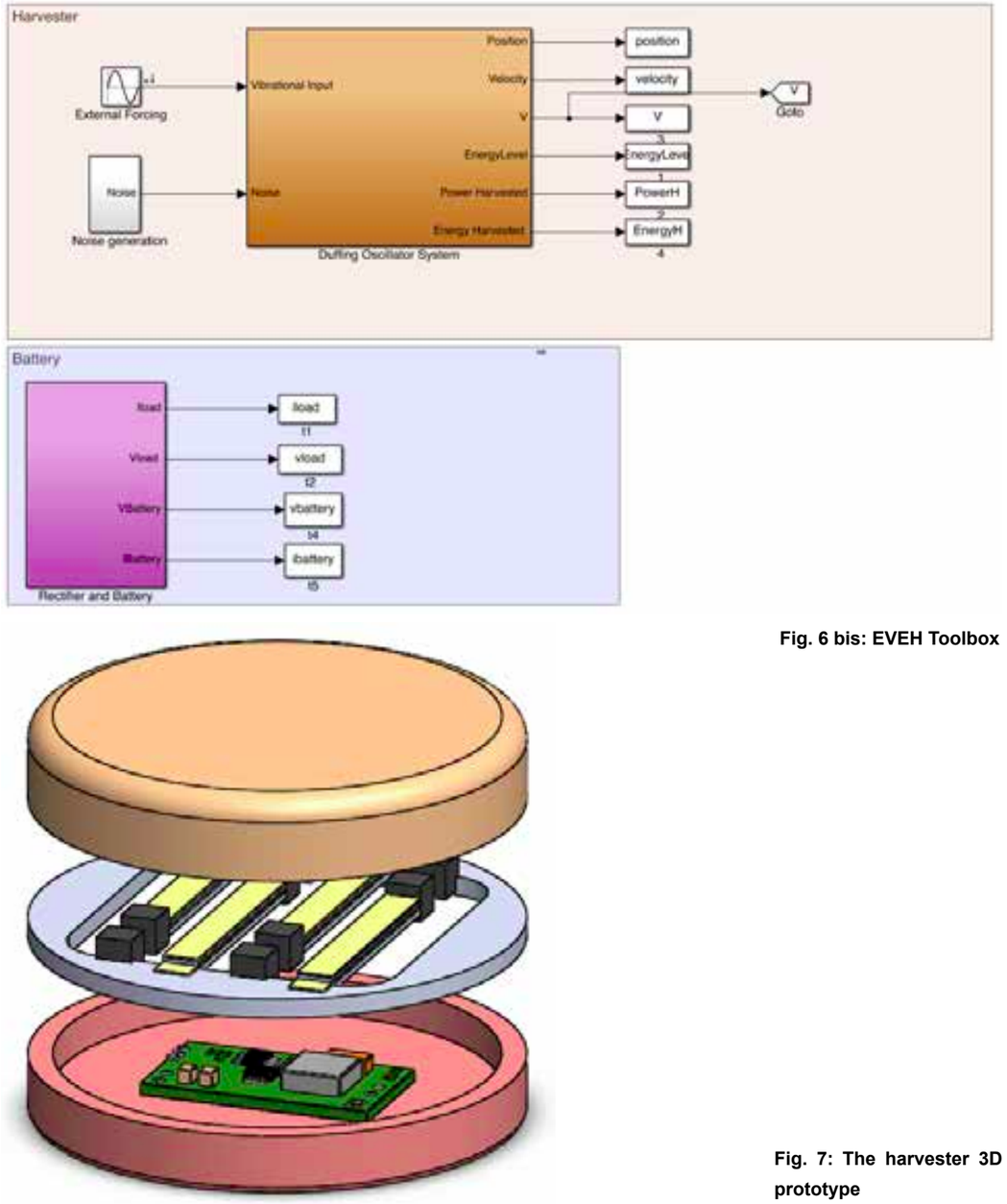


Fig. 6 bis: EVEH Toolbox

Fig. 7: The harvester 3D prototype

ECOFRONT

Exploring the Frontiers of Cold Spray

Project

3

ECOFRONT

EXPLORING THE FRONTIERS OF COLD SPRAY

ECOFRONT
Exploring the Frontiers of Cold Spray

Principal Academic Tutor
Mario Guagliano
Department of Mechanical Engineering, Politecnico di Milano

Academic Tutors
Monica Ferraris
Department of Applied Science and Technology, Politecnico di Torino
Alberto Guardone
Department of Aerospace Engineering, Politecnico di Milano
Barbara Previtali
Department of Mechanical Engineering, Politecnico di Milano
Chiara Vitale Brovarone
Department of Applied Science and Technology, Politecnico di Torino
Sara Bagherifard
Department of Mechanical Engineering, Politecnico di Milano

External Institutions
Impact Innovation GmbH (Haun, D)
Helmut Schmidt University (Hamburg, D)
Technical University of Brno (Brno, CZ)
Centre de Projecció Térmica (CPT) - Universitat de Barcelona (Barcelona, E)
University of Nottingham (Nottingham, UK)

External Tutors
Peter Richter, Sr.
Impact Innovations GmbH
Professor Frank Gaertner
Helmut Schmidt University
Jan Cizek
Technical University of Brno

Belgirate, Winter School 2016. All the team members on the last day of ASP Winter School. From left to right: Mehdi Hadi, Gaetano D'Elia, Maria Vittoria Zuccoli, Paolo Caputo, Martina Genta, Gianluca Roscioli, Fabio Pino.

Josep Maria Guilemany
Centre de Protecció Térmica (CPT) - Universitat de Barcelona
Tanvir Hussain
University of Nottingham

Team Members
Paolo Caputo
Space Engineering, Politecnico di Milano
Gaetano D'Elia
Mechanical Engineering, Politecnico di Torino
Martina Genta
Biomedical Engineering, Politecnico di Torino
Mehdi Hadi
Mechanical Engineering, Politecnico di Torino
Fabio Pino
Space Engineering, Politecnico di Torino
Gianluca Roscioli [Team Controller and Communication Coordinator]
Material and Nanotechnology Engineering, Politecnico di Milano
Maria Vittoria Zuccoli
Mechanical Engineering, Politecnico di Milano

Project description
Cold Gas Dynamic Spray, also referred to as simply Cold Spray (CS), is a new, solid-state particle deposition process for producing coatings of different types. Its peculiarity is that it exploits kinetic energy rather than thermal energy, thus making CS a reduced environmental impact technology. The basic principle consists in accelerating solid powders through a de Laval nozzle toward a substrate. When the impact velocity exceeds a threshold value, called critical velocity, particles endure plastic deformation and adhere to the surface. The advantages of this technology are several, such as low energy demand, production of dense and thick coatings, no microstructure modification of the powders, no oxidation, no toxic wastes, applicability to a wide choice of material combinations (metals/metals, metals/polymers...) with tailored and customized properties and wide range of functionalities of surfaces and interfaces. Its range of applications is very broad too, going from engines to biotechnology, from conductive coatings to metallization of polymers, from wear to dimensional restoration and repair. But CS is also suitable for obtaining three-dimensional solid parts, since there is no theoretical limit to the thickness that can be built up, thus being a suitable technology for additive manufacturing. The limits and the frontiers of Cold Spray are far from being completely identified.

The goal of the project is to draw the next frontiers of Cold Spray through technological and economic assessment of new possible applications. Main objectives are:
- Assessing CS technology potentialities in relation with other competing thermal technologies for material coating;
- Investigating new innovative applications for the technology;
- Developing some demonstrators that explain how CS technology can be applied in different fields and studying their performances;
- Proposing technological improvements to optimize process performance.

The core of the project has been the focus on developing three carefully selected applications, assessing both their technical and economical feasibility, and one technological improvement. The four fields addressed are:
- Ti-Ag-HA Prosthesis Coating: titanium-silver-hydroxyapatite (Ti-Ag-HA)

coatings have been studied in order to be deposited on a tibial prosthesis, aiming at both reducing post-surgery infection probability and increasing cellular adhesion to the implant;
- Inconel 718 Additive Manufacturing Components: CS potentialities have been assessed by comparing CS sprayed specimens with samples produced with Selective Laser Melting (SLM) technology;
- Amorphous Metals Thick Coating: CS has been able to deposit a thick coating of amorphous metal;
- De Laval Nozzle Optimization: the nozzle geometry has been optimized with the aim to increase CS deposition efficiency and productivity.

In order to do so, the project required strong multidisciplinary interactions, varying from mechanical and material engineering to space and biomedical fields. In the first phase, everyone familiarized with the process and developed proposals for generating the solution. Once the fields of interest had been chosen, tasks and skills have been carefully thought.

Martina Genta took care of the biomedical application of the project. She studied the coating's properties, carried out biomedical tests at Politecnico di Torino on Ti-Ag samples and analysed the results obtained, assessing CS potentialities in the field.

Gaetano D'Elia and Mehdi Hadi, Mechanical Engineers, were in charge of carrying out lab works at Politecnico di Milano on additive manufacturing specimens produced (both CS and SLM). Gaetano focused on mechanical characterisation of Inconel 718 CS specimens pre-heat treatment, analysed results obtained and compared them with post-heat treatment specimens and with SLM samples. Mehdi particularly concentrated on manufacturing and mechanical characterization of Inconel 718 SLM specimens and dedicated himself to the analysis of results coming from of all the samples (CS and SLM specimens).

Gianluca Roscioli is the only Materials Engineer. Initially interested in developing hydrophobic coatings with amorphous metals, he finally managed to produce thick coatings of amorphous metals in collaboration with Centre de Protecció Térmica (CPT) and Universitat de Barcelona. He also helped with mechanical characterisation of Inconel 718 samples at Politecnico di Milano.

Paolo Caputo and Fabio Pino, the two Space Engineers of the team, focused on studying the De Laval Nozzle geometry and on optimising its dimensions. They developed a model describing gas-particles flow through the nozzle and, using simulations, worked on the design of an improved nozzle.

Maria Vittoria Zuccoli, now Mechanical Engineer but former Management Engineer during Bachelor's Degree, worked on analysing CS costs to assess industrial and economical feasibility of the process, concentrating in particular on Ti-Ag-HA coatings and Inconel 718 components (CS vs SLM costs). She also helped with mechanical characterisation of Ti-Ag and Inconel 718 specimens at Politecnico di Milano, especially regarding heat treatments of the latter.

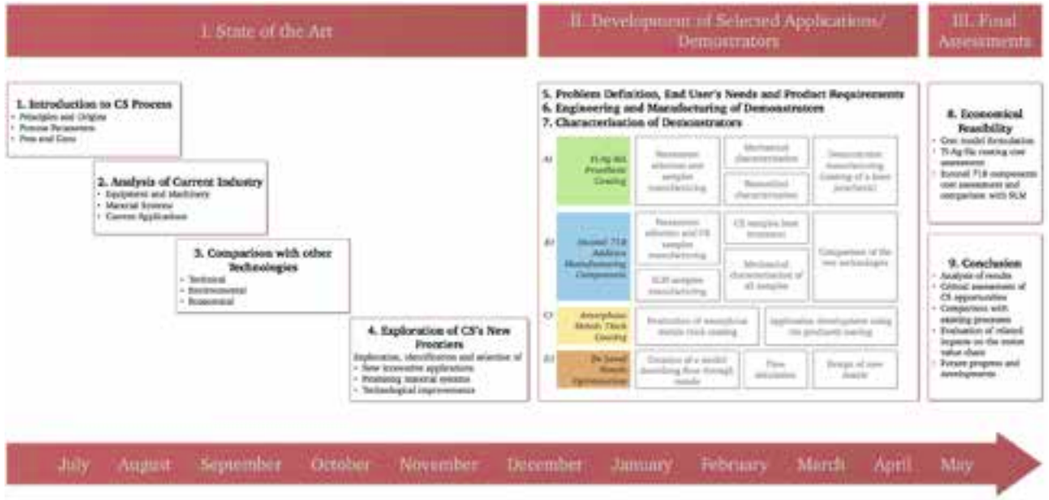
Abstract

The aim of the project is to draw the next frontiers of cold spray (CS), a new, solid-state coating deposition technology. At first, the process and its advantages and disadvantages have been assessed. Then, current equipment, materials and applications have been studied, in order to outline present technological limits from the study of recent innovations in the field. Subsequently, cold spray technical, environmental and economic impact in comparison with competing processes (thermal coatings, additive manufacturing technologies) have been analysed. At this point, the explorative phase of the project began, and new innovative applications, promising materials systems and technological improvements have been investigated and selected. Indeed, the project focused on developing four high-potential applications in four different fields, and on assessing both their technical and economical feasibility. First of all, three different demonstrators produced with CS technology were developed in biomedical, additive manufacturing (AM) and materials fields respectively. Regarding the biomedical demonstrator, properties of titanium-silver-hydroxyapatite (Ti-Ag-HA) coatings have been studied in order to be deposited on a tibial prosthesis, aiming at both reducing post-surgery infection probability and increasing cellular adhesion to the implant. For what concerns additive manufacturing, CS potentialities have been assessed by comparing CS sprayed specimens with samples produced with Selective Laser Melting (SLM) technology. Regarding the materials field, a thick coating of amorphous metal has been deposited. Finally, the fourth application consisted in optimizing nozzle geometry to increase CS deposition efficiency. This has been achieved through the creation of a model able to describe and simulate the flow throughout the nozzle, thus enabling the design of a new nozzle. In conclusion, technical performance assessment of CS, compared to other thermal and additive technologies, has been accomplished, in addition to economical feasibility study focused on the biomedical and additive manufacturing applications. A final critical assessment of CS opportunities evidenced how CS impacts the entire value chain and compared the results with present processes.

Munich, October 2015. Principal Tutor with the team members having dinner at the famous Hofbräuhaus in Munich, during the visit at Impact Innovations.

Understanding the problem

In the preliminary stage of problem definition, it has been key to outline the main steps to follow. Three macro-phases, both in terms of activities content and chronological development, have been identified: State of the Art, Development of Selected Applications/Demonstrators and Final Assessments.



Project's Gantt diagram with description of the steps followed.

The first step to make has been to develop the State of the Art. Initially, Cold Spray process has been analysed in terms of principles, origins and process parameters. Also, its advantages and disadvantages and its most important potentialities have been underlined. Then, the analysis of the recent innovations in the field let to define the present technological limits, both as regards equipment and machinery and in terms of current material systems and applications. Furthermore, CS has been compared to competing processes (thermal coatings, additive manufacturing technologies) on technical, environmental and economic level. In this first period, the expertise of external institutions, such as the world leader in cold spray plants manufacturing Impact Innovations, has been fundamental in order to understand and study the process. To this aim, the first trip organized has been to Impact Innovations in Haun, Bavaria (D), where team members experienced real use of the technology.
Finally, at this stage, stakeholders' needs and requirements have been outlined in general, focusing on partners such as Impact Innovations, and on other Institutions (Brno University of Technology, Helmut Schmidt Universität in Hamburg and Centre de Projecció Térmica – Universitat de Barcelona) that could have become interested in ECOFRONT project in a second moment.

Munich, October 2015. Visit at Impact Innovations and tour of Munich by day and by night.

Exploring the opportunities

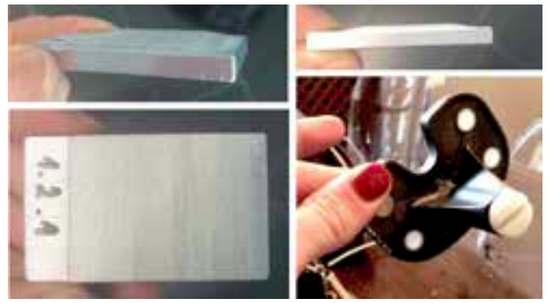
After that CS technology had been studied in depth, the explorative phase begun. Indeed, the analysis of current industry allowed to outline present technological limits through the study of recent innovations, preparing the field for the proposal of innovative ideas and solutions. New potential applications, promising material systems and technological improvements have been suggested. For instance, due to the fact that CS is capable of producing thick, dense and oxydes-free coatings, it could be used for biomedical applications (deposition of TiO2, ZnO or TiAg coatings), nano-structured coatings, development of multilayer foams, coating of thermally loaded components, hydrophobic coatings, additive manufacturing components, amorphous metals deposition, electrical conductive coatings and metallization or deposition of polymers. Furthermore, technological developments could focus on the study and optimization of large nozzles and/or multiple nozzles to increase productivity, on the development of out-of-view nozzles to allow coating of complex shapes and on the optimization of nozzle geometry for nanopowders spraying.
After deep discussion and alternatives evaluation, four fields of interest have been selected:

- Ti-Ag-HA Prosthesis Coating
- Inconel 718 Additive Manufacturing Components
- Amorphous Metals Thick Coating
- De Laval Nozzle Optimization

Also during the explorative phase, the role of the partners has been crucial in order to understand which could have been the most promising proposals.

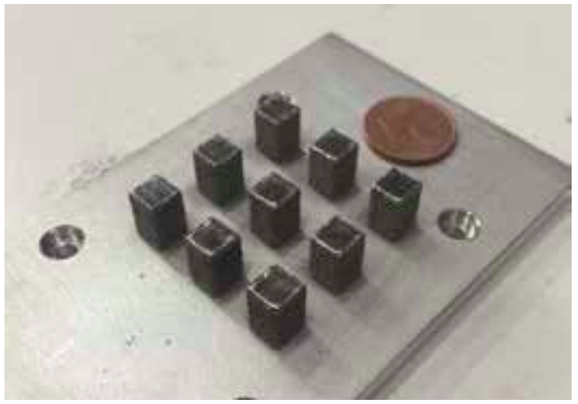
Generating a solution

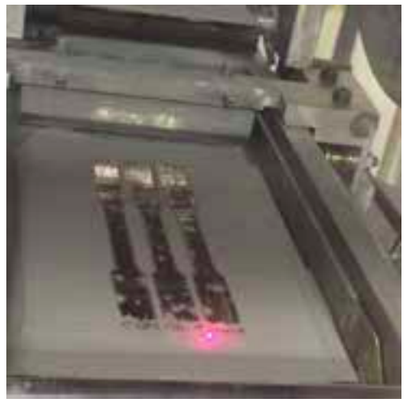
The selection of the four demonstrators to be studied marked the beginning of the second phase of the project, during which the applications were developed in practice. For each one of them, the problem to study has been defined, along with the end user's needs and products requirements. Then, demonstrators have been designed and manufactured, in order to be characterized in the following step. This way it has been possible to assess their properties and compare them to similar existing solutions. In particular, the Ti-Ag-HA Prosthesis Coating focused on using CS to deposit a Ti-Ag-HA metal matrix on a Titanium knee-prosthesis in order to both decrease infection probability due to the presence of Silver and increase cellular adhesion to the prosthesis by means of Hydroxyapatite. Ti-Ag coated samples were mechanically and bio-medically characterized and their properties were studied. Regarding Inconel 718 Additive Manufacturing Components, CS has been used to manufacture specimens to be heat treated and characterized and subsequently compared to samples produced with Selective Laser Melting (SLM) technology. Politecnico di Milano and Politecnico di Torino have been fundamental for the development of the first two applications, since they made available all their laboratories and facilities to allow us to characterize the demonstrators. Instead, CPT – Universitat de Barcelona helped us developing the third application. In their facilities, it has been possible to deposit thick coatings of amorphous metals. Finally, the De Laval nozzle currently used has been optimized in terms of geometry and dimensions so to increase productivity and deposition efficiency, following the steps of creating a model that describes the flow through the nozzle, simulating the flow and designing the new nozzle.
As final assessment, the economical feasibility of CS has been evaluated by means of cost model formulation. With demonstrative aim, Ti-Ag-HA prosthesis coating and Inconel 718 components' costs were calculated, and the latter were compared to SLM ones.



Politecnico di Milano, January 2016. Ti-Ag samples from Impact Innovations and the knee prosthesis before coating.

Politecnico di Milano, March 2016. Cold Spray Inconel 718 samples after tensile test, pre heat-treatment (left) and post heat treatment type A (right).





Politecnico di Milano, March 2016. SLM Inconel 718 samples for process parameters optimization.

Cold Spray process is still very young and still needs to be discovered. The aim of this project has been to explore the new frontiers of the technology, through technological and economic assessment of new possible applications. The main objectives of assessing CS potentialities and investigating new innovative applications have been met. Three demonstrators/applications have been produced and studied and a massive technological improvement to optimize process performance has been proposed. The project opened the way to further studies in the fields addressed, in order to fully exploit the technology at its best.

The next steps for the project are presenting the studies at the Conference CORSAIR that will be held at Politecnico di Milano next 29-20-1 June-July 2016 and publications regarding the results obtained related to the four applications.

CPT – Universitat de Barcelona, May 2016. Spraying system used to deposit the amorphous metal thick coatings.

Main bibliographic references

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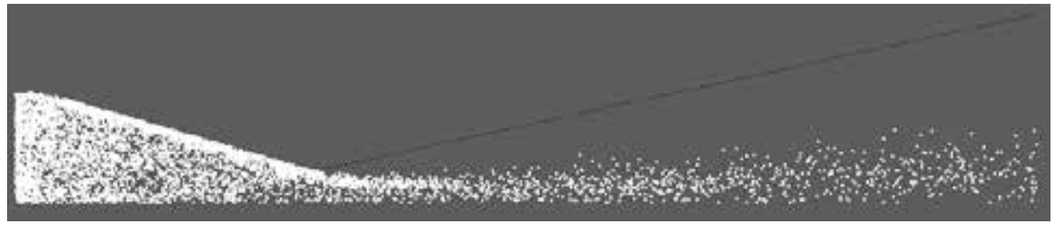
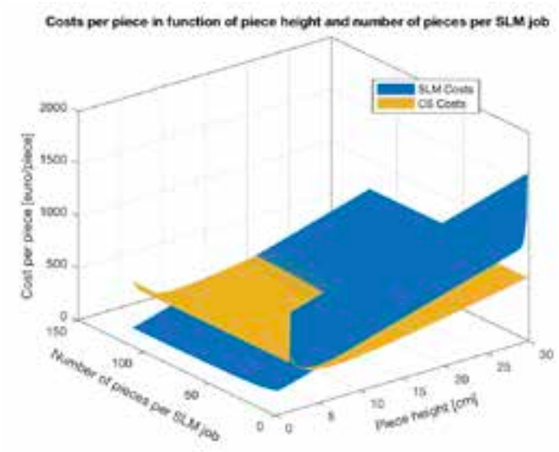
Additional material

Websites http://www.impact-innovations.com
Videos https://www.youtube.com/watch?v=dErRoEKuloo



OpenFOAM simulation of gas-particles flow through the De Laval nozzle.



Cost comparison of CS and SLM additive manufacturing components, in function of parts dimensions.

Partner Institutions’ Logos

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INTEGRAGREEN

Integration of additive manufacturing and machining processes in view of green and sustainable development

Project

4

INTEGRAGREEN

Integration of additive manufacturing and machining processes in view of green and sustainable development

Principal Academic Tutor

Luca Settineri
Department of Management and Production Engineering, Politecnico di Torino

Other Academic Tutors

Bianca Maria Colosimo
Department of Mechanical Engineering, Politecnico di Milano
Luca Iuliano
Department of Management and Production Engineering, Politecnico di Torino
Paolo Priarone
Department of Management and Production Engineering, Politecnico di Torino

External Institutions

APR S.r.l., Pinerolo (To)

External Tutors

Leonardo Napoli, Innovation Engineer, APR S.r.l.

Team Members

Francesco Beccarisi
Mechanical Engineering, Politecnico di Torino
Pasqualino Bianconi
Industrial Production Engineering, Politecnico di Torino
Mattia Cenedese
Mechanical Engineering, Politecnico di Milano
Ruggero Colombari [Team Controller and Communication Coordinator]
Industrial Production Engineering, Politecnico di Torino
Mattia Durantini
Automation Engineering, Politecnico di Milano
Amalia Foglia
Mechanical Engineering, Politecnico di Milano
Emanuele Grossi
Mechanical Engineering, Politecnico di Torino
Antonio Russo
Mechanical Engineering, Politecnico di Torino

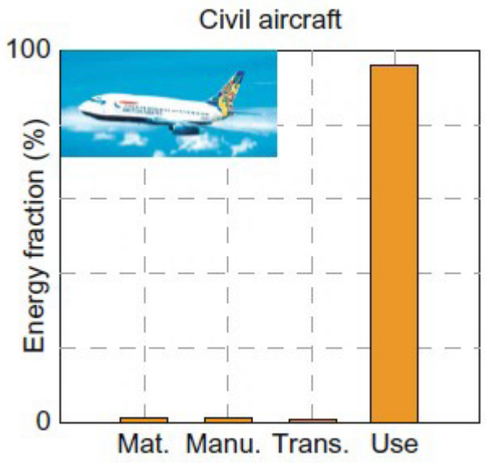
Project description

Subtractive manufacturing, in which a machine cuts shapes from metal blocks, may waste as much as 90% of the original material (workpiece). By building something additively, even to only approximately the right shape, and then milling it, such wastage can be extremely reduced. Subtractive techniques are well-established, and probably they will not be substituted by Additive Manufacturing (AM). However, the factories of the future will use 3D printers alongside milling machines, presses, furnaces and equipment for plastic injection molding.

In this context, the aerospace industry is one of the applications where the potential of this technology can be exploited. The need of lightweight and high performance structures and materials, the low lead time and flexibility of production, the big environmental impact and the elevated costs of aircrafts lifecycle are all issues that additive manufacturing can solve or at least partially mitigate. Indeed, additive manufacturing processes for metal parts, starting from metal powders and melting them layer after layer (as Electron Beam Melting, Selective Laser Sintering, and Selective Laser Melting), are promising candidates to work alongside traditional processes. The research scenario is still largely unexplored, both considering technical solutions as well as environmental impact assessment. From the technological point of view, for additive manufacturing, a preliminary component re-design stage is necessary to exploit the potential of this technology in freeform fabrication. FE-assisted design, applying topological and topographical optimization of components, has to be used to reduce the overall weight without undermining the product performance. Moreover, the parts produced using additive manufacturing techniques as EBM, unlike others metal-sintering techniques, are almost fully dense and void-free. The high vacuum makes AM suited to manufacture parts in reactive materials with high affinity for oxygen, e.g., titanium. However, surface quality is usually not sufficient to match the strict quality requirements for aerospace components, and finishing machining operations are needed after AM.

Overall, within the framework of this project, the technological integration between additive manufacturing and machining processes has been in-depth investigated (aiming to create the optimum integration of different processes within the sustainable development context). The results of the project include the multidisciplinary qualitative and quantitative comparison of various solutions (in terms of technological feasibil-

Energy need of a civil aircraft during its life cycle

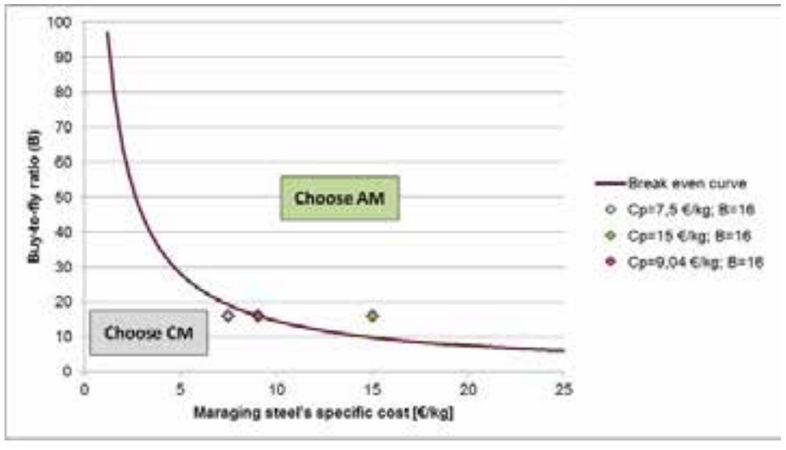


ity, part quality/integrity, sustainability). For both the technologies (additive manufacturing and conventional processing) the optimal process parameters has been numerically and experimentally optimized. Appropriate metrics and indicators for a comprehensive evaluation have been identified and developed. Aiming to green sustainable development, energy and materials consumed in each phase (generating waste, heat, and solid, liquid and gaseous emissions) have been monitored and/or estimated. A life cycle assessment (LCA) approach has been applied on both processes, developing the tools for assisting the decision-making stage, which can be incorporated into the business strategy development framework.
The final, achieved result of the project was the acquisition of knowledge and tools necessary to promote the process integration. The use of a multidisciplinary approach (involving designers, technologists, and management) led to an undisputed added value to the project. Indeed, this approach made the team to split into these working groups: mechanical engineers of PoliTo studied the design problem, PoliMi students instead followed the technological stream while Industrial Engineers focused on the managerial (cost and sustainability) side of AM.

Abstract

The Additive Manufacturing technology is one of the agents responsible for the 4th industrial revolution for at least three reasons. First, it offers the possibility to produce complex parts without the design constraints of traditional manufacturing routes. Second, scrap rates for AM parts are usually below 5%, compared to scrap rates of more than 90% with many complex milled parts. Third, the high geometrical complexity design that can be achieved exploiting functional integration and topological optimization leads to lightweight and more performant structures.
Consequently, the current production paradigm is changing in terms of two key future visions: sustainability and cost minimization. In this prospective, the purpose of this project is to investigate the potentialities of the groundbreaking AM technique, defining the conditions and the fields it dominates the conventional processes. Furthermore, an aerospace component is re-designed for AM production and its manufacturing process is studied in details exploring difficulties and advantages.
First of all, we tried to answer the one-billion question “should we go with Additive Manufacturing or keep producing with Conventional Manufacturing?”. We created a cost breakeven model able to provide a preliminary idea regarding the technology to adopt, knowing the buy-to-fly ratio and the materials cost. However, the model we propose only assesses manufacturing costs. By performing a streamlined Life Cycle Assessment, we came up with the conclusion that in the aerospace field the product use phase has greater impacts on costs and environment than the product-manufacturing phase itself. Therefore, even when Conventional Manufacturing (CM) seems to be more convenient, there is still the chance that an additively manufactured product may hold competitive advantages and can be sold at a higher price, thus legitimizing the use of an apparently more expensive technology.

Breakeven analysis of additive manufacturing: the graph shows the whether or not AM is convenient with respect to CM depending on the material cost.



We experienced this weight lightening in the component that was the object of our studies: with an iterative process of topological optimization, computer aided re-design and finite elements analysis, we could reach 16% weight reduction with a slight increase in the structure safety factor. In addition, the manufacturing process itself was examined and re-shaped for AM production and this gave us the possibility to deeply understand the correct parameters and the material limitations. Eventually, we had the opportunity to prototype the component to see the results of our job.

Understanding the problem

APR S.r.l., a company based in Pinerolo (To), is specialized in the manufacturing of aerospace components, with customers among the biggest firms in this sector. They want to exploit additive manufacturing in order to re-design a component commissioned to them, asking us to assess its technical feasibility and the rationale to supplant conventional manufacturing.
Lightweight is fundamental in a field like aerospace, in which minimum reductions in weight may lead to huge savings in terms of fuel consumption and CO2 emissions. According to a report issued by Lufthansa, a reduction of weight of 1 kg from an aircraft leads to save approximately 52 kg of kerosene per aircraft each year. Another study, from SKF, shows how a weight reduction of 1 kg on an aircraft holds potential for a reduction in emissions of CO2 equivalents of nearly 6 tons. Now, considering that up to 10 kg can be removed by just redesigning some components and that in 2013 the global commercial fleet was made up of 20,130 aircrafts, the potential held by AM in terms of environmental impacts reduction is soon assessed.
Thanks to AM, the high geometrical complexity design that can be achieved is able to exploit functional integration and topological optimization, leading to lightweight and more performing structures. Optimization is the process of determining the best design to fulfill the final user requirements without violating the external constraints. The part to design must be optimized in order both to minimize the part weight and to guarantee functionality and structural performance.
Component weight reduction and overall material savings are then the main directives of the project. For this reason, each feature is analyzed to be re-designed in a shape such that it would be lighter than the original one and also possible to be manufactured. The technological challenge for this project, then, is to produce a workpiece designed for conventional machining using an additive manufacturing process: Selective Laser Melting. In doing so, on one side, it is required to face the limits of the process according to the material and the machine used; on the other side, it is very important to take advantage of the new opportunities that come with the new technique. The process does not meet every technical specification of the workpiece (for instance, it is not able to make a very good finishing) and, when this occur, a further study is required to find capable traditional means and to understand how to use additive manufacturing to provide a near net shape object that could minimize the further material removal that results into scrap.

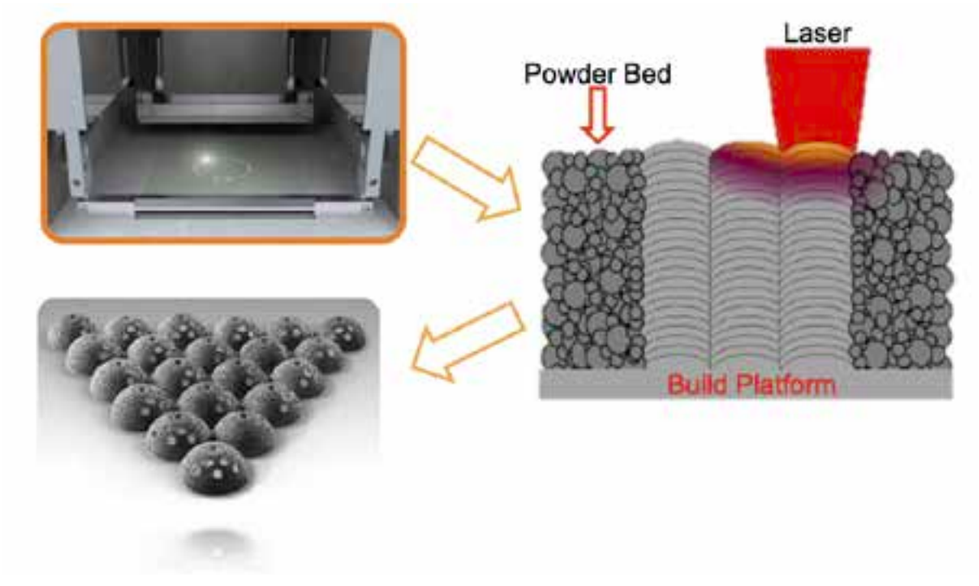
Exploring the opportunities

In the past, in order to reach the optimum design, a mix of judgment, experience, modeling, experiments other than theoretical engineering tools were used. Nowadays, the increasing number of variables with conflicting objectives and constraints requires the adoption of the computer-based optimization that allows the evaluation of many more design combinations

thanks to the available enormous processing power and sophisticated algorithms. Optimization methods applied to structural analysis have been integrated in various Computed Aided Design (CAD) and Finite Element Modeling (FEM) software such as Abaqus and Ansys. For additive manufacturing, a preliminary component re-design stage is necessary to exploit the potential of this technology in freeform fabrication. FE-assisted design, applying topological and topographical optimization of components, has to be used to reduce the overall weight without undermining the product performance. By following this approach, given an initial material distribution, topology optimization produces a new landscape by scaling densities of the elements in the solution domain. The main aim of the topographical optimization process applied to structures is the variation of the location of the material in order to reduce stresses.

Topological optimization steps for our case study

For what concerns the manufacturing process itself, many alternatives have been taken into account before the production of the workpiece. First of all, the kind of process additive manufacturing: nowadays Selective Laser Melting is the most popular for the steel production, but also other techniques have been analyzed such that Electron Beam Melting and Laser Cladding. More in detail the design of the workpiece for the additive manufacturing process required a dual approach to analyze the feasibility of new shapes. Indeed, it has to take into account the particular solutions for each features (conventional solutions have been compared with the most popular in additive manufacturing such as lattice and honeycomb structures), but they need to be compatible with the positioning of the workpiece into the machine, which may compromise the overall result.



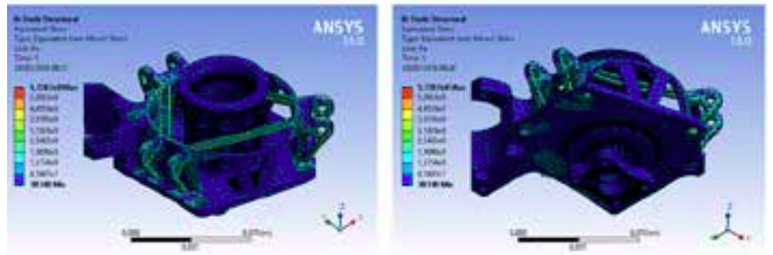
Scheme of Selective Laser Melting Process

Generating a solution

The case study was split into a re-design problem, aiming mainly to achieve a significant reduction of material, and a technological one, adopted to explore in details the features of AM production. The two solutions were not to be considered as alternatives, but as complementary approaches to the problem.

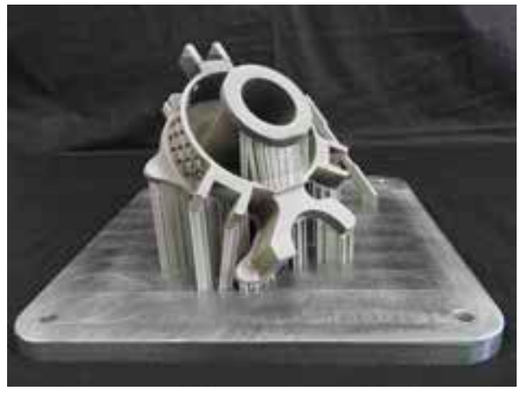
As regards the first approach, the so called ATOM (Abaqus Topolology Optimization Module) lifecycle was followed to reduce the material keeping safety factor unchanged. After modeling the boundary conditions (loads and constrains) based on the working conditions provided by the company, a Finite Element model of the piece was generated. Then, an iterative procedure was performed, involving successive topological optimizations and stress analyses of the modified designs. At each step a comparison between the stress analyses of the corresponding modified design and the original one was performed in order to check the safety coefficient and to verify the absence of stress concentration areas. Three consecutive modifications of the design were obtained: the last one has been able to produce a weight reduction of 16%, with an almost unvaried maximum value of the safety coefficient. The corresponded saving of 21g in a part of 133g showed that a potential extension of the process to the entire aircraft can lead to several Kilograms lightening, with substantial benefits for payload and fuel consumption.

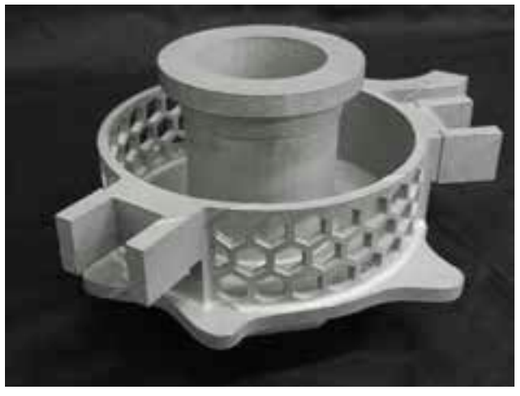
For the actual production of the component we decided to adopt a mixed design similar to the original (for traditional machining), but with many features thought for the SLM process (chosen for the availability of the Renishaw AM 250 with the collaboration of the Polimi AddMe.Lab) such as the honeycomb structure.



FEM analysis of the optimized part of the case study

In this way, we tested on one side the capability of additive manufacturing of re-using traditional design while bringing a huge saving on the material, and on the other the potentiality of the new possibilities. Furthermore, we identified the optimal process requirements in order to modify the part and set up the manufacturing process accordingly. However, some of its characteristics are still uncertain, for example the decided position of the workpiece in the machine is already testing the limits of the material due to the 45° vertical inclination (as a matter of fact, we detected material





Technologically optimized component after 3D print and finished component

losses). For this reason, and in order to test the manufacturing feasibility of the already elaborate component, we did not push the machine to the limit adding further lightweight complex structures as the lattice one.
The process we undertook and the experience we got from this project made us confident that, as material properties and the machine size limitations will be overcome, the adoption of additive manufacturing techniques will increasingly impact the aerospace industry.

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ISY WIRE U

Internal Synergies for Wiser Resources Use in University Campuses

Project

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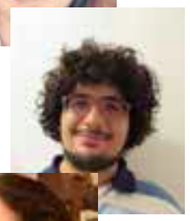
Internal Synergies for Wiser Resources Use in University Campuses

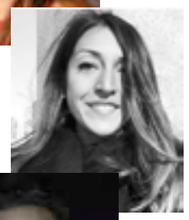
Principal Academic Tutor
Stefano Paolo Corgnati
DENERG Dipartimento di Energia, Politecnico di Torino



Academic Tutors
Patrizia Lombardi
DIST Dipartimento Interateneo di Scienze, Progetto e Politiche del Territorio, Politecnico di Torino
Simona D'Oca
DENERG Dipartimento di Energia, Politecnico di Torino

External Institution
University of Cambridge

External Tutor
Minna Sunikka-Blank
Department of Architecture, University of Cambridge



Team Members
Miriam Bertola [Team Controller]
Civil Engineering, Politecnico di Torino
Massimo Buratto
Architecture - Construction and City, Politecnico di Torino
Caterina Caprioli
Architecture - Construction and City, Politecnico di Torino
Michele Giuliano Carlino [Communication Coordinator]
Mathematical Engineering, Politecnico di Milano
Valentina Valentina
Chemical Engineering, Politecnico di Milano

Project description

The global imperative to reduce carbon emissions and to improve the sustainability of our activities is compelling. The University clearly must contribute by addressing our own operations, but as a higher education institution we are also ideally placed to influence the future through the education of our students and our world-leading research. The aim of this project is to get all tip-top students to work on a shared vision of future campuses, to facilitate the active participation of the University community in reducing the collective environmental impact. The ultimate strategic objective is to improve the environmental performance of our buildings and the University's physical infrastructure by moving towards carbon neutral energy performance, adopting environmentally conscious procurement practices, building community resilience and shared goals, reducing resources consumption and eventually engage fully with the student body, to ensure the involvement of all key stakeholders for carbon emission reduction. The campus may then represent the test bed for all current research projects for energy reduction hold in the different departments, and be the laboratory to test new solutions for occupant behaviour awareness, low carbon policies, zero energy buildings design and green procurement. Both professors and external companies will offer their set up experiments and technologies to be applied hands on real campus cases. Students can know better than any other what is needed for the campus of tomorrow, and may apply their knowledge/ideas/vision relating to energy consumption, green commitment, graphical interfaces, awareness raising, cost (economically and environmentally speaking) communication.
Expected outcomes will outline possible campus contexts in which existing technologies can be applied for improving campus sustainability management, user satisfaction and lower energy/maintenance costs. As meta-results, the focus on internal assets will provides insight into the socio-technical reasons as to why University buildings might 'underperform' in terms of their energy consumption and resource management. Hinge to upon appropriate communication with building occupants may promote consciousness and understanding of the need for action and how to act, overcoming the ineffective yet common provision of energy use data alone. Comparison within gold practice and innovations adopted in other campus can introduce in POLITO/POLIMI the seed for a change at minimum cost while using exceptionally gifted and enthusiast students, as well as the latest IT solutions, as vectors for new strategies for energy reduction.

Abstract

Sustainability has become an international agenda; and due to its size, complexity, and influence in society, it is important to enhance sustainability in Higher Educational Institutions (HEIs). Our team divide the big and wide terms of sustainable university into six clusters: Protocols, Economic and Feasible studies, Building Efficiency, Energy Efficiency, Food and Waste, and User Engagement. Each clusters results in different actions to achieve sustainability and indicators to measure the effectiveness of the actions. Therefore, a multi-criteria analysis should be performed in order to land final decisions, for example the creation of sustainable strategic plan, which is efficient, effective and economic.
The multi-criteria analysis involved in the project is to analyse the six clusters with all the actions and indicators through the use of Analytic Hierarchy Process (AHP) by using a software called Superdecision. A specific case study, "Retrofitting of Stirling Library" in the University of Cambridge, is introduced as an example of how complex it might be to decide sustainable actions even just for one building. Weight for each clusters, actions

and indicators were decided based on the existing boundaries to apply the final solution. We also perform a sensitivity analysis in order to see how changing weight can impact the final solution.
The final aim of our work is to provide as many as possible actions and indicators, with relative networks of interdependencies, as the foundation to arrange a strategic plan for sustainable university. These networks can be used as a basis of multi-criteria analysis where the stakeholders can get a view on how a single action can affect many other aspects. In the end, some recommendations for PoliMi/PoliTo is proposed. Using the multicriteria analysis methods, and following our network/map of actions and indicators, several scenarios are analysed, which give different outcomes for each cluster.

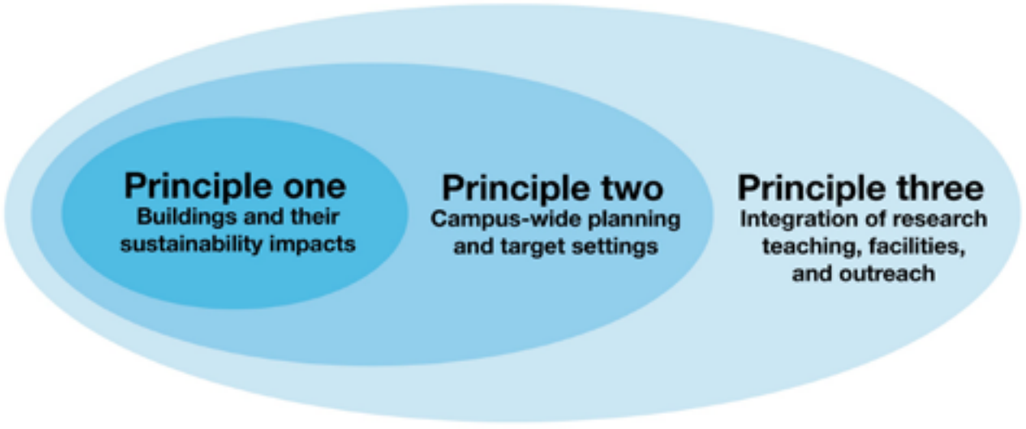
Understanding the problem

Promoting sustainability in University is not an easy job to be done. HEI is a complex society consists of different stakeholders with different objectives. The key actors are students, lecturers and academic staffs who will make in the transformation of current practices and lifestyles. Also, it consists of different buildings and elements which serve different purposes. Many aspects should be considered, and it is necessary to analyse each component of sustainability towards each aspect before making a final decision on the strategic plan. This leads to the needs of multi-criteria analysis. We identify six clusters in which there is the room of sustainability improvement, they are:

1. Create a common framework (Protocol)
2. Reduce operation and management costs (Economic)
3. Increase the building efficiency on site (Building)
4. Enhance the energy efficiency (Energy)
5. Reduce creation of wastes (Food & Waste Management)
6. Increase energy awareness among users (User Engagement)

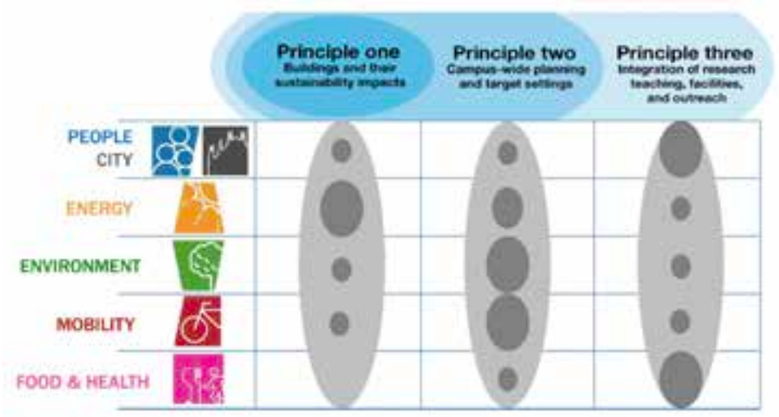
Initiatives for sustainability in universities is mainly based on three principles set by ISCN-GULF: International Sustainable Campus Network - Global University Leaders Forum (Picture 3). Based on these principles, Politecnico di Torino (PoliTo), Politecnico di Milano (PoliMi), and Università Ca' Foscari Venezia (Ca' Foscari) developed their pathway towards sustainability (Picture 4, 5 and 6). We performed analysis to their experiences and outlined possible actions and indicators in which existing or new technologies can be applied for improving campus sustainability.

Principles of ISCN/GULF

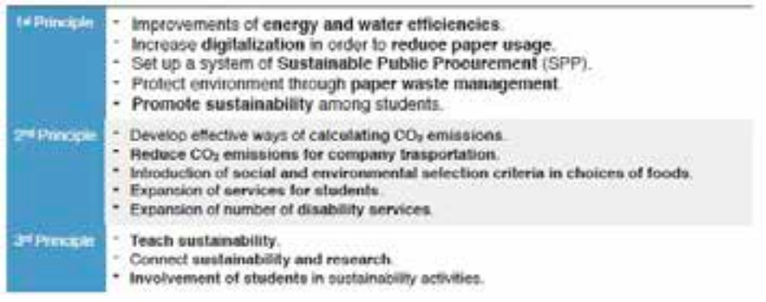


Dimensions / ISCN Charter	Energy and Buildings	Purchasing and Waste	Urban Outreach	Mobility and Metropolitan area	People and Food
Principle 1	Resource Use				
	Building design aspects	Waste, recycling, local emission			
Principle 2	Institution-wide carbon targets		Master Planning	Transportation	Food
					Social protection and safety
Principle 3	Social Integration				
	Commitments and resources for campus sustainability				
					Topical integration

PoliTo five dimensions of sustainability overlap with the ISCN-GULF principles



PoliMi sustainability themes overlap with the ISCN-GULF principles

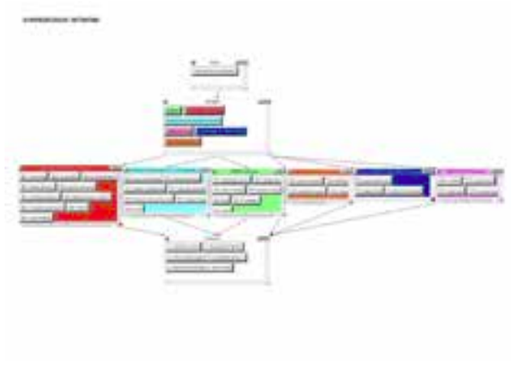


Ca' Foscari sustainability goals clustered in three ISCN principles

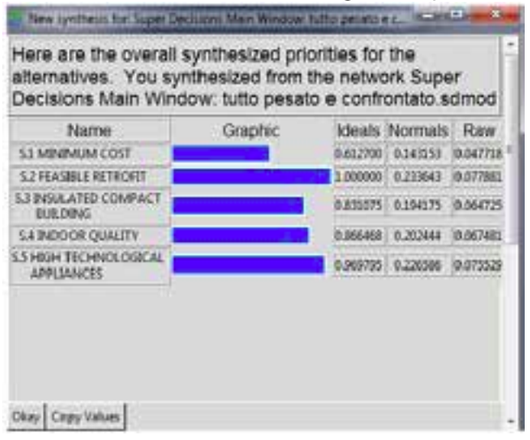
Exploring the opportunities

In order to showcase on how complex it is to do a multi-criteria analysis, our team has decided to pick one real problem being faced by University of Cambridge, particularly Stirling Library (Picture 7). There are occupants' comfort problem within the building, such as windows surface, type of indoor quality, use of renewable sources, OPAC insulation, use of automatic/ manual control system, appliances' change, materials, user engagement, and type of adopted protocols.

Stirling Library in University of Cambridge



AHP Network of multi-criteria analysis for retrofitting of Stirling Library



Final Ranking of Solutions for retrofitting of Stirling Library

Our team worked to find which are the possible solutions and actions within the six clusters, measured by indicators. Analytic Hierarchy Process (AHP) within the Superdecision software is used for the decision making process. Indicators are depended on their own cluster and linked to all alternatives. Without the help of a useful software, this analysis will be extremely difficult. Even for a single building of library, a complex network of multi criteria analysis should be done.

In order to collect the possible solutions, we defined the primary goal of interventions. The analysis was conducted through energetic retrofit taking into account costs of interventions, money savings, and life cycle cost, etc. for a cost-optimal solution. Five scenarios have been identified:

1.MINIMUM COST: minimizing the costs of interventions

2.FEASIBLE RETROFIT: particular attention to pay back periods, LCC and cost of interventions, with the application of new energetic appliances

3. INSULATED COMPACT BUILDING: energetic, plant and involucre performances are maximized

4. INDOOR QUALITY: using natural and recyclable materials, a HVAC total automatic system in order to maximize the internal environmental quality

5. HIGH TECHNOLOGICAL APPLIANCES: maximizing the technology innovations, without taking into account the costs of interventions but only the money savings

Then, according to each cluster, we created the network in the software from the table of indicators which we prepared based on the study from PoliMi, PoliTo, and Ca' Foscari (Picture 8). The software, through the pairwise comparisons tables, generates all the weights, which are used for the evaluation. The final ranking of the possible solutions takes into consideration both the importance of the clusters and the weights of indicators inside them. After weighting and linking all the indicators and solutions, it is possible to obtain the final ranking (Picture 9).

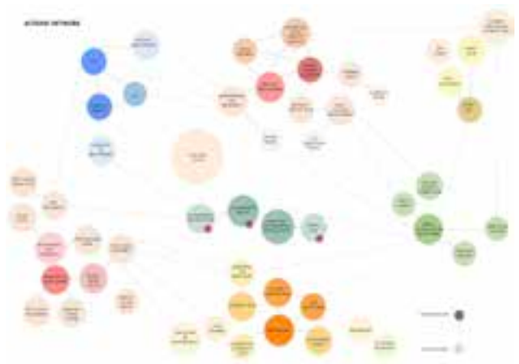
Based on the software, it recommended "Feasible Retrofit" as the solution that tries to obtain the maximum indoor comfort possible without having too high cost of intervention. The evaluation of the weights has produced a ranking on which solutions ("Insulated Compact Building" and "High Technological Appliances"), that have level of energy performance and systems efficiency more relevant than those of the winning one, are less interesting than the "Feasible Retrofit" solution, thanks to its lower costs of intervention. However the cost of intervention is not the only decisive parameter. In fact, the solution with lowest cost of intervention ("Minimum Cost") is ranked as the least interesting one. This shows us how a network within indicators can give different result as what a human can think of.

In order to verify the work, a sensitivity analysis is done to see how the change of weight will impact the recommended solution. Modifying the clusters' weights it is possible to understand that the best solution changes in relation to the cluster's variations (Picture xx. Nodes: Building Efficiency, Energy and Economical and Feasibility study); left: no weights change; right: maximum value for node parameter). So, if the goal of the retrofit is specific (for example, improvement of user engagement activities, reducing paper waste etc.) it is necessary to maximise the weight related to the cluster and the best choice changes each time.

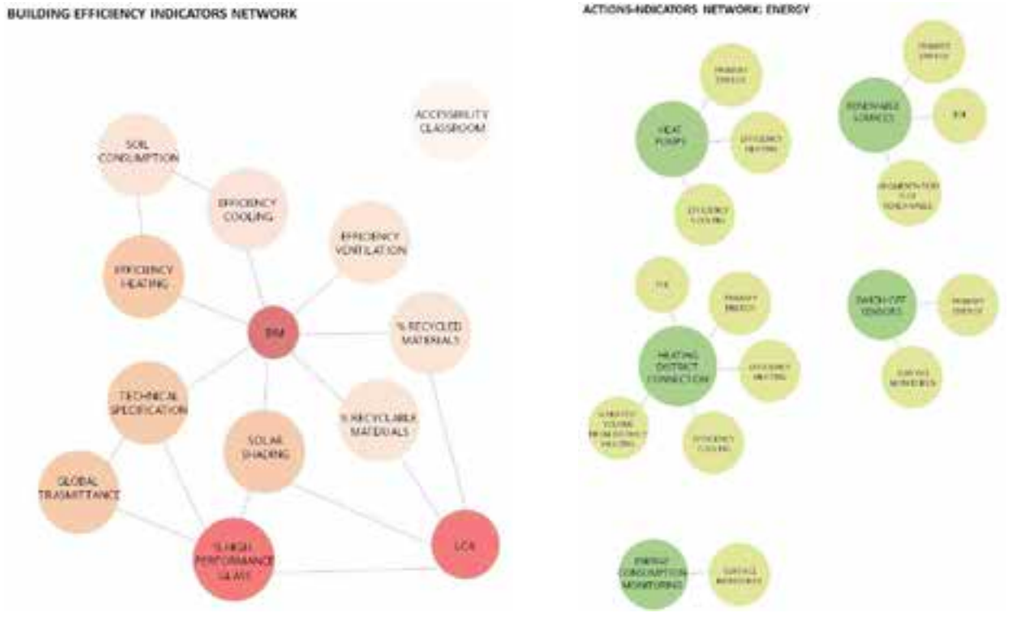
Generating a solution

The analysis conducted from PoliTo, PoliMi, and Ca' Foscari, has made possible the creation of a list of actions and indicators. These indicators and actions is further analysed creating a network based on ISCN Principles, and also matching three different universities in Italy. In this report, we present only the networks of actions (Picture 10), network of indicators in Building Efficiency cluster (Picture 11), and network of actions-indicators in Energy cluster (Picture 12). For the complete networks, please consult the full report.

The project's aim is not to create a rigid network, to which each decision has to adapt itself, but to have a model and tool for evaluating that can be adapted in relation to each specific university necessity.



Networks of actions



Network of indicators in Building Efficiency cluster and Network of actions-indicators in Energy cluster

Using the decision making software (ANP/AHP), we are able to formulize which action is most preferable to achieve the desired result of each university by setting the indicators as point of measurement. Each university should choose from the list the indicators that are more suitable for them and should weight each parameter.

Some recommendations were made for PoliTo, PoliMi, and Ca'Foscari, which are reduce energy consumption through natural ventilation and

thermal mass of building which requires continuous update of BIM model, having LCA and LCC in place for overall economic study, use monitoring devices to improve energy usage, Green purchasing (local food production) and recycling for food and waste management, engage users through web-platform thanks to digital innovation, and finally to obtain different international certifications for objective comparison among universities.

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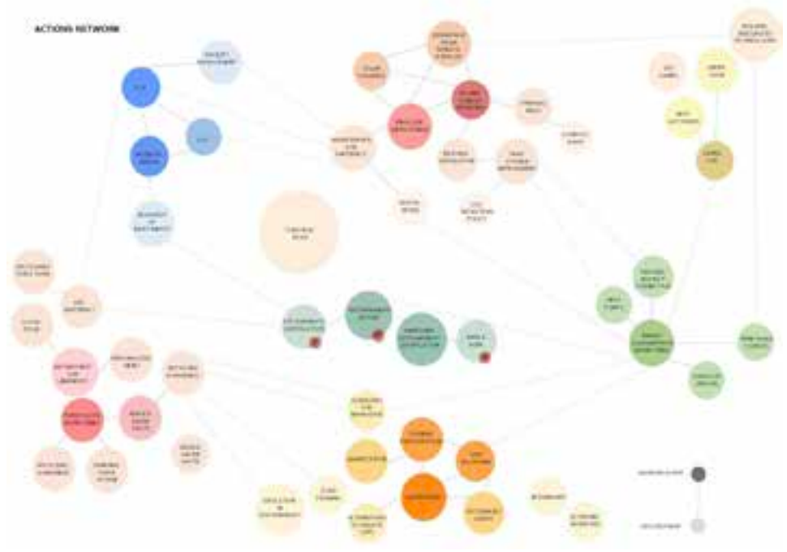
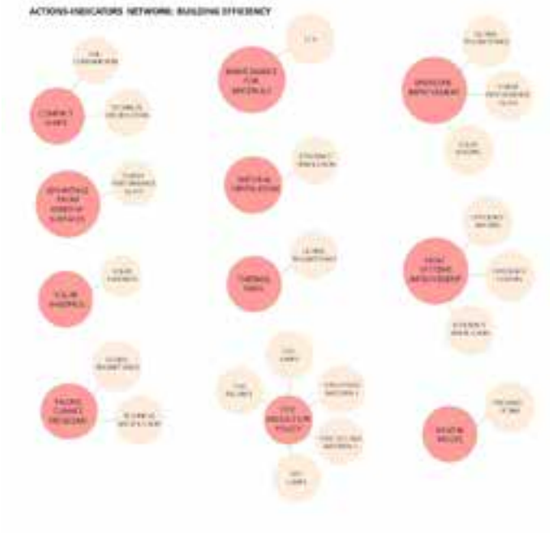
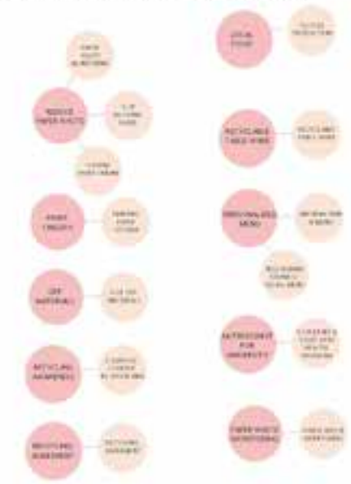




ACTIONS-INDICATORS NETWORK: ENERGY

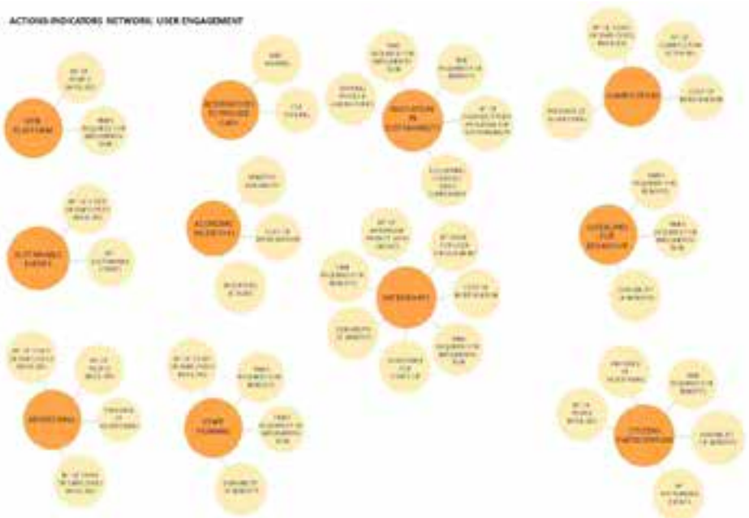
ACTIONS-INDICATORS NETWORK: FOOD AND WASTE MANAGEMENT



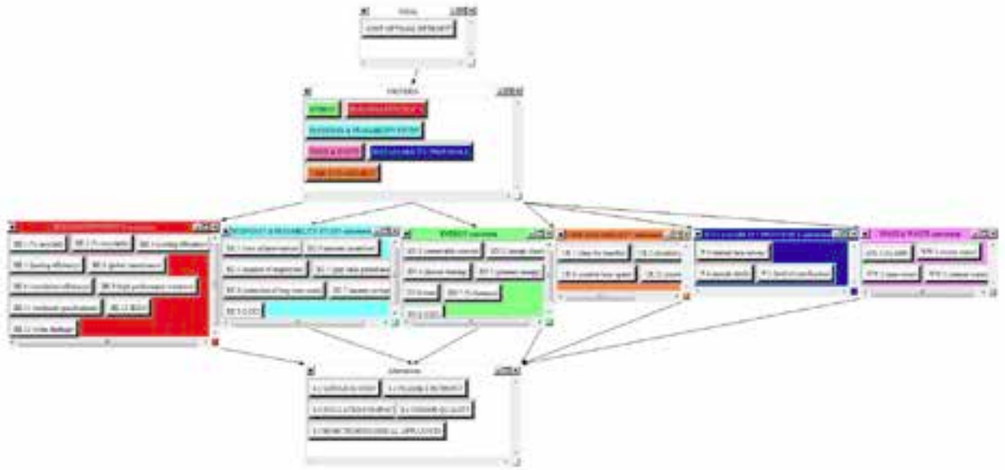
ACTIONS-INDICATORS NETWORK: SUSTAINABILITY PROTOCOL

ACTIONS-INDICATORS NETWORK: ACTIONS FROM DIFFERENT AREAS

ACTIONS-INDICATORS NETWORK: USER ENGAGEMENT



SUPERDECISION NETWORK



Project

6

G-NEO COLLOIDS

Development of novel guanidino-glycoside based nanoparticles and nanogels for an efficient delivery of unmodified therapeutics

G-NEO COLLOIDS

Development of novel guanidinoglycoside based nanoparticles and nanogels for an efficient delivery of unmodified therapeutics

Principal Academic Tutor

Alessandro Volonterio
Department of Chemistry, Materials and Chemical Engineering "Giulio Natta", Politecnico di Milano

Academic Tutors

Alessandro Sacchetti
Department of Chemistry, Materials and Chemical Engineering "Giulio Natta", Politecnico di Milano
Simone Vesentini
Department of Electronics, Information and Bioengineering, Politecnico di Milano
Fabrizio Giorgis
Department of Applied Science and Technology, Politecnico di Torino
Filippo Rossi
Department of Chemistry, Materials and Chemical Engineering "Giulio Natta", Politecnico di Milano

Team Members

Aldieri Alessandra [Team Controller and Communication Coordinator]
Biomedical engineering, Politecnico di Torino
Catania Giovanni
Physics of complex systems, Politecnico di Torino
Cavallaro Sara
Biomedical engineering, Politecnico di Torino
Pigoli Lorenzo
Chemical engineering, Politecnico di Milano
Sarao Stefano
Physics of complex systems, Politecnico di Torino
Sclocchi Antonio
Physics of complex systems, Politecnico di Torino

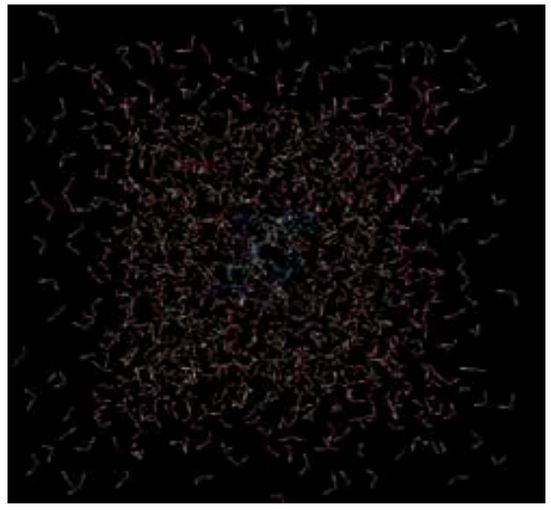
Project description

The overall goal of the project is the development of guanidinoglycosides, in particular guanidinoneomycin (GNeo), decorated nanogels for the lysosomal delivery of unmodified cargos.
Guanidinoglycosides are a new family of non-toxic cellular delivery vehicles made by replacing all the
ammonium group on aminoglycoside antibiotics with gainidinium group. Unlike other guanidinium-rich
transporters (e.g. Tat and oligoarginine peptides), the cellular uptake of guanidinoglycosides occurs at nanomolar concentrations and exclusively depends on cell surface heparan sulfate proteoglycans (HSPGs). While all the cells express HPSGs, providing a high density of binding sites for ligands, increasing the valency of the guanidinoglycoside trasporters retains specificity for heparin sulfate and provides reagents that can target a broader range of cell types. It has been demonstrated that GNeo-conjugated enzymes reach the lysosome and reconstitute missing enzyme activities in fibroblasts from patients with mucopolysaccharidoses (MPS) disorders. One limitation of the existing technology is the requirement to conjugate the enzyme to the carrier via chemical ligation since some enzyme do not retain full activity when conjugated in this manner. Encapsulating the enzyme in a carrier such as nanogels that contains GNeos in its periphery potentially circumvents this limitation.
In this project, we planned to bridge together the expertise of different groups working at Politecnico di Milano, Politecnico di Torino, and Istituto di Ricerche Farmacologiche "Mario Negri" concerning organic synthesis, biology, molecular and physical characterization, and molecular modeling for the synthesis, characterization and biological evaluation of PEI-PEG-based nanogels decorated with GNeos for the selective delivery into the cellular lysosome of unmodified cargos. We emphasize that the success of this project would provide a universal platform for the delivery of hypothetically any kind of unmodified cargos, from small molecules drugs to high molecular weight biomolecules, such as proteins, enzymes or genes, to facilitate therapeutic approaches to diverse disorders.

Tasks and skills

Thanks to the particular multidisciplinarity of the team, it subdivided into three main sectors each member could focus on.
Lorenzo Pigoli: worked in Politecnico di Milano laboratory to perform the synthesis of the compounds of interest. This activity required in fact constant checks of the several substeps, leading to the final product.
Alessandra Aldieri, Sara Cavallaro and Stefano Sarao: concentrated on the so called computational part of the project.
Alessandra Aldieri: always with the support of Stefano and Sara, worked mainly on the simulations concerning the analysis of Neomycin and Guanidino-Neomycin, whereas Stefano and Sara dealt with the study of the bigger and more complex structure including PAMAM and PEG-PEI, in order to achieve a comparison between the two.

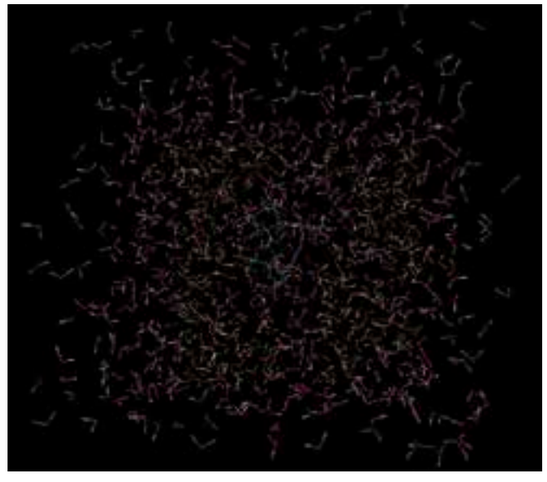
Giovanni Catania and Antonio Sclocchi: finally, worked on the physical characterization of the synthesized compounds and tried to perform advanced spectroscopic techniques to analyze the chemical compounds, in order to fully comprehend their final structure.



Neomycin and GuanidinoNeomycin represented in the box of water created for the MD simulations (images created with Visual Molecular Dynamics)

Abstract

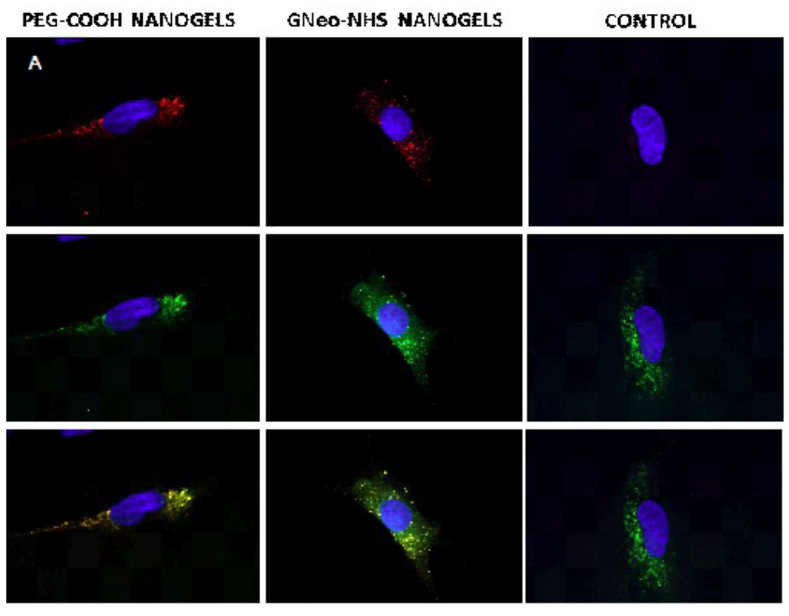
Main purpose of the project has been the synthesis of a new nanogel based on a PEG-PEI copolymer decorated with a modified guanidino-glycoside compound. This nanogel should then offer the possibility to embody an antitumoral drug which did not need to undergo any previous chemical modification.
The great strength of this nanogel is its ability to interact with the heparan sulfate, one of the most represented glycosaminoglycan in our body, present on the membrane of almost every cells. Thanks to its interaction with heparansulphate, the newly modified nanogel can be easily internalized by the cell, and the drug potentially released. At the same time, the selected copolymer is totally biocompatible and biodegradable, without showing any cytotoxic effect on cells at all.
This project is clearly in the extremely actual field which deals with nanomedicine. Traditionally, antitumoral drugs are administered systemically, even though this type of administration has several drawbacks. In particular, the main issue concerns the need that the concentration of the drug resides for the longest time possible in the therapeutic window, i.e. in a concentration interval where it can be effective. To fulfill this need, the concentration of the drug often overcomes toxicity levels, with severe consequences on the whole organism. The actually spreading trend, on the other hand, aims at the possibility to irreversibly damage tumoral cells, minimally altering the physiology of the healthy ones. The antitumoral drug, through a controlled release, is forced to be selectively internalized only by specific cells, the tumoral ones in this case.
Although the synthesis of the nanogel could seem the core part of the project, it was rather articulated into three main parts: the synthesis, a computational part which dealt with molecular dynamics simulations of Neomycin and Guanidino-Neomycin before, of a more complex structure, trying to include the nanogel as well then. Guanidino-Neomycin represents the specific molecule which is able to interact with the proteoglycans found on cell membranes. There was, as a consequence, a significant interest in the comprehension of its structure in an environment similar to the human one. Neomycin is the chemical molecule easily found in commerce, which underwent guanidination to reach the final design of the interacting molecule, its analysis was considered of potential interest too.
While the computational and chemical parts could be performed in the meanwhile, the one related to the physical characterization was forced to follow the synthesis of the compound. It dealt with the use of spectroscopic techniques, Raman spectroscopy in particular to achieve a deep analysis of the neo-synthesized compounds.



Neomycin and GuanidinoNeomycin represented in the box of water created for the MD simulations (images created with Visual Molecular Dynamics)

Understanding the problem

From the perspective of the developed project, an extremely challenging and significant problem could be faced: the administration of drugs to patients affected by tumors, challenge of vital importance. This Project follows the actual leitmotiv which focuses on the possibility to release the drug just once it has been internalized specifically by tumor cells, managing to leave the healthy ones unaffected.
Since the main purpose of our project was the design and realization of a new drug delivery system, patients and their needs were the starting points, and have been the starting point of this specific field of research, which nowadays in increasingly spreading. The core idea behind it was the research of an alternative solution to the traditional way through which anticancer drugs are administered. The systemic administration in fact, turns out to be extremely harmful for patients. High doses need to be given and these not only act on tumor cells, but on every cells in the body. Although the drug acts mainly on cells which reproduce faster, such as tumor cells, in order to achieve the most effective therapy, doses exceed the systemic toxicity levels, so that the concentration of the drug in the body is for the longest time possible within the therapeutic window, i.e. the range in which it can have successful effects.
Purpose of the project was to design and produce a decorated nanogel able to, via the drug controlled release, overcome these significant limitations.



The localization of the GNeo-nanogel (red) within lysosomes (green) of fibroblasts dermal cells

Exploring the opportunities

Controlled release systems have been designed to enable superior control of drugs exposure over time, to assist drugs in crossing physiological barriers, to shield drugs from premature elimination, and to guide drugs to the desired site of action while minimizing drugs exposure elsewhere in the body.

Many studies have demonstrated that nanosystems have a number of advantages over micro or macro systems. Generally, nanosystems have relatively high cell uptake when compared to micro ones, and they are available to a wider range of cellular and intracellular targets, due to their small size and mobility.
At the nanoscale level, it is also possible to incorporate targeting ligands that allow particles to bind preferentially to specific cell types and, therefore, promote the uptake and drug release into those cells.
Among natural and synthetic polymers potentially useful in the field of drug delivery, hydrogels have shown particularly interesting characteristics. The porous structure is able to allow drug loading, concurrently protecting the drug from enzymes or low pH in the stomach. Besides, the delivery could be not only pH driven, but also temperature or even electrically driven.
Nanosized hydrogels in particular, i.e. nanogels, have attracted attention as multifunctional polymer-based drug delivery systems [Raemdonck et al.]. They are highly versatile, as far as both drug encapsulation and drug release are concerned. The main reason why hydrogels confined to micro- and nanoscopic dimensions are more and more increasing interest of researchers is the possibility to deploy them in areas of the body not easily accessible by macroscopic hydrogels. Their nanoscale dimensions besides, allow them to rapidly respond to environmental stimuli, which is a non-negligible characteristic for triggered drug delivery.
Many drug molecules suffer severely from many impediments such as low solubility, off-target toxicity, instability or inefficient transfer across biological barriers, all of which significantly hamper their in vivo use, nanogels may represent the solution able to overcome many of these drug delivery issues.
As far as the minimization of negative effects on healthy tissues is concerned, a fundamental aspect which strongly affects the success of this innovating drug administration is that tumor tissues could be selectively targeted by the nanocarriers. In fact, they exhibit particular characteristics, including an enhanced blood vessels permeability as well as specific ligands on cell membranes. Ligands often vary according to the type of tumor, so that specific nanocarriers can be designed.

Generating a solution

The main goal of our project has been identified in the synthesis of a new nanogel based on a PEG-PEI copolymer decorated with a modified guanidino-glycoside compound.
With regarding to the shielding of nanogels, most research is focused on PEG-based nanogels, or their surface modifications using a hydrophilic PEG shell [Raemdonck et al.].
Different types of degradable nanogels are currently being explored with the aim of enhancing the intracellular delivery of encapsulated drugs. Degradability of the system would in fact be essential, lowering toxicity and avoiding accumulation in the body upon repeated administration. Cationic PEI-cl-PEG/Pluronic nanogels as an example, were made degradable by the use of branched PEI polycations in which PEI segments were linked via disulfide bridges.
Besides, in order to achieve an efficient controlled drug release system, the creation of multifunctional conjugates consisting of dendrimers and guanidinoglycosides could be a satisfactory solution. PAMAM would seem to be a good candidate as dendrimer because of its ease of synthesis, commercial availability, well defined geometry and chemistry. However, it has the big disadvantage of having a high toxicity inside the human body, which makes it not so much efficient for drug delivery applications. Polyethylenimine based hydrogels overcome this problem, so they have been chosen as the drug delivery nanocarriers for this research project. The first aim of this research study is to demonstrate the possibility of cellular internalization of PEI-PEG-GNeo based hydrogels. PEG-PEI nanogels introduced into cells culture with a concentration equal to 0.1 mg/ml or even lower do not reduce cell viability. They can, as a consequence, be considered cytocompatible. This concentration threshold does not, moreover, interfere with an adequate delivery. Nanogels manage indeed to deliver the active compound through cellular membrane without interfering with nuclear activity.
Finally, a fundamental additional aspect, which also highlights one of the great novelty and advantage of the designed system, is the fulfillment of an effective cellular uptake. With respect to other unmodified drug nano-carries, the use of a decorated nanogel fosters the bond between nanogel and cellular membrane and as a consequence, makes the internalization much more effective. Specifically, this aim was reached through chemical modification (guanidilation) of a commercially available product, Neomycin.
Fig. 1-2 Neomycin and GuanidinoNeomycin represented in the box of water created for the MD simulations (images created with Visual Molecular Dynamics)
Aminoglycosides play a fundamental role as antibiotics. They represent indeed a family of polycations which can selectively inhibit prokaryotic protein biosynthesis. Recent studies have shown that by converting the amine on aminoglycosides into guanidine groups can improve the RNA affinity. Upon guanidinylation, cellular uptake has been demonstrated to be enhanced 10-fold for tobramycin and 20-fold for neomycin [Luedtke et al.]. In general, differently from aminoglycosides, guanidino glycosides show a significant efficient uptake by eukaryotic cells. Guanidine-containing modified products might facilitate cellular transport of pharmacologically important cargo molecules [Luedtke et al.]. This could be due to the guanidinium groups on the glycoside core which may be able to facilitate the translocation across the cell membrane. According to Sarrazine at al. this process depends on cell surface heparan sulfate proteoglycans.
Fig. 3 The localization of the GNeo-nanogel (red) within lysosomes (green) of fibroblasts dermal cells

Main bibliographic references

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E-MOD

Electric MObility Development in Italy:
a multidisciplinary evaluation

Project

E-MOD

Electric MObility Development in Italy: a multidisciplinary evaluation

Principal Academic Tutor

Mario Grosso
Department of Civil and Environmental Engineering, Politecnico di Milano

Academic Tutors

Alberto De Marco
Management and Production Engineering, Politecnico di Torino
Matteo Savaresi
Electronics, Information and Bioengineering, Politecnico di Milano
Ezio Spessa
Department of Energy, Politecnico di Torino

External Institutions

Italian Regulatory Authority for Electricity Gas and Water
Stazione Sperimentale dei Combustibili (Fuel Experimental Station)
Ricerca Sistema Energetico
ABB

External Tutor

Giuseppe Mauri
Ricerca Sistema Energetico

Team Members

Awaz Alfadil Alkhalifa Mohamed
Environmental And Land Planning Engineering, Politecnico di Milano

Claudio Giuseppe Carnabuci [Team Controller]
Environmental Engineering, Politecnico di Milano
Gregorio Cioppa
Mechanical Engineering, Politecnico di Milano
Federico Consonni
Chemical Engineering, Politecnico di Milano
Emanuela Di Carlo
Chemical Engineering, Politecnico di Milano
Qianqian Li [Communication Coordinator]
Mechanical Engineering, Politecnico di Milano

Description

The project addresses the topic of electric mobility following a multidisciplinary approach, in order to answer the most common concerns, to analyse strength and weaknesses and to assess further need of improvements.
First of all, the current status of Electric Vehicle (EV) availability on the market and of the recharging infrastructures are analysed, both worldwide and in some specific countries.
The environmental aspects of Electric Mobility (EM) are analysed with a comprehensive approach. Direct atmospheric emissions are compared to those of traditional vehicles, and the same for internal and external noise emissions. The exposure to electromagnetic field inside the vehicle is also assessed, as well as the release of heat during standard driving cycles. This step of the project is conducted in cooperation with Stazione Sperimentale dei Combustibili (SSC), where two electric vehicles and an internal combustion one were tested during two days on a dynamometer test bench. A Life Cycle Assessment (LCA) is then performed, with special emphasis on the sensitivity of the results to the type of energy used for recharging in order to check whether the emission savings during the use phase are able to compensate the higher impacts of the batteries production phase. The energy aspects are mainly addressed by analysing the possible role of EVs (when plugged and not in use) as energy storage devices integrated to the smart grid.
The economic aspects are addressed by suggesting possible business models in order to promote a quicker development of electric mobility in Italy. This is addressed by looking both at the sale of EVs and the development of the recharging infrastructure.
Finally, some social aspects are addressed, in order to analyse the further barriers that prevent users to opt for EV mobility and the influence of hot issue on the social network
The following case studies are critically analysed.

- The strategy of E-mobility promotion adopted in Norway, USA and China. Heavy subsidies for EV (not only in economic terms) have sky-rocketed their sale, rising some concerns on other categories (i.e. the use of priority lanes restricted to buses and taxis)
- Electric Mobility Industry Companies such as Tesla Motors, FastNed and BYD.

Group Picture - Attending eCarTech 2015, Munich

Tasks and skills

Awaz Alfadil: took care of the social aspects part, developing the EV & Dieselgate platform and analysing Cluster Analysis results.
Claudio Carnabuci: focused on the processing of data from the experimental tests conducted at SSC and acted as team controller.
Gregorio Cioppa: analysed the Italian EV market situation, later proposing infrastructure-cantered incentives for the EM-2030 plan.
Federico Consonni: performed the value chain analysis and business models proposal, followed by TCO calculations for the EM-2030 plan.
Emanuela Di Carlo: took care of the LCA part, performing comparisons and sensitivity analyses by using the commercial software SimaPro.
Qianqian Li: elaborated experimental test results, analysed EV markets in pioneer foreign countries and contributed to the technological roadmap development.

Abstract

Climate change concerns, urban air pollution and new regulations in the transport sector are shifting the attention to Electric Mobility, recognised as the most sustainable solution to alleviate these environmental problems. However, technological and infrastructure problems are limiting its scale-up only to few countries, and Electric Vehicles in Italy still represent a niche market.
The E-MOD project was developed in this framework, with the aim of:
- analysing if the current Italian socio-economic context is suitable for an EV scale-up;
- assessing local and global-scale environmental benefits given by wider EV adoption;
- investigating what new business opportunities a shift towards EM could give;
- propose a strategy for EM development in Italy.

The first task was carried out by comparing Italian sales and government incentives with those of pioneer countries in EV adoption. Social aspects were then assessed creating the EV &Dieselgate web-platform to monitor people's interest in the topic from social networks, through Word Association and Thematic Cluster analyses.
Experimental tests at Stazione Sperimentale dei Combustibili allowed to show EV benefits compared to Internal Combustion Engine Vehicle (ICEV) in terms of noise, brake wear Particulate Matter (PM), heat release and Electro-Magnetic Field (EMF) emissions. Carbon emissions were instead compared through the LCA method, highlighting the limits of EVs by analysing the sensitivity to battery size and electric energy mix.
A Value Chain analysis allowed to assess which new business models could arise from a shift towards EM, and vehicle-to-grid together with battery 2nd life were selected as the most attractive ones.
Based on the above, we developed a technological roadmap for a wider EV adoption in Italy: the EM 2030 plan. A strong incentive campaign, focused on infrastructure development, should precede a second phase, when the implementation of a proposed Vehicle-To-Grid (V2G) business model would lower EVs Total Cost of Ownership (TCO) in such a way to make them an economically viable option, even more convenient than ICEVs.

Understanding the problem

Our project investigates Electric Mobility from a multidisciplinary perspective, aiming at studying the strict influence between social, political, economic and environmental issues.

EVs for the moment only accounts for 0.1% of sales, because of the lack of stable EV companies interested in the Italian market. In addition, synergic approaches are required for an effective infrastructural development, providing both fast and slow recharging stations, due to the need to integrate urban driving and medium-long range transfers. Furthermore, the diffusion of EVs in Italy will be also related to the regulatory incentives and policies at local or national level, which are the key-priorities in other countries already experiencing a large-scale EV adoption.

Experimental tests at Stazione Sperimentale Combustibili

EVs are generally associated with both positive and negative environmental issues. The former include the absence of tailpipe emissions, the lower CO2 emissions compared to ICEVs (fundamental in order to match the objectives of COP 21), the possibility to exchange energy with the electric system as energy storage devices, and the lower noise emissions. The latter are often associated with the possible exposure to Electro-Magnetic Fields during driving or to the global concerns in case of using electric energy coming from dirty sources such as coal. However, in general, EM is seen as an interesting starting point for urban air quality improvement and lower carbon emissions.
Finally, it is important to mention the social aspects, which are the influencing factors for the raise of EVs market in Italy. Indeed, the presence of physical and ideological barriers can heavily prevent users to opt for EV mobility. Generally, citizens are uncertain about the technology and its potential, or about the possible risks and opportunities.

Exploring the opportunities

The widespread diffusion of any new technology represents a challenging task from a practical, economic and social point of view: these struggles have to be faced by any innovation, and obviously, EVs are not excluded from the list. Although EVs were born before ICEVs, their decline was due to lower driving ranges, scale-up difficulties and scarce economic appeal: these problems need to be solved if a wider EV adoption is desired.

Electric cars sales in Italy

We therefore analysed which factors were able to trigger a robust growth in EV sales in pioneer countries such as USA, Norway and China. In all cases, EVs share is proportional to both the number of promotion actions taken by governments and the number of installed chargers.
In China, tax-free policies allowed EV sales to increase by an impressive factor of 25 from 2012 to 2015. In Norway, benefits such as road-toll exemption, free parking and bus-lane access were introduced, and EVs now have a 22% market share. In the US, incentives were extended to cars, battery and charging station manufacturers, showing how the government role is fundamental if EVs want to be pushed in the market.
However, government incentives cannot represent a long-term solution to increase EVs economic appeal. Therefore, a Value Chain (VC) analysis was performed, showing how a wide EV adoption could affect the traditional automotive VC, creating new business opportunities, which could make EM profitable in the long term.

Value Chain analysis showed how the presence of a large battery pack significantly affects the manufacturing part, but the major transformation is due to the substitution of the fuel value chain with energy distribution and charging. In particular, the inexperienced connection of electricity generation and automotive value chains is the key factor for the rise of new business models, which could help making EVs more economically viable. Last, a literature survey highlighted how studies on the local-scale environmental impacts of EVs are absent, while only few LCA studies focused on the Italian energy mix are present, thus proving the great innovation potential of our analyses.

Generating a solution

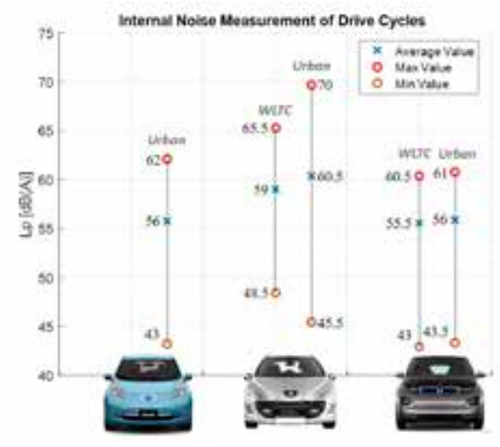
On the environmental aspects side, the tests conducted at the Stazione Sperimentale dei Combustibili highlighted significant environmental benefits given by the use of EVs in substitution of conventional ICEVs:

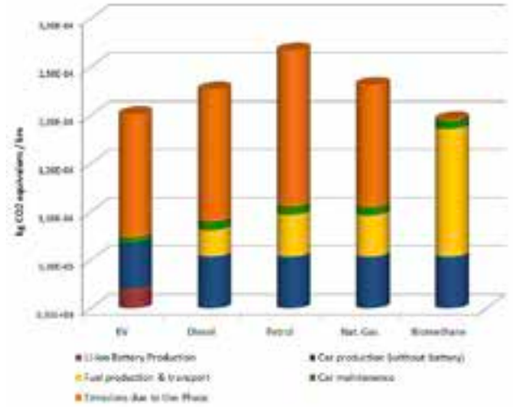
- Sound pollution proved to be at least 20% lower, and higher benefits were observed at low speeds typical of urban traffic;
- PM emissions from brake wear resulted about one order of magnitude lower (in terms of maximum particle concentration) than in ICEVs. Moreover, the possibility of regenerative braking allows to use brake pedals less frequently, further reducing solid emissions;
- EMFs exposure proved not to be dangerous for human health, being the reported value more than 60 times lower than the limit.
- Heat release was assessed to be 1/5 of the corresponding EV counterparts.

LCA analysis showed the benefit of EV adoption also in terms of Global Warming impact: a reduction of Greenhouse Gas (GHG) emissions of 11% and 25% was observed compared to respectively Diesel and Petrol vehicles, whereas Biomethane-powered cars give similar results to EVs.
Sensitivity analyses demonstrated how EVs might give climate change benefits only as long as a sufficient share of renewables is present in the energy mix (lowering emissions up to -60%), and if battery pack weight does not exceed certain limits (in terms of capacity, 40kWh).
From the EM promotion point of view, our study was focused in three directions:

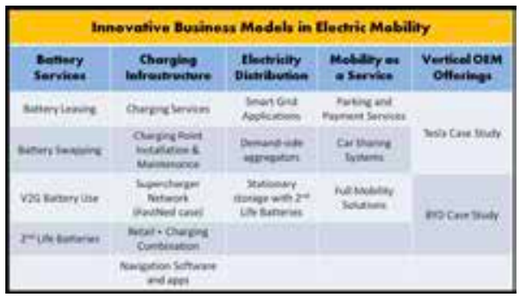
- Creation of a list of possible profitable business activities, that start-ups or venture capitalists might consider when investing in the EM sector. The list has been drawn after performing the Value Chain analysis and analysing the 3 case studies of Tesla, BYD and FastNed.
- Selection of Vehicle-to-Grid and Battery 2nd life as the activities with the highest economic potential. From this perspective, utility companies would operate as intermediaries between EV owners and grid operators. The former would take advantage of discounts in charging rates if they leave part of their spare battery capacity available to the latter. Battery capacity could be exploited either to provide grid ancillary services or to balance fluctuations in energy demand and supply, especially in a future with high renewable energy generation.
- Suggestion of a technological roadmap to be implemented in Italy in order to trigger EVs' sales, considering the current market situation and the experience of successful countries in EV promotion. A first phase characterised by significant government incentives, and especially by the implementation of a robust charging and Smart-Grid infrastructure could pave the way to a second phase, where V2G technology could be the key player in making EV even more economically convenient than ICEV. Indeed, the Total Cost of Ownership of EVs and Diesel cars could be practically equal in case of a widespread use of V2G technologies. Increasing oil prices could then even make EVs a more convenient option. Finally, among the outcomes of our project we have created the EV &Dieselgate web platform: this tool could be extended in the future for an assessment of social perception of EM on both national and global scale.

Internal Noise EV vs ICEV



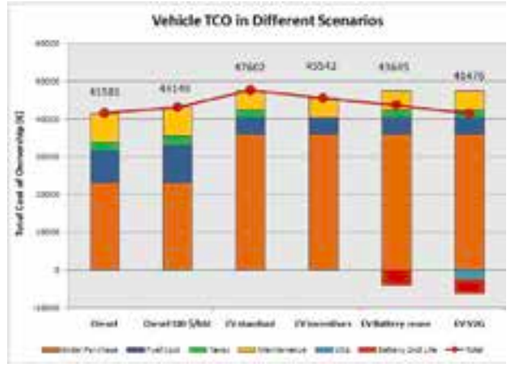


CO_2Emission Comparison



Business Models in EM

Modified EV Industry Value Chain



TCO Comparison

Modified EV Industry Value Chain

SMART LIGHT

Development of a smart automotive taillight system

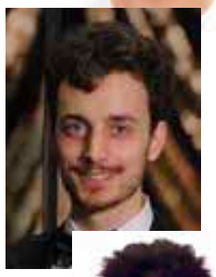
Project

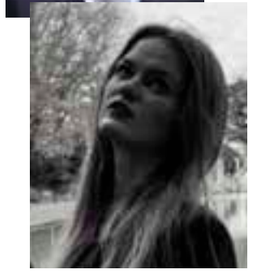
8

SMART
LIGHT

SMART LIGHT

Development of a smart automotive tail-light system





Principal Academic Tutor

Marco Masoero
Energy Department, Politecnico di Torino

Academic Tutors

Giulio Ceppi
Design Department, Politecnico di Milano
Luca Iuliano
Department of Management and Production Engineering, Politecnico di Torino
Franco Maddaleno
Electronic Department, Politecnico di Torino

External Institution

OLSA S.p.a.

External Tutor

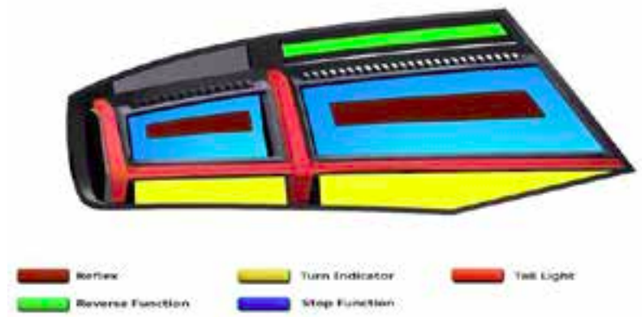
Antonino Germanotta, *OLSA S.p.a.*

Team Members

Alessandro Artoni [Team Controller]
Energy Engineering, Politecnico di Milano
Mattia Landolfi
Mechatronic Engineering, Politecnico di Torino
Mario Murari
Physics Engineering, Politecnico di Milano
Luca Pasqualone
Nanotechnologies for ICTs, Politecnico di Torino
Julien Roux [Communication Coordinator]
Mechanical Engineering, Politecnico di Torino
Iuliia Timofeeva
Mechatronic Engineering, Politecnico di Torino

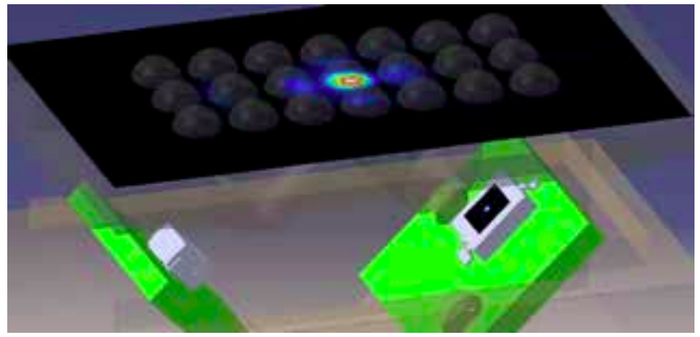
Project description

The Smart Light project aims at developing an innovative LED car taillight able to adapt its operation to variable environmental conditions. The goal is to guarantee an optimum light output, improving both the driving experience and the general circulation safety in presence critical visibility conditions.
A team of six students has carried out this task with the support of OLSA Group, an Italian company specialized in automotive lighting that played the role of main industrial partner. Due to the complexity and specificity of the car market, the project started with a series of seminars held by OLSA experts, which introduced the LED technology and helped defining the project design requirements. Because of the diverse skills of each team member, it has been deemed more efficient to split in three subgroups, each dealing with different technical issues.
After having analyzed the requirements set by automotive regulations, the first step has consisted in the production of a new electronic design of the taillight, without changing its functions (tail, stop, fog, turn, and reverse).
Using the Audi TT3 rear light as basis, the team developed a new layout, which includes a microcontroller and a DC/DC converter. The first component greatly empowers the taillight, managing the information coming from the sensors with a reduced number of cables, while the second device allows to efficiently drive the boards with a constant voltage at nominal value of 13.5 V.



Audi TT3 Rear Light

Another core activity has been the design of a rain and light sensor, a device able to read the external environmental conditions and to produce an output voltage that the microcontroller can interpret. For the rain sensor, the team considered two alternatives: an in-house design, based on the variation of the reflectivity index with the medium, and a more general-purpose device, using the in-flight time information. Both have been experimentally tested so to validate their behavior and identify a correlation between the rain intensity and the output voltage.



Light Rain Sensor Simulation Arrangement

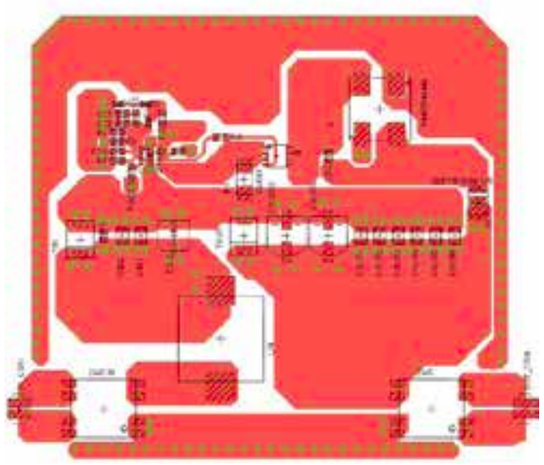
Based on the sensor signal, the microcontroller drives the LEDs by means of a PWM. In this first version of Smart Light, the taillight can respond only to 4 different external conditions: low/high luminosity and rain/no rain. As a future development, it is very likely that the device will be able to deal with more environmental conditions, ideally modifying its behavior continuously with weather. The team wrote the microcontroller software using the C language in CodeWarriors ambient.
Finally, since each electronic component produces heat in a closed taillight system, the most critical PCBs have been verified against thermal overloads. In particular, each board has been simulated as a 2D element under the most critical environmental conditions prescribed by the carmakers regulations (85°C) to verify that the temperature of each critical component does not exceed the specified limit value.
In conclusion, this 10 months long project output consists in the design of a smart taillight able to effectively react to varying environmental conditions thanks to the inclusion of sensors and of a microcontroller able to manage the LEDs driving.

Tasks and skills

Alessandro Artoni: applied his skills as Energy Engineer in the thermal analysis of the printed circuit boards by performing software simulations in order to verify the proper functioning of the device in operating conditions. Moreover, he managed the project budget as Team Controller.
Mattia Landolfi: as Mechatronics Engineer IT-oriented, led his efforts in the development of software architecture and code structure, also contributed to the electronic circuit design. He spent his last energies in a challenging mission: trying to act as designer developing the team logo.
Mario Murari: as Physics Engineer, concentrated his efforts to the devel-

opment of the rain sensor. He exploited his competences in the design and testing of the Smart Sensor. He was also involved in the electronic circuit design.

Luca Pasqualone: thanks to his hybrid competences in Electronics and Physics, took care of the electronic circuit design and contributed to the sensor development. The main effort was dedicated to generating possible solutions for the circuit supply, trying to bring innovative concepts in the automotive electronics.



SEPIC Board Design

Julien Roux: in his role of Communication Coordinator, managed the contacts between the whole group, the tutors, the external partners and ASP administration. He also brought his scientific experience into heat transfer problems, verifying the taillight resistance to thermal overloads by means of appropriate simulations.

Iuliia Timofeeva: as Mechatronics Engineer, worked on the microcontroller software, developing the code in the CodeWarrior ambient and coordinating it with the sensor inputs. She took part in the electronic circuit design as well.

Abstract

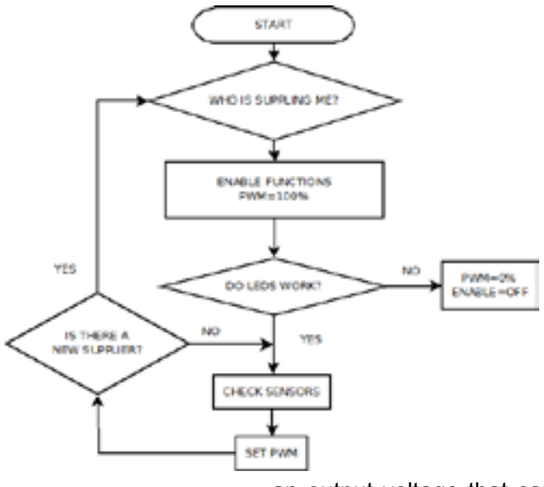
The Smart Light project consists in the development of a car taillight that is smarter than what is currently available on the market. The objective is to overcome the mere signaling function of ordinary rear lights by producing a device that is able to effectively deal with variable weather conditions, so as to always guarantee an optimum lighting for any possible driving situation.

This task has been carried out with the support of OLSA Group, an Italian company specialized in automotive lighting applications. The entire design process has been accomplished accounting for the requirements of the partner company and following the stringent regulations of the automotive industry.

The first activity has consisted in the new electronic design of the taillight, standing that its main functions (namely tail, stop and fog, turn, and reverse) did not change. Using the Audi TT3 rear light as basis, a new layout has been created, including a microcontroller and a DC/DC converter.

In order to detect the environmental conditions, the team has studied a sensor able to produce an output voltage that can be interpreted by the microcontroller. Two alternatives have been analyzed and tested: a device that measures the reflectivity index variation with the medium, and a proximity sensor based on the time-of-flight principle. A software code for the microcontroller has been written so as to modify the LEDs driving by means of a PWM in order to control light intensity as a function of the sensors output.

Finally, thermal simulations on the most sensitive printed circuit boards have been performed under the most critical environmental conditions prescribed by automotive regulations, so as to verify that every component temperature is lower than the limit value reported on the datasheet.

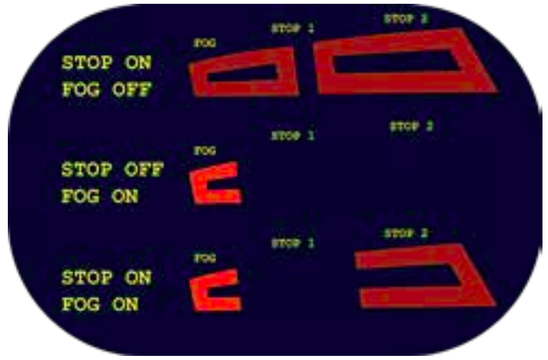


Software Structure

Understanding the problem

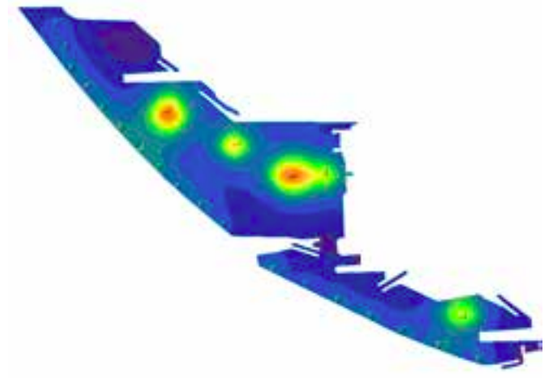
The lighting technology for car market applications, because of its importance ensuring circulation safety, is a demanding product under continuous evolution. OLSA's objective, while proposing the Smart Light challenge, was to design a smart LED rear light able to effectively deal with variable environmental conditions and eventually to react to them.

Due to time and economic constraints, the final design builds on an existing device, i.e. on the mechanical housing of the Audi TT3 rear light. The principal modification of this light consisted in allocating the room previously occupied by the turn progressive lighting for a microcontroller and a sensor, i.e. for the elements making the taillight smart. In addition to OLSA's needs, especially regarding the economic feasibility of the new design, the general requirements of the automotive industry have been considered in order to develop a product that is fully compliant with the international directives, notably provided by the Automotive Electronics Council in the AEC-Q100 regulation. In brief, the following requirements have been identified:



Stop & Fog Activation

- Use standardized components as much as possible;
- Implement processors able to communicate with the body computer and in particular to provide a feedback on possible failures;
- Diminish electromagnetic noise, i.e. electromagnetic interference (EMI) and compatibility (EMC);
- Reduce the number of cables, so to cut costs and limit electromagnetic issues;
- Verify each PCB against thermal overloads, deriving from adverse environmental and driving LED conditions;
- Manage light intensity properly.



Taillight Thermal Simulation

Exploring the opportunities

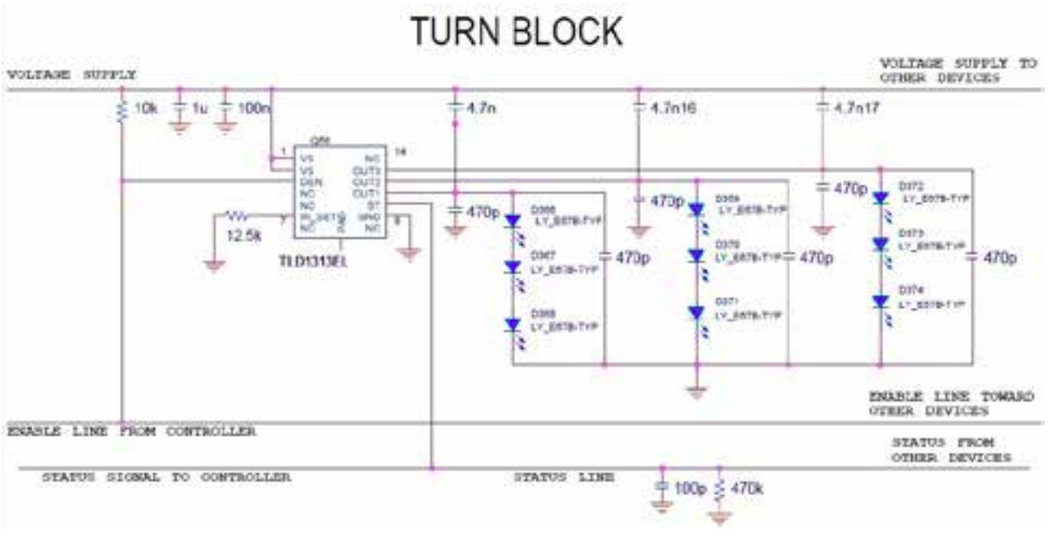
The two main issues to tackle have consisted in the identification of a system enabling the taillight to sense the environmental conditions and of a strategy to adapt light intensity accordingly. In order to measure the outside conditions, four main situations among the theoretically infinite possible combinations have been considered, namely the ones corresponding to good/bad weather combined with day/night time. Indeed, the rear light intensity should be higher when the visibility is low or when the solar illumination is already strong, so that the following driver is still able to spot the taillight signal. On the other hand, light intensity must be reduced during night time as an excessive illumination, besides representing an energetic waste, could be annoying for other drivers.

A combination of humidity and luminosity sensors has been initially proposed, assuming that a high percentage of water in the air could be a good indicator for the presence of fog or rain. However, besides the fact that humidity is not such a reliable parameter, the sensor would need a direct communication with the outside, while, because of both structural and aesthetic reasons, the sensing element is required to be fully enclosed in the rear light. The following proposal consisted in a system composed by an infrared LED, a photodiode, and ad hoc lenses to focus the light. More in

detail, by exploiting the total internal reflection phenomenon it is possible to indirectly gauge, from inside the light, the amount of water lying on the taillight external surface and correspondingly vary the LED PWM duty cycle.
Even a solution as simple and straightforward as a change of the light intensity as a function of the atmospheric conditions is not easily implemented at the electronic level, because of the complexity of the circuit controlling the rear light. First, it has been necessary to include a microcontroller (MC) in the printed circuit board, next a strategy to control the current generators driving the LEDs had to be identified. In a first basic design, the MC directly drove each of the 12 integrated circuits present on the PCB, causing unacceptable electromagnetic interference (EMI) problems. Since each component luminosity needs to be scaled by the same amount so to leave unaffected the taillight aesthetics, an innovative solution such as acting directly on the circuit power supply was proposed. This required a dedicated electronic power element, namely a voltage pre-regulator (SEPIC), whose design was assigned to Silvia Bruno, an Electronic Engineering master student at Politecnico di Torino. Such an innovative solution for the automotive industry, besides greatly reducing EMI, results in improved circuit stability.
As an additional feature, it has been proposed to add piezoelectric/thermoelectric actuators mounted on the internal plastic surface, with the aim of shaking/heating the plastic of the taillight in order to clean it from rain, snow or ice. However, due to the high cost of the components and, again on aesthetic grounds, to the limited available surface to be occupied, this solution has not been considered worth of the investments it requires.

Generating a solution

The whole solution generating process started with the identification, together with OLSA, of the main issues instrumental to the creation of a new generation of rear lamps. The concept requires the development of a specific electronic circuit and the design of an innovative rain sensor.



Turn Function Circuit Block

From an electronic standpoint, this new solution demanded the complete redesign of the rear lamp circuit, taking into account the new requirements introduced by the microprocessor and the sensors. In particular, the addition of a DC/DC converter (SEPIC) at the circuit inlet allowed reducing the supply voltage variability, due to the high battery tension fluctuations (6-20 V), thus keeping the supply voltage constant and equal to the optimum value of 13.5 V. It is worth noticing that the voltage pre-regulator, combined with the LED-driver current generators, represents an ideal operative mode for the rear light from a thermal standpoint, easing the process of thermal verification of the device.
In order to assess the external atmospheric conditions independently from the Engine Control Unit, a rain sensor, referred to as Smart Sensor and capable of discriminating the presence of water drops on the rear lamp outer lens, had to be designed. This sensor exploits the fact that water and air refractive indices are different enough to produce a variation in the output voltage signal that can be interpreted by the microcontroller, triggering a correspondent correction of the LED driving so to obtain the required luminous intensity. The sensor design started with extensive simulations on CATIA VI to verify the device functionality and proceeded with the creation of a prototype, whose testing confirmed the software simulations results. A second sensor (STM VL53LOX), whose working principle is based on the time-of-flight, has been equally characterized experimentally and may result more convenient depending on the application, therefore representing an alternative to the Smart Sensor.
An innovative microcontroller (TRK-S12ZVL), produced by Freescale, was selected to effectively manage the rear lamp. This device has been programmed in such a way to be able to interpret the sensor output and correspondingly change the PWM duty cycle so to adapt the light intensity to the actual environmental conditions. The use of a microcontroller also allowed decreasing the number of cables from 6-7 to 3, with benefits ranging from cost savings to a reduction in EMI issues. In addition, TRK-S12ZVL has the interesting feature of completely turning off when not used, thus avoiding unnecessary energy consumption.
In conclusion, the Smart Light project resulted in the development of a smart and innovative rear light solution, able to adapt the light intensity to the variable environmental conditions in conformity with all the technical regulations. This concept, thanks to its enhanced performances and low production costs, is expected to find immediate applications in the car market, while improving the safety standards and the overall driving experience.

E-ADAST

Environment-driven Adaptive Structure

Project

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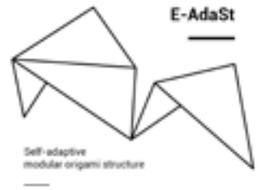


E-ADAST

Environment-driven Adaptive Structure

Principal Academic Tutor

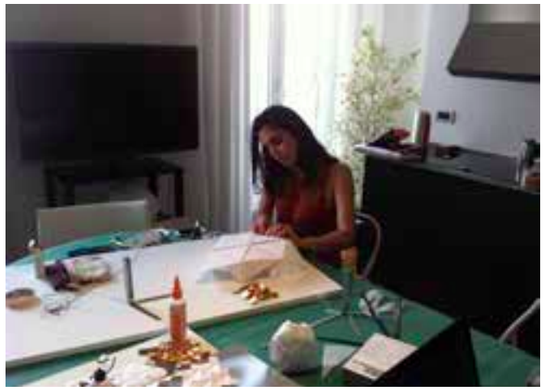
Stefano Mariani
Department of Civil and Environmental Engineering, Politecnico di Milano

Academic Tutors

Francesco Braghin
Department of Mechanical Engineering, Politecnico di Milano
Eugenio Brusa
Department of Mechanical and Aerospace Engineering, Politecnico di Torino
Valter Carvelli
Department of Architecture, Built Environment and Construction Engineering, Politecnico di Milano
Stefano Invernizzi
iDepartment of Structural, Geotechnical and Building Engineering, Politecnico di Torino

External Tutor

Lodovico Migliore
MIGLIORE+SERVETTO Architects



Silvia A., Viola and Matteo working on the MATLAB and Grasshopper simulations

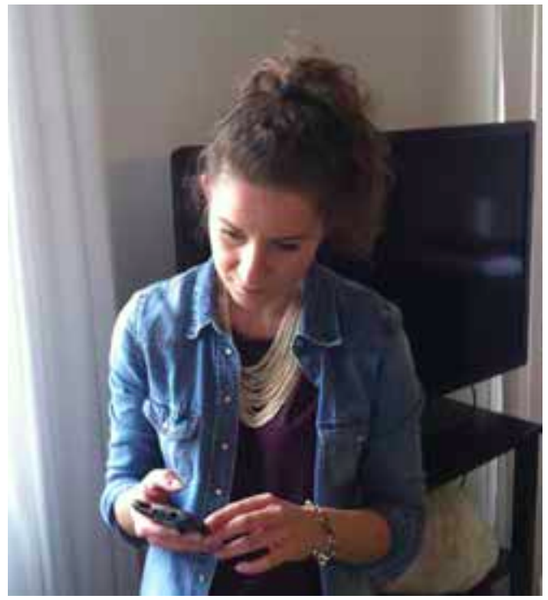
Silvia F. working on the prototype

Team Members

Silvia Andreozzi
Mathematical Engineering, Politecnico di Torino
Gaia Ilenia Bessone
Interior Design, Politecnico di Milano
Matteo Botto Poala
Architettura, costruzione e città, Politecnico di Torino
Martina Bovo
Architecture, Politecnico di Milano
Silvia Fernandez de Alaiza
Architecture, Politecnico di Milano
Emanuele Giargia
Mechanical Engineering, Politecnico di Torino
Alessandro Niccolai [Team Controller and Communication Coordinator]
Mechanical Engineering, Politecnico di Milano
Viola Papetti
Mechanical Engineering, Politecnico di Milano

Project description

In the past, structures in several domains have been conceived to have a time-invariant geometry or configuration and to withstand environmental excitation with a negligible change of their mechanical properties. Advanced monitoring strategies are currently proposed to assess their health condition and resilience, for a consistent prediction of their lifetime. Those strategies are based on the integration of sensors, electronics used to process signals, and mathematical models implemented to detect any damage and predict its effect on the structural health.
Bio-mimicking is a natural development of such monitoring systems integration. Goals of making structures adaptive to variable environmental conditions and of optimizing the behavior of the system are pursued by inducing some change in the configuration as is typical for smart systems. To adapt the structure layout, functional materials or deployable geometries, coupled with appropriate control strategies can be suitably applied.
Very flexible spatial configurations have been envisaged in this project, focusing on lightweight structures whose capability of self-adapting to variable environmental conditions and (possibly) interaction with humans is strongly based on an embedded smartness tailored on customer needs.
Passive structural adaption has been attained through properly selected, deployable/compliant origami-like mechanisms. Active adaption has been then explored by exploiting (in principle) microsensors and actuators. Such multidisciplinary investigation has been driven by parametric modeling with a purposely developed software like Grasshopper.
The project has addressed the primary goal of closing the gap between the fields of smart materials and compliant morphing civil structures, to provide answers to some main challenges currently envisioned under the umbrella of smart cities development.



Viola implementing MATLAB simulations

Gaia working on the prototype

Tasks and skills

Silvia Andreozzi: supported the project in all of its phases, adapting her mathematical skills to the encountered challenges and giving an organic perspective on the work.
Gaia Ilenia Bessone: with her design experience, stimulated the development and analysis of the concept during the research phase and the finalization of the project.
Matteo Botto Poala: implemented from scratch the parametric simulation in Grasshopper and deepened the analysis of specific applications and performance indicators.
Martina Bovo: supported the project both during the research phase and actuation of the concept, by encouraging and backing the construction of the prototype.
Silvia Fernandez de Alaiza: contributed to the finalization of the project and the architectural synthesis of the work, by means of 3D simulations and high-resolution images.
Emanuele Giargia: participated to conferences and, thanks to his engineering background, had an important role in numerical simulations and

Martina taking pictures of the physical models

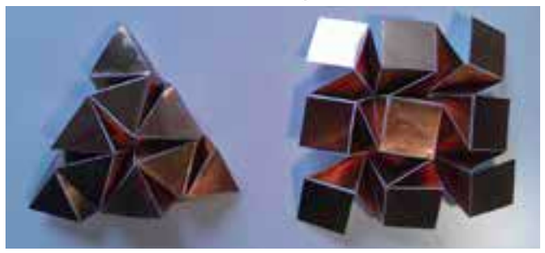
site-specific analysis.

Alessandro Niccolai: has been the coordinator of the team throughout all the project. He provided the MATLAB numerical simulations and the Arduino actuation.

Viola Papetti: helped with the mechanical analysis and modelling of the structure. She contributed to the integration and synthesis of the different stages of work.

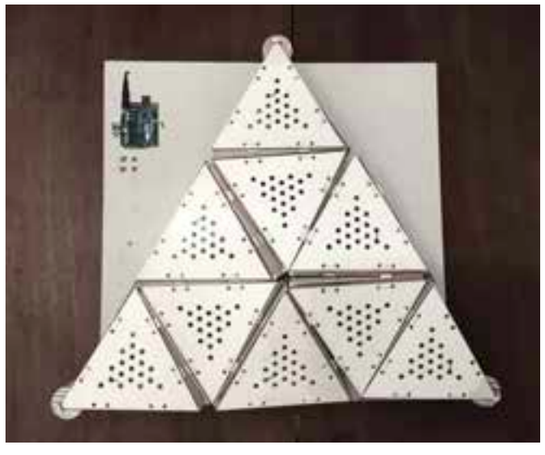
Abstract

Thermal, acoustic and lighting comforts are fundamental aspects in the design of sustainable or resource efficient buildings. The need for low-impact structures is compelling in a world dominated by power demand and threatened by energy shortage. In order to respond to this need, our work has focused on a performative, environment-responsive structure that exploits rigid origami folding and deployability, inspired by features derived from the natural world through a biomimetic approach. Origamis have recently become an inspiration for engineers, architects and designers, leading to many types of applications.



Origami experiments

The concept of origami has been tailored for a specific geometry, chosen as a module of an adaptive solution able to change the relevant degree of openness by adjusting its spatial configuration. These modifications in the structure happen in response to the variations of environmental parameters like lightning, noise and temperature, all recorded by a network of embedded (micro)sensors. The structural deployment is induced by linear electric motors with a discrete positional control logic. The actuation is set at some key points, chosen on the basis of the origami kinematics, in order to take advantage of the origami geometries to create complicated movements with a linear actuation. Independently of the scale, at varying physical properties of the panels mounted on the frames, the proposed solution can have different applications for near-future buildings and outdoor pavilions: in interiors for sound absorption and acoustic insulation; in exteriors as a shading, UV filter or light refraction system. In the latter case, the adoption of e.g. dye-sensitized solar cells as panels can also promote the (at least partial) self-powering strategy for the adaptive structure. The efficacy of the proposed solution stands in promoting building efficiency and improving the comfort performances for some site-specific applications, standing as a possible answer to one of today's main urban challenges.



Final physical model in the closed configuration

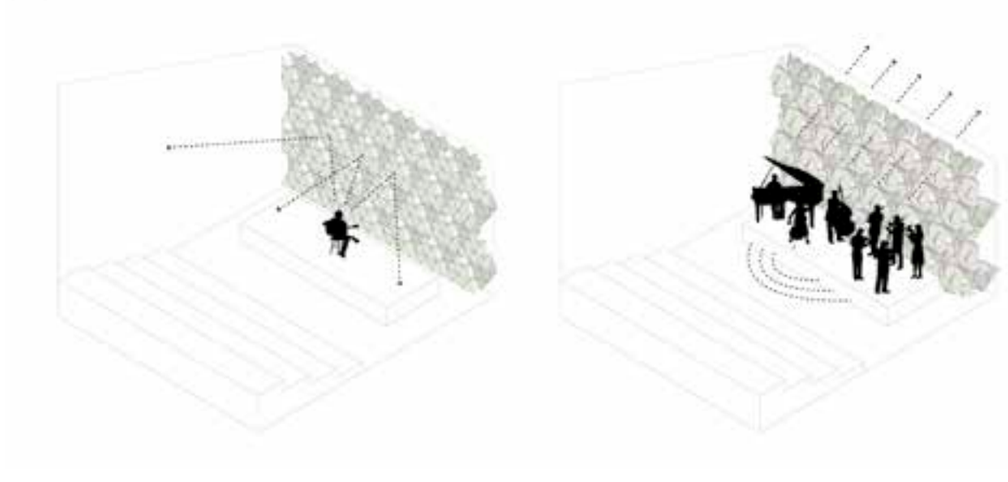
Understanding the problem

The proposed frame of research was the one of Adaptive Structures, implying therefore the study of a smart interaction between the object and the surrounding environment. Since the research domain is extremely wide, in order to define our concept some criteria taken into account were: innovation, feasibility on the market and multi- and inter-disciplinarity.

Society, constructors and citizens are getting more and more interested and concerned in the use of smart technologies applied to the urban context, with the attempt to implement sustainable environmental control. Our project falls within the field of smart development and aims to tackle the environmental control issue by an innovative design. On the base of this initial statement, the main stakeholders have been identified and consequently needs and requirements have been set, in order to clarify the tasks to be developed. The specific target of the work has been carried out taking into account the needs of the stakeholders, which have been identified as the Space Occupants, the Designers and Architects, Construction, Production and Maintenance Industry and the Investors. The target became, therefore, to design a Green oriented adaptive structure, embedded with a User Friendly System and able to provide Environmental Comfort. Moreover, the structure must ensure the convenience and competitiveness of the investment on the market and a significant energy cost reduction.

Final physical model seen from the bottom

This exploration of the needs translated in the ultimate goal: the design of an innovative environmental-control-system responding to energetic sustainability awareness which can be implemented through a modular, light structure, economically effective mainly thanks to its energy saving mechanism.

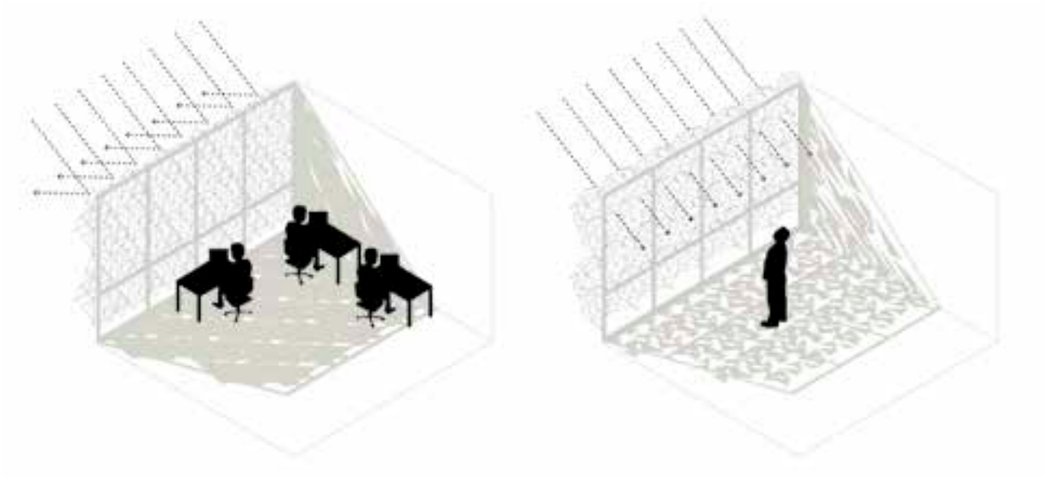


Acoustic application

Exploring the opportunities

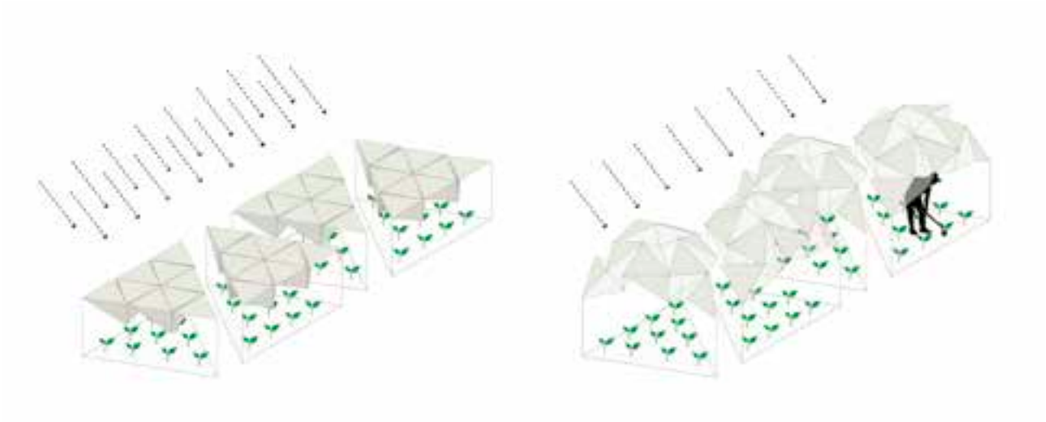
Bearing in mind the investigation carried out in the preliminary stage of the project, we proceeded with the analysis of the state of the art and with an intense and accurate research process.

The participation at some international conferences highly related with the topic helped us to understand how far research had gone in the field, giv-



Shading application

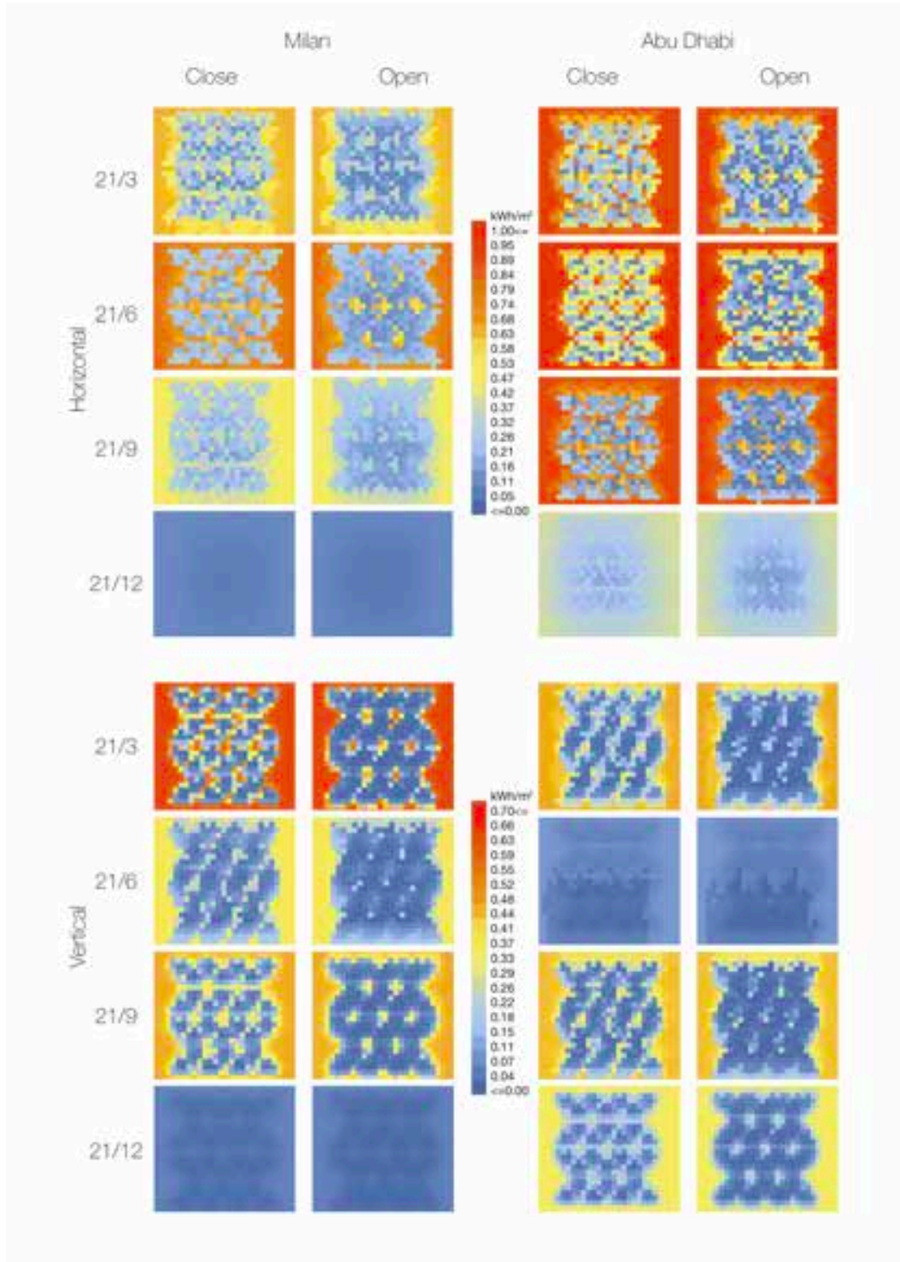
ing an important contribution to the recognition of the possible challenges and to the generation of possible solutions. In particular, the Conference on Smart Materials, Adaptive Structures and Intelligent Systems (SMASIS), which was held in Colorado Springs from 21st to 23rd September 2015, allowed us to explore the subject of Shape Memory Alloys. However, we found out a few drawbacks to this approach, such as the difficulty in the production and its cost and the lack of models for the control stage. This brought us to choose a development of our project focused on linear electric motors with a positional control logic. Another attended conference was the International Conference on Adaptive Structures and Technologies (ICAST), held in Kobe from 14th to 16th October 2015. The topics that were addressed in the lectures helped us to reflect on deployable structures and their features (modularity, bending, configurations, ...), and to deepen the investigation on a biomimetic approach, well realized through origami's digital and physical prototyping. Moreover, we explored



Agricultural application

the possibility to develop a further level of interaction of our structure (e.g. to harvest energy or to collect data over time).
Finally, the research on case studies let us gain a more general and comprehensive perspective on the topic. In our investigation, we had a careful look at characteristics such as adaptiveness and deployability. Just to mention two relevant cases, we examined in depth the exterior façade of

University of Southern Denmark, Campus Kolding (designed by Henning Larsen Architects) and the Al Bahr Towers in Abu Dhabi (conceived by Aedas Architects). This study gave us the chance to identify the main characteristics of our own project and to address some of the limitations that existing structures may show.



Site-specific simulation of solar radiation: Milan and Abu-Dhabi

Generating a solution

After the analysis of the state of the art and the exploration of different opportunities, in the latter and final stage of our project we proceeded with generating our own solutions to the aforementioned challenges. The mod-

ule of our structure consists of a Resh and Christiansen type of origami, composed of thirty-three triangular panels, and is connected to the supporting structure by means of spherical joints that allow any rotation. More complex flat geometries can then be obtained by the repetition of a single module. The folding/unfolding movements are realized by moving on a linear trajectory the central vertex, called pivoting point: depending on its position, basically on its out-of-plane motion perpendicularly to the folded, reference configuration, the spatial arrangement of the entire module is defined. The self-adaptiveness is finally guaranteed by a network of (micro-)sensors for, at least, lighting and temperature, embedded in the modules. Such sensors provide the information to the PID positional control logic, which moves the structure accordingly through an electric motor.

A large part of existing solutions for adaptive or morphing civil structures are focusing mainly on the selection of specific smart materials, which shows limited capabilities of flexibility and adaptiveness. These issues are easily addressed by the use of the folding/unfolding process of rigid origami structures, whose main advantages are customization, sustainability, aesthetic value and easiness of actuation and control. The origami structure can be integrated in different types of buildings, and its adaptiveness allows the adoption for both indoor and outdoor uses. In fact, it can be easily personalized by exploiting different materials (and relevant physical properties) or movement features depending on the specific application (glasses for UV filter, temperature control or light refraction and wood for sound absorption and acoustic insulation). Moreover, some applications have an additional energy saving purpose: by optimizing light conditions, and thus by controlling the indoor temperature, it allows the reduction of energy consumption, which leads to a minimization of the impact on the environment and the overall expenses. This energy efficiency purpose can also be exploited by means of self-powering photovoltaic panels mounted on the structure. Further to that, the required technology is relatively easy to implement and conceived in order to keep the costs for maintenance, manufacturing and energy consumption affordable during the whole life-cycle. In conclusion, the origami structure allows infinite possibilities of customization, satisfying practical users' needs and being also environmental friendly. The validation of our concept has experienced different stages: first, we implemented numerical simulations in Grasshopper and MATLAB; then, we proceeded with the construction of a prototype, whose adaptiveness and movement have been developed by using an Arduino system. More specifically, in Grasshopper we simulated the kinematics of the origami, and the equations of motion were solved in MATLAB. This latter stage was necessary in order to avoid (as much as possible) bifurcation and other kinds of geometrical instabilities regarding the constraints at the connections with the base structure. In fact, the structure may display instability when it opens with some spatial orientations of the flat support structure. The problem can be explained by the lack of rigidity at the joints between faces, and has been solved by adding an extra stiffness through linear or rotational springs.

Final visualization of the façade application, night

Final visualization of the façade application, daytime

Final visualization of the façade application, view from the interior space

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DREAM

Drone tEchnology for wAter resources
and hydrologic hazards Monitoring

Project

DREAM

Drone tEchnology for wAter resources and hydrologic hazards Monitoring

Principal Academic Tutor

Carlo De Michele
Department of Civil and Environmental Engineering Politecnico di Milano

Academic Tutors

Francesco Avanzi
Department of Civil and Environmental Engineering, Politecnico di Milano
Alberto Bianchi
Department of Civil and Environmental Engineering, Politecnico di Milano
Alberto Cina
Department of Environment, Land and Inf. Engineering, Politecnico di Torino
Paolo Maschio
Department of Environment, Land and Inf. Engineering, Politecnico di Torino
Livio Pinto
Department of Civil and Environmental Engineering, Politecnico di Milano
Marco Piras
Department of Environment, Land and Inf. Engineering, Politecnico di Torino

External Institutions

Regione Piemonte

Team Members

Alberto Donizetti
Mathematical Engineering, Politecnico di Milano
Giulia Giani
Environmental Engineering, Politecnico di Torino
Giuseppe Giarrizzo
Mathematical Engineering, Politecnico di Torino
Alessandro Negrini
Computer Science Engineering, Politecnico di Milano
Alessandro Rampazzo
Automation Engineering, Politecnico di Milano
Gianluca Savaia
Automation Engineering, Politecnico di Milano
Enrica Soria [Team Controller and Communication Coordinator]
Mathematical Engineering, Politecnico di Torino

Project description

Nowadays, expected effects of climate change at local, regional and global scales endanger hydrologic budgets of Alpine regions. An example is the massive shrinkage of mountain glaciers, with the consequent problem of water resources reduction for civil population and ecosystems. Therefore, it is very important to monitor glaciers' evolution, in order to allow an estimation of glaciers' reduction and possible effects on the hydrologic cycle.

This research work aims at investigating new technologies and tools, especially Unmanned Aerial Vehicle (UAVs), for monitoring natural hazards and evaluating water resources at different scales.

Research method analysis mainly followed three steps. In the first step, after careful comparisons and reflections analysis, the eastern slopes of Monte Rosa and its long glacier tongue (Belvedere glacier) has been selected as test site. Usually, glacier thickness and area evolution are monitored using time-consuming field activities, e.g. analysis based on point stratigraphy and mass balances or radar sounding, which do not allow to obtain a continuous-time, detailed and accurate information about surface and volume evolution at fine spatial resolutions. In this framework, we have used a fixed-wing UAV to acquire RGB images, in order to generate a dense DSM (Digital Surface Model). The acquisition was carried out with two different campaigns of measurement in October 2015. After this initial phase, management of data collected during field campaign followed. The images have been elaborated with different photogrammetric software in order to investigate the ratio quality of the product/time consumption, with respect to hydrological purposes. The DSM obtained has been compared with other DSMs realized in parallel with images dating back 2009 taken from aircraft, making a multitemporal analysis, and estimating the volumes' variations and trends of the glacier. Finally, in the third step hydrological analysis and observations, according to the result got in the second phase, has been performed. In order to check the real validity of the results, they have been compared with the existent literature in alpine areas.

Tasks and skills

Alberto Donizetti: beyond the help provided during DSM construction phase, he tackled the main issues of the hydrological analysis providing his deep knowledge in statistics and applied mathematics;
Alessandro Negrini: helped during the DSM construction phase, overseeing all the different steps and using its capabilities to automate some of the processes concerning the treatment of data. He also contributed to a great extent in writing the dissertation and making sure all the different parts were well coordinated;
Alessandro Rampazzo: gave its deep contribute during the phase of choosing the right drone and the proper sensors equipment thanks to skills acquired studying automation engineer. In addition, he gave a significant help during model creation phase;
Enrica Soria: offered her help in all the phases of the work, adapting her skills in mathematics and managing throughout the entire period. Not to

mention the fact that she always took care of the communication with professors;
Gianluca Savaia: carried out state of the art studies on drones and provided an important support during dissertation writing phase;
Giulia Giani: provided a consistent help thanks to her high competencies in environmental engineering during DSM model creation. A special mention for the post data analysis phase when she was able to capitalize her strong abilities in using GIS during result analysis phase;
Giuseppe Giarrizzo: contributed with his mathematical competencies to the data analysis, from data collection phase to the creation of the final DSM. He spent a lot of time in validating the model coming out with excellent results.

Abstract

Climate change is happening now: temperatures are rising, rainfall patterns are shifting, glaciers are melting and the global average sea level is rising. Everyone seems to know about it, but unfortunately most of this common knowledge is based on misinformation rather than on scientific facts. The truth is that it is actually very difficult to understand what is going on: given the complexity of environmental phenomena, scientists are still working on proper models and collecting additional data, so that there is a great need for suitable monitoring strategies. The project focuses on the ambitious goal of investigating an innovative technology for data collection: paying due attention to some constraints, mainly in terms of quality and cost, this work consists in evaluating the performance of a new monitoring systems: the development of a complete and efficient workflow for use of the drones in glaciers' melting monitoring field and the performance of some hydrological analysis performed after having estimated the glacier melting through the years also thanks to additional data (e.g., temperature, snowfalls, …) kindly provided by third part institutions. We can confirm that drones are a valid alternative to preexistent techniques adopted in this field; among the many, two main advantages have been pointed out as most important: higher accuracy and stronger versatility.

Understanding the problem

In recent years, drones have been successfully employed in many fields (e.g., agriculture, transportations, search and rescue, news reporting or sports) and we think they may help monitoring glaciers' melting thanks to their relatively small cost and great versatility. Still, there are many technical issues and the tradeoff between quality and implementation costs is a crucial matter: there is definitely room for improvement, which makes the project all the more challenging.
In order to extensively investigate the UAV technology, we had to address the following matters:

- the evaluation of existing airborne supports and cameras, the determination of technological limits and the possible set-up of new sensors;
- the design and the execution of field surveys;
- post-processing activities and a comparison with existing methodologies (like terrestrial laser scanner) to quantify the benefits of sensors in environmental sciences.

Underpinning the research is a fixed UAV platform (eBee SenseFly) capable of autonomous, programmable missions with a range of over 12 km2.

As test set the eastern slopes of Monte Rosa and its long glacier tongue (Belvedere glacier) has been selected. This valley glacier lies at the base of the east side of Monte Rosa and it stretches from its peak of 2200 to about 1800. The area is particularly interesting because this glacier is one of the few Alpine glaciers which are not retreating but moving down the valley: our survey of the area was meant to gather data in order to better analyse and explain its movements.

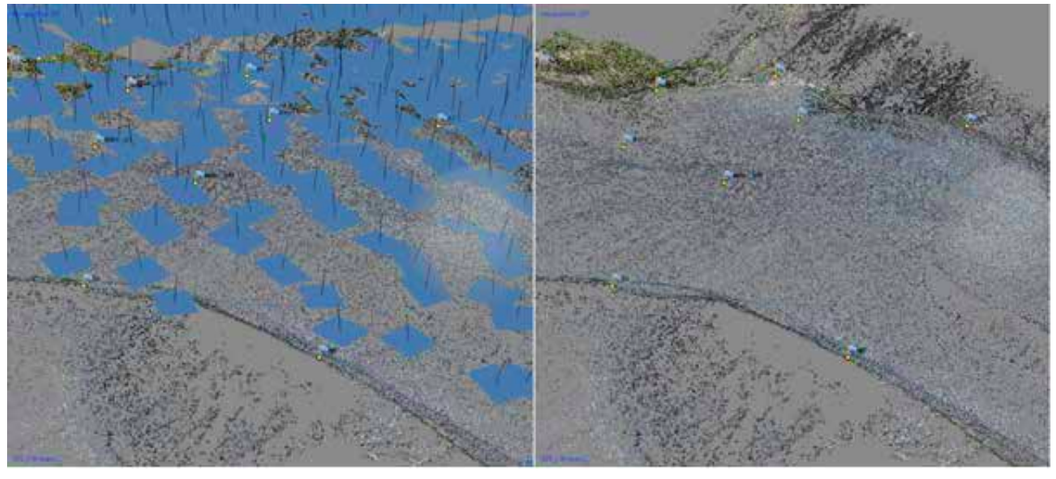
Exploring the opportunities

Considering the nature and scale of the observed processes, it would not be a stretch to claim that projects like ours may have a huge impact on society. Climate changes and water supply alone actually concern the whole population:

- Civil Protection More morphological information can improve the understanding of critical phenomena and lower some risks (e.g., avalanches or landslides, …);
- Valley inhabitants The glacier is one of the most important natural elements influencing the climate in the valley, its evolution may produce significant changes to the environment with direct consequences for the whole population, both from an individual and economic standpoint.
- Regione Piemonte Being responsible for the management of the territory, such institution is obviously interested in the matter of studying and knowing the dynamics of the Belvedere glacier. An increased knowledge of the area may result in an optimization of the plans for the development of local communities as well as in an improved offer for tourism (e.g., sky lifts and resorts rather than trekking and mountain biking).
- Agricultural industries Estimating the quantity of water they can rely on thanks to the snow is an actual need for them, especially in terms of forecast and water supply management. In addition, the planning and construction of agricultural infrastructures like dykes, dams or channels also relies on the knowledge of both accumulation and dispersion of the water resource.
- Hydroelectric companies The glacier is a hydrological resource, so that any increase in the knowledge of the Belvedere may actually interest such companies. Not only the Snow Water Equivalent (SWE) provides information about the size of the water resource, but also forecasting and

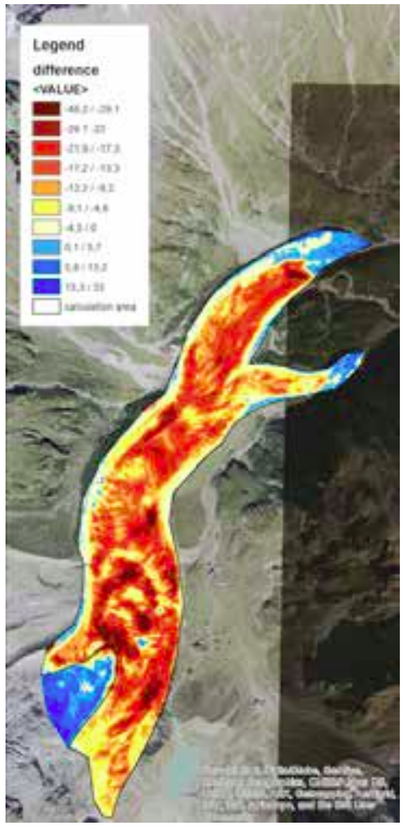
Fig. 1: eBee mapping drone by SenseFly

Fig. 2: Photoscan, 3D model generation



information related to the timing of peak discharge can help hydropower plant operators maximizing the power production.

- Drone and sensors manufacturers New applications of drones for research purposes and area monitoring could lead to new developments in the drone industry. Furthermore, since this field of application is absolutely recent, its full potential has yet to be revealed: there may be economic opportunities both in research developments for cutting-edge technologies (e.g., patents) and in use optimization.



Erosion and accumulation map

Generating a solution

The project was structured in different steps and phases which lasted for different days, weeks or months. After some training sessions with our tutors both in Turin and in Milan in September 2015, the field activity started in the first week of October 2015. It has been decided to use a small size drone with a light payload, which did not allow the use of direct photogrammetry technique, due to the impossibility to load high performance inertial platforms or other sensing equipment typically heavy and bulky. Moreover the eBee SenseFly we adopted had the notable advantage to cover our interest zone in less flights than multirotor drones. During those day frames of the glacier were taken by the drone and coordinates of markers, points easily traceable for geo referencing the model, were collected by means of different remote sensing instruments. In the post processing phase, data have been elaborated, from the coordinates whose accuracy were improved introducing differential corrections, to the pictures, which were processed in Photoshop in order to get a better quality. The next step was to build the desired outputs of our analysis: DSMs and orthophotos. Different computer vision software have been tested, in particular APS, LPS and PhotoScan. This approach had a double effect: probing many alternatives for the same problem and checking the results with a cross validation. Discarding LPS for the difficulties in matching ground control points in the pictures, and APS which, although its high precision and efficiency, was too connected to the frames from the drone and useless for building the 2009 model, PhotoScan was chosen to be used, thanks to its versatility and robustness. Afterwards a validation of the errors of the model phase followed. It was one of the first attempt to map a so extended area, therefore checking the model was a delicate task due to the high resolution requirements on the one hand and to the few ground control points available, with respect to the ample area, on the other one.

Once we had obtained the two models, we analyzed them using ArcGIS. The two DSMs were overlapped in order to evaluate the temporal evolution of the glacier, clustering zones characterized by different values of erosion. A global erosion of 18.7 million m3 was found, which is a result coherent with data reported in the article [1] by Diolaiuti G., D'Agata C. and Smiraglia C., (Belvedere Glacier, Monte Rosa, Italian Alps: Tongue Thickness a Volume Variations in the Second Half of the 20th Century). Indeed, the reduction in terms of volume revealed by our calculation could be the continuation of the increase in temperature and reduction of precipitation process begun in mid 1980s.

As a final step, some investigations regarding the “melting speed” of the glacier from 2009 to 2015 were performed. The main goal of this step was the estimation of the so called degree day factor (DDF) of the glacier, that is a factor that in some sense summarizes the ice melting speed. Its mathematical formula is $DDF = \frac{\sum_{i=1}^{n} \Delta Mi}{\sum_{i=1}^{n} Ti^{+} \Delta T}$ where ΔT is the length of the time interval during which the average temperatures are defined, n is the number of such intervals, Mi is the amount of ice melt during the $i-th$ interval and Ti^{+} is the positive value of the temperature expressed in Celsius degrees. Its unit is $\frac{mm}{°C\ day}$

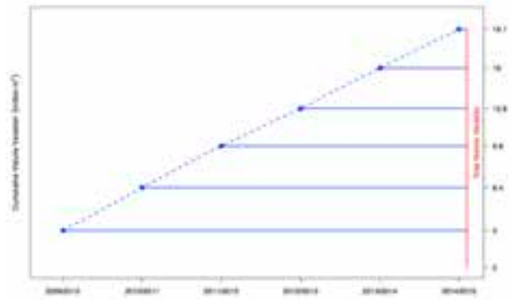
Actually, the formula was used in an equivalent form: $DDF = 1000 \frac{\Delta Vgl / Agl}{\sum_{i=1}^{n} Ti^{+} \Delta T}$

where ΔVgl is the volume glacier variation in cubic meters, Agl is the area in squared meters and 1000 accounts for the conversion from meters to millimeters.

Some additional assumptions have then been made in order to correctly compute the DDF: Belvedere glacier was considered as a closed and without debris system. If on one hand this implied to be bounded to underestimate its effective value, on the other it allowed us to compare its value with existent literature dealing with its estimation in alpine areas, such as the one conducted by Nicholson and Benn [2], where a DDF of 1.81 $\frac{mm}{°C\ day}$ was estimated. From our project a DDF of 1.61 $\frac{mm}{°C\ day}$ has been obtained.

Even keeping in mind that the two coefficients have been evaluated using completely different techniques and procedures and that there may be some variability due to the temperature, wind, radiations, debris dishomogeneity and instrumental precision, it is nonetheless encouraging to see that the two values have reached an agreement at least in terms of belonging to a reasonable interval. In sight of this, we can confirm that drones are a valid alternative to preexistent techniques adopted in monitoring natural hazard and evaluating water resources at different scales.

A second campaign took place in April 2016, in which we started to explore the potentiality of drones also in snow depth measurement, in particular trying to deepen its advantages and disadvantages with respect to classical techniques such as direct measure of snow depth through probes in a discrete number of points and laser scanning. These data will pave the way to the DREAM2 project, whose members will continue our process exploiting the framework defined by the DREAM team.



Cumulative glacier melting over the years

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OPEN BUILDING

Open Building for Future Healthcare Environments

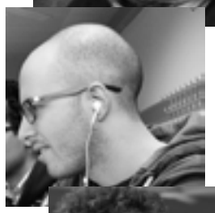
Project

open+ building
FOR FUTURE HEALTHCARE ENVIRONMENTS

OPEN BUILDING

Open Building for Future Healthcare Environments






Principal Academic Tutor

Stefano Capolongo
Department of Architecture, Built Environment and Construction Engineering, Politecnico di Milano

Academic Tutors

Fiammetta Costa
Department of Design, Politecnico di Milano
Gabriella Peretti
Department of Architecture and Design, Politecnico di Torino
Riccardo Pollo
Department of Architecture and Design, Politecnico di Torino
Francesco Scullica
Department of Design, Politecnico di Milano
Maddalena Buffoli
Department of Architecture, Built Environment and Construction Engineering, Politecnico di Milano
Emilio Faroldi
Department of Architecture, Built Environment and Construction Engineering, Politecnico di Milano
Maria Pilar Vettori
Department of Architecture, Built Environment and Construction Engineering, Politecnico di Milano

External Institutions

CNETO & Fondazione CERBA, Italy
SItI, Italy
BTC srl, Italy
GALA spa, Italy

External Tutors

Luigi Colombo
GALA spa
Maurizio Mauri
CNETO & Fondazione CERBA
Werner Rainer
BTC srl
Carlo Signorelli
SItI & Università degli Studi di Parma

Team Members

Tarek Afifi Afifi
Materials Engineering and Nanotechnology, Politecnico di Milano
Khadijah Al Khuwaitem
Product Service System Design, Politecnico di Milano
Mirco Alberini [Team controller and Communication coordinator]
Materials Engineering and Nanotechnology, Politecnico di Milano
Andrea Brambilla
Architecture, Politecnico di Milano
Alice Franca
Building Engineering, Politecnico di Milano
Mattia Palumbo
Sustainable Architecture, Politecnico di Torino

Project description

Among the research activities promoted by the Cluster in “Design of Health Facilities” of Politecnico di Milano, the ASP project, called OPEN BUILDING, has investigated the flexibility issue in architectures for health. In fact, one of the most important challenges that healthcare structures have to cope with is to be resilient to economic, social and medical changes and, in the same time, to ensure that the system, services and assets respond to the constantly changing needs and the specificities of the different geographical places and organizational models.
Although currently there are several companies that realize prefabricated technologies, starting from the Open Building approach, studied by several international scholars and applied only in one hospital in Switzerland, and the current application of Plug-In rooms in hotels, a research group develops a new multidisciplinary approach to the open room in hospital wards, already predisposed to respond to several functions through the substitution of finishing panels.

Team members during the visit at Moises Broggi Hospital, Barcellona, April 2016

In fact, starting from the Open Building approach in healthcare stated by prof. Kendall, the design approach can be summarized into three areas: Primary System, in which the modules are plugged in the structural framework; Secondary System, through the Plug&Play approach, represents the prefabricated sub-structures that host the skeleton with all the implants and needs for all the typologies of hospital rooms; Tertiary System, that features both the furniture and all the finishing elements and allows to transform immediately the room. The resulting product is a prefabricated room, transportable in three parts and able to accommodate a variety of fit-out changes: in fact, the interior space is defined by a series of customizable wall panels with foldable furniture and integrated functions; the tripartition of the sub-structures provides the possibility of removing the room and repurpose the building.
Through a multidisciplinary point of view, the project was realized considering some criteria (healing environment, hospital and room layout, flexibility,

Team members in Belgirate during the Winter School, March 2016

structure and construction, soft qualities, materials and technologies) that influenced the design of the Open Room. Moreover, the development of the research work requested a multidisciplinary analysis of several users' needs and layouts' functions, and the collaboration with several companies and experts on the healthcare field, as well as the visits to several international case studies permitted to consider several design strategies and technical aspects related, for example, to hygienic issues, soft qualities, maintenance aspects and so on.
In conclusion, the research work started as a concept and it was developed for giving rise to a new approach for future hospitals. It provides intrinsic flexibility that allows care quality improvement directly empowering the hospital to update its services constantly. It needs to be more and more detailed in its prototype feasibility, but the presuppositions started with this ASP project are very ambitious.

Task and skills

Tarek Afifi Afifi: carried out the structural analysis and materials selection for the room panels. He deepened the hygienic requirements connected to materials in healthcare environments and considered the patient's visual impressions alongside Khadijah.
Khadijah Al Khuwaitem: was responsible of the overall visualization of the project and the design aspects of the room, as well as business modelling. She analyzed the light scenarios and the impacts of interior design on patients and medical staff, carrying out also interviews.
Mirco Alberini: coordinated the team as well as managed logistics and accounting throughout the whole project. He gave technological suggestions and collaborated with Tarek for the materials analysis, especially considering the impact of smart windows.
Andrea Brambilla: focused on the conceptual development of the project and helped to organize the group work. He appraised the costs of the actual production and installation of the inpatient room, following Khadijah's business suggestions.
Alice Franca: analysed the structural feasibility of the solution, managing transportation issues. She also dealt with the analysis of technological details, alongside Mattia, and studied the implants integration.

Mattia Palumbo: studied the technological details of the concept. He carried out light simulations with Khadijah as well as renderings of the final appearance of the inpatient room. He gathered information about domotics and medical trends through interviews.

Abstract

In recent years, many studies have revealed the increasing rate of hospital obsolescence. This fact is a reflection of the fast pace at which contemporary society and medicine evolve. Therefore, each part of the hospital should be designed to adapt to fast changes without having a big impact on the daily routine of patients and medical staff. The Open Building project joins flexibility and quality of care, exploiting the homonym approach developed by Prof. S. Kendall on a smaller scale and empowering the hospital to constantly update its services.
The resulting product is a prefabricated inpatient room transportable in three parts and able to accommodate a variety of fit out changes in both technology and function, in the short as well as in the long term. In fact, on the one hand the interior space is defined by many series of wall panels with different foldable furniture and integrated functions. Colors, lights and materials are part of the customizable pallet of items that contribute to enhance the healing standards inside the room, ranging from a basic to a premium endowment. On the other hand, the tripartition of the modular room provides the possibility of removing it from the Primary structure and repurpose or dismantle the building at its end-of-life.
This technical solution has been studied addressing six main categories of interest by which the aforementioned concepts may be applied, from healing environment and layout considerations to materials and soft qualities. The team, after the concept development phase, performed a structural assessment and characterization as well as a costs appraisal to better evaluate the feasibility of the project.

Understanding the problem

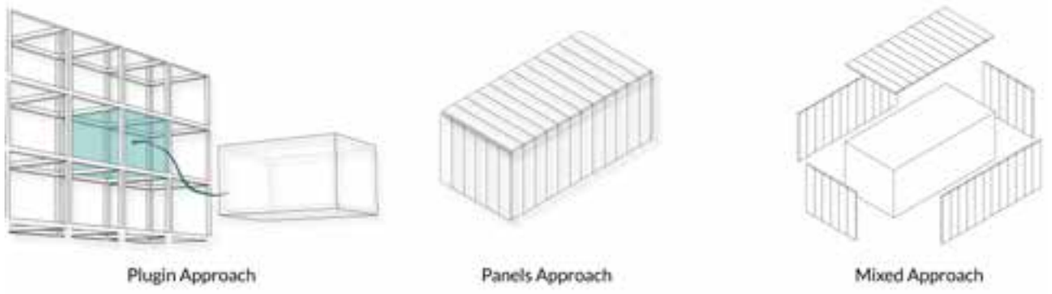
What the Open Building project tries to accomplish, is to apply a flexible approach in planning an inpatient room for future healthcare structures in order to solve the more and more pressing problem of hospitals' obsolescence. Nowadays, healthcare facilities become unsuitable for their purpose just after few years of their construction. An approach that tries to tackle with these issues is flexibility: it is the ability of a building to answer to services, functions and environment changes in the short, medium or long term, based on users' needs. This capacity for transformation may be ensured only by a building designed from the beginning in accordance with technological, structural and plant engineering criteria specifically oriented towards adaptability of the entity itself. However, the design should not forget to promote the best healing environment possible inside the room, increasing comfort and quality of care by providing a calm and soft environment. All the social, environmental and managerial issues, such as the ones related to construction and maintenance must be take into account.

Exploring the opportunities

A way to deal with flexibility in several building typologies such as residential and hotel is the Open Building approach. It is a constant surface flexibility strategy that deepens the ability to change and adjust to new layouts without increasing the original area. This can happen, as stated by prof. Kendall, by the definition of three systems: a Primary structure, a Secondary (the Components) and a Tertiary one (the Equipment). Consequently, functional redistributions may be exploited in order to design inner spaces

with a high level of adaptability.
Nowadays, several existing hotels and office buildings are designed with prefabricated rooms that allow variations in creating the interiors combining materials, lighting and furniture. However, even if the guest and inpatient rooms are very similar, the hospital's layout is different from the hotel's one for several logistical and functional aspects, since differences persist on rooms dimensions, engineering plants, furniture and materials. Starting from the know-how on prefabricated bathrooms and operating rooms, as well as several experimentations in terms of flexibility in the American and European contexts, it is possible to investigate the design of a prefabricated inpatient room. During the preliminary research activity, six main criteria and relative case studies have been defined: healing environments, soft qualities, layout, flexibility, construction and materials. They have provided fundamental milestones for moving towards innovative solutions as well as a link between theory and practice into a multidisciplinary framework.
Two alternatives have been then taken into account: as first the plugin concept, which embeds the idea of a smart, contemporary and prefabricated room as a modular element deliverable on site; as second the Industrial, Flexible, Demountable building approach (IFD), which leads to the production of panels in advance and their assembly on site, providing good flexibility but longer installation times than the plugin concept.
The final solution has the ambition of merging together the two previous ones.

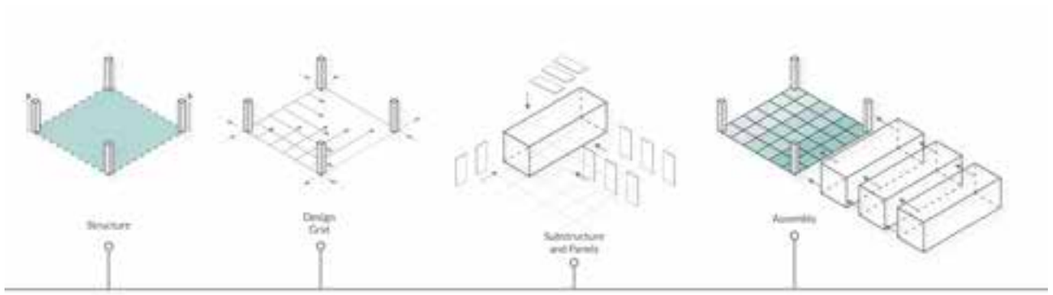
Different approaches to flexibility



Generating a solution

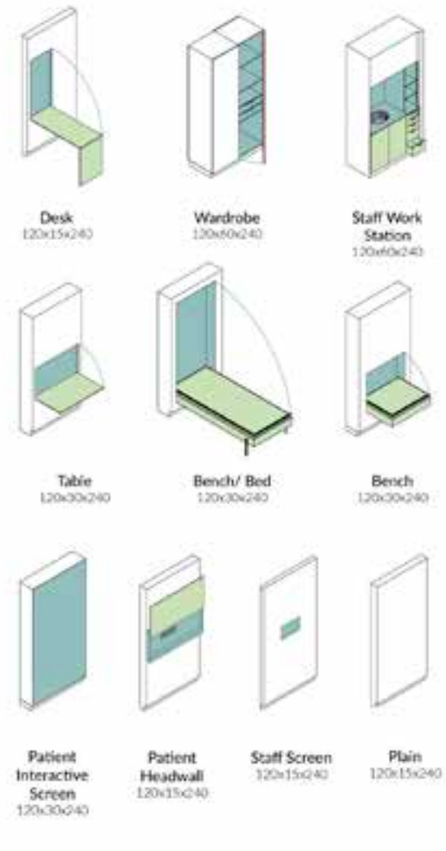
The Open Building concept applied to a smaller scale has led to the definition of an Open Room: a modular system that allows flexibility inside hospital rooms using advanced prefabrication processes of production, delivery and assembly.
According to this framework the project has the ambition of merging both an IFD approach, providing flexibility through panels (Tertiary System) in the short term and a Plug & Play concept, providing flexibility also in the medium and long term (20-40 years) (Secondary System).

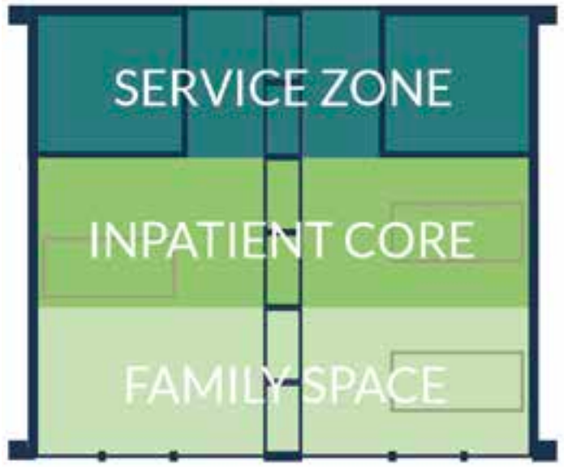
Structure, design grid, substructure and assembly



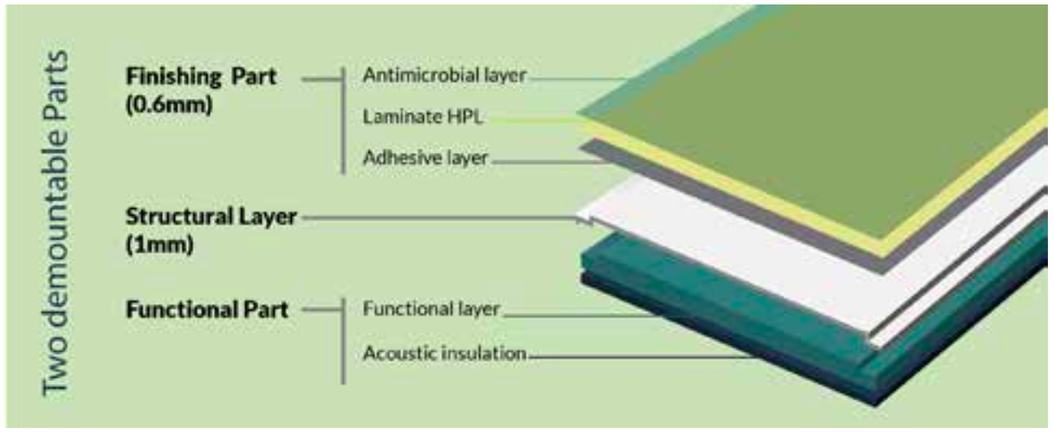
In general, the aim of the Primary System is to accommodate a variety of floor plans and equipment layouts over time, thus the structure should not be dependent on the secondary system. The allowable dimensions for a structural grid in order to design flexible layouts have been chosen between 6.00 and 9.00 meters. Major examples of flexible hospitals have been also compared to create a structural frame model into a parametric environment. It has therefore been possible to create an abacus of feasible combinations between the structural grid, the space for the room and the functions allowed inside. A second crucial aspect is the design module dimension: it should be balanced, neither too small for production and assemblage time waste, nor too big for logistic and handling issues. The analysis of hospital furniture and spaces led to the choice of a 120 cm module with submodules of 60 cm. The combination of those two basic elements has helped to define the structural frame as a rectangle of 6.90 m x 8.40 m (inter axle) with two inpatient rooms.
The Secondary system, known as "Fit-Out", is the Component level and, should include the entire inpatient room module. Considering transportation constraints and the design grid as well as lightness and demountability requirements, three identical sub-structural frames with dimensions 2.40mx8.10mx3.30m (WxLxH) have been defined and structurally appraised. These "boxes" assume the role of a Secondary system with the predisposition of all the possible implants such as water, air, electricity and gases.
The Tertiary system is generally called Equipment. It includes all the items that, due to an intensive use or rapid technological upgrades, are able to last only 5 to 10 years.
Using the 120 cm design module it is possible to create finishing elements, which embed different functions, according to the required performances and to the room layout.
Generally, these modules are organized in order to create a configuration divided in 3 main areas: the service zone, the inpatient core and the family space.
As far as materials are concerned, the finishing layer of these elements have been chosen in order to reduce hospital acquired infections, using smart active antimicrobial materials. Several solutions have been proposed in order to satisfy designers' choices while keeping flexibility, hospital and users requirements into account to provide the best selection.
At this level, colors are selected in order to support the patient's conditions and give a positive impact. They are distributed among the room areas giving a color code to each one of them, thus facilitating the patient's ability to recognize the surrounding space.
One the other hand, dynamism was the key factor in designing the lighting system. An innovative solution has been exploited for the windows of the room with the use of smart electrochromic windows: thanks to a voltage variation they can become dark and change the light and heat trans-

Abacus of all possible furniture units

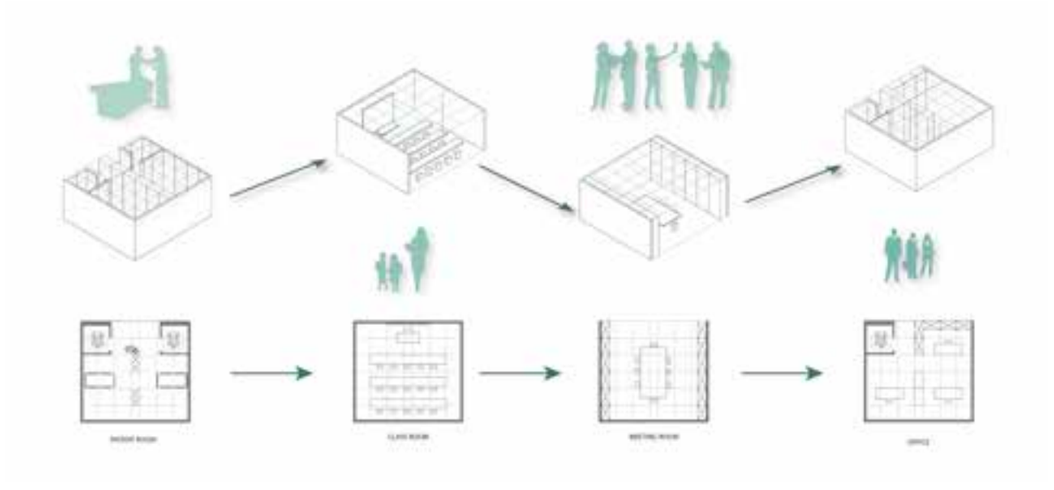




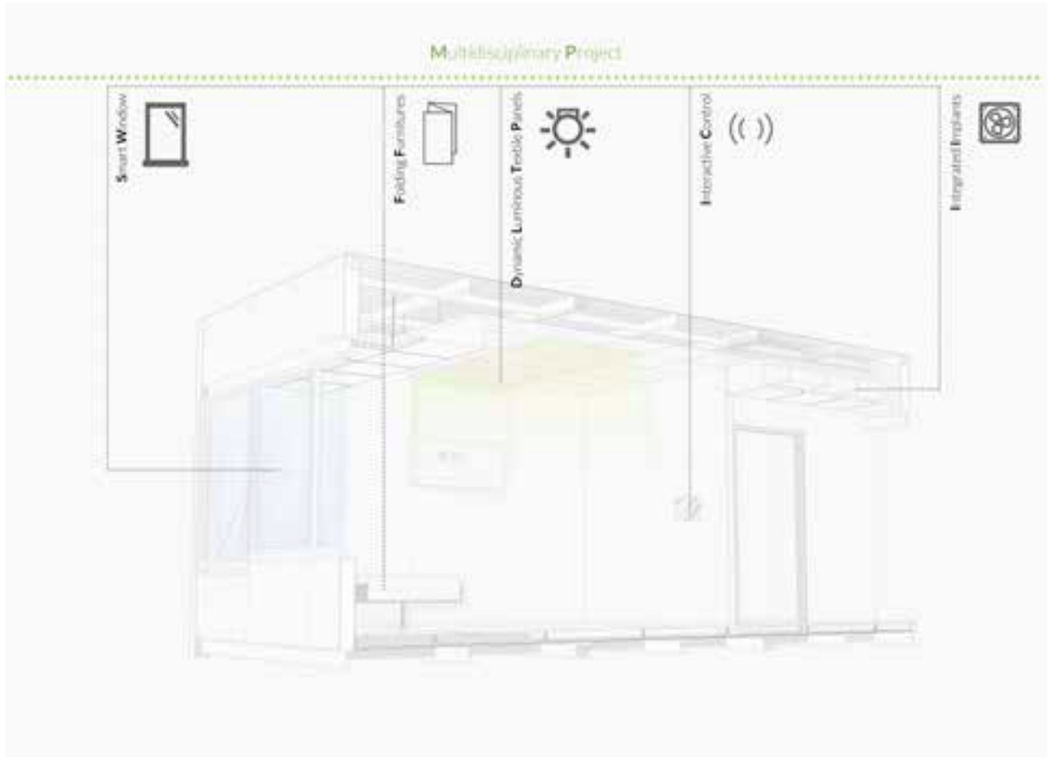
Room functional areas



Stratigraphy of the panel



Open Room 3D section



Open Room customization perspectives

mission. This technology improves the energetic efficiency of the module and empowers the patient. In fact, by combining natural and artificial lighting systems, dynamic lighting is created, improving the quality of the environment and changing continuously to answer mutable needs. In the long term perspective, all elements of the tertiary system can be modified enabling the room to change its appearance, capacity or function.
At last, the total cost for production, delivery and assembly of the three piece modular unit has been preliminary appraised in order to compare the prefabrication approach with the traditional one. The understanding of the actual feasibility in field will open future scenarios of prototype realization.

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BUZZWORD

Sensing fashion brands through social networks

Project

Buzzword

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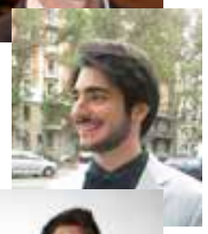
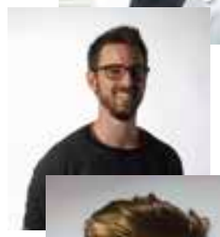
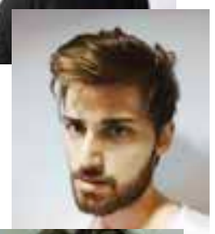
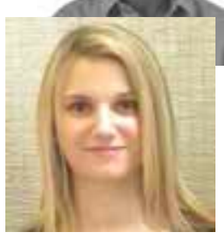
Sensing fashion brands through social networks









Principal Academic Tutor

Paola Bertola
Department of Design, Politecnico di Milano

Academic Tutors

Elena Baralis
Department of Control and Computer Engineering, Politecnico di Torino
Marco Brambilla
Department of Electronics, Information and Bioengineering, Politecnico di Milano
Chiara Colombi
Department of Design, Politecnico di Milano
Federica Vacca
Department of Design, Politecnico di Milano

External Institutions

Fluxedo
Wardroba

External Tutors

Andrea Vaccarella
Fluxedo
Federico Della Bella
Wardroba

Team Members

Luca Grassano [Team Controller]
Mathematical Engineering, Politecnico di Torino
Umberto Di Fabrizio
Computer Science and Engineering, Politecnico di Milano
Michele Invernizzi
Communication Design, Politecnico di Milano
Manuel Impellizzeri
Communication Design, Politecnico di Milano
Pasquale Mangano
Computer Engineering, Politecnico di Torino
Marco Manino
Computer Engineering, Politecnico di Torino
Silvia Massi [Communication Coordinator]
Mathematical Engineering, Politecnico di Torino

Project description

Buzzword focuses on innovation opportunities offered to the Fashion System by the new digital paradigm. In fact, it aims to design a product concept of an ICT tool for Social Media monitoring and analytics specifically designed for fashion brands, in order to increase their capability of refined business intelligence upon sentiments and behaviors of consumers on social networks.
The project has been developed considering a selection of 29 emerging Italian fashion brands, chosen on the base of an ongoing research on Italian NewCos curated by tutors from Polimi -evaluating their social media presence potentially more pervasive, being them “digital native brands”, and considering their financial capacity of investing on traditional media lower than the traditional older brands’ one but also their impossibility to internally manage all digital functions related to communications and retailing. The project consisted in three main aspects:

- Social network monitoring and data collection
- Data analysis and extraction of trends and insights
- Data visualization.

It has been developed applying analytics over two main social networking platforms, namely Twitter and Instagram. Despite being different in kind and dynamics, these two platforms provide most of the insight for the fashion market, given their level of immediacy and visual dimension.
The developed solution -as a means to understand brands’ presence and effectiveness on Social media in term of quality of interactions with other fashion stakeholders, ability to communicate a clear and relevant message in different occasions and to different publics, dynamics of intercommunications with other brands- will allow to increase the possibility to identify, predict, and respond to consumer sentiments and behavior with respect to fashion products based on deeper quality information, developed from quantitative data, and not relying on classic dimensions such as number of followers or likes.

The partners

The involved partners are two Italian digital start-ups, Fluxedo and Wardroba, both incubated in PoliHUB, Politecnico di Milano startups incubator, demonstrating Politecnico di Milano community’s strong culture of collaboration and support between students, alumni and industrial partners.
Fluxedo designs products for real-time management of operations and Big Data, and the integration of Internet of Things to simplify and support strategy and decisions for private and public entities. Their experience in data analytics and solutions has been fundamental for Buzzword. In particular a product such as eventOmeters, an integrated solution that merges Internet of Things, data visualization and mobile development for big events, created in partnership with Eurotech, has represented a virtuous example and a base which to start from to develop data categorization and evaluation.
Wardroba is a fashion social commerce with a selection of emerging and edgy brands and designers. On Wardroba users get inspiration from the community, search and create outfits, save their wishlist in a digital wardrobe, and buy products from new brands. They have supported the project supervising the results of analysis and offering their suggestions about the level of relevancy and potentialities of applications of results on the field, being them experts in fashion e-tailing

Tasks and skills

Luca Grassano: coordinated the groupwork, developed the databases for the Network analysis and assessed the statistical aspects related to the quality of data classified by crowdsoucing.
Umberto Di Fabrizio: helped building the Instagram scraper, set up the database of images tags and used it to train the Neural Net. He analyzed the posts to extract clusters.
Michele Invernizzi: took care of the graphic aspects of data visualizations, milestone presentations and the report’s layout.
Manuel Impellizzeri: helped monitoring the 29 fashion brands in their social media history and created the logotype of “Buzzword”.

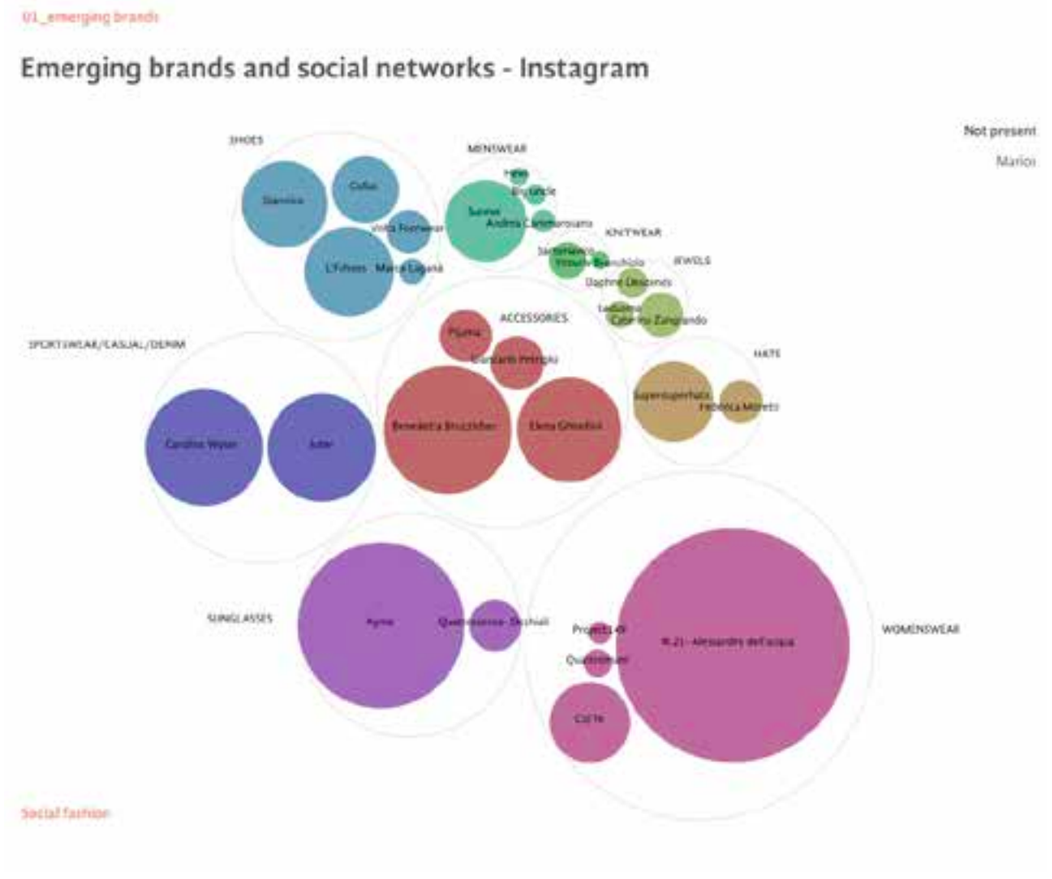
Pasquale Mangano: coded a part of the Instagram Scraper and managed the classification of Instagram's posts through Crowdflower.
Marco Manino: programmed one of the web scrapers and helped in pre-processing data as well on analytics of collected data throughout the course of the project.
Silvia Massi: contributed to investigate and define the domain of application of the tool and helped to interpret the results obtained from a strategic point of view.

Abstract
In the Digital Era, social media provide to the fashion industry a powerful tool to stimulate discussion and build brand awareness, along with improving consumer relationships through interactivity and networking. As a result, social platforms like Facebook, Twitter and Instagram are mostly exploited to promote engagement but also to develop digital marketing strategies to increase online sales and retail store traffic.
However, well established companies and emerging ones have different approaches on social networks, which reflect their needs and goals in relation to their size and audience; legacy brands aim to reinforce their presence by establishing an online experience that is more accessible to the customers, while young designers try to develop their own identity and to gain visibility.
In this perspective, the objective of this project was to develop, by applying quantitative and qualitative analyses, a tool useful to support emerging fashion brands in building up incisive and profitable social strategies and to measure their success in terms of brand identity and awareness creation.
As a Solution, we propose to create a tool able to categorize social media posts and to carry on descriptive statistics about the brands themselves. For instance, our architecture would be virtually able to classify each post of a brand in a category and define the principal aspects of the brand in terms of frequency of
- Post of a certain category: which types of posts do brand A use the most?
- Marketing strategy: does the brand post more about products or fashion events?
- Relationship to other brands: is brand A similar to brand B given the type of posts?

In our context, a high level of complexity is faced since the content to be classified comes from social media and it is the result of natural language expressions, symbols and images. Hence, the system has to be able to read and see social media posts in order to extract core information used to analyze and categorize them.
This poses two main technical issues on the task: the ability of the classifier to understand natural language which is intrinsically ambiguous and the necessity to understand the key components of a picture.

Project description
In the era of digital communications Social networks represents a powerful marketing tool descending from the "bites revolution". Having the ability of evaluating a brand's reputation in a community could help a company to better address his marketing campaign.
In this scenario, the project of the team aimed to design a product concept of an ICT (Information and Communication technology) tool for Social Media monitoring and analytics specifically designed for emerging fashion brands.
The project has been structured in four main stages, each of them identifying an intermediate objective to achieve in order to move forward to the next one. They can be summarized by the following activities:
1. State of the art analysis
2. Social network monitoring and data collection
3. Data mining and tool modeling
4. Data visualization and results

Understanding the problem
The preliminary phase was devoted to a general understanding of the perspective of fashion brands, mainly focusing on the Italian reality with reference to small-medium designers. Twentynine emerging fashion brands were monitored in their social media history. After categorizing them on the basis of the number of followers, years of activity and fashion branch, the team carried a research on best fashion social media campaign strategies aimed to highlight differences between emerging brands and legacy ones in order to understand their approach in the use of social media. Moreover, once defined the state of the art in social media analysis and the existing solutions (e.g. SocialOMeters by Fluxedo), the team reflected upon the characteristics that the tool should have satisfied in terms of usability and capability to extract useful information from the data.



Brands' presence on Instagram

Exploring the opportunities
The most challenging problem to deal with was the content classification: this does not require simply to monitor some well-known quantities, but to

understand deeply the application domain in order to pre-define a set of possible outcomes for the algorithm. Nowadays, the problem of classification is addressed through lots of algorithms developed to implement different techniques, some of them represent the classical tools from statistical analysis (e.g. logistic regression, naive Bayes classifier), while some others consist of more recent approaches from machine learning, such as neural networks or random forests. They provide an established technological state-of-the-art from data science to accomplish this task; the choice of which method to use in a particular domain is not always clear at the beginning of the work and implies different trials, sometimes even ending with a multi-approach solution.

The data collection phase represented one of the most important and delicate point in the project, since this had to guarantee high quality data for the analysis and it could significantly limit and impact on some feasibility aspects related to the following steps.

The first design decision was where the data should come from, as three major data sources were available: Facebook, Twitter and Instagram. At first glance, it was clear that Facebook was the least appropriate one, due to his hybrid nature that would make hard to handle it and even more importantly, we spotted a very limited use by our fashion brands. Twitter, as Instagram, with his short text full of hashtags and key-words seemed to be a better choice, that's why the team focused on it before it became clear that it was less appropriate for its lack of images that are essential for fashion brands and for complete comprehension of the context. Our final data core was Instagram that perfectly combines the main nature of Twitter and the use of images that could clarify the nature of the post content.

Another important decision to make was how to store data. Our first attempt was to use SQLite as a backend since it is easier to use, but data coming from real-world are difficult to express through the rigid logic and plain relations of old-school relational database. Besides in such a promising project, thinking just about our small experiment is limiting, so performance of the statistical analysis has to be taken into consideration in order to easily scale-up when dealing with much bigger data. All these thought led us consider using non-relational databases based on JSON – easily manageable through Python.

Some examples of labelling by Clarifai

Moreover, the research of an Image Tagging tool that could identify meaningful objects in the Instagram's pictures was crucial while developing the framework: to reach the goal it was decided to adopt Clarifai's recognition technology, creating a program that takes the images previously downloaded from Instagram and collects their labels.

Generating a solution

Social media monitoring was the starting point of our development: our team analysed the social media presence of the 29 emerging fashion brands assigned.

From that analysis, we could synthesize 7 recurring main categories that could embrace each single post in our brands' social media (Product promotion, Event promotion, Brand insights, Magazine citation, Commercial promotion, Showroom and Other).

After having collected the data of interest, the project addressed three main directions of analysis through machine learning or data mining in order to provide different perspectives about the extracted content with respect to our users' requirements and to potentially useful insights.

Concerning the Content Classification, the team relied on Crowdflower, a crowdsourcing platform that allows users to access an online workforce of millions of people to categorize, label and clean data in a very short time by paying a relatively small fee. Different approaches of classification were compared in terms of quality of ratings, since a gold standard was not readily available.

Even of our work is based on offline data, the ability to automatically classify each post into a category through an Automatic post labelling enables the tool to run real time. Indeed, the importance of the manual labelling phase is that could allow to train a Neural Network using our examples to automatically label the post.

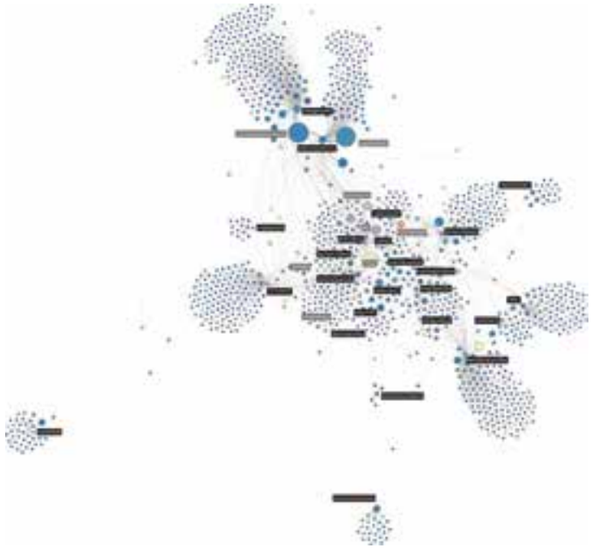
Two types of related analysis were performed: the first one aimed to identify the amount of data necessary to have a high accuracy, the second one to explore the parameter space of the neural network.

The second direction – Similarity analysis – aimed to identify common traits among brands, trying to extract their relationships with respect to the language used as well as hashtags occurrences. The output was provided in terms of clusters of brands.

This point of our work is really promising since it can be translated in a collection of good and worst practices to orient brands' strategies towards a profitable use of the social media instrument.

The last direction – Network Analysis – had the aim of visualizing the connections (intended as mentions) between different actors within our brands social media scenario.

The findings allow the involved stakeholders to define their relative positioning in terms of social media relationships, which kind of figures they should reconsider in order to pursue a differentiation strategy and which other they should approach with the aim of moving towards a desired location in the network or mimicking some "gold behaviours".



Visualization of the Network

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THE AGE OF SMART FACTORIES

New ICT for the Automotive Supply Chain of the future

Project

THE AGE OF SMART FACTORIES

New ICT for the Automotive Supply Chain of the future

Principal Academic Tutors

Paolo Neirotti
Department of Management and Production Engineering, Politecnico di Torino
Emilio Bartezzaghi
Department of Management, Economics and Industrial Engineering, Politecnico di Milano
Arianna Alfieri
Department of Management and Production Engineering, Politecnico di Torino

Other Academic Tutors

Raffaella Cagliano
Department of Management, Economics and Industrial Engineering, Politecnico di Milano
Luciano Pero
Politecnico di Milano

External Tutors

Leonardo Gorno
Supply Chain Management, FCA Group
Julien Etienne Mascolo
Centro Ricerche Fiat (CRF)
Giuseppe Bramante
ICT Information Systems for Manufacturing, FCA Group
Tommaso Giunti
Centro Ricerche Fiat (CRF)

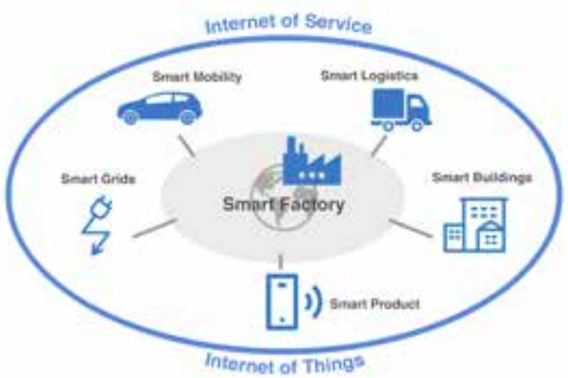
Team Members

Ambrosi Francesca
M.Sc. Architecture, Politecnico di Milano
Buo Ettore
M.Sc. Mechanical Engineering, Politecnico di Milano
Ferrieri Mauro
M.Sc. Industrial Production and Technological Innovation Engineering, Politecnico di Torino
Rivetti Alice [Team Controller and Communication Coordinator]
M.Sc. Industrial Production and Technological Innovation Engineering, Politecnico di Torino
Spaggiari Martina
M.Sc. Mathematical Engineering, Politecnico di Milano

Xu Jinou
M.Sc. Management Engineering, Politecnico di Milano
Zhao Qianwen
M.Sc. Product Service System Design, Politecnico di Milano

Project description

In this project students primarily explored how emergent Information and Communication Technologies (ICT) can affect manufacturing companies, increasing the efficiency and effectiveness in handling information. The exploration of new ICT-based solution was focused on supply chain management activities and was “pulled” by some specific issues of efficiency improvement set by Fiat Chrysler Automobiles (FCA).
Specifically, students explored how emerging technologies in the field of robotics, telecommunication systems (e.g. RFID) and augmented reality could make many processes and jobs more efficient in the FCA’s supply chain management function. Students had to play a consultant role, envisaging and validating (from both a technological and economic feasibility point of view) how new applications of the industry 4.0 paradigm could help



smartfactories

in solving some critical operational problems in supply chain management. Specifically, the team of ASPers tackled three challenges:

- how RFID, GPS, and cloud based technologies could make the tracking and tracing of containers more effective in global inbound shipments and reduce the number of containers that are temporarily out of control or irremediably lost;
- how robotics could support and augment human labour in warehouse management or make labour less physically demanding for what concerns routings and picking process;

- how augmented and virtual reality technologies can be used in to make quality control more effective in the detection of defects and damages created during the transportation of cars from factories to distribution centres.

inbound

The first challenge was the one that raised the highest interest in FCA, being the container tracing a complex process that is one of the sources of critical inefficiencies in the firm's supply chain. As such, students made an in-depth technological validation of the proposed solution and modelled the drivers of economic value stemming from investing in the identified ICT-based solution. Some visits to the lab on RFID of Politecnico di Milano gave students a unique support in their technological exploration. The objective of multidisciplinarity was pursued at two levels:

- by exploring and validating how ICT-based technologies could support the company in dealing with real-case processes of supply chain management;
- by assessing how the identified and designed solutions could support the environmental sustainability of the company's logistic processes.

In this process students could take advantage of two company visits (one in Maserati plant and one in the distribution center in Turin) and of many meetings with specialists for supply chain management in FCA and in Centro Ricerche Fiat.

Tasks and skills

Technical

Ettore Buo: mechanical engineer, together with Jinou Xu, management engineer, focused their attention on the technological feasibility of the proposals, with a structured approach on all technical aspects and their application in the field of Automotive 4.0. Thanks to a thorough analysis, from the state-of-the-art to the on-site studies, they managed to reach a sustainable and interesting insight for the Supply Chain of the Future of the project's main stakeholder, FCA.

Business

Alice Rivetti: the team leader, and Mauro Ferrieri, the two industrial production engineers of the team, thanks to their academic background that combines technical knowledge together with business skills, were fully dedicated in studying the business feasibility and the implementation roadmap of the final proposal. They were also engaged in defining the main requirements for FCA and converting them in specific needs.

Mathematical

Martina Spaggiari: mathematical engineer, deeply studied and designed the mathematical model that structures the cost analysis of the final proposal, with a focus on the sensitivity analysis related to cost-benefits of the implementation for the stakeholder.

Design

Francesca Ambrosi: architect, and Qianwen Zhao, designer, are the two team members that have dedicated their efforts in structuring the proposals from an architectural and design perspective, studying the physical implementation of the solution with a new environmental-friendly prototype, that was combined with an innovative materials approach.

Abstract

The ASP project "The Age of Smart Factories: New ICT for the Automotive Supply Chain of the Future" was commissioned to the group by Fiat Chrysler Automobiles and Centro Ricerche Fiat with the aim of presenting the students with some concrete and specific issues affecting a complex automotive supply chain, in order to analyse the currently available technologies and come up with multidisciplinary enhancement proposals in line with the corporate values of reliability, transparency and innovation.

The project team was guided through the problems with the help of the internal coordinators and external tutors, whose remarkable availability is worthy of mention. This phase was followed by a state of the art analysis and field studies, which eventually led to three separate proposals, each one addressing a specific area of interest: robotics implementation in warehouse management, use of augmented reality technologies in outbound logistics, and employment of advanced systems for automatic identification and tracking for inbound logistics.

The third proposal, envisioning a combination of RFID and GPS capabilities through the use of cellular-like solutions operating in a Low-Power Wide-Area Network (LPWAN), proved to be the most attractive under a business perspective, and was therefore further elaborated with the development of a comprehensive feasibility study, suggesting a sustainable path to follow in order to ensure a smooth and efficient implementation of the new technologies. Moreover, the management and mathematical skills of the team were coupled in the formulation of a cost sensibility func-

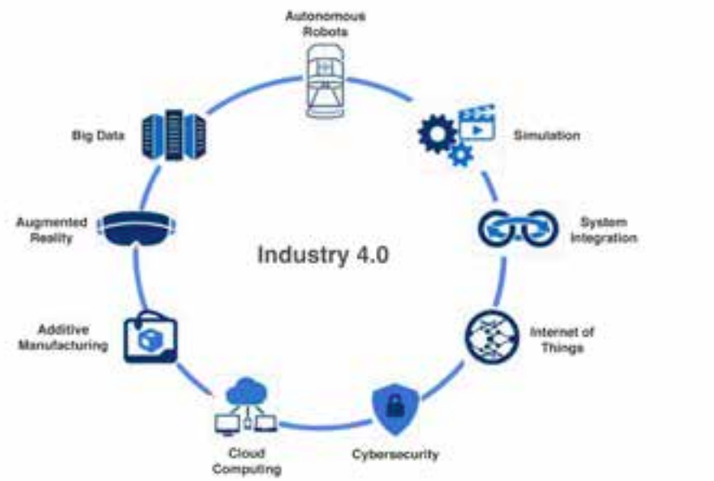
tion able to model the costs distribution at the variation of pre-determined parameters, resulting crucial in the evaluation of the long-term financial benefits of the potential investment. Finally, the creative mind-set of group members was key in developing an innovative tag prototype with enhancements in both shape and materials, proving once more the benefits of multidisciplinary teamwork.

tag on metal

The project team was able to produce a proposal representing a considerable enhancement to current solutions, allowing for bi-directional communications between a number of devices interconnected in an integrated network. Its implementation could potentially result in improvements in the quality of information collected, its quantity and its reliability, contributing to the shift towards a more transparent supply chain, ready to tackle the challenges that the Internet of Things is creating for the automotive industry.

Understanding the problem

New technologies are affecting more and more the way we live and the way we produce value in every business field. Industry, in particular, is taking advantage of the enormous opportunities disclosed to carry out a new revolution, which has been named “Industrie 4.0”.
The novelty relies on the connection of embedded system production technologies and smart production processes, whose main exemplifications are the Internet of Things (IoT) and the use of Big Data.
Our project first followed the interest shown by FCA to continue exploring what was done in a previous ASP X cycle regarding the modification on the information flows with new production systems such as World Class Manufacturing (WCM). In particular, the new project should have been an extensive analysis about the advantages that new technological developments can bring to these new ways of working.
However, FCA later realized that it could be more interesting and valuable to find solutions for some of the big problems affecting the efficiency of Automotive Supply Chain. In particular, FCA asked to look for the exploration of the new ICT (e.g. big data, machine learning, IoT, 3D Printing) in different sectors, such as inbound and outbound logistics, containers and warehouse management.
Supply chain executives are indeed facing an era of complexity and rapid change, where increasing number of companies involved in any value chain and general tendency to outsource non-core activities create a number of challenges never faced before. In particular, issues like cost reduction, end-to-end visibility, risk management, customer’s involvement and globalization demand more and more efforts and resources to industrial companies.
The Automotive industry is affected by all these problems since the OEMs have to co-ordinate thousands of suppliers while reducing time and money wasted in a market that grants very small margins. In this context, it is evident that an early and seamless introduction of new ICT can lead to big advantage in terms of efficiency with respect to other competitors.

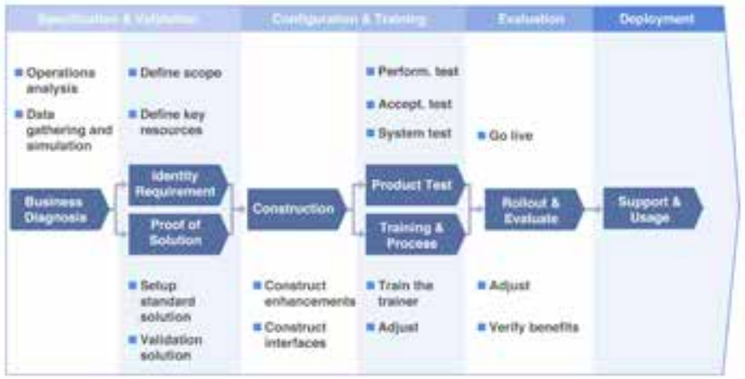


industrie 4.0

Exploring the opportunities

After the shift in topic, the team had the opportunity to visit the production line of Mirafiori, where the interest of FCA in this project was clarified. Since various problems exist in the production management, the main emphasis was set on four of the operational areas: Inbound logistics management, Warehouse management, Outbound logistics management and Container management. At the meantime, the major limit raised by FCA was the unfeasibility in cutting labour forces, which means that the adoption of new ICT should be acting only as a tool supporting the workers rather than a substitution of human activity.
Starting with a throughout study of all the recent ICT applications, a special emphasis was stressed on those solutions that could be adapted and adopted in the automotive supply chain. Then, a further adjustment was made by combining the inbound logistics and container management, since potential synergies were discovered in terms of investment reduction.
Regarding this first area, the main challenge was the low visibility on containers and inaccuracy in container information. The team considered solutions combining application of RFId and Internet of Things to allow FCA having a better centralized control on their real-time movement. Thanks to the visit to IoT lab of Politecnico di Milano, a further step was made possible by an expanded knowledge of the existing platforms. At this moment, one of the telecommunication platform (SIGFOX) was carefully studied since it allows the customer to check remotely the information of containers through a track and trace service provider. This proposal simplified the initial effort of implementation, allowing a richer and value-adding information linked to the specific containers.
Considering outbound logistics management, the proposal discovered the potentialities in the application of Augmented Reality, where the equipped smartphone-connected glasses for every employee would provide in-time

instructions to the workers. This goes strictly in line with the idea that technology could enforce human beings in assisting their complex manual procedures.
Finally, for warehouse management, the proposal initiated by the team was inspired by the warehouse robotics. Thanks to Amazon Kiva robot, more and more effort was put by various companies in the R&D for this kind of application. The matured technology allows to operate with different pallets' dimensions and weight, which would reduce the idle effort on daily operations.



inbound-impl

Generating a solution

Among the three proposals, the one related to inbound logistics and containers' management turned out to be of particular interest for FCA and the reasons are the following.
Firstly, the containers' lost is a relevant problem in their daily activity, not mainly for the economic value of the objects, but rather for the organizational problems that such a lost can entail in the production line.
Secondly, the technical implementation of the solution could be smoother as it involves the use of an operated telecommunication network (SIGFOX) that already exists. Furthermore, the technology itself is quite simple and the added value is not given by complexity, but it is obtained through the interaction of several existing technologies in a smart and efficient way.
Thirdly, the investment required is lower than the one related to other technologies (e.g. robots, smart glasses) and it could provide immediate and tangible benefits. So, while the other proposals represent a possible future (e.g. vision of 2020) of the automotive industry, the one related to containers' management could be applied "here and now". That's why the team have decided to take this direction proceeding in the work.
The team's proposal addresses the need of FCA to have real-time and accurate information on the location of containers, avoiding manual inputs (the main cause of errors) throughout the supply chain. The improvement of the information available leads also to the minimization of inventories, to the increase of the turnover and to the (almost) certainty that the right parts and components are available in the production line when they are needed.
After analysing several different technologies that could be used for tracking purposes – including RFID, NFC, GPS, and LPWAN – the team came to the conclusion that the most aligned to FCA requirements would be a hybrid cellular and GPS-based technology supported by SIGFOX service.

SIGFOX is an operated telecommunication LPWA (Low-Power Wide-Area) network "providing global cellular connectivity for the Internet of Things". The users do not have to handle any installation or maintenance operation and SIGFOX works in the following way: the devices simply emit a signal in an available frequency, the signal is detected by the closest base stations, decoded and forwarded to the network backend; then the network handles some protocol operations and forwards the information to the users' application (protected with hash mechanism and a private key specific to the device). SIGFOX is made particularly interesting by the following technological aspects: small dimensions of the tags with embedded GPS, low energy consumption, great resistance to interference, sufficient memory capacity for storing essential information (like tag ID and content), extended network coverage. Therefore, it could be possible to have almost a perfect reliability while moving in those countries where the network is already established.
To complete the work, the team have identified and quantified the expected benefits and costs related to the IT investment, following the structure suggested by John Ward in "Building Better Business Cases from IT investment". Finally, the team has used the knowledge acquired to structure an implementation roadmap, to produce a preliminary NPV financial analysis of the investment and to make some sensitivity analysis on volumes and discount rates.

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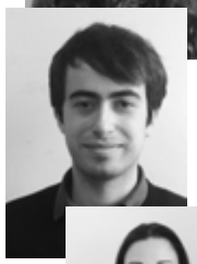
MO.MO
MOVING MOZAMBIQUE
FROM FREIGHTS TO PASSENGERS

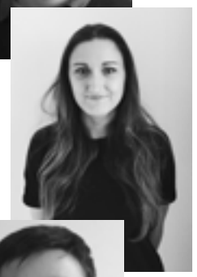
A strategic evolutionary framework for the design of railway network in developing countries

Project

MO.MO
MOVING MOZAMBIQUE – FROM FREIGHTS TO PASSENGERS

A strategic evolutionary framework for the design of railway network in developing countries





Principal Academic Tutor

Antonella Contin
Department of Architecture and Urban Studies, Politecnico di Milano

Academic Tutors

Pedro Ortiz
Visiting Professor, Politecnico di Milano
Paola Pucci
Department of Architecture and Urban Studies, Politecnico di Milano
Francesca De Filippi
Department of Architecture and Design, Politecnico di Torino
Alessandro Frigerio
Department of Architecture and Urban Studies, Politecnico di Milano
Alessandro Floris
Department of Architecture, Built Environment and Construction Engineering, Politecnico di Milano
Andrea Zammataro
Department of Architecture and Urban Studies, Politecnico di Milano

External Institutions

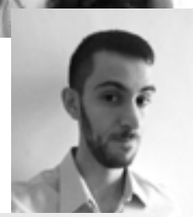
Systematica Srl
ItalFerr S.p.a, Direzione Sviluppo Mercato Estero
MIT Dept. Urban Studies and Planning
Università Alma Mater Bologna

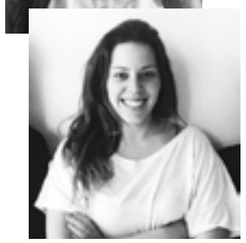
External Tutors

Diego Deponte
Systematica Srl
Raffaele Lorusso
ItalFerr S.p.a, Direzione Sviluppo Mercato Estero
Gabriel Eduardo Lanfranchi
MIT Dept. Urban Studies and Planning
Massimiliano Musi
Università Alma Mater Bologna

Team Members

Anita De Franco
Urban Planning and Policy Design, Politecnico di Milano
Andrea Govi
Architecture, Politecnico di Milano
Chiara Lippi
Architecture, Politecnico di Milano
Matteo Losurdo
Architecture, Politecnico di Milano
Tommaso Raimondi [Communication Coordinator]
Architecture, Politecnico di Milano
Josè Alberto Ramos Mejia
Environmental and Geomatics Engineering, Politecnico di Milano
Lei Sun
Urban Planning and Policy Design, Politecnico di Milano
Maria Sole Teberino
Architecture, Politecnico di Milano
Valerio Verdecchia
Aerospace Engineering, Politecnico di Torino
Liu Ziwei
Interior Design, Politecnico di Milano
Laura Zura – Puntaroni [Team Controller]
Architecture, Politecnico di Milano





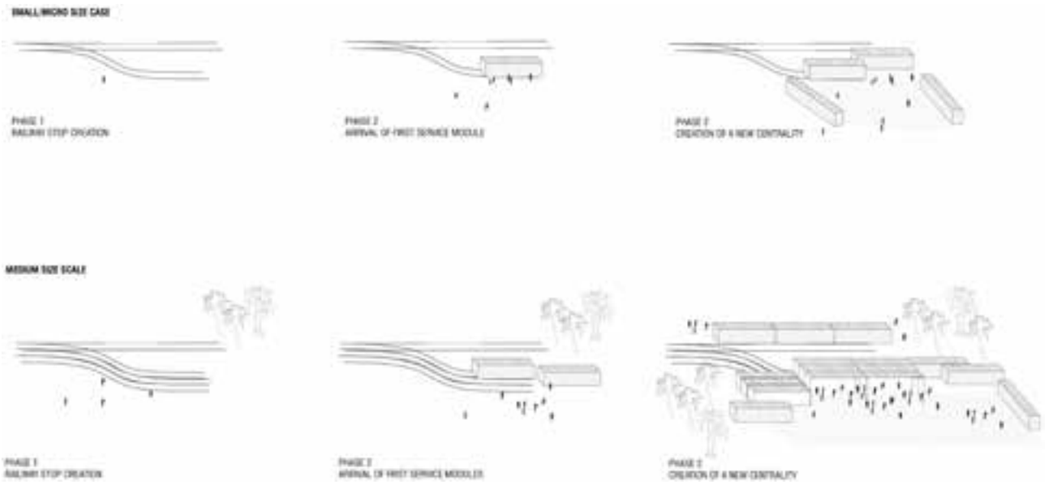
Project description

Out of the thirty cities with the highest rate of growth in the next decade, twenty-four will be African. It's just the beginning of an urban transition in Africa that is forecasted to take almost 80 years, compared to the 200 years that it took in Europe.
M.O.M.O project promotes an investigation on inclusive and co-created strategic frameworks related to the design, improvement and networking of railway lines in a general reframing of transportation policies in Mozambique. Accessibility, as a basic urban and metropolitan right, takes up the challenge of designing economically feasible railway systems dedicated to freights, with the long-term aim of transforming them in hybrid systems open to passengers.
In Mozambique the risk for dynamics of exclusion, impoverishment, deepening inequality and ecological distress is thus, really high. Expectations related to the development of the energy industry and the rise of agricultural and tourism sectors, as well as all the concerns related to the fragile environmental conditions, require the definition of a strategic framework able to guide public decisions and private initiatives to promote economic redistribution and a fair development through consensus building. As in these regions there is not a local metropolitan culture, the forecasted high growth rates, alongside with an explosive population growth, produce the need to look for unprecedented settlement patterns. Fostering a smart growth for different contexts requires innovative interpretation and planning-designing tools. Metropolitan areas have a threshold beyond which only mass public transport can provide the means to be competitive, inclusive and safe. The only mass public transport with a load capacity of 45.000 passengers/hour is provided by rail, either commuter or metro. The project will focus on railways as possible armatures for sustainable growth and on their stations as metropolitan hinge-points. Well-run railways can do the heavy lifting of economic development, offering the capacity and services required by many types of industries at a cost much lower than road transport
Freight transportation is most likely the basis for further railway development, but it's necessary to evaluate the traffic-generating potential over time and the possible scenario through a careful multicriteria analysis considering also environmental, social, economical and cultural issues at different scales.
The too rapid urban growth and the low rate of planning can compromise the future possibilities of introducing and managing sustainable and intensive infrastructures. Railway and urban planning can/must be combined in order to better fit population increase and environmental protection. The

project relies on previous studies and projects realized by some of the academic tutors and the external institutions.

Tasks and skills

Architecture: MOMO group is mainly composed by Architects in charge of the physical dimension of the project, so everything concerning analysing, mapping, planning, designing and thinking of new solutions. Tommaso Raimondi particularly contributed in the socio-economical part of the project and on how the development of the urban space may affect the local society and its culture. As team controller he managed the relationships with tutors and external institutions. Chiara Lippi and Andrea Govi were mostly involved into the proposal of new project solutions for Nacala and Montepuez. Laura Zura - Puntaroni and Matteo Losurdo helped in the first phase of the territorial analysis, understanding the different features of the new railway's path, its main advantages. Maria Sole Teberino together with the first analysis of the state of art, also helped in merging together the work of the other research in the group, harmonizing all the elements in the overall prototype.



Development of plug-in stations in secondary centres

Urban Planning: As Urban Planner, Anita de Franco managed the general organization of the project. Together with Sun Lei, she framed the strategical framework of action gathering together territorial data and philanthropic researches for local contexts, especially for the cities of Namuno and Mueda. The contribution of planning in this sense helped to understand the burden of the project action looking also at the legal, economic and political asset of the country. Jointly with the engineers they developed and operated the database for the MCA through Geographical Information System software, particularly crucial for understanding the scale of the strategy, feasibility and operability of the system.

Engineering: Valerio Verdecchia as an Aerospace engineer focused on the analysis of data and the description of the economical impact on the main cities and on the general population, alongside with the design of the business model. Jose A. Ramos M., as a Civil and EGE, was in charge of researching the general requirements of a railway, it's current situation and analyzing the feasibility of the rail proposals to maximize benefits over risks, while also realizing a preliminary costs analysis.

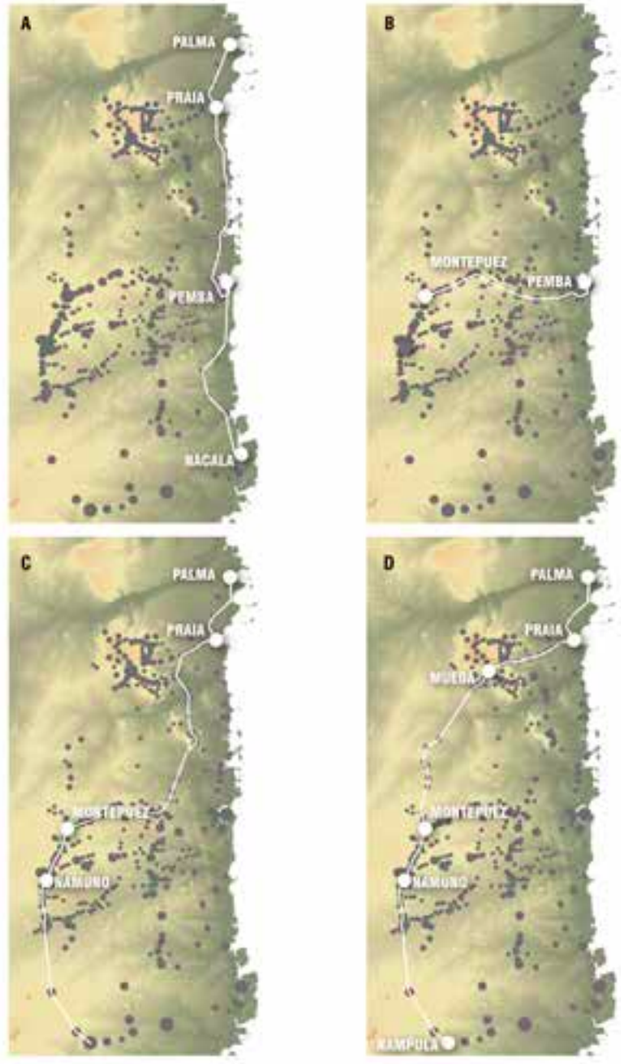
Design: Liu Ziwei's contribution as a designer was particularly focused of the characteristics of the plug-in system, especially the rolling stock. The proposals took into consideration not only the design of the module itself, but also the selection of the possible services, the internal and external feature of the containers and the operational aspects both for service providers and consumers.

Abstract

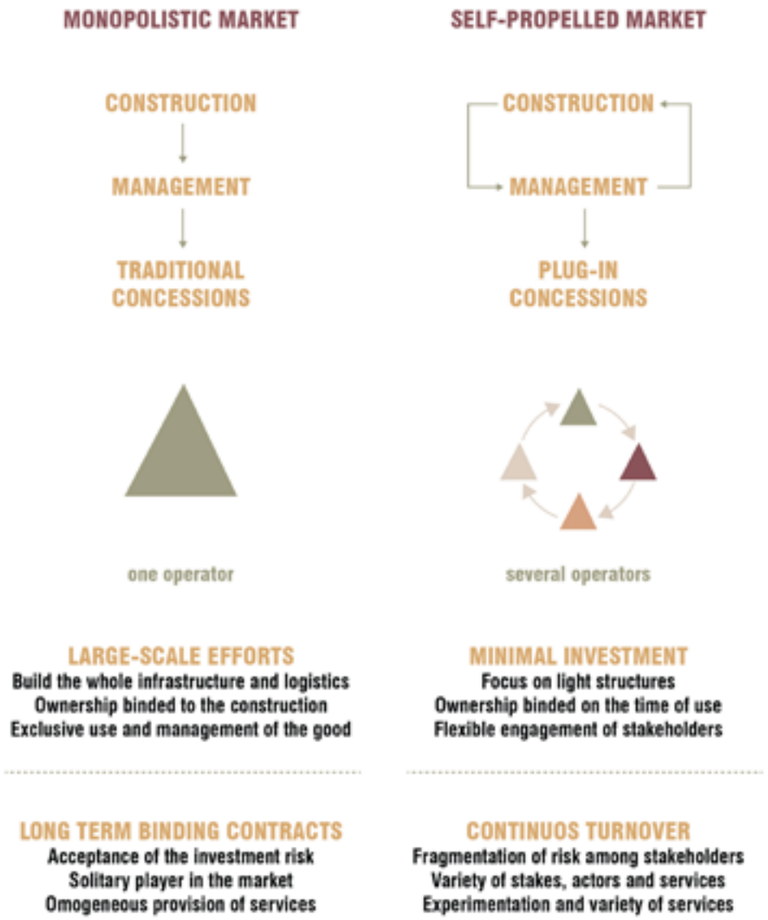
What does it mean to build a national railway, that can switch from freights to passengers in a developing country? Which relations and connections have to be taken into account? Is it possible to enhance the potentiality of a growing nation taking into account both needs of local population and stakeholders' perspective? How to develop an innovative business model that can help to approach the new urban challenges? Can such a model of development become replicable and applicable to different realities? Transportation is one of the indicators for quality of life measurement, and railway is one of the most reliable options for public transportation to face high volume, low cost, and environmental friendly systems. In Mozambique, due to resources exploitation, nowadays freights transportation occupies most of the railway routes in the country, leaving few space for passengers, even if this sector has experienced an encouraging growth in recent years.

MOMO develops an investigation on strategic frameworks related to the design, improvement and networking of railway lines in Mozambique, both at regional and national level, as a tool for life quality improvement. The focus of the research is a railway connection through the northern part of the country, linking the province of Cabo Delgado with the south, intersecting the three main trans-national corridors that connect this country (and its ports) with neighbouring landlocked African countries.

An innovative multi-scalar approach has been applied to both metropolitan topics (seen as part of a big system in which the engineering components are prevalent) and systemic topics (studying their local and urban implications). What really stands as the main goal of the project is to seize the opportunity offered by the railway to provide local urban and rural population with an innovative and collaborative path to sustainable development, both economical and human, identifying a priority ranking for future private and public investments. The development of this information system is focused on a deep research on the knowledge, the dissemination and the promotion of the conservation of the African culture, studying the relations between them and the project, in order not only to save this traits, but to



MCA path options.
(A-Coastline)
(B-Montepuez Pemba)
(C-Midlands 1)
(D-Midlands 2)



Plug-in system specification

guarantee a sustainable preservation in the future.
The first of the phases in which the project is articulated is the reconstruction of the state of the art on the research object: at the level of social-economical-environmental survey, in terms of methods of acquisition and storage of data, in terms of application of techniques and tools for the spatial and territorial geo-references. The project also experiments a territorial strategy and the formulation of a business model which involves different partners and investors, able to promote a social growth based on national and international organizations' investments. Finally, a study of control systems from third parts is fundamental to enhance a future to the project and to tackle the high level of corruption of the country.

Understanding the problem

The railway system is quite underdeveloped in Africa, with a particularly critical situation in Sub-Saharan countries, and Mozambique in line with the macro-regional framework. Most of the infrastructural system was built during the colonial era and often was abandoned when national African states gained independence. The first step in approaching the Mozambican case is to understand the history of the existing lines: in Mozambique, the majority of them connects the main ports with landlocked countries, moving west-east direction and defining three main corridors. The situation is quite stable and, even if many projects have been financed, no real improvement to the system has occurred. We have tried to understand in which direction railway lines in Africa are moving from an economic point of view and from a legislative point of view. The huge changes that are occurring in Africa influence the forecast for the demand of the next decades; the population shift from rural to urban areas, the general increase of population, as well as the economic growth, suggest that new system of transportation will be needed. However, financing these expensive infrastructures tops as a major issue.
A railway infrastructure involves a large number of stakeholders and addresses a wide variety of actors. In particular, considering the coexistence of freights and passengers movement, it is necessary to take into account many factors, from the broad socio-cultural and geopolitical context to the specific laws and policies of a country. To understand how a new backbone-railway line could trigger an innovative urban development, we considered first of all Mozambique from a social point of view: we analysed the rates of poverty and illiteracy, as well as the health situation and the religions practiced. From the study of common lifestyle it is possible to deduce the socio-spatial patterns of local populations. Moreover, the analysis of urban growth and the comparison of the Mozambican case with the wider Sub-Saharan development process defines a framework at a macro-level, necessary for the design of a strategic railway line.

Exploring the opportunities

One of the main challenges of the project is to propose a way to transform the railways in Mozambique from freights to passenger use by the understanding that the population growth is expected to be fast, and that rail is the most reliable transportation method for high volumes of people; a solution has to be given for other countries experiencing similar challenges.
Working on a project of this magnitude requires first to be aware of the situation of the country different domains, such as social, political, economical, infrastructural and environmental; general research among these areas was needed to place ourselves closer to the project. Likewise, understanding our strengths and capabilities was useful to have a panorama of what could be proposed; our different disciplines as professionals and the institutions working side by side with us gave us a clear view of where the project could go. Data collection was the starting point, and one of the biggest challenges, since not many reliable and up to date information was found for the several fields needed; the deeper we were trying to go in a topic, the lesser information we found; this showed us also the few studies or investigations performed on the locations of our interest.
Mo.Mo was asked to focus on the social, territorial and urban implications that a new strategic infrastructure could have. Because of the variety of contexts in Mozambique, one of the main issues was to understand the differences between urban areas and rural areas and how the railway path could trigger urban transformation through policies and investments.

Scheme for the reuse of a container

The relationship between freight transportation and economic development directed the research to locate key areas of agro-food, mining and industries, tourism and infrastructural hubs; these findings and the timing of the project made the team agree to narrow the attention on a specific area of intervention and apply a general strategic approach to the urban development of the provinces of Capo Delgado and Nampula The design process and strategic framework of intervention has been translated in project proposals at two different scales, territorial and urban, supporting new concepts arisen during the research. The confrontation between our findings and the advancement of Systematica researches brought attention to some peculiar cities that could be considered strategic for the future development. The project was intended to set a national vision for the country, but, because of time and resources limitations our focus areas are Nacala, Namuno, Montepuez and Mueda.

Generating a solution

Starting from a strategic and economic analysis and according to the stakeholders' requirements, the innovative plug-in system that we propose aims at increasing the social impact of the construction of a new railway line, likewise at defining new forms of urban development. It consists mainly in the idea of moving not only freights and passengers, but services as well. In order to fulfil all the objectives, we designed a modular, replicable, movable, fast and cheap solution which consists in supporting the classical mining concession system with the insertion of an increasing number of partners. This way, the concessions fee the mining (or agricultural, or timber) company shall pay are reduced by the State, in exchange for the condition of sharing the infrastructure with other users. Public transport authorities can use the rail to set a passenger commercial transport system, or even issue concessions to privates who may want to engage this market. The modules are freight wagon converted into service providers, or substituted with wooden containers, each dedicated to a specific function. Different partners can decide to use the railway to move their services, and serve a wider population with a low purchasing power, with the same capital investment. We identified several different possible partners, such as poverty eradication organisations and utilities service providers, but also electricity storage or water purification services, and even private healthcare and education, if adequately supported by public co-investments.
Our vision for Mozambique includes movable electric generation solar plants to counterbalance the poor access to electricity, water conservation and purification modules to tackle water scarcity, itinerant pharmacies and vaccination centres, alongside with wandering libraries and classrooms. The modules can be plugged-in one to each other on dedicated rails, so that semi-permanent stations are realized and shared amongst the biggest villages, or they can be settled in a permanent way in appropriate stations in the largest cities. Also, the logistics hubs this system would require can become seed for the development of a process industry, for example for food packing or freezing, or for timber pre-processing, or for little local manufacturing enterprises, which would have access to low-cost transport services. Of course, this system has huge implications on the urban scale, as villages and cities would evolve alongside the railway, and following its directions, but in a completely different way with respect to the western cities. In fact, the continuous redeployment of the modules would eliminate the centrality of the railway station, and spread it in different levels of time and space amongst the districts of a city and even amongst neighbouring villages.

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MUSEUM CLUSTERS ICT

New digital and interactive spaces for new museum clusters

Project

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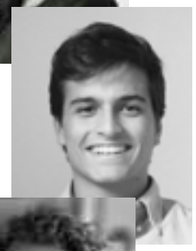
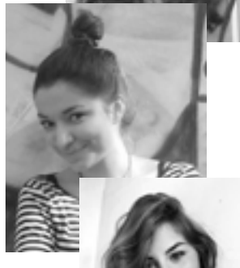
MUSEUM CLUSTERS ICT

New digital and interactive spaces for new museum clusters





Principal Academic Tutors

Alessandro De Magistris
Department of Architecture and Urban Studies, Politecnico di Milano
Patrizia Bonifazio
Department of Architecture and Urban Studies, Politecnico di Milano

Academic Tutors

Alessandro Armando
Department of Architecture and Design, Politecnico di Torino
Gennaro Postiglione
Department of Architecture and Urban Studies, Politecnico di Milano

External Tutors

Carlo Della Pepa
Comune di Ivrea
Renato Lavarini
Coordinamento Cabina di regia per la candidatura di Ivrea, città industriale del XX Secolo a Sito Unesco
Irina Korobina
Schusev State Museum of Architecture, Moscow

Team Members

Kristina Azarić
Architecture, Politecnico di Milano
Enrico Pinto
Architecture, Politecnico di Milano
Sanja Platiša [Team Controller]
Architecture and Preservation, Politecnico di Milano
Federica Torri
Architecture - Building Architecture, Politecnico di Milano
Srna Tulić
Architecture - Architectural Design, Politecnico di Milano
Zeynep Tulumen
Architecture Construction and City, Politecnico di Torino
Matilde Valagussa [Communication Coordinator]
Architecture, Politecnico di Milano

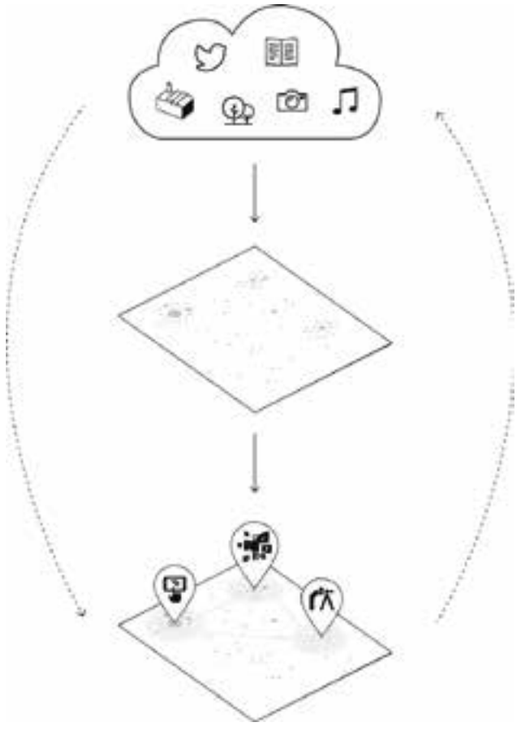
Project description

In recent years, there are many methods whose purpose is to use the tools of the digital culture to analyze, map, and manage information about territorial and architectural transformations, and to address the complexity of the preservation and of the project related to the theme of the architectural and cultural heritage. We are facing on the other hand a redefinition of the spaces used for culture, recognizable in the mutation of the nature of the museum spaces at the international level because of a greater economic and cultural interest of the urban development.
The huge mass of collected data and their spatial perception are the focus of the proposed project. The project aimed to define a concept with the following starting points:

- To investigate the potential of the plot of these two innovative phenomena;
- To investigate how the perceptive, spatial and interactive analysis of a given context implements / changes in turn data collection and potentially increases the chance to experience applications and to provide useful hybrids both in the field of project and in different disciplines that contribute to the use of cultural heritage.
- To explore the horizons of digital developments understanding how the new digital dimension interacts with the spatial (and perceptive and interactive) dimension and how the concept of public space changes and therefore, its project mutates.

As a main area of the project , we have chosen the museum clusters of different nature and state – they could be under development or potentials; they could be museum urban districts or territories seen as diffused museums but always in context of a particular relevance- that allow to investigate the issues raised by the project at different scales.
1. The project has analyzed the quality and the potentials of data coming from mapping systems that use free and open database, openwebgis, ..; and some of the most innovative digital platforms in the proposals for the elaboration of projects within the innovative field proposed by digital humanities (as www.zeega.org) to collect data that are considered useful for "reading" the different contexts and experimenting different tools for the design of spaces, that have been living a densification of data and information.
2. The project has analyzed innovative museum clusters of different nature and uses the experience of ASP projects launched in the IV and IX cycle and the expertise of the involved institutions.
The project is experimental and, after different phases of analysis, we were focused on the creation of a concept which put in evidence some important issues related to the dynamic and shared idea of heritage. As a consequence, through informative and interactive systems, we reached a dynamic and shared definition of cluster.

Map - from physical to virtual



Tasks and skills

Kristina Azarić: she was concentrated on understanding the use of digital technologies as a tool for representing the heritage, and the application on virtual museums, for which she did case studies. Together with Srna, she thought about the future of the project and developed project implementation timeline as well as a business model.
Enrico Pinto: he was focused on the development of the physical intervention in the public space, and implementing multi-sensorial experience as an important way to perceive a cluster.
Sanja Platiša: (Team Controller) She was focused on understanding broadening definitions of cultural heritage and effect on the project, as well as understanding all stakeholders that can be interested in the project and possibilities to manage them.
Federica Torri: with the prior knowledge of GIS technology, above all, she was concentrated on developing the map by using and managing all the information available.
Srna Tulić: her focus was on deep theoretical analysis, especially defining the cluster muse-

The Five step model: how memoMAPP works

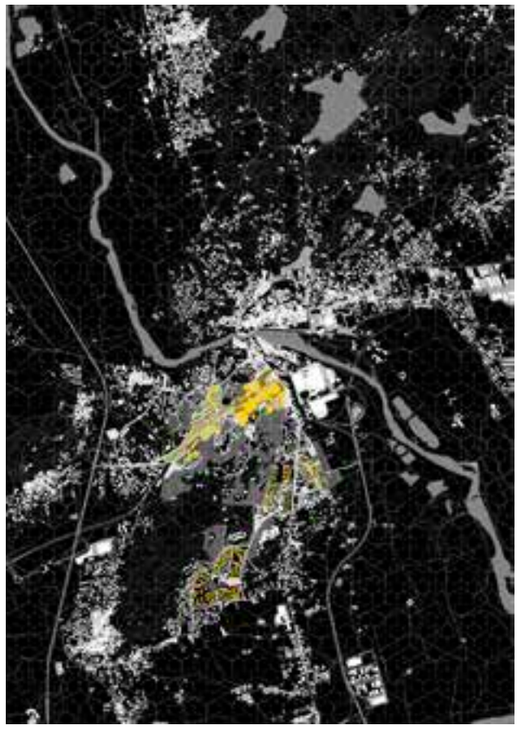
um, and applying these findings in our project area. Together with Kristina, Srna thought about the future of the project and developed project implementation timeline as well as a business model.
Zeynep Tulumen: she was working the most on case studies and exploring new roles of museums, understanding the framework of the project.
Matilde Valagussa: (Team Communicator) Her focus was understanding the concept of cultural heritage, especially industrial heritage in the case of Ivrea, and defining potential interventions.

Abstract
In the 21st century, changes in economy, politics, culture and social life caused changes in the role of museums. This project aims to respond to the contemporary and future needs of museums, considering digital technologies as important tools in communication between all users. Our interpretation of possible solution is reflected in MemoMapp project, that is based on complementarity between digital technologies and public space. Physical space, thanks to digital technologies, gets another layer of meanings. Being connected, they create a museum cluster and possibility to perceive the heritage that until then wasn't recognized.

Keywords
Museum, cluster, heritage, digital, technologies, virtual

Understanding the problem
Theoretical approach that was followed was understanding and contributing to the debate of cultural heritage and shifting perspectives in the museum filed. Answering to the question what is a cluster museum, what are its constitutive parts and what defines its boundaries was necessary to have the clear idea of possible interventions, also considering the relationship between the public space and digital technologies as tools for managing and manipulating it. Another question related is: "what will cultural heritage be like in the future?"
The project is based on the concept of integration of digital technologies into the interpretation and definition of cultural heritage. More specifically, defining museum cluster with the help of digital tools. It is a proposal of finding a new way to relate cultural spaces with digital technologies, emphasizing the potential and significance of controlling the spatial experience in public space, and also creating new relationships and experiences with the users. We want to take advantage of the use of digital technologies because of their possibility to add new interpretation layers and visitor interaction into physical spaces of museums, and not only museums, but also public spaces. This project shows how the museum clusters can emerge visible and recognizable through the spatial interventions and digital platform that unites them. The aim is to make emerge the cluster using complementary digital and analog interventions.
Ivrea, the industrial city, born as a cluster of everyday life, planned in its complexity, can be in the future a cluster museum, center of culture and incubator of technologies. We can interpret it with its industrial heritage as an already potential cluster museum, diffused along the streets and surrounding areas. A smart intervention in the public space, with a parallel construction of an interconnected web platform is supposed to create the identity of the Industrial city as a cluster museum. Having discussed the concepts of heritage and cluster museums, and applied to the case of Ivrea, intention is to reinterpret everything that is considered heritage (buildings, public spaces, memories…) with the use of digital technologies, in order to create a space that is perceived in a different way by the users. Digital technologies in this case are the tool of unification because they

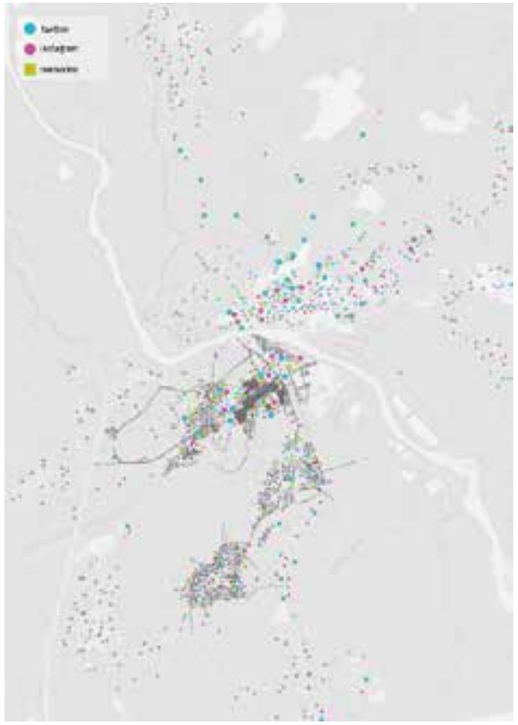
Ingredients of the map



Ivrea Cluster's map

contribute in defining this heritage.
Challenging definition of cultural heritage nowadays represents a framework of the project. Theoretical analysis led us to the conclusion that cultural heritage is a more complex notion than before and it demands a new interpretation. Traditional museum cannot respond to its needs in a correct way. In order to understand current museum paradigms, we have done case studies of different types of museums to be able to extract their common attributes and define the direction of work. On the other hand, deep analysis of digital technologies used in 21st century was important to open our minds towards new possibilities of representing, but also experiencing and interacting with heritage.

Exploring the opportunities
The question of creating new digital and interactive spaces for museum clusters was a more complex issue than it was seen in the beginning. As soon as we make our way into the subject, we understood that there were a lot of concepts and issues to deal with, clarifying their meaning, value and perception in the new society. Thus, our first attempt was to lean ourselves on a strong theoretical part which can help us to identify our vision. The most difficult part was to take a side and formulate our point of view concerning each of the concepts, such as heritage, cluster museum, pub¬lic space etc. That is why we found ourselves studying literature from different sources and trying to synthesize all that we have found significant in a strong statement which spells out us and our vision. Subsequently, after the proclamation of our vision, the practical part of the project was a natural process that almost self-developed.
We have tried to underline an emerging prob¬lem of the need of new innovative spaces for emerging museum clusters, and to develop a possi-



Map about Social network and memories

ble programmatic solution which could eventually help administrations and institutions to make citizens, tourists and users of every kind understand the importance and the new meaning of heritage, breaking its conventional perception, developing a methodol¬ogy which achieves to integrate the new heritage into our daily life. We have focused on developing a methodology, which can be extracted as a model for any exiting or emerging museum cluster. Furthermore, we have made an effort on the integration of ICT to physi¬cal spaces, as the new generation is an interesting shift factor of contem¬porary society towards the model of 'Digital Life'. This is an important prerequisite regarding future transformation processes of the cities and the innovative procedures, in order to reach a new interpretation of space for heritage. We have tried to avoid a banal path which remains in one dimension and local-specific, but we revealed the bi-dimensionality between the virtual and physical world, which gives us the opportunity to create a potential model to be abstracted and adapted to a broad range of places.

Generating a solution

The methodology adopted to solve the question of digital and interactive spaces for museum clusters started with the understanding and a complete analysis of stakeholders identification, their categorization and values iden¬tification. This was important in order to have insight into the real interest of institutions for this topic, that defines also the feasibility of the project later on.

Web interface

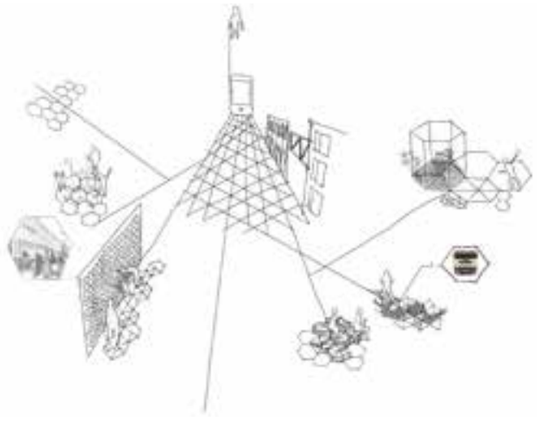
The proposal is dealing with interventions in two dimensions, virtual and physical one.

The first step is realization of a Map, which is constructed in the vir¬tual dimension, where any kind of data and information can be presented and stocked. We have developed criteria for choosing the type and characteristics of data that have to be used in order to respond to the needs of the project. The Map provides a virtual interaction with the users and it acts as a recording, and also decision-making tool for the following step. It has the merit to keep together all the pieces of the clus¬ter's puzzle, made of various elements of different nature which concur in the heritage of the city, even if it is continuously changing. Its use can be various and personal, as discovery tool or navigator in the space, even the daily public space, which can be explored in new ways, in a sort of epiphany. The map is implemented with punctual elements made by geo-refer¬enced public from social networks such as posts on Twitter, Instagram, Flickr, Facebook. This material has with no doubt the limit to be an unofficial source and relatively hard to control, but on the other hand, it opens a completely new freedom of readings and interpretations. The "knowledge" provided (if it is possible to define it like that) is generally made by fresh and actual critical positions, related to topics which people are sensitive to. In addition, the possibility for users to interact through existing tools they already know and are daily used to, increases the ease of use in participating to public social debates. Once this kind of data is collected, the most critical issue is the filtration of contents which indeed enhance the definition of heritage.

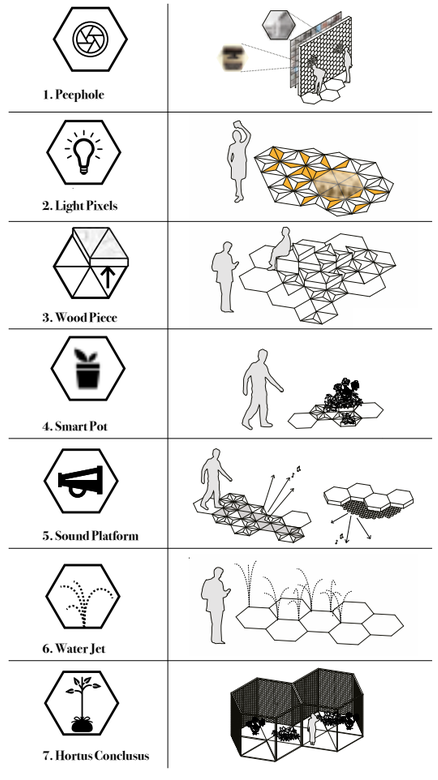
The second step is an urban intervention, which is constructed in the physical dimension, and provides multi-sensorial interaction with the users. We call these interventions the new urban monuments. The urban intervention consists of seven intervention typologies, to be disposed on the ideal grid through the cluster museum. Since the analysis recognized a shifting boundary of the idea of the cluster museum, the intervention has been divided in several phases of development. Every phase - and the first one in parti-cular - will have a determining component of analyzing and registering the users' interaction with the public space, in order to guide the successive phases towards a more correct definition of the cluster museum. The seven installation typologies are meant to bring closer the digital and the physical world. Their presence on the map show how important has become for our culture to explore the space through our digital devices and gives a prefiguration of what the space has to offer to the user.

Smartphone interface

MemoMapp, as a final product, is a platform that gives the possibility to users to explore the cluster museum, but also interact with it. Their physical presence in the space is enriched with additional layer of meaning, through the use of digital technologies. It is enabled to stimulate all the senses, by seeing, hearing, smelling, touching…



Urban intervention scheme and Urban intervention's proposals



MEP-WEAR

Data logging about cities

Project

MEP-WEAR

Data logging about cities

Principal Academic Tutor

Sara Comai
Department of Electronics, Information and Bioengineering, Politecnico di Milano

Academic Tutors

Matteo Matteucci
Department of Electronics, Information and Bioengineering, Politecnico di Milano
Raffaella Mangiarotti
Department of Design, Politecnico di Milano
Secil Ugur Yavuz
Department of Design, Politecnico di Milano
Paolo Tamborrini
Department of Architecture and Design, Politecnico di Torino
Paolo Prinetto
Department of Control and Computer Engineering, Politecnico di Torino
Giuseppe Airo' Farulla
Department of Control and Computer Engineering, Politecnico di Torino

External Institutions

STMicroelectronics
Others: Mapability, UILDM, Società Cooperativa Sociale Arcoiris, Lions Club Milano Borromeo

External Tutor

Daniele Caltabiano
STMicroelectronics

Team Members

Andres Sebastian Calvachi Gomez
Product Service System Design, Politecnico di Milano
Francesco Frulio [Team Controller and Communication Coordinator]
Product Design for Innovation, Politecnico di Milano
Gabriele Perfetto
Physics of Complex Systems, Politecnico di Torino
Gianluca Picco
Electrical Engineering, Politecnico di Torino
Lucia Rossazza
Computer Engineering, Politecnico di Torino
Erfan Sheikhi
Mechatronic Engineering, Politecnico di Torino

Project description

The main goal of MEP-WEAR is the proposal of a wearable device for the collection of data about cities, to improve the quality of life of the citizens. MEP-WEAR stems from the MEP (Maps for Easy Paths) project, a project awarded by the Polisocial program of Politecnico di Milano, whose aim is the enrichment of maps with information about the accessibility of urban pedestrian pathways for people with mobility problems, like persons with

The team attending the Wearable Tech Torino

disabilities, elderly, parents with strollers, and so on. With MEP, data about accessible paths, pictures about obstacles and other useful information about accessibility are collected through common smartphones or tablets, exploiting the sensors and the camera available on such devices. The idea of MEP-WEAR is to extend the solution to wearable devices, which could be also more convenient for people with motor impairments. During the first phases of the MEP-WEAR project, i.e., during the study of the state of the art and the brainstorming process for ideas generation, the team and the tutors identified possible extension of MEP in multiple directions, while incorporating the original purpose of city accessibility enhancement. Indeed, a wearable device, possibly connected with a smartphone, allows not only to include many more specific sensors, but it also makes possible to satisfy needs and requirements of a wider target audience.

MEP Team brainstorming at the Wearable Tech

Interesting results have been obtained thanks to a very close-knit and active team: Francesco Frulio (MSc in Product Design for Innovation, Politecnico di Milano) and Andres Sebastian Calvachi Gomez (MSc in Product Service System Design, Politecnico di Milano) have given their contribution to all the design-related parts, from the survey for requirements analysis to the mockup of the user interfaces for the visualization of the collected data, to the detailed research on material, shape, ergonomics and attractiveness of the wearable device, to the design and development of a 3D-printed mod-

el. On the other hand, Lucia Rossazza (Msc in Computer Engineering), Gabriele Perfetto (MSc in Physics of Complex Systems), Erfan Sheikhi (MSc in Mechatronic Engineering), and Gianluca Picco (MSc in Electrical Engineering), all from Politecnico di Torino, brought to the project the needed technical perspective, focusing both on technical and economic aspects and ranging from software and architecture design to prototype development and testing; carrying out qualitative and quantitative data analysis of survey results; developing the business canvas model and applying other management tools. The result of the multidisciplinary competences of the team is a wearable solution characterized by efficiency, effectiveness, flexibility, and customizability, considering also the trade-off between reliability and low-cost technologies, without overlooking usability, ergonomics, and aesthetic aspects.
The MEP-WEAR group has also taken advantage of partners like MapAbility, UILDM, Società Cooperativa Sociale Arcoiris and Lions Club Milano

Mep Team during a meeting with the tutors

Borromeo to better investigate users' needs; the hardware prototype development of the wearable device has been carried out with a close collaboration with STMicroelectronics.

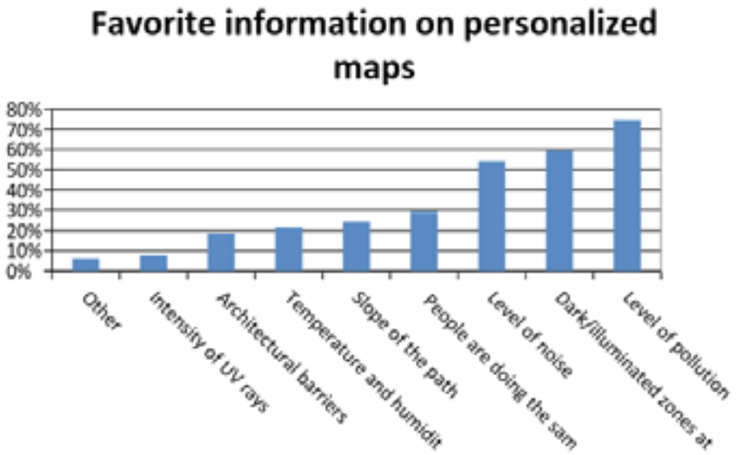
Team members working

Abstract

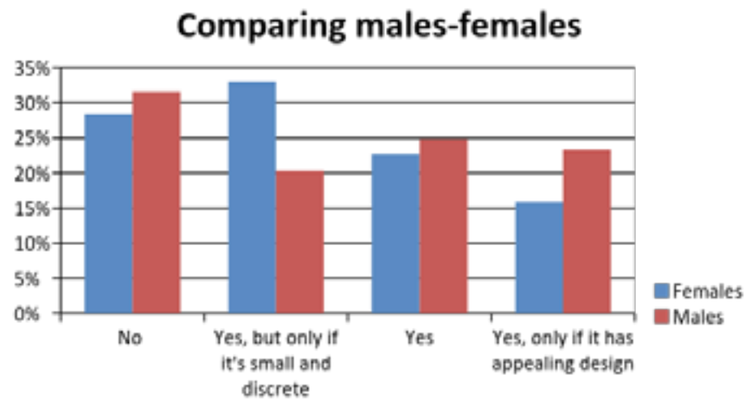
The proposed solution is a wearable device ecosystem, called IOM (Internet of Mobility), consisting of: a wearable device, which exploits a set of different sensors to collect several environmental data; a multiplatform application delivered both on mobile and web platforms, for an intuitive and appealing visualization of the collected information. Around the wearable device, however, there is much else, since people wearing it will feel part of a community collaborating for the wellbeing of the city. IOM represents the network of the wearable device users that in an unobtrusive way collect (Big) data about the environment while moving in the city; collected data are sent to remote servers, where they are stored, processed and then made again available to final users in the form of interactive and customizable maps through mobile and web applications. Not only final users, but also external interested stakeholders, such as municipalities, will have access to these open data, in order to carry out a deep and wide analysis which could bring to light previously unknown and valuable information and correlations that might be exploited to improve life conditions in the city as well as the city itself.
In a future scenario of a well-diffused service, it would be possible to have near real-time, continuous, widespread and detailed maps about temperature, humidity, UV, light, noise and pollution. Thanks to this data, sharing the life in cities will be easier and pleasant, contributing to individuals' wellbeing and to that of the whole community. Besides, MEP-WEAR team is pretty confident that this kind of service will produce not only immediate and tangible changes on citizens' lifestyle and correlated stakeholders, but also long-term effects, from the enhanced life conditions in cities and the resulting greater attractiveness of the townscape itself and increased touristic flow, to the birth of innovative products, services and businesses able to discover new values in the aforementioned data.
In this context, the MEP-WEAR project is contributing to the birth of an innovative and disruptive change in the concept of environmental data acquisition, moving from the traditional fixed sensors networks to dynamic and "living" networks, where every citizen represents a moving measuring station.

Understanding the problem

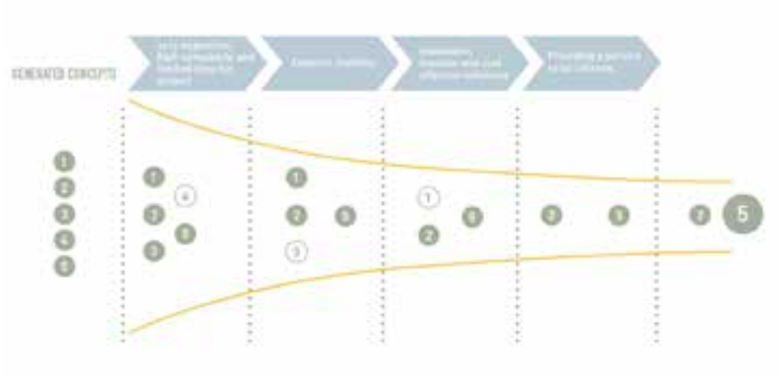
The MEP-WEAR project deals with the issue of gathering data about cities, processing and returning them to citizens in order to enhance their life quality. All these operations have to be performed with a wearable device. The present project, namely, takes input from external institutions like MapAbility, UILDM, ARCOIRIS, Lions Club and STMicroelectronics. In particular the project in exam is a complementary activity to the yet existing MEP project that is also related to cities data storage, but with particular focus to path accessibility for people with disabilities.
Within this context and with such first target to satisfy, the group has started the activity by making brainstorming activities aimed at generating ideas in a divergent way about wearable devices and related services.
The idea eventually chosen regards a wearable device, together with an application and a web platform, capable of measuring and storing environmental data (like the level of pollution, darkness/illumination of roads, temperature, etc...) in order to make them accessible both to the single user and to the community, in the form of raw data or personalized maps. The team has chosen this concept in order to satisfy fundamental users' needs like flexibility, customizability (such a device can in fact meet the requirements of very different users personas ranging from a pregnant lady to a runner, to people with disabilities) and efficiency, in terms of power consumption.



Townscape data people would like to monitor as emerged from the survey conducted by the team



Women and men's preferences about the aesthetic of a wearable device



Funnel graph for the concept decision making

Among the aforementioned needs one has furthermore not to forget the aesthetic aspects of the product, the latter in particular has to be appealing and easy to use. The solution has eventually been designed as being part of a clients network in order to meet the willing of many customers in taking part and improving the life quality of the whole community.
To better refine and satisfy such needs the team has carried on a survey that has been spread among very different customers' classes in terms of geographical provenience, culture and age. The following analysis therefore constitutes the fundamental basis from which the final concept refinement and implementation takes place.

Exploring the opportunities

As already said above, our project started with the study of state of art on wearable technology, phase which has helped us in understanding which could be some needs and requirements which have been remained unaddressed till now, a very significant aspect for the development of our solution. We identified five main competitors in devices that exploit sensors to measure data about the environment all associated with mobile apps that displays the data collected.
However, a closer look has revealed the existence of opportunities that the competitors currently are not exploiting. First of all while the majority of competitors keep the data close within its service, IOM has focused on the possibility of sharing and open them to fully exploit their potential. Moreover, the majority of competitors apps provides services restricted to a specific field, without providing a complete user experience because of the lack of a multisensorial approach. IOM has overcome this lack by gathering previously disjointed offers from many competitor in just one App.
However, we can state that the one of the most significant research activity the group has carried on is the survey, named "Living the city", crucial in driving the group's final decision towards a truly user-centered design activity. The reason for the creation of a survey was to better understand the problem and users' attitudes and interests about the wearable technology sector identifying their needs and requirements and accordingly, shape our service around those needs. This has allowed the team to group all the possible identified users in 6 main personas (the movement impeded, the runner, the walker, the biker, the exploiter and the external users), considered as the target users for our service. In a nutshell, the performed analysis acquires a critical role in directing the project activity, both at the level of hardware/software features specifications and at the product's design.
The design of the device was another critical challenge as the set of sensors inside and the fact that it has to be worn over the clothes, have influenced its final shape and material construction. In fact, many materials has been explored such as aluminium and other metals, later discarded in favour of polymer because of their high price and possible interference with the electronic inside.

The team working on the first prototype of the wearable device

First 3D printing experiment

3D printed shell

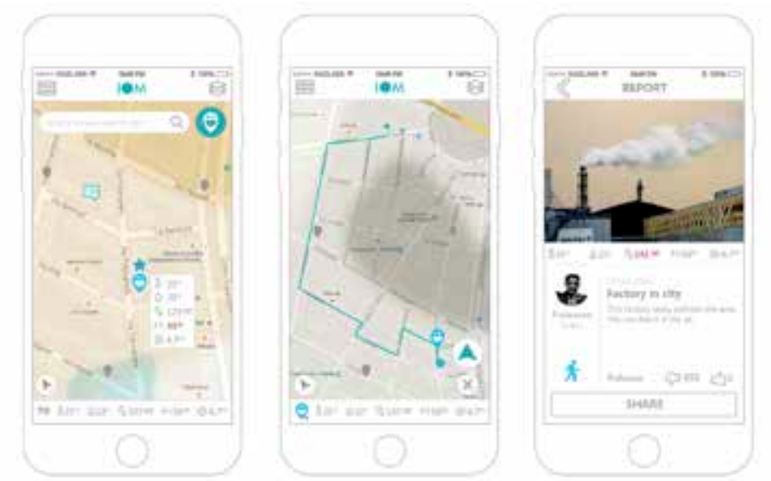
User Journey Map

Generating a solution

The proposed final solution is IOM (Internet Of Mobility), whose basic idea is to develop an application for mobile devices that interfaces with a wearable device which contributes to the mapability of the city in an alternative way. The wearable device features different sensors, which are temperature, humidity, UV, light and noise. Key points of the overall service are interactivity and customization: the maps and the creation of personalized paths offer to the user an experience fitted to his/her own needs of that particular moment. The chosen solution allows to store and process anonymous data, therefore enabling everyone to access them. It's easy to clearly understand the high potential of our solution: by making third parties exploit the value in our data, in the future we may see prospects for the birth and improvement of new products, services and businesses. For example, knowing which paths people are used to do, can be very interesting for planning the

Web platform screens showing humidity data and zone

new shops, restaurant, public and private services; environmental data are instead exploitable by real estate companies, energy service provider or photovoltaic system provider.
A detailed design of the overall service was performed. The IOM Mobile Application and the IOM Open Web Platform, will work side by side with the wearable device designed in order to collect the data through the various sensors it contains. Both mobile application and web platform will be open to everyone, even though with some limitation: only the users who will buy the IOM Wearable will be able to create his own personalized path by login-in in the app and web platform.
The approach used for the development of the wearable was not as often happen in product design, by starting shaping the aesthetic shell and only subsequently putting inside the electronic components. On the contrary the design has started from the inside, building a shell around the sensors board. The concept comes from the idea of creating a wearable device that could be used both as a badge and then attached directly to clothing, both as a watch and then fastened to the wrist.
This solution comes from a basic necessity for the functioning of the project, namely the collection of environmental data from the device. This means that the latter must always be in contact with the air and therefore cannot be positioned below the user's clothes. The design has not been just theoretical: with the help and support of the STM Microelectronics part-



Some of the IOM mobile application screens showing how the app displays the users' data

ner the team developed a working prototype of the device, proving the effectiveness and potential of the project.
IOM operates in the scenario this paradigm shift that the world is living in these days, in which IoT and connected devices are re-shaping our lives and cities, giving an idea of what the future might bring to us soon.

Top view IOM wearable device

The IOM wearable device

View of the final STMicro-electronics prototype

IOM wearable used worn as a smartwatch

IOM wearable used on a bike to collect data while cycling

IOM wearable worn as a pin badge over clothes

Main bibliographic references

- F. Long, "Real or Imaginary: The Effectiveness of using personas in product design" 2009.
- L. A. I. a. G. M. Atzori, The internet of things: A survey, 2010.
- S.Lovell, D.Rams, As Little Design As Possible, 2010, Phaidon

Useful links

Project blog:
- http://mep-wear.tumblr.com

Link to the “Living the City” survey created by the team:
- https://docs.google.com/forms/d/1GXvhjclwXJ7yB-LBESR3sM_ldpWNcLb6D2hqfFrZYuY/viewanalytics

Link to the analyzed data from the survey:
- https://drive.google.com/open?id=0B0NqWeXIO3jSWlRMUm5rRmctbWM

ADAM03

MEMINI, a Watch to remember
Wearable technologies for elderly care

Project

MEMINI

ADAMO3

MEMINI, a Watch to remember - Wearable technologies for elderly care

Principal Academic Tutor
Fulvio Corno
Department of Control and Computer Engineering, Politecnico di Torino

Academic Tutors
Emanuele Lettieri
Department of Management, Economics and Industrial Engineering, Politecnico di Milano

External Institutions
Principal institution: Caretek S.r.l
Other Institutions: Consoft Sistemi S.p.a.

External Tutor
Luca Feletti
C.O.O. of Caretek

Team Members
Catalina Castellanos Castaño
Product Service System Design, Politecnico di Milano
Nicola Ferri
Computer Engineering – Embedded Systems, Politecnico di Torino
Federico Andrea Iannarone
Architecture, Politecnico di Milano
Pietro Lombardo
Management Engineering, Politecnico di Milano
Giulia Piantoni [Team Controller and Communication Coordinator]
Management Engineering, Politecnico di Milano
Giuseppe Luigi Leandro Russo
Computer Science and Engineering, Politecnico di Milano

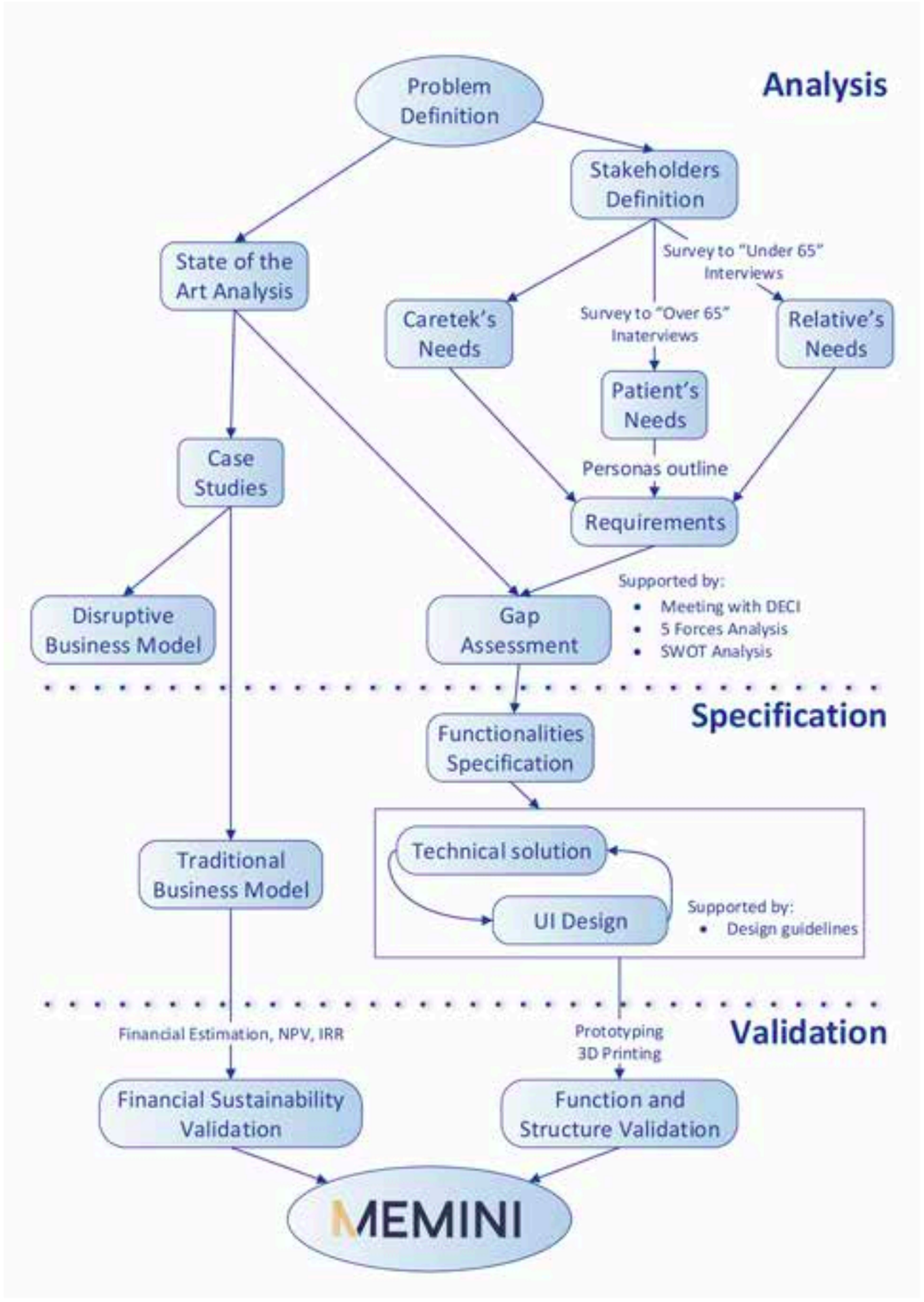
Project description
The MEMINI project aims at exploring a new generation of wearable devices that could be used for addressing the needs of the even growing elderly population.
The project is firmly grounded in the domain of Ambient Assisted Living (AAL), that includes technical solutions for creating more accessible and more helpful home and life environments for people with special needs.
The approach followed in MEMINI is both incremental and innovative. Incremental, because it built upon the extensive experience brought by the industrial partner, Caretek, and by other industrial and academic experts working on related projects. Innovative, because it adopts a horizontal, open and standard-based system architecture, contrary to most available and proposed solutions, that tend to use a proprietary and vertical approach.
The study follows rigorous and multi-disciplinary methodologies, as shown in Figure 2, that cover the wide domains of user requirement analysis, market analysis, product and service development, technical specification and design, business planning, and final validation. Each domain is tackled with the most suitable methods, and information is circulated and cross-validated across the different activities, to reach a comprehensive and holistic vision for the final proposed product: the MEMINI system.
The multidisciplinary skills of the students composing the group, ranging from electronics to architecture, from management to service design, from computer science to economics, were successfully integrated both in the MEMINI product, and especially in the process unrolled by the group.
MEMINI is composed of a wearable smartwatch, a base station, and a cloud service, complemented by a comprehensive suite of embedded, mobile and web software applications. The system is internet-enabled, and exploits the connection given by the base station or, when outdoor, by the user smartphone. The system is oriented both to the user in need (elderly or with mild dementia), as well as to his family, caregivers and doctors, thanks to the availability of relevant data on-line.
The technical aspects of the system have been designed according to the best technologies available on the market for computing, sensing, communication, battery, and materials points of view, always keeping into account procurement and production costs. In parallel, the economic aspects have been sorted out by exploiting a modern service-based progressive offer, that could be right-sized according to market and user demands.
The feasibility of the proposed MEMINI system has been assessed, both from the technical and economical points of view. In addition to being a specific concrete and feasible solution, MEMINI is also a platform upon which a new breed of devices (mobile, wearable, domestic) and of health-related services could be designed for the future of Ambient Assisted Living.

Tasks and skills
All team members performed the initial state of the art analysis. Then, sub-teams were formed: Tech Team (Nicola and Giuseppe), Mgmt Team (Pietro, Giulia, Federico, Catalina).
Catalina Castellanos Castaño brought a user centered design perspective in creating surveys, Personas, analyzing requirements, barriers and GUI. She made App and Website mock-ups and graphics of report.
Nicola Ferri: main referent for the TechTeam. He took part in the Hackathon in Turin and in meeting with DECI, designed a feasible architecture and realized the prototype, demos, dashboard, website, application.
Federico Iannarone proposed a design for all solution. He designed the

smartwatch and base station, prepared drawings and renders, in addition to digital and 3D printed models. He also created surveys, performed interviews and took part in DECI meeting.
Pietro Lombardo took care of deeper case studies analysis, business model definition. He was the main responsible for feasibility analysis of the solution.
Giulia Piantoni: team leader (controller and coordinator). She took care of the communications with tutors and among members of the team and of putting together results, took part in DECI meetings, survey analysis, interviews and shaped business model, marketing plan, market analysis, feasibility analysis.
Giuseppe Russo helped in designing a feasible architecture. He took part in Hackathon and realized dashboard, application, demos.

Abstract

Nowadays in the western world, two main trends are giving birth to several opportunities and threats from social, political, legal, environmental and economical perspectives: the aging population and the third wave of the digital revolution. IoT and wearable devices in particular are technologies that enable new products and services for wellness and for elderly.
This project wants to (i) understand the evolving needs of elderly affected by Mild Cognitive Impairment (MCI) and other related stakeholders, (ii) discover how the market is currently addressing them (including technology and service provided), (iii) provide clear directions and plans to a company similar to Caretek (a young Italian SME, producing ADAMO, a wearable for elderly) willing to create a new solution in this market and profit from it.
Through literature review, interviews, surveys and multiple case studies, this research has been able to collect all the necessary insight to address its objectives. It has been found out that: (i) Elderly and their relatives need a peace of mind that can be granted only through enabling and enhancing independence (also through remembering supported by technology), contact capability in case of emergency and prevention of stronger impairments; (ii) Two technologies (AAT and Wearable devices) are currently used for addressing the identified needs. In the wearable market, the top 20 companies own the 85% of the customers. However, there is space for differentiation and niche capturing in the MCI application of wearables. (iii) Companies like Caretek can create a new product service, namely Memini, developing excellence in customer intimacy. Differentiation emerges in developing a system of interconnected and independent devices that provides ad hoc functionalities for elderly with MCI.
The defined solution (product/service and related business model) is feasible both from a technical/design and economic perspective. Useful recommendations and indications for future steps are provided. They are sufficient to start the testing phase of the prototype created and enable a company like Caretek to start a new entrepreneurial challenge.



Flow chart

Understanding the problem

The project was developed by investigating the current context, market offer, technological developments and, most importantly, by understanding the stakeholder's needs and requirements giving special attention to the end user.

Understanding who are the main stakeholders and their needs is the base for a user centered design [1]. Surveys, interviews and a personas method have been used for this goal.

It has been found out that main consumers are elderly people with MCI, and their relatives are important actors in the purchase decision. The first ones are 65 to 75 years old, with a medium to high level of education and living independently. The second are mainly between 40 to 50 years old, with a full time job and medium to high income.

After conducting a series of surveys, both with people above and under 65 years of age, semi-structured interviews with potential users and professionals and a literature review, the following guidelines were used to develop the solution.

The use of an object to which the end user is accustomed to wear highly improves its acceptance, thus a watch was selected as the wearable. The focus needs to be on the user experience and how the different actors interact with the service as a whole. Regarding MCI, it was established that as a heterogeneous condition, it is difficult to fit the user into a group and the solution needs to be modular to accommodate to different degrees of memory impairment.

The understanding of the context and the user's needs as well as the requirements from all the different stakeholders lead to frame the project by finding a gap in the current market and developing a user centered design considering desirability, feasibility and viability.

Exploring the opportunities

As stated by analysis of Statista[1] , the whole market of wearable devices is increasing and the trend will continue worldwide: in 2010 its value was around 6.3 million US$ and the forecasted value for 2018 is of 12642 US$, led by wrist worn gadgets.

As result of the state of the art analysis conducted through case studies it has been proved that the wearable market is full of opportunities: their identification can start by providing a customer segmentation. The following points want to identify per each main segment the related needs and existing solutions.

• Young adults: they use wearables during their free time or at work, to keep track of their health, amount of physical activity and connect multiple devices (Solutions: E.g. ViFit).

• Sporty people, athletes and coaches, need resistant products that provide useful amount of data (Solutions: E.g. AIQ, Boogio, Tanita)

• Patients. In this category there are both patients in rehabilitation or people suffering from chronical diseases (Solutions: E.g. Boogio, WinPack, Biovotion Solution).

• Elderly people, that live at home and may have diseases, but want to be more independent from caregivers (Solutions: E.g.: AMON, The Better Alert System, Lively, GoSafe). Currently available solutions do not answer all the users' needs: there is space for innovating in this niche market.

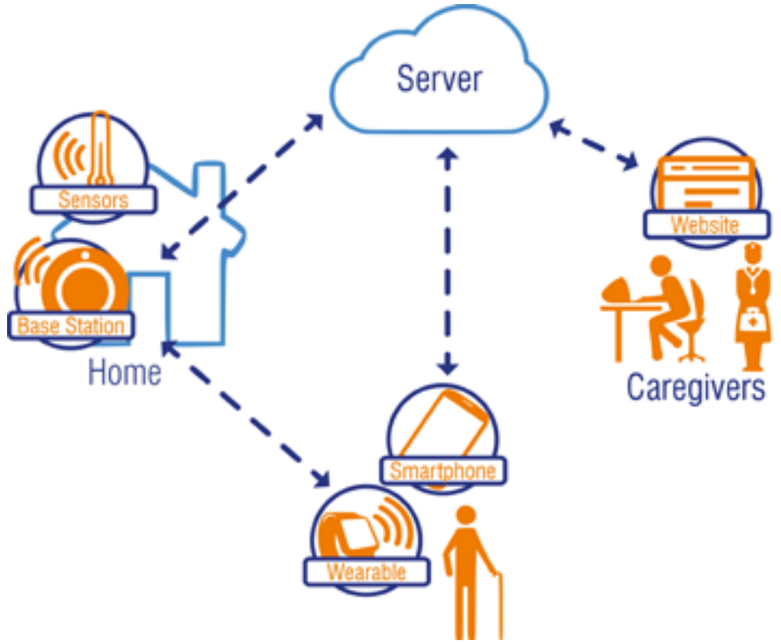
Considering suggestions from all the named solutions and focusing then on the wearable market for elderlies, interesting features are identified:

[1] http://www.statista.com/statistics/203722/smartphone-penetration-per-capita-in-western-europe-since-2000> 2014 (accessed October 2015)

- Emergency Button, in the form of a base station or wearable device (often a pendant or a watch) connected to a base station
- Fall detection, performed by a wearable device communicating with a base station
- Outdoor monitoring

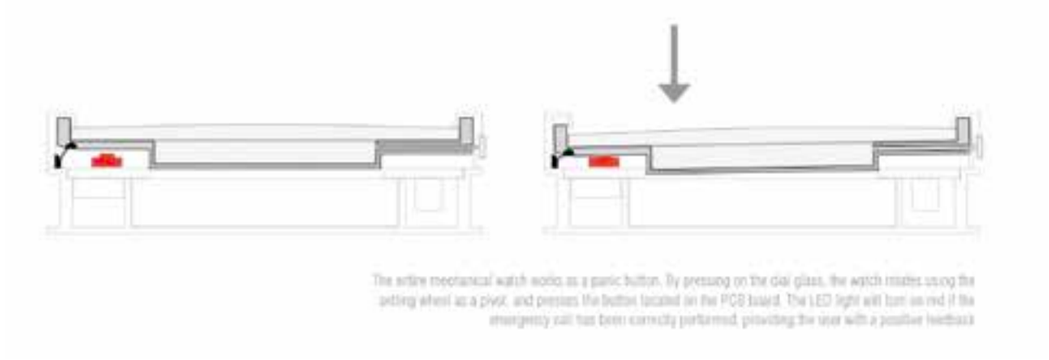
However, devices satisfying all of the above, do it at the expense of battery life, since GSM and UMTS connectivity or even GPS require them to be charged every day. The problem, as pointed out by Caretek, is that the elderlies would not like to charge their watch every day. Conversely, the surveys carried out show that outdoor monitoring is one of the most requested features. Alternatives to the current battery technology have been explored, but energy density in batteries is quite steady, and energy harvesting techniques are not even close to providing sufficient power for our use case.

The final solution aims, among others, to solve the technological barrier of battery life by using a smartphone as a backup base station, since the surveys have shown that most elderlies already use a smartphone.

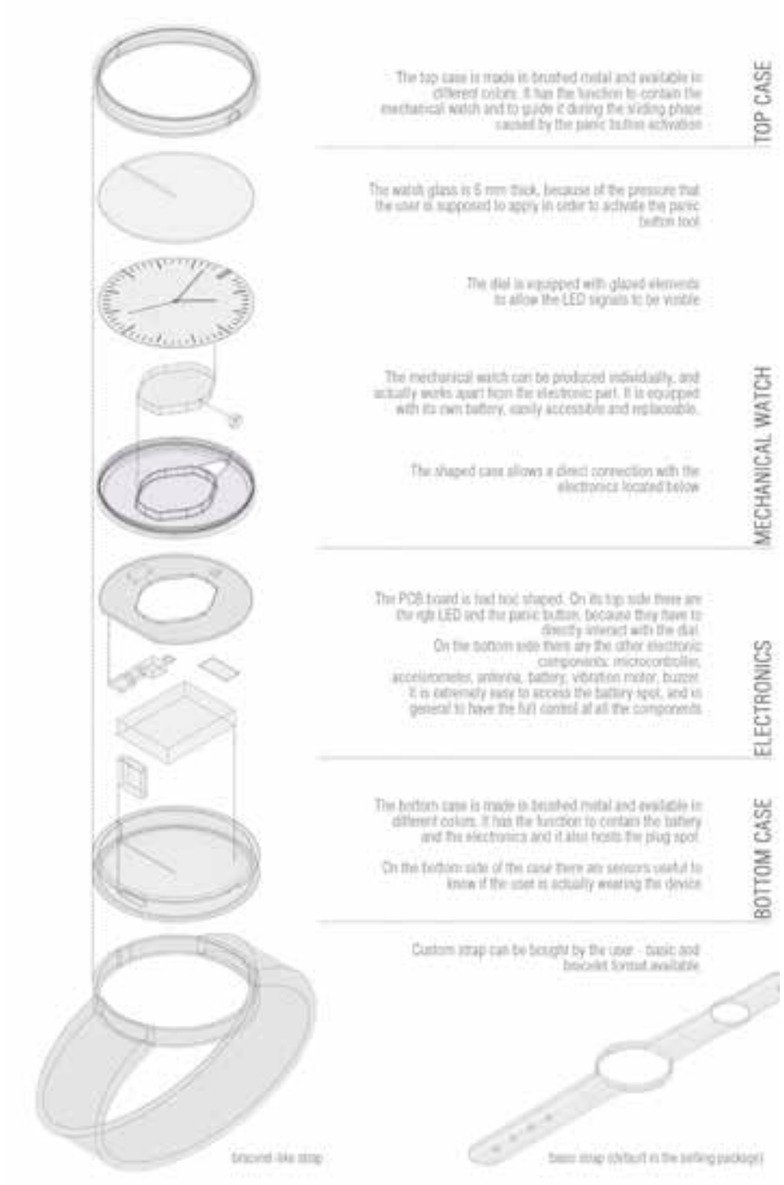


Solution

Smartwatch

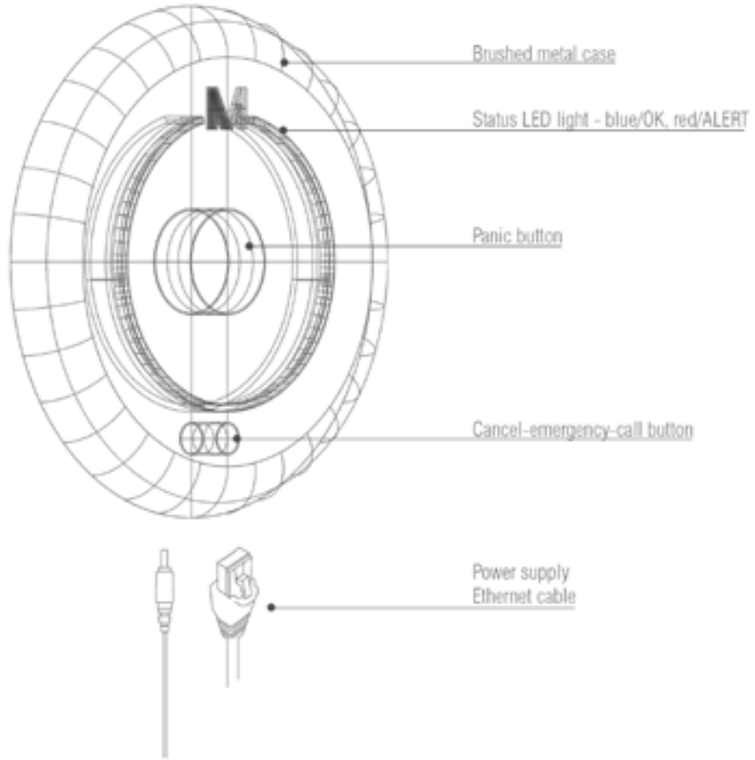


Panic Button



Components of SMart-watch

Components of base station



Base station

app mockups

website mockup

Generating a solution

The main outcome of the project is the creation of Memini, a wearable for elderly people, especially those with MCI. Considerations regarding their physical and mental condition have been key for designing both the interfaces that they will encounter as well as the product that they will be wearing.
Memini is the opportunity to support elderly and give them value in terms of:
• Independence: with a navigation system and an emergency signal button, the MCI-affected elderly increases the ease of living alone
• Remembering: remembering taking drugs, appointments and others
• Contact: through the functionalities of Locate, Emergency Call and Measure Environment, enhance the ease of contact caregivers or relatives in case of emergency situation and be located.
• Quantify Yourself: ability of monitoring activities and of having rough data analysis, provided both to elderlies and to the relatives or caregivers.
• Preventing: using Serious Games. More and more required and used by rehabilitators and doctors, licenses of serious games are acquired from external providers
The solution can offer all of the above through the following components:

- a wearable, a watch to be worn by the elderlies
- a base station, to be installed in the home of the elderly, along with optional connected sensors .
- a Memini smartphone application
- a web service, providing both an API for the devices and a website

All of this is possible nowadays at a reasonable price, because of the growing diffusion of mobile internet connectivity and smartphones. These technologies, which are progressively entering everyone's everyday life, serve as foundation for some of the most important functionalities of Memini, such as outdoor monitoring and geolocation. In fact, the smartphone is used to provide internet connectivity to the watch when it cannot connect to the base station
As for the traditional base station, prices for advanced microcontrollers have dropped considerably in the last few years, allowing the development a flexible, secure and maintainable device with a lower budget.
Memini is inspired by the Design For All principle, addressing some of the shortcomings of its competitors. Memini is meant to be usable and pleasing to the eye, to provide safety, wellness, functionality, respecting the dignity of the individual that will use it. It is designed to be recognizable, but not a reason of labelling and social exclusion [2].

Main bibliographic references

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For further information on ASP:
Web: www.asp-poli.it
YouTube: www.youtube.com/asppoli
E-mail: info@asp-poli.it

Communication design
Annarosa Zucca

Graphic editing
Officine Gutenberg

Photos
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Project Coordinator
Maria Grazia Comini