PRINCIPAL ACADEMIC TUTOR
Stefano Capolongo, Dept. ABC, Politecnico di Milano

ACADEMIC TUTOR
Claudia De Giorgi, Dept. DAD, Politecnico di Torino
Cesare Maria Joppolo, Dept. DENERG, Politecnico di Milano
Cristina Masella, Dept. DIG, Politecnico di Milano
Giulio Mondini, Dept. DIST, Politecnico di Torino
Gabriella Peretti, Dept. DAD, Politecnico di Torino
Riccardo Pollo, Dept. DAD, Politecnico di Torino
Francesco Scullica, Dept. DESIGN, Politecnico di Milano
Virginio Quaglini, Dept. ABC, Politecnico di Milano

EXTERNAL TUTORS:
Lino Ladini, Architect, CADOLTO
Thomas Fritsch, HT Group
Andrea Zamperetti, Architect, Salini Impregilo
Alberto Beretta, Engineer, Oppent
Antonio Cianci, Engineer, Airlite
Franco Mola, ECSD
Christine Nickl-Weller, ENAH
Maurizio Mauri, Doctor, CNETO & Fondazione CERBA
Fausto Francia, SItI – Società Italiana di Igiene
Daniela Pedrini, Engineer, SIAIS
Gaetano Settimo, Istituto Superiore di Sanità

TEAM MEMBERS

Francesca Bullo
Industrial Production Engineering, Politecnico di Torino

Emmananda De Martino
Civil Engineering
Politecnico di Milano

Natasha De Santis
Architecture
Politecnico di Milano

Chiara Fignon
Architecture
Politecnico di Milano

Zhao Shuyi
Systemic Design
Politecnico di Torino

Executive summary

Quick obsolescence of facilities, given to the rapid and technological evolution, is one of the main issues that hospitals have to face today. It has been demonstrated that hospitals' lifespan has reduced from almost 500 years to no more than 100 years. Therefore, hospital designers are challenged to find solutions to adapt to this rapidly evolving environment (CAPOLONGO, 2012).
Since XXI century many researchers, scholars and designers have tackled the subject of buildings' flexibility, trying to develop a concept that could respond to these fast-evolving needs, not only in the medical fields (Habraken, Astley, Kendall, etc..) However, when dealing with healthcare facilities, an additional element should be considered: complexity. In fact, first of all, the different requirements of several stakeholders have to be considered and satisfied. On the one hand, patients that should be hosted inside an environment where safety, decorum, comfort and hygiene are granted. On the other hand, medical, administrative staff as well as workers, volunteers and service providers should also be taken into consideration, since they have to spend a large amount of time inside the building and have completely different and sometimes conflicting needs. In addition, efficiency and rapidity should be constantly granted to patients and other users, therefore, the need for flexibility should not, in any way, stop or disrupt the daily activities performed inside the hospital.
Starting from these considerations, this project represents the second step of a research started two years ago by OPEN BUILDING group belonging to the ASP XI Cycle and has the objective of reinforcing the concept by demonstrating its technical feasibility and practical implementation as well as expanding it to several functions inside healthcare facilities. In fact, the concept was developed only for single and double inpatient room by the previous team.
Starting from the Open Building concept (Kendall, 2000), the previous project team was able to scale it down by providing a rough design of the Open Room, ensuring flexibility inside inpatient wards. According to their approach, the whole building, as well as the room are divided into three different parts depending on their durability: Primary, Secondary and Tertiary structure, which are closely interconnected.
The aim of HOS.T research project is, therefore, to deepen the analysis, precisely defining structural requirements, production, installation and transportation constraints and to try to adapt the previous Open Room concept to several different spaces inside an healthcare facility, such as for example staff break room, doctors' offices, ICU room and several others. of 9.6x2.5x3.5m, which is able to host several different functions, and that could easily be plugged in and out from a fixed structure. The room is divided into three separate and independent parts that perfectly fits with transportation maximum allowed sizes and that is able to grant adaptability both on the short and the long term. Once the three modules facility site to be "plugged-in" inside the Primary concrete structure, realized in parallel with the operations performed inside the manufacturing plant. Finally, internal spaces are defined by a series of removable panels, equipped with adaptable furniture that can respond to specific function needed. Given the module size and weight, many existing installation solutions were explored, to come up with the design of a customized platform and a specific mechanism used to easily push the module inside the "partially hollow" concrete structure. Since the concrete structure plays an important role in hosting the modules, it has been designed and equipped with innovative technologies, such as hydraulic jack and PTFE bearing pad, making it a very unconventional structure compared to the common building.
Due to the complexity of the subject, multidisciplinary approach was fundamental to address and find a balance between the several existing requirements and constraints. Several case studies and previous researches were analysed, and experts' points of view consulted during meeting and technical visits in healthcare facilities, in order to come up with a solution that could practically and technically be implemented. The advantages generated by this new approach cover multiple aspects, such as time saving, high flexibility and long-term cost reduction.
The time required to complete the building which is almost halved if compared to the one needed for a traditional construction. Off-site and on-site operations can be performed at the same time, reducing the project

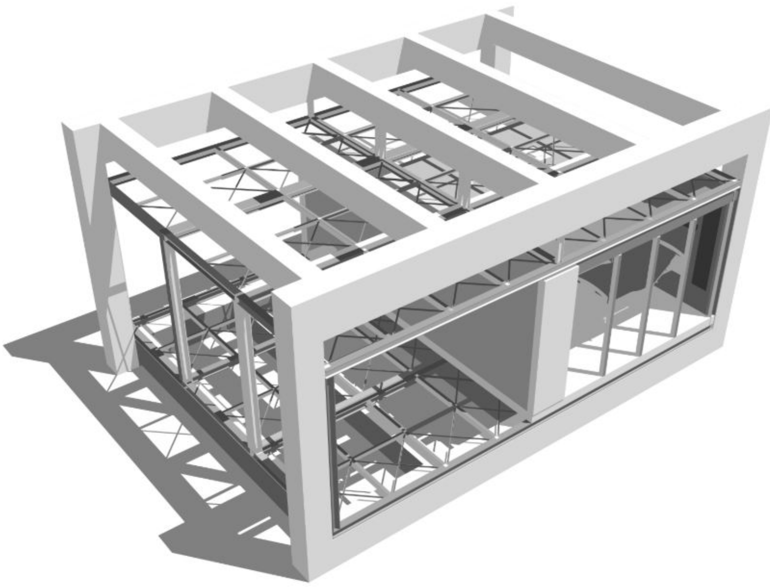
Wan Chih-Wei
Interior Design
Politecnico di Milano

Devin Tan
Civil Engineering
Politecnico di Milano

schedule, as well as the project budget. It can be argued that the prefabricated techniques are not excessively innovative solutions since they have been used for centuries. However, over the years, it has always been considered as low-quality technique, often used for temporary solutions. Today, opinions are changing, since new materials are being used which are characterised by a very high quality and long duration and several architects and designers are finally seeing the benefits brought by prefabrication. In addition, the more innovative element of this project is not really connected to the modules' construction technique, but rather to the concept that is hidden behind the Open Room: a flexible space that is able to keep up with changing demand, that can be easily moved and perform several functions, realized with high quality and hygienic materials.
On the other hand, the Open Room solution is able to create economic benefits, hidden behind a quite high initial investment. As a matter of fact, the cost estimation that was made referring to materials and standard operations prices revealed that the initial cost is much higher than the one generated and that the solution will be unlikely adopted by public institutions. Nevertheless, the time, money and interventions that are saved thanks to the implementation of this solution should also be considered as part of the cost estimation and analysis.

Key Words

Open Building, Flexibility, Healthcare System, Hospital, Prefab



Project description written by the Principal Academic Tutor

According to the World Health Organization (WHO), the environment is defined as 'an integrated system of human and physical factors exercising a significant effect on health, considered not only the absence of disease but as a complete physical, mental and social state'.

One of the most important challenges that architectures for health must cope with is to be resilient to social, economic and clinical changes and, meanwhile, to ensure that the healthcare system, services and assets respond to the constantly changing needs and the specificities of several country's healthcare system and organizational models.

The rapid evolution of medical knowledge and technological tools determined healthcare facilities' unsuitableness after few years of their construction. Therefore, scholars and professionals, involved in hospital design, are called to look at new strategies in order to respond to the current and future challenges.

Starting from these needs, the more consolidated approach is to ensure flexible health facilities. Flexibility is the ability of a building to respond to service change to different time cycles. In relation to the health issues, the flexibility in hospitals should include a multi-scale vision ensuring real efficiency of the services provided with respect to continuous changing systems, social and economic needs, epidemiological trends. Flexibility can range from the planning level to the local services' network system, from the health buildings in which delivers all the services to the mono-functional environmental units; all these layers should be structured with respect to organizational and managerial levels in an adaptive and resilient way.

In recent years, the knowledge in flexibility to adapt to service change has been developed and analysed by several scholars from different study fields: it is the ability of a structure to be able to change its functions and environments in the short, medium or long term, based on the costs and users' needs. This capacity for transformation can be ensured only by a building designed in the pre-design phase in accordance with technological, structural and plant engineering criteria specifically oriented towards the flexibility of the entity itself.

As a consequence, flexibility has become an essential key point which all the operative and future hospitals must achieve. In recent years research in the healthcare building sector has been focusing on systems highly adaptable from the technological to the structural scale, from the building plant engineering to functional level. Several research groups are developing design strategies to improve the flexibility for the design of significant spaces which are essential to ensure high levels of quality to the growing number of new demands.

Then it is clear that hospital project, often unsuitable to meet the organizational complexity's needs of a healthcare facility, is subject to changes over time. It is necessary to define technological and constructive solutions that permit the environmental flexibility to guarantee future changes with minimal impact on the entire building systems and users.

Currently, several scholars are deepening the Open Building approach: it deals with a strategy based on constant surface flexibility, the ability to change and to adjust to new layouts without increasing its area. There are spatial and functional redistributions and the attempts to design inner spaces with a high level of adaptability. By reducing excessive and useless dependencies and entanglements among these components of the project, it is possible to ensure their operation without interference or damage to the others. A preliminary distinction between durable elements and those that are more prone to be changed, allows easier, quicker and low cost actions and a greater level of customization. Sometimes, this kind of approach can be useful when dealing with quickly changing regulations and strict bureaucracy that does not suit the long timeframe of the designing and constructing process of complex structures, such as healthcare facilities. For the application of the Open Building approach to healthcare facilities, it is necessary to individuate three systems: Primary System (the Structure), Secondary System (the Components) and Tertiary System (the Equipment).

Starting from this approach, a research work is giving rise to a prefabricated module system for hospital environments able to guarantee maximum adaptability in inpatient wards. Starting from the know-how on prefabricated bathrooms and operating rooms, as well as several prefabricated hotel rooms, it is possible to imagine and design a prefabricated inpatient room during the construction phase. It

can be of easy installation and replaceable in case of changes for maintenance and/or modification of the function. This is easily seen that several existing hotels and office buildings are designed with prefabricated rooms that change for different users and present possible variations in creating the interiors by combining colours, materials, lighting, furniture, etc.
As new trends require greater emphasis on research and outpatient clinics' spaces, inpatient wards will always be present in a hospital. Its layout is very different from a hotel one for several logistical and functional aspects, but the user's rooms are very similar, although differences persist on their dimension, engineering plants, furniture and materials. The patient hotel tries to merge these two typologies, in fact it is a hotel that offers accessible rooms for discharged patients and some outpatient clinics and a specialized staff (nurses and doctors) within the structure.
The structural grid must be regular and should guarantee the maximum future flexibility (predictable layouts) and futuristic one (unpredictable layouts). It is crucial to understand and define the maximum adaptability of a structure over time and therefore the dimensional issues should guarantee several future scenarios. Current trends introduce technologies that permit the constant and variable flexibility. Moreover, structures realized with reinforced concrete or steel are preferable with structural framework between 7 and 8 m. In addition, several case studies present technologies that allow fix prefabricated modules to the façade, such as the Martini Hospital in Groningen, or to transform setbacks spaces, verandas and terraces to improve the environments' dimension.

.

Team description by skill

The team is composed of Master students from different discipline and each of us contributes to the project in correspond to his/her capabilities. Given the size of the team, the communication is carried out in both verital and horizontal manner so that everyone is always updated and no information is lost. Regardless of our position in the structural organization, everyone plays an important role in making the project works as a whole. In overall, the job description for each member is listed as follow:

1. Devin Tan
   Role: Team Leader, Team Controller, Structural Engineer, and BIM Drafter
   Job Description: Arranging both internal and external meeting with tutors and stakeholders, Identifying and distributing workload according to deadline, Managing budget and project expense, Conceptual study of room layout, Conceptual and preliminary study of the structure and construction procedure, Integrating the structural drawing in BIM.
2. Emmananda De Martino
   Role: Structural Engineer and Construction Manager
   Job Description: Conceptual study of structural design and construction procedure, Cost estimation of the modular room, Construction time management of the modules.
3. Francesca Bullo
   Role: Logistic Manager, Production Manager and Business Analyst
   Job Description: Transportation analysis of the module, Production process of the module, Business model estimation, Cost and time estimation of the modular room.
4. Natasha De Santis
   Role: Design Coordinator and Architect
   Job Description: Coordinating the design team, performing preliminary and detailed design of the rooms including layout, wall panels, ceilings, and materials.
5. Chiara Fignon
   Role: Architect and Marketing
   Job Description: Performing preliminary and detailed design of the rooms including layout, wall panels, ceilings and materials, preparing project book and poster.
6. Zhao Shuyi

Role: Furniture Designer and Marketing
Job Description: Identifying and designing all of the furniture elements inside the rooms, 3D rendering of the rooms, Printing flyers, Making promotional video.

7. Wan Chih-Wei
Role: Lighting Analyst, BIM Manager and Marketing
Job Description: Conceptual study of room layout, Lighting analysis of the rooms, Integrating architectural drawing in BIM and checking BIM model to ensure zero clash between structure and architect element, 3D Rendering and Virtual Reality of the rooms, Making promotional video.

Goal

The concept of Open Room developped by a previous ASP research team is capable to solve the current flexibility issue. However, the concept still needs to be refined and explored even further. As a matter of fact, hospital is not only about inpatient rooms; there are other rooms whose functions can be considered essential so that the hospital can work as a whole. Moreover, different rooms have different needs and requirements, which means that some minor or even major adjustments might be required. In addition, flexibility is not restricted to a single room; it also concerns the interaction between each room and the possibility of changing the room layout every day due to different needs.

The aim of current HOS.T team is, therefore, mainly linked to the deepening and extension of the concept developed by the previous ASP Cycle. As a matter of fact, one of the main weaknesses of the previous Open Room project was the fact that just one room had been designed and studied, without considering the possibility of using the same concept to integrate other functions inside the same space. It is true, indeed, that single inpatients rooms are probably the most common and used environmental units inside an healthcare facilities, given to the increasing number of chronic diseases and the decrease of the average duration of hospitalization. Moreover, studies are showing that single rooms are preferred with respect to double or multiple rooms. However, several users should be considered inside hospital scenarios and several needs should be addressed too, to be able to offer the most complete, flexible and efficient solution.

Keeping all these elements in mind, a preliminary selection of environmental units was made, on the base of the function performed and the frequency with which these rooms could be found inside a healthcare facility. In addition, low implant redundancy has also been selected as a criterion to define the rooms and functions that the Open Room could address. More redundant and simple rooms were therefore selected, and several possible layouts proposed before coming up with the final one. Compared to the XI Cycle, HOS.T project provides a wider solution, gathering seven different functions inside one single room.

Beyond increasing room flexibility, HOS.T research group was also required to provide a “stronger” solution, especially from a structural point of view. The three structural layers – Primary, Secondary and Tertiary structure – should be thought and designed as a whole. Every part should be studied separately from the other ones, with its own characteristics and requirements but then, they should be joined together to be sure that no conflicts exists between the different elements. The final output of the project, indeed, was supposed to be a ready to be installed room for which all the possible issues connected to construction, module manufacturing, transportation and installation had been addressed and solved.

That is the reason why, compared to the previous project, the construction and installation phases were more deeply analysed and customised solutions were provided, in order to present a complete and functioning concept, under several points of view.

Understanding the problem

Healthcare infrastructure planning, design and its project management involve a complex interaction of factors that determines the distributions of its resources. In the planning process, these factors are interrelated and an interdependent multi-disciplinary approach is required in order to organize the hospital in an efficient way over the time. A strict division of works inside the team of designers (engineers, architects, etc.), producers and customers is impossible since the solution that can be functional from an engineering point of view, may be inapplicable for architectural needs or vice versa. At thé dame time the needs of producers and customers must be taken into consideration for the evaluation of the healthcare facility feasibility.

As a consequence, the designers should look for some "shearable constraints" in order to implement all the operations connected to such a project.

What is currently happening is that hospital designs are incapable of adapting to the needs connected to hospital organizational complexity and keeping up with the ever-growing capacity of hospital technologies (Astley et al., 2015).

As a consequence, the flexibility has become a key element for all the changes due to the progress of medical and technological acknowledges.

In addition to that, sustainability has become one of the most widely recognized issue around the world. Healthcare facilities, being one of the most integral, social and economic infrastructure to support the lifeline of a city, are also a subject of this matter.

In fact, hospital obsolescence has experienced a fast increase over the past decades, which ultimately will lead to a major sustainability issue (Capolongo et al., 2012).

In several developed countries, this issue has been tackled by governments that decided to incorporate this concept into their local regulations. As a result, new facilities nowadays are required to consider sustainability as an input in their design, while all the old facilities are to be assessed of its sustainability performances (Capolongo et al., 2014).

Exploring the opportunities

New technological trends and attention to patients' needs have strongly influenced the way in which new hospital layouts are designed.

From the architectural point of view, the main layout typology is the "slab" but new trends are introducing the "vertical monobloc" to shape the hospital. The functions hosted by the former layouts are mainly diagnosis and cure, administration and reception with an intrinsic flexibility in the spatial organization. For what concerns the second possibility, there can be 3 common different organizations of layout, that can be easily seen in the table below:

Double fold body

Triple fold body

Fivefold body

The research on hospital layouts and configurations is an ongoing process. It is of big interest the Piano-Veronesi (2001) made by the arch. Renzo Piano and the Italian Ministry of Health, dr. Umberto Veronesi, of that time. This research aimed at studying the functional organization and spatial distribution for the contemporary hospital, both considering the technical and social point of views. Four levels of intensity of care are considered: intensive care, high care, day care, day surgery, low care. The Piano-Veronesi project did not give structural design rules but offered functional and typological plans and sections with several proposals of spatial organization even at the inpatient room scale.

The evolution of the hospital layouts is going towards the application of the structural flexibility concepts; this leads to the use of primary structures which must be as much regular as possible in order to be easily divided into modules of dimensions 7 to 9 meters ensuring the passage of the wheeled beds in the inpatient rooms.

The first attempt of merging flexibility and prefabrication was in the 30s when Buckminster Fuller designed and produced prototypes of residential units easy to assemble with a two-piece prefabricated bathroom. After the Second World War, many studies were conducted on prefabrication so as to satisfy the rapid demographic growth; in the Sixties, flexibility became a dominant aspect in the building constructions.

It was not only a matter of housing, but also for healthcare facilities the concepts of flexibility were made in practice in the last decades. The first and most famous solution is the use of containers: it allows future expansions but it does not allow changes in the so-called “primary” system since containers are also part of the structural element. However, their dimensions are small so that the comfort of the inpatients inside is reduced.

A second approach to solve the flexibility need is the use of some prefabricated panels which constitutes the internal walls of the hospital: the Industrial Flexible and Demountable (IFD) Building. This technique implies that there must be a complete planning and design of the internal layout of the room in advance so as to let the company produce all the panels. Some instructions must be given in order to mount on site the panels.

The advantages of this approach are multifold: the workers are exposed to less risks on site since the complete production of panels is done in a safe and controlled environment, the construction time is reduced since the production of panels starts even before the actual building phase and the time spent for the assembly is much lower than the one required for ordinary wet technologies, very high flexibility of the internal spaces since panels can be removed, changed or even upgraded.

Generating a solution

Having understood the complexity of a hospital, which are the needs of the community, the state of the art and the trends for the future, it has been possible to design a solution that took into consideration all the concepts aforementioned, with a specific attention towards flexibility.

The intention was to apply the Stephan Kendall’s Open Building approach and the Open Room concept to develop a design procedure obtaining smart, contemporary and prefabricated rooms inside modular prefabricated elements deliverable on site. The aim of this innovative system is realizing multiple room layouts and configurations, within the same dimensions, in order to have a variety of solutions according to several different needs.

After a deep analysis of the two solutions advantages and drawbacks, the decision was taken to mix them together and come up with a concept which could grant flexibility both on the long and short term. Therefore, modules have been designed with an IFD approach in order to have the most flexible solution, without having to renounce to the advantages of a rapid construction and installation procedure. In fact, a prefabricated modular room, divided into three parts (modules) for easy transportation, have been designed. The modules are then put in a primary structural frame with a plug-in mechanism and assembled once positioned inside to form the different rooms. As a consequence, the flexibility would be ensured both in short terms (5-10 years with IFD approach) and in long terms (20-40 years with Plug-in concept).

National and international case studies have been analysed in order to define the most suitable structural grid for the primary system, which is between 6.00 and 9.00 meters. In addition, the study of hospital standards and spaces required to host furniture and technical equipment, finally led to the definition of a rectangular structural grid which could host seven different environmental units with different functions.

The secondary structure, composed of three separated modules as well as the tertiary system are totally manufactured inside the factory and are then transported on site to be plugged inside the primary structure.

Main bibliographic references

Afifi, T. A., Khuwaitem, K. A., Alberini, M., Brambilla, A. Franca, A., Palumbo, M. (2015). Open Building: Open Building for Future Healthcare Environments (Unpublished ASP paper). Alta Scuola Politecnica, Milano, Italy.

Anvari, B., Angeloudis, P., Ochieng, W.Y. (2016). A multi-objective GA-based optimisation for holistic Manufacturing, transportation and Assembly of precast construction

Astley, P., Capolongo, S., Gola, M., Tartaglia, A. (2015). Operative and Design Adaptability in Healthcare Facilities. TECHNE, 9, pp. 162-170.

Astley, P., Hind, R., Mills, G., Price, (2011) A Open infrastructure planning for emergency and urgent care

Bernd Rechel, Stephen Wright, Nigel Edwards, Barrie Dowdeswell, Martin McKee (2009). Investing in hospitals of the future.

Brambilla, A. (2015). Open Room For Future Healthcare Environments: A Prefabricated Room for New Strategies in Hospital Flexibility (Unpublished master's thesis). Politecnico di Milano, Milano, Italy.

Cadolto Brochure, available at: http://pdf.medicalexpo.com/pdf/cadolto/cadolto-brochure/

Capolongo, Bottero, Buffoli, Lettieri (2015). Improving Sustainability During Hospital Design and Operation, Springer

Capolongo, S., Buffoli, M., Nachiero, D. (2012). Flexible Healthcare Structures: Analysis of Possible Strategies and Technologies. Ann Ig, 24, pp. 543-552.

Capolongo, Buffoli, Nachiero, Tognolo, Zanchi, Gola (2014). Open building and flexibility in healthcare-strategies for shaping spaces for social aspects.

Capolongo, S. Buffoli, M., Gola, M., Rostagno, M., Nachiero, D. (2014). Making Hospital Healthier: How to Improve Sustainability in Healthcare Facilities. Ann Ig, 26.

Capolongo et al. (2014). Flexibility in Healthcare structures.

Carlisle, P. (2017, June 19). Debut for Two Liebherr High-Top Tower Cranes on World Tallest Concrete Module Structure in Singapore. Thailand Construction. Retrieved from: http://www.thailand-construction.com/debut-for-two-liebherr-high-top-tower-cranes-on-worlds-tallest-concrete-module-structure-in-singapore/

David Allison (2015). Developing a Flexible Healthcare Infrastructure

Eric I. Antillón, Matthew R. Morris and William Gregor (2015, October 12) A Value-Based Cost-Benefit Analysis of Prefabrication Processes in the Healthcare Sector: A Case Study

Gateway, M. [Mersey Gateway] (2016, June 19). Mersey Gateway – Moving the MSS to Its Sixth Casting Position on The North Approach Viaduct. Source: https://www.youtube.com/watch?v=Lry-gDQ2WgI

Kendall, Teicher (2000). Reidential Open Building

Kendall S. (2007) Open Building. A Systematic Approach to Designing Change-Ready Hospitals

Kendall, S., Kurmel, T., Dekker, K., Becker, J. (2014). Healthcare Facilities Designed for Flexibility: The Challenge of Culture Change in Large U.S. Public Agency.

Kronenburg Robert (2008). Portable Architecture-Design and Technology.

Legmpelos Nikolaos (2013, May 10) On-site Construction Versus Prefabrication

Liu, J., Soleimanifar, M., Lu, M. (2017). Resource-loaded piping spool fabrication scheduling: material-supply-driven optimization Moore, C. (2017, March 5).

Marriott Expands Its Modular Construction Initiative to Accelerate Growth. Digital Trends. Retrieved from: https://www.digitaltrends.com/home/mariott-modular-hotel-rooms/

Matt, D.T., Dallasega, P., Rauch, E. (2015). On-site oriented capacity regulation for fabrication shops in Engineer-to-Order companies (ETO) pp. 197-202

Matt, D.T., Dallasega, P., Rauch, E. (2014). Synchronization of the manufacturing process and on-site installation in ETO companies pp. 457-462.

McGraw Hill Construction (2011). Prefabrication and Modularization: Increasing Productivity in the Construction Industry.

Mills, Grove, Egan (2015). Breaking the Pre-fabricated Ceiling-Challenging the Limits for Modular High-Rise.

Moiseenko Ivan (2017, March). Economical feasibility of prefabricated solutions in healthcare design and construction industry.

Morby, A (2015). Mersey Gateway Bridge-Building Machine Ends Run. Construction Enquirer. Retrieved from: http://www.constructionenquirer.com/2017/01/09/mersey-gateway-bridge-building-machine-ends-run/

Mortenson (2014). Prefabrication Research Study Results

Smith Ryan E., Timberlake James (2010 by John Wiley & Sons, Inc.). Prefab Architecture. A guide to modular design and construction ù

Youyi Zhang (2017). A Framework to Improve Modular Construction Manufacturing Production Line Performance

www.promozioneacciaio.it for amount of steel computations

http://www.comune.milano.it/wps/portal/ist/it/amministrazione/trasparente/OperePubbliche/listino_Prezzi/Edizione+2018 for material expenses