Advanced Construction and Building Technology for Society
Joint CIB - IAARC Commission on “Customized Industrial Construction”

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“Advanced Construction and Building Technology for Society”

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Foreword

CIB Working Commission, W119 on “Customized Industrial Construction” has been established as the successor of former TG57 on Industrialization in Construction and as a joint CIB-IAARC Commission. Prof Dr Ing Gerhard Girmscheid, ETH Zurich, Switzerland (Coordinator of the former TG57) and Prof Dr Ing Thomas Bock, Technische Universität München, Germany are the appointed Coordinators of this Working Commission.

The workshop is hosted by the Chair for Building Realization and Robotics located at TUM within the Bavarian high tech cluster, the Master of Science Course “Advanced Construction and Building Technology” and by IAARC-Academy representing the research training program of the International Association for Automation and Robotics in Construction (IAARC). The workshop will concentrates international researchers, practitioners and selected top-students coming from 8 different professional backgrounds (Architecture, Industrial Engineering, Electrical Engineering, Civil Engineering, Business Science, Interior Design, Informatics, Mechanical Engineering).

Industrialization in Construction will become more customer oriented. Systems for adaptable manufacturing and robot technologies will merge the best aspects of industrialization and automation with aspects of traditional manufacturing. Concepts of mass customization can be implemented via the application of robots in construction and building project/product life cycle as prefabrication processes, on site and in service as socio technical systems. Topics include, but are not limited to the following aspects of Automation and Robotics in Construction:

- Industrialized Customization in Architecture: Mass Customization off site, Factory Production, Logistics and Factory Networks, Production
- Logistics/ Site Automation and Robotics: Mass Customization on site, Site Automation, Site Robotics, Site Logistics for Automation, Systems and Technologies, Automation and Robot oriented Site Management
- Automation and Robot Oriented Design: Design and Buildings Structures Enabling efficient use of Automation and Robotics, Modularization, Product Structure, Building Information Modeling

Due to insufficient number of submissions, the current CIBW119CIC Workshop has been postponed for next year (2013). The included submissions in this set of Proceedings comprise contribution of the 2011 MSc ACBT students, which are going to be orally presented to the new academic year (2012-2013) MSc ACBT students. We would like to inform you that the call for the next official CIBW119 Workshop will be made in March 2013, hopefully to obtain a greater number of submissions in order to successfully host the event.
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Mass customization limitation and guidelines in prefabricated construction

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Purpose In the start of 20th century, most economies in the world were industrialized economies. This industrialization introduces the mass production concept along with other strategies like mass distribution, mass marketing and mass media¹. Mass production covered most industries in our life and one of the newest industries which adopt mass production strategy is building construction industry. However, a combination of advances in information and technology (Robotics and advanced equipment ) is making the production increasingly possible to mass customize - to rapidly respond to consumers with customized products at mass production prices². Mass customization in prefabricated building construction industry is a new strong tool based on integrating organizational structure over the whole value chain corresponding with information flows between enterprises product, machinery, robots, customer and all complementary sub-processes³ but in the other hand this mass customization should be controlled by some guidelines depending on some aspects like the type of building (wood, brick or concrete ), architectural aspect, location and climate where the products are targeted. Method By studying and analyzing the different types of prefabricated building construction methods (linear production, 2D production, 3D production ) which apply the principle of mass customization production the author presents the degree of customization for each method, the type of relationship between the factory and the customer and the rules which control this relation. Results & Discussion After studying and analyzing those methods of prefabricated construction and the relationship between the customer and the factory, the author considers a set of general guidelines for building design should be adopted as standards in building mass production industry according to all the data and information acquired in this research and with the respect of architectural and civil engineering standards in construction along with the consumer needs, moreover the guideline will redraw the role of the architects in building production industry.

Keywords: Industrialization, Mass Customization, prefabrication, building production, Mass production, guidelines.

INTRODUCTION
The industrial revolution(1750-1850) made a big changes in the world economy, because it almost effect all industries in every person life start from food and agriculture industry ends with transportation, by innovating a new technologies and machines which enhancing the performance of productivity in all of these fields, this improvements could be seen clearly in manufacturing industry, before the revolution, manufacturing was depending on tools and human labor and it was so slow and costly for both side the manufacture and the customer, after the revolution and the integration of new technology and machines the flow of work start to be faster because it start depending on machines, tools, and human labors in that order and of course the products efficiency was improved. After 1850 the market demand for products start to increase and add more pusher on the factories because of the increasing number of population specially in cities after the immigration of the people from superb to the cities this immigration is conceded as one of the result of industrial revelation, so they started to adopt a new strategy which called “mass production” this strategy aim to product a large amounts of standardized products, including and especially on assembly lines⁴, this concept had its maximum popularity in 1910 establishing the first moving assembly line by Henry ford which reduced the production time for model T cars from 728 hours to 1.5 hours⁵. Some of the manufactures start to add more value for their products by introducing the custom made products, this marketing strategy makes the customer to pay more for getting the product which satisfying his exact needs but in the other hand it will cost more and not all of the customers will afford it, from this point most of manufactures start to think more about the customer needs and step by step the customers start to be a part of the production progress then the mass production market moved toward new strategy which called mass customization is fast emerging as a popular business strategy which aims to also cater to individual expressed needs of end users at prices closely comparable to mass produced items⁶. This strategy covered most of industries in the world economy and had a great feedback from the customers. One of the newest
industries which adopt mass customization strategy is prefabricated building construction.

Fig.1. Henry ford first moving assembly line for ford for model T cars (1913)

This paper studying and analyzing the different types of prefabricated building construction methods (linear production, 2D production, 3D production) which apply the principle of mass customization production the author presents the degree of customization for each method, the type of relationship between the factory and the customer and the rules which control this relation.

**Prefabricated Building Construction Methods**

There are three types of prefabricated building construction methods each one of them is specify for different kind of materials, these types are:

1. Linear production (brickwork).
2. 2D production (wood and concrete work).
3. 3D production (steel frame units).

**Linear and 2D Production:**

In this type to design, build and market a home requires consideration of both products and services. A building consists of many components, which can be considered as ‘products’, while design, construction and marketing are usually regarded as ‘services’. To generate a housing development, these two aspects are again involved with housing materials and systems as the products and the design and construction of these homes as the services. When viewed as a ‘system’ for designing, producing and selling a product, “mass customization” is impossible without customizable products or communication services. In this case the services are where the customers can be interact with the factory to help them customize an end product. At the design stage the customer should determines the configuration of their home from choices given by the factory by using a selection catalogue to enable clients to easily choose from the many options. Basically the customer can choose colors of the walls, materials which are used in the house, kitchen, toilets, lighting, doors, windows and all other details which provided by the factory with full consulting service from the architects. After that all of these data transport to construction and civil engineers who will decide how many prefabricated building components (product) they going to need and what size of this components. In addition to that they provided a customer relationship management which aim to strengthen its continuous contact with its long-term customers, and warranty for their houses which could reach up to 25 years.

Fig.2. relationship between degree of customer adaption in production progress and the cost of the product.

Fig.3. The customers with the architect in the design stage (Baufritz factory)
3D production:
In this kind of building prefabrication production, Japan is taking the lead as the most advanced and industrialized fabrication systems in the world. prefabrication companies like Toyota Home is the best example to describe mass customization in 3D production.

Fig. 4. Toyota home logo

Toyota’s innovation a new manufacturing process shortly after the Second World War. Many of Japan’s industrialists were impressed by America’s speed in which they could build aircraft and vehicles utilizing the Ford mass production model of automation, assembly line, and economies of scale. In starting a new with these processes, they could evaluate the short comings of the Ford model, with a new critical eye and develop their own process known as the “Toyota Production System” or TPS. This system has been highly praised and received awards around the globe for its focus on people through mass customization and utilization of economies of scope and made an extension of conventional marital - information flows “Push production” in to a new concept based on current demands "Pull production ” this new concept aim to make the factory output to be pulled by the customers instead of pushing, so it will give the chance for the customers to have a complete synchronization between production progress, materials suppliers and the customer demands and needs.

Fig. 5. how the push / pull production works

Several industries, other than the automotive sector, have been using this production model as a basis in which to ground their own practice. Toyota Home saw the housing industry as no exception to the principles of TPS Toyota has taken 5 of its 14 principles used in automating and applying them to the prefabricated housing market.

Fig. 6. Toyota production system

The basic tenants include:
1. Just-In-Time
2. Jidoka
3. Heijunka
4. Standard Work
5. Kaizen

the Heijunka principle is giving costumer the ability to customize facilitates both customer predictability and product variety, Toyota Home keeps inventory low and in constant supply. Toyota accomplishes this by manufacturing directly to customer order. Standard work allows for Toyota Home to keep a well-stocked supply of raw materials. The future owner of a home will go to the Toyota home park where they may browse many of the options and select specifics. The Toyota home website allows patrons to virtually apply a variety claddings, colors, exterior /interior ornament in a customizable environment to suit their needs and tastes. All of these options are based on the same raw materials kept in stock so when the order is issued, they can be pulled off the shelves and go through the process of assembly to component to module to whole house erection on site. Not all of the elements that are compiled to make the Toyota Home modules and finally the completed structure are customized. From the decades of producing automobiles, Toyota understands the principles of utilizing standard components and systems make the drive towards efficiency much simpler. Each year a handful of car models are produced, many of which are modifications of the previous year’s production. A basic model with minor modifications over several years allows Toyota to understand the core structure of the automobile, and thereby produce the part with greater effectiveness and reduced cost. Therefore, the modules are standardized with customization built into the configuration and relationships between modules. The Toyota Home models: Vietriq, Smart Stage, and Espacio Mezzo are made unique by the modules
that make up the final house. There are 12 modules to a home, depending on the size requested by the owner. The modules themselves are built with a steel frame that can be easily adapted to the often-varying lengths of modules. Each of the modules’ steel frames is specifically designed for Japan’s seismic activity. When the Toyota’s modules are locked together, the structural frames of the modules in tandem create a rigid structure. The spaces inside the modules may be delineated by interior partition walls or may be defined as needed. Standard work allows the manufacturer and consumer to be extremely confident that the product they produce and receive will be of the utmost practiced quality. Toyota’s confidence is expressed in offering a guarantee of up to 60 years on the life of the prefabricated house.[12]

Gridlines and Conclusion

Mass customization covered most of industries in the world economy and had a great feedback from the customers, especially in prefabricated building construction industry, because of the integration of advanced information and technology in prefabricated building construction industry (Robotics and advanced equipment). After studying the three types of prefabricated building construction methods and the degree of customization for each method, the type of relationship between the factory and the customer and the rules which control this relation, the Author come out with some general guidelines to control this relation. these guidelines are :

1. Each prefabricated building construction methods have its own elements like main structure, components and main frame or skeleton all of them related to the main core of the building these elements are designed, manufacture, examine and testing by architect, civil engineers, construction engineers and mechanical engineers from factory itself to provide highest level of quality and comfort for the product ( building ) and maximum efficiency of load bearing, and climate resistance, these elements are the only things cannot be customized in the whole production progress in the other hand the costumers can control only the visual aspects ( color and texture )of this element.

2. At the design stag the architects should have the main role, they will provide for the customers two options, to choose one of the readymade modules which provided by the factory then add some changes by the customer to meet his own demands with total support from the factory architects or ask the architects to make a new design for them and provide them with some their detailed information which help the architects to come out with best design which meet the customer specific needs. This design will be presented to the customer, get there feedback and comments then modify it regarding these comments. the changes in the design should not have any conflict with architectural aspect and standard.

3. The factory should provide for the customer all the support which he will need to select his options by affording a full details catalogs presented in very attractive way ( computer or physical version), this catalogs should have a variety of options for each elements and detail of the building which can be customized with the help of the factory architects. This step will save a lot of time for both sides ( customer and the factory ).

4. After completing the design stag and starting with production progress the factory should keep the customer updated in all production steps and keep ready for and kind of modification from the customer, also they should give him exact date of handover.

5. With handing over the factory have to give quality certificates and warranty To prove performance, quality and durability of the house and its sub-systems to the customers. and providing for the building regular inspection and long term maintenance.

Fig.7. Module fabrication at Toyota Home factory in Japan.

Fig.8. Rendering of one of Toyota customizable home designs
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Automated Horizontal Building Construction – A new Paradigm

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**Purpose** Construction has always been a labour intensive industry, but the demographic changes, high-wage manpower and their shortage are the factors posing new challenges especially for the developed countries. This paper outlines the study for a construction project to meet the new challenges. The aim of the study and initial idea was to provide a construction solution for an urban environment while integrating certain design parameters, creating least disturbance to neighbours, applying modern construction engineering techniques and management to limit the structure erection time down to ten days. In most of the Japanese automated construction systems like Shimizu’s SMART and ABCS & Big Canopy of Obayashi, robotic trolleys/cranes are used for transportation and positioning of building elements. These systems have vertical material transportation/delivery systems for high rise buildings, but there is nothing significant for rapid construction if the buildings are longer horizontally. **Method** Seven design parameters are analysed and available real world models are studied. These parameters are decentralized energy generation, in-situ farming, in-situ resource utilization, life-work integration, rapid construction, Ubiquitous-city design and on site & off site logistics. Although, it is found difficult to fully integrate these parameter in designing the building. An underground building construction is selected, and is emphasized to mainly integrate in-situ farming as one of the design criteria. Pre-fabricated customized elements, construction automation and robots are used to reduce the labour consumption and completion time. The past two decades have witnessed an intense/active search among researchers for suitable ways to introduce robotics into the construction field. The future points to the application of IT to the construction robots for the overall processes of civil engineering work from the planning and design stages to the maintenance management. **Results & Discussion** As a result of study, the concept of a new construction robot is presented which performs horizontally. It will receive the stack of building elements from a suitable starting point and will move horizontally on the rails to reach at required location for placement. These rails are the structural members of the building as well. The proposed robot can be used for horizontal on-site logistics in combination with robotic cranes to expedite the construction progress. This will set a new paradigm of horizontal building construction in the future, but at the moment still there is plenty of room for improvement pertaining to robotics and automation.

**Keywords:** Building Construction, Automation, Construction Robotics, future perspective

**INTRODUCTION**

Socio-demographic changes are posing more challenges in addition to common construction worker problems like health & safety issues and on-site hazards. Demographic change studies dealing with elderly population growth reveal a relatively rapid increase towards the ageing society. Young worker in developed countries are already not much interested in this industry because of working conditions. It is expected that in the next half century the proportion of elderly people will increase from 7% in 2000 to 16% in 2050. This situation demands for technological solutions with the changing needs.

In Japanese manufacturing industry, research and introduction of automation and robotization was started in 1950’s. In 1970’s they were enjoying fruits of their efforts and labor productivity and labor conditions were much improved. Following that of manufacturing industry the research in construction industry was started around in 1980’s. The nationwide research activities and the research results are introduced.

As a result, at least ten weather protected automated construction systems were developed in Japan till 1995 by different companies. Currently many single task construction robots are also used in combination with automated construction systems. These have the vertical material delivery system for building construction.

This study deals with the horizontal building construction. The first phase is comprised of research on design criteria to meet the modern day needs of building construction in a city area. This includes the study of seven design parameters and their applications. The problems confronted to integrate these parameter in building construction are analyzed. The result of this procedure affected the overall concept, and opened the new direction to discuss. Finally a new approach is presented for horizontal building construction.
RESEARCH GOAL
Construction of buildings in downtowns have more issues like logistics problem in the busy day life, unavailability of storage/laydown area, disturbance to neighbors in a commercial area etc. These problems are catalyst to adapt a new approach of construction. With the technological advancement, it is already possible to reduce the construction time. The induction of automation and robotics in construction is changing the trend from construction to “production” of buildings. So a target of on-site building structure erection was limited down to ten days. The idea was to develop a construction solution for cities to implement the rapid construction on site with a concept of thinking a building as a high-quality product or a service that needs to be delivered rather than as construction. It was to be considered that the finished building itself should be highly independent (in terms of energy, resources, food, work) with life work integration at the same time.

RELATED WORK
Different automated systems are used for the horizontal infrastructure projects. Kawasaki Heavy Industries developed an automated tunnel construction system for the sea-bottom tunneling work. It is composed of shield machine and automated segment handling and assembly systems.

This system is contributing to increasing productivity and shortening construction period of time of tunnel construction work. The similar system was successfully applied to the construction of the Dover Tunnel. Correct positioning of TBMs is essential to avoid accidents, driving these machines underground is not possible without proper positioning system. It may take up to few weeks to determine the exact position and alignment. Lately, an automation solution is developed to this problem in Canada which integrates automation control mechanisms, innovative computing algorithms, and wireless network technologies. A user friendly 3-D platform is provided to describe the TBM’s real-time position state, the tunnel design and the construction progress. It aids project managers in making critical decisions on a near real-time basis. There is already the concept of horizontal skyscraper and one realized example is of Vanke Center, a mixed used building, completed in 2009 at Shenzhen, China. Its elevated structure also provides an enhanced function of protection from damage in the event of tsunami.

Fig.1. vacuum carrier lifted segments from the flat car, first use of vacuum erectors on Kawasaki TBMs

Fig.2. Horizontal Skyscraper, The Vanke Center

The architectural design, carried out by Steven Holl Architects, uses the concept of a floating ground line that results in a horizontal skyscraper over a maximized landscape. An architectural rendering of the building is shown in Fig.3.

Fig.3. Three-dimensional view showing the architect’s rendering of the building (image created by Ying Gao)

In USA, eVolo Magazine Skyscraper Competition 2011, the second place was awarded to Yoann Mescam, Paul-Eric Schirr-Bonnans, and Xavier Schirr-Bonnans from France for a dome-like horizontal skyscraper that harvests solar energy, collects rainwater, and preserves the existing urban fabric at ground level thanks to its large skylights and small footprint.

Fig.4. dome-like horizontal skyscraper
STUDY AND LITERATURE REVIEW
The first step towards the research goal was to study and analyze the design parameter with the real world examples.

Decentralized energy generation
To provide a decentralized energy generation, different practiced energy resources were studied along with related physical factors, technologies, disadvantages, storage and the efficiency. Wind, waste, sunlight, heat, kinetics and water are different energy resources at present in use. Wind power is one of the renewable energy resources to make useful energy by windmills, wind pumps or sails. It also has less environmental impacts. Many Countries like USA, Germany, India, UK, Spain, China, Italy, Canada, France and others are already using it for power generation.

Organic waste is a resource that needs to be tapped and not to be wasted into landfills or reduced to ashes and dust in incinerators. The renewable energy produced from anaerobic digestion process can be seen as a good reason for many communities to start transformation of our valuable resources. Electricity production and the usage in internal combustion engine are the common examples of biogas. Sunlight is another widely recognized renewable source of energy which is free of cost and clean energy with negligible environmental impacts. It can be utilized for power production using different technologies like photovoltaic panels (silicon/organic) and artificial photosynthesis.

Kinetics is another energy resource; human movement can also be used to produce energy by piezoelectric effect. Commuters on the Tokyo station walk on a piezoelectric sheet which generates electricity when pedestrian step on it.

Water can also be used for power generation by using water splitting, turbines or pumped hydro storage technologies. High rise building can produce power from rainwater as it falls from almost 200m in a 50 floor building.

In-situ farming
In-situ is a Latin phrase which translates literally to ‘In position’. This parameter encourages to make use of on-site available resources and harvesting the one’s own farm at his location. Vertical farming is a good way to implement in cities. There are different options for in-situ farming like aeroponics (process of growing plant in air or mist environment without soil), wall system (mounting panels to the wall with required quantity of water supply) and hydroponics (growing plants using mineral nutrient solution). Different technologies had already implemented pertaining to these options like aerofarm, parabienta, plantlab/nuvege, verticop and omega garden. First high intensity vertical hydroponic system of its kind is installed at Paignton Zoo in England to feed the animals.

In-situ resource utilization
As per this parameter, it is preferred to use the on-site available resources. The examples of in-situ resource utilization can be seen in the past like the people of the mid-coast region of Perú have used totora (plant) to build their caballitos de totora, small rowed and straddled fishing vessels, for at least 3,000 years. The Uru people, an indigenous people predating the Inca civilization, live on Lake Titicaca upon floating islands fashioned from this plant. The Uru people also use the totora plant to make boats (balsas) of the bundled dried plant reeds.
Cherrapunji, a sub-divisional town in the East Khasi Hills district in the Indian state of Meghalaya is famous for its living bridges. These people know the techniques to grow the roots of ficus elastica (rubber tree) into large bridges, and they are practicing it from hundreds of years.

According to NASA, in-situ resource utilization will enable the affordable establishment of extraterrestrial exploration and operations by minimizing the materials carried from Earth and by developing advanced, autonomous devices to optimize the benefits of available in-situ resources. Lunarcrete, also known as "Mooncrete", an idea first proposed by Larry A. Beyer of the University of Pittsburgh in 1985, is a hypothetical aggregate building material, similar to concrete, formed from lunar regolith, that would cut the construction costs of building on the Moon. There is an idea of lunar pad construction on moon using the lunarcrete.

Life-Work integration

It is a tendency and flexibility of having a choice for the employees in an organisation to have different options available to choose regarding working hours, location and decision making, considering the needs and liabilities beyond work. This is something like juggling the five balls at once i.e; work, family, friends, health, spirit (or self). One of these balls (Work) is of rubber, but dropping a glass ball like family or health can cause an irrecoverable damage.

This parameter can be integrated not only in organisations but infrastructure as well to provide the facilities for the workers.

Employers like Xerox offers flexible working hours, job sharing and flexible spending cost for child care. Beddington Zero Energy Development (BedZED) is an environmentally friendly housing development in Hackbridge, London, designed by the architect Bill Dunster to support a more sustainable lifestyle.

British developed the baily bridge during the World War II for military, and used extensively by British and US forces. These are portable, prefabricated and no special tools required for construction. The bridges were strong enough to carry tanks. The design was modular and the modern baily bridges are still in use.
There are other products like Wenzlau military shelters, modular tentage system (MTS), MECC (mobile expandable container system), air beam and air frame are available in the market for fast deployment related to shelters.

**U-city design**
The aim of U-city is to create a built environment where any citizen can get any services anywhere and anytime through any ICT devices. Tremendous speeding in ICT development has brought the conventional city in terms of intelligence, innovation and evolution to E-city and then to U-city. Many cities around the world have constructed the digital infrastructure under “smart city” or “intelligent city” projects like Stockholm (Sweden), Philadelphia (USA) and Songdo (Korea). Korea is striving to attain its ultimate vision of creating a “ubiquitous” society. Many of local governments are interested in becoming U-City, and New Songdo’s U-City project, to be completed by 2014, is the biggest such initiative among those underway at various locations around the country and the world.

![Fig.10. Songdo u-City, South Korea](image)

As an IT leader, Japan took a lead and switched from e-Japan to “U-Japan Strategy”. Since 90’s after the digital city of Kyoto, the U-City approach is adopted in Osaka City and continues to spread in the country. Currently, “Tokyo Ubiquitous Technology Project” is in progress, and a feasibility study experiment is being conducted in Ginza from February 1 to March 31, 2012.

**On site & off site logistics**
Production home building possesses characteristics similar to manufacturing processes, such as the construction of more or less similar houses repeatedly and a growing demand for mass customization of homes. As a result of these similarities, larger home-builders often attempt to view their production system as an assembly line process. Just in time (JIT) is a production strategy that strives to improve a business return on investment by reducing in-process inventory and associated carrying costs. JIT inventory systems expose hidden cost of keeping inventory, and are therefore not a simple solution for a company to adopt. The company must follow an array of new methods to manage the consequences of the change.

On site & off site logistics play an important role in the JIT philosophy. This philosophy was subsequently adapted by Toyota and other Japanese manufacturing organizations after its origination in Japan in 1950s.

Pit stops is a good example to analyze how the many functions are performed to a racing vehicle in few seconds like refueling, tires change, repairs and mechanical adjustments. The age of the modern pit stop arrived when changes were made to the sporting regulations for the 1994 season to allow fuelling during the race. By the time refueling was banned again at the end of 2009, a driver’s visit to the pits had become breathtaking in its speed and efficiency. Such is the skill of mechanics that routine tyre stops can be over in under three seconds.

Cranes are typical to be used for on-site material logistics. Japanese automated construction systems are utilizing robotized cranes and vertical delivery system by making use of modularity and pervasive technologies in construction. RFID technologies are already in use in many industries for logistics and product tracking in a highly automated environment. Kiva Systems, Inc. uses game-changing automation technology for distribution centers that helps companies simplify operations and reduce costs while increasing strategic flexibility. Using hundreds of autonomous mobile robots and sophisticated control software, the Kiva Mobile-robotic Fulfillment System enables extremely fast cycle times with reduced labor requirements, from receiving to picking to shipping. The result is a building that is quick and low-cost to set up, inexpensive to operate and easy to change anywhere in the world. Fast company magazine has announced Kiva system as world’s 23rd most innovative company.
The concept of a huge plane would have a cargo capacity of 1400 metric tons, and a range of 10,000 nautical miles with a main mode to fly 20-50 ft. over water. It would also fly overland at an altitude as high as 6100 m with a decreased range of about 6500 nautical miles.

**CONCEPT DEVELOPMENT**

The site Munich “Marienhof” (near Marienplatz) was selected in the downtown. It is a free space since World War II, located directly behind the Munich City Hall. Here the Marienhof area had been completely destroyed and was not re-built in order to mitigate Munich’s hi-density.

![Fig. 12. Location of site in Munich City from Google Maps](image)

The location is surrounded by commercial area, and many of the road around are only accessible by pedestrians. The area has tourism importance and people come here for shopping. The park on this site was providing a good green public space to counteract the city’s downtown area. So we decided to construct something underground to keep its public space intact as much as possible. Low building footprint, easy subway access, better sound insulation and less design restrictions were advantages of constructing underground.

On the other hand, generation of revenue beyond a public part was also important to attract the investors while conserving the old architecture of the historical site by not introducing a new architectural typology.

![Fig. 13. Location behind Marienplatz (city’s main square) from Google Maps](image)

Since Karlsplatz is the lowest subway station and its 34m below surface, so we assume that Marienplatz subway station is 24m below ground. The initial idea was of 6 storeys underground which may go up to 20m deep.

**Interim Concept**

We started with an idea of simple pyramidal volume displaced from the ground to create a gap leading down into the subway station. After excavating down to subway lines, subway is then utilized to transport prefabricated modules into the site for erection.

![Fig. 15. Basic idea and stacking of the modules after off-site logistics through subway](image)

The two different options regarding energy harvesting were considered: Windows can double up as surfaces to capture and harvest energy from sunlight through solar window technology, and harvesting energy from the braking power of the busy subway train lines below.
Fig.16. Orientation of prefab. modules in a cascade manner to allow sunlight to pass through floors

Fig.17. Conceptual Sketches (Left) Hotel modules (Right) Isometric view from top

Fig.18. Interim Idea about the utilization of space

The construction of shops and hotel idea further developed to underground farming and commercial hub.

**Hotel and Shops**
Pyramidal hotel structure separated from the shops lining the passageway down to the subway station.
Findings: The hotel doesn’t benefit from the underground quality, people like nice view around

**Underground Farming and Commercial Hub**
- Possible to do mass farming in indoor controlled environment.
- Position of the sight right above the subway station makes it suitable as a fresh food production hub.

Fig.19. Idea Development

**Final Concept**
After the final concept inception of construction of Underground farming and commercial hub, the final space utilization was decided. The V-shaped air ventilation and sunlight passage was modified into circular shape for better air circulation and visibility.

Fig.20. Site Plan

Fig.21. Floor Plans

First level is designed as an open market where indoor products can be sold. Second level has incorporated restaurant and food serving facilities. Third floor is comprised of special area for spa and healthcare services-nutrition/cosmetics based on plants and organic products. Botanical garden area gathers several types of plants and also a space for learning botanical sciences on the level four underground.
It has been further analyzed that:
- Different space utilization steps towards the life work integration specially for the workers of farming.
- Power plastics developed by Konarka by using OPV technology can be used for the energy generation.
- Aerofarm technology is feasible for urban farming or vertical farming.
- ABB is global leader in power and automation. Currently they are developing a project in Warsaw, Poland, in which they are using Transformers, Rectifiers, Switchgears, their SCADA system and an Energy Storage System. Gavin Hudson of ABB writes that the energy that will be recovered from a single, decelerating Polish metro car is enough to power a 60-watt light bulb for more than a week. The same technology can be used at our site as it is closed to Marienplatz subway station.

**CONSTRUCTION**

As the site is located in a congested city area, so it was found difficult to simply perform the on-site logistics of the building modules with the tower cranes. It was really important to create minimum disturbance to the commercial hub all around with many tourist. Even if the modules are transported from subway, it required bigger tower cranes with high capacity. Normally, the heavy vehicles are not allowed to enter into that area. So it was thought to adapt a completely different approach.

It was decided to use small sized prefabricated elements which could be transported easily on site. The study of on-site logistic methods in other industries revealed a technology which can be borrowed for construction. Inspired by the rail construction and maintenance machinery like rail loader, rail sleeper change machines and especially from track laying machines which automatically pick the rail sleepers and place on site accurately, a new concept of on-site horizontal logistics is proposed.

![Fig.22. Cross-sectional view](image)

**Area Distribution:**
1. Pedestrian corridor: designed for entrance but also as a passage integrated into the open market area.
2. Open market area: it contains the designated spaces and facilities for the market sellers.
3. Restaurant area.
4. Indoor farming: is developed on 3 levels of the building and interconnected by elevators in order to transport the products via subway to customers.
5. Spa and healthcare area.

![Fig.23. CPG500 Track-laying Machine Set for High-speed Railway](image)

Working on the same principle the proposed robot will collect the stack of building elements, and will move horizontally to the destination for automatically placing of elements like roof panels. It will move on the rails which also act as the structural members of the building.

At this stage the design is proposed for the horizontal on-site transportation of roof panels which will be placed on the structural members of the building. These panels are divided into three standardized sizes to fit on all locations despite of different curves and round shapes.
First the columns and beams are erected in a conventional way. Then the structural members (rails) with dual function are installed to run the robot. These rails are permanent structural members to the building. Panels are produced in 3typo-dimensions:

1- 3.25 x 4.25 x 6 (m)
2- 2.05 x 3.25 x 6 (m)
3- 1.10 x 2.05 x 6 (m)

These panels can be installed as a standardized module in the building.
The panels are designed with grooves at the required location to act as malfunction. So that those can easily be placed at right position, and make it easy for robot arm to screw it. The robots can be moved from one floor to another after the completion of each floor through a vertical mast attached with the structural members of the building.

DISCUSSION AND CONCLUSIONS

The proposed robot will provide the fast on-site logistics and higher mobility in elements transport and handling. Same like rail road construction; it will establish a new paradigm of horizontal construction with better usage in congested areas where tower cranes are not possible. There is a need to standardize the prefabricated building elements and robot oriented design to maximize the use of robot to make it economical. It still has room for improvement, but at this stage, its prototype can be developed to make it a part of an automated construction system.

Japan is already having demographic change issues, and has started using automated construction sites from last two decades. A dramatic change in this regard is anticipated especially in developing countries. All this situation predict the more use of pervasive technologies and robotics in construction.

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Feasibility of new technologies in construction applied in new developed countries

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Purpose Nowadays, the prefabrication and automation construction industry in developed countries has improved the quality of the construction industry\(^1\) in terms of working (employees) and living (Housing). This industry has focused in wealthy countries such as Germany, Japan, Korea or the USA "industrialized Countries (IC)", countries that had develop their own technologies. On the other hand Newly Industrialized Countries\(^2\) (NIC) could make a weak trough into even more aspects of the socio-cultural-economic environment. The proposed research aims to study the feasibility of the introduction of those new technologies from IC to NIC, as well as identifying the necessary conditions to reproduce those scenarios with local conditions. Therefore with that background it would be possible to establish a possible direction for its evolution Method There is a lot of literature and research concerning economic, social and political differences between IC and NIC\(^3\), there are some studies about the evolution of the industry in general, but there is limited information about the transference of technology in the construction industry. With the statistic data from companies and countries it will be possible to set a path for the future of local developments in NIC. An analysis on existing Companies and systems, and their product development, production technology, modularization, mass customization, will draw the aimed results. Results & Discussion The change in the construction industry in NIC is certainly going to happen. In order to improve the industry, and not only to copy, it must be tropicalizing. The conditions regarding economy, environment, society and culture are mandatory milestones in order to adapt the technology to local requirements. An example of today's situation is the massive construction in suburban areas in Latin America

Keywords: Building Production, Automation in Construction, Construction industry Innovation, Mass Customization, Prefabrication Industry in construction.

INTRODUCTION
The automation of contraction could be a factor to change developing countries in order to generate a better industry, to lead better life quality and to improve the human development. The construction as an industry is dangerous and not normally regulated this scenario is especially worst in NIC. The housing situation in these countries is a major deterrent to the general develop of cities, society and produces problems in national level. Examples as the Favelas in Brazil, the shanty towns in south Africa, marginal barrios spread all over Latin America and Slums all over the world, are breeding places for vandalism, drug abuse, crime and general violence, factors that reduces the possibility of development and a better quality of life.
 Approximately 1 billion of people live in urban areas of the NIC, and this number is expected to rise up to 2 billion in the next 20 years, since the urban population is growing more than ever, especially in less developed countries\(^4\). The conditions of those countries are changing faster than ever because of the global economy, affecting the habitant, the cities and the environment. Worldwide the construction industry is one of the most dangerous, with the high rate of fatalities and injuries in work\(^5\). The most developed countries have a bunch of laws to keep workers save, but in developing countries (even the advanced ones) there are not strict laws or regulations for this propose. Salaries are really low, and a big amount of people is working without having social security privileges, causing a big impact on the development of the industry, the society and finally the country. In addition to this, the workers of this industry could barely afford construction as the ones they produce, due to the high rates of the real state. In contrast with this situation the industry of manufacturing and fabrication is growing and the conditions and safety of their workers is improving, they are getting better job quality, better salaries and they have to increasingly specialize.

The automation in construction is improving the life of workers, owners and neighbors already in Japan, Korea, and Even Germany. The developing countries should follow this kind of industry, but with the appropriate measures to tropicalize the final products, according with characteristics such as weather conditions, natural resources, price, social needs etc.

GLOBAL ECONOMICAL CONDITIONS
The NIC could have several definitions depending of the organization or institution that defines it. According to the World Back (WB) the development index of this classification is also related with the gross national income, or product per capita. The WB has
divided the countries into 5 categories\(^5\) (figure 1); the groups are: low income, $1,025 or less; lower middle income, $1,026 - $4,035; upper middle income, $4,036 - $12,475; and high income, $12,476 or more. According to this information, the WB call the NIC, “transition economies”, about 28% (figure 2) of the population of the world is part of this classification. This also means that more than a quarter of the world population is making the transition into developed economies, better industries, better possibilities of human development, and also in a need of new solutions for the urban and housing conditions to improve their quality of life.

The fast growing of this economies, that represent so much people in the world, the construction industry has to be ready to react in the same velocity to the issues that will come with the development of this countries.

### Comparison between NIC and IC

By comparing the NIC and the IC construction industry, can be concluded that automation in Construction is a milestone to the proper develop of the Construction industry in NIC, and a way to help those counties to have a sustainable develop. Tropicalization of automation is an actual need for developing countries with growing population and the increase of mega cities. NIC should develop their own technology and techniques, they should use their specific resources and a create awareness to the advantages that automation will bring to develop of those nations; NIC should recognize that automation is not a reason to lost jobs but to create a better working conditions, and to improve the quality of life. The comparison between NIC and IC, has follow certain parameters that affect the population and construction industry, such as life quality, natural disasters, response to the growth of urban areas, industry and social changes.

Life quality.- Japan has achieved very high level of technology. Their innovations especially in the building industry could reduce the cost of housing and increase the number of houses build. For the first time in 2008 more than half of the world population lives in the cities; 13 of the 20 largest metropolitan areas are located developing countries, and there is a huge need to provide homes for all those people, fast, small and flexible. From this list\(^7\) of the 20th more populated cities only London(38th), New York(47th) , Kobe(49th) and Tokyo(46th) are located between the 50th cities with best quality of life, the rest are not even mentioned. Enormous megalopolis such as Mexico City, Sao Paulo, Dehli, Buenos Aires, Rio de Janeiro, Shanhai, Beijing, Jakarta, Istanbul etc. Have a very low life quality because of several reasons, from over population to an insufficient public transportation, with the exception of plenty of cities China, and some efforts in Mexico city and Istanbul to have subways, built in the last decades and mainly with the help of tunneling machines (also considered automation in construction), many of this cities from NIC countries don’t have an underground network, one or the worst examples is Jakarta, with more than 28 million habitants and a poor public transportation system (figure 3).
In addition to poor infrastructure, one of the biggest problems in NIC is the social inequality. About 90% of the economy of these countries is controlled by less than 10% of the population (figure 4); hundreds of thousands of people live in poverty, in inadequate conditions, unsafe houses and environments. The automation in construction could be the key to improve the life of these people by decreasing the cost of construction with higher quality, and providing better conditions to the workers.

Natural disasters.- Unfortunately, also those mega cities have something else in common, natural disasters. Earthquakes are common in many of those cities, together with flooding, and landslides. All over the world natural catastrophes take the life of thousands of people, together with buildings and infrastructures. Poor countries are the less prepared for this. The earthquake in Haiti destroyed a lot of cities and it will take many years to rebuild them, in Japan is a matter of few years to rebuild and improve the infrastructure to be ready for the next one. The reason is not only the money, but the research made in earthquakes and education, and the fast reaction of the population and also but not less important is their infrastructure and industry to build fast and safety. Those two points are very important in order to improve the quality of life and the human develop of people from developing countries that live in slums, Favelas or shanty towns etc. Several examples have shown us the inconvenience of totally remove them, so the change has to be gradual. The main propose to go to Japan will be to learn their automated systems in building industry and figure out how to change them in order to be able to apply them in developing countries. There are several advantages too in developing countries, such as the weather and less expensive workforce. In contrast with the actual living situation for thousands of families around the world, automate construction will not only improve their housing situation, but will provide new regulated and safer jobs, and in a long term their own research in this field.

Response to the growth of urban areas.- Current solutions for growing cities are not sustainable, huge horizontal construction is destroying fields. Low quality houses have a short time life, bad social environment and in long term produce new slums and shanty towns. Those communities made by housing development companies, only cares on profits without even care of urban design, social interaction, flexibility, or sustainability. Those mass housing areas are away from the city, with poor infrastructure, services and quality control, away from any life-work integration, live there means to travel more than 2 hours to go work. Only the GEO Company (Figure 5) had made 460,000 homes which currently provide housing to 2 Million people.

This examples show us that there is actually a market for mass production of houses, because there is a need for housing production, but under which circumstances? By continuing developing this kind of houses the extension of the city will grow together with more and more problems, this develop causes more problems than the ones that they try to solve.
Industry.- The Manufacture industry in developing countries is growing faster than ever, China, Brazil, Mexico, Korea and many others are trying to develop their industry to grow to the levels of Germany, USA, or Japan. Mexico and Brazil are trying to bring in international brands to manufacture there, Korea is developing their own products to improve its industry, and China is a mixture from both. From those examples maybe the most developed is Korea, their research in technology had taken them close to the level of Japan, meanwhile Mexico and Brazil are still dealing with foreign companies.

A great example in the industry as NIC, is Korea. Korea is following the advances in technology made by Japan but with their own research and creativity, Latin American countries should lend from the steps of Korea to grow their construction industry, but developing their own system based on their social need, weather need, human resources and technology.

One of the most notable advances of Korea are made in the automation in construction. This industry was mainly developed in IC, with Japan at the vanguard and some contributions from the north European countries, and Germany. Korea, as a minor actor between the Asian tigers has develop all its technologies into a higher level, closer to Japan than to China. Developing its own technology and systems in different brands. In the construction industry in particular they develop an Automatic Construction System Based on Robotic Cranes for Frameworks of High-rise Buildings (figure 6), something just done before in Japan.

Social Challenges.- Together with the social inequity, NIC will have to deal in the next years with the ageing population and the demographic change.

IC had created in the last decades different systems, procedures and social policies to respond to this imminent problem. In technological terms Japan and Germany have made the biggest steps into ambient assisted living, and general and medical distance care. The challenge for NIC is the absence of policies and solution for the problem that is getting closer. The world population pyramid (figures 7, 8 and 9) is changing a lot, and in the next few decades the NIC will have the same issues related with ageing population as the IC.
Without proper response in policies and technologies this problem is going to produce even more reaction in NIC than in the IC, which are already trying to solve. There must be an awareness of this in the NIC in order to develop their own initiatives and technological advances, aimed to help their own and specific needs, different from the needs in the IC.

CONCLUSION
The change in the construction industry in NIC is certainly going to happen. In order to improve the industry, the technologies have to be tropicalizing, and not only to copy. The conditions regarding economy, environment, society and culture are mandatory milestones in order to adapt the technology to local requirements. An example of today’s situation is the massive construction in suburban areas in Latin America (figure 5).

It is useless just to copy the technology, it is important to understand it, and for the NIC develop their own to continue improving the living quality and human develop. In the same way there is no need to start from zero, as we read in the last pages, the Industrialized Countries had already deal with a lot of the similar problems, and even though the idea is not to copy but to reinterpret and tropicalized those technologies, Newly industrialized Countries had to open their markets and different industries (from construction to services) to the new era of industrialization, in order to be able to provide solutions for different circumstances.

It is important to improve the construction industry and take it to the next level, to automation. For developing countries it would be a real challenge, but actions have to be taken before the technology we have now gets obsolete. It is not only about solve poverty and save money, it is also about improve the quality of the buildings. Modularity specially could be the clue to archive those goals. With mass production of units and modules will be cheaper in order the provide housing and building to the less fortunate, and improve or attach more systems and technological gadgets to the ones that can afford it. This means cost could be reduce for the ones that need it, and improvements could be attached for the ones that can afford them.

In countries with such social inequity, solutions for the ageing population need to come fast. The automation cold help not only to provide houses to more people, but also to reduce cost and be able to provide extra services for the ageing and disable. The new megalopolis from the NIC don’t have the basic infrastructure to provide mobility to all their inhabitants, rapid construction such as tunneling could provide this infrastructure, and this is the most basic example. With automatic tunneling more underground lines could be made, more water infrastruc-

ture, electricity etc.

With automated construction and the reduction of cost attach to it, could help to improve the medical infrastructure, build more hospital and clinics, create new spaces for the ageing and disable, and many other advantages.

After the comparison and the reasons listed before, we can conclude that in a short term, the evolution of construction technologies will take the NIC to the next generation of Buildings. In fact there is a huge need for those countries to start working in their own technologies, such as Korea is doing now. The already existing manufacturing technology in NIC is a good background to start their own researches, studies and posterior develops.

The feasibility of new technologies in construction applied in New Developed Countries is real. The fact that they don’t have any previous precedent could be an issue or an advantage. NIC could learn not only from the existing technologies from IC, the most important they could learn from their mistakes.

In economic terms, the NIC represent a huge product in the global economy, by applied new technologies only in China, Brazil, India, Korea and Mexico, we are talking about billions of costumers and need to be fulfilled, in comparison with the already tired markets of the IC, the NIC represent bigger incomes and market opportunities. Even with the huge expenses of starting an enterprise, research or industry in the NIC, the cost will be probably be reduce after a short period of time due to the big revenues that those huge new markets can provide.

Finally, because of social, economic, and development reasons, the introduction an application of new technologies in construction are not only feasible but is going to be the next trend in the close future.

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A “DIY” Home Personal Production System

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Purpose Rapid Prototyping, also known as ‘Additive Manufacturing’, ‘Three Dimensional Printing’, ‘Solid Freeform Fabrication’ and ‘Layered Manufacturing’, are terms referring to a group of techniques used to quickly fabricate a scale model of a physical part or assembly using three-dimensional computer aided design (CAD) data. Working similarly to a regular computer printer, with its Input/Output system but in a 3D manner, the technology, although a revolutionary invention, has not yet prominently spread out commercially, nor made its way to personal domestic use in spite of its techniques being available since the late 1980s in the areas of models production and prototype designs. Although the technology has not seen a rapid progression as other modern computerized technologies normally do nowadays in relatively short periods of time, it is easy to foresee the revolutionary changes and innovations it could bring about if it did become realistically feasible for personal use at one’s own home. Method In oppose to previous and current developments in this field, which have concentrated on commercial Rapid Prototyping, in this paper, an abstract concept of a potential Home Rapid Prototyping System design is introduced, going towards Personal Fabricators* and Home Manufacturing, with a modular approach to both its design and its functionality, while also emphasizing on the prospective value of its output and productivity. Results & Discussion The aspects intended to be heightened in this paper with this particular conceptual design include the factors that define an individual’s productivity at home and subsequently estimating their output’s contribution to society, considering the value of home manufactured products if they were to become better alternatives to market goods. In addition, the approach is intended to propose future solutions for Rapid Prototyping system designs in order to bring the technology into practical feasibility and availability.

*Universal fabrication machines, which materialize three-dimensional things from digital data.

Keywords: Rapid Prototyping, Personal Production System, Domestic Fabrication

INTRODUCTION
Although a relatively new term, Rapid Prototyping is a sort of 3D printing technology that has existed for decades, however, it has not yet prominently established itself in the market. Current developers and firms using this technology provide “services” rather than the product itself. This paper represents a conceptual design of an at-home Rapid Prototyping system for personal use, highlighting the substantial interface between the system and the average user, identifying its potential advantages, while focusing on convenient ways of making it applicable for domestic use.

CONCEPTUAL DESIGN OF A HOME RAPID PROTOTYPING SYSTEM
A comprehensive system consisting of three separate main cubical units: Design Unit, Manufacture Unit and Recycle unit, in sequence according to their use in the production process. A modular design is applied to the concept.

The first stage of production starts with the Design Unit which allows the user to enter their thoughts and ideas directly into a computer through hand sketching, computer drawings and plans which are later processed by the computer into 3D CAD figures and data sent to the fabrication stage to produce the physical 3D objects.

The second stage is where the fabrication procedure occurs, in the Manufacture Unit. The user is able to own as many as these Manufacture Units according to their needs of products to be made and their products’ range of materials. Every single Manufacture Unit produces products of a specific type of material, ex. Plastic Manufacture Unit, Metal Manufacture Unit, Wood Manufacture Unit, Glass Manufacture Unit, Textile Manufacture Unit, Rubber Manufacture Unit, …etc.
The third stage includes the Recycle Unit, which is used to process a product into its original raw material or to process a used product into a new product.

Unit 1. Design Unit: consists of a touch-screen computer with a foldable keyboard pad and a foldable sketching pad attached. The structure when in use, continually adjusts itself to the user’s position, posture, height and their viewpoints via integrated sensors.

Unit 2. Manufacture Unit: consists of cubic box that includes all the parts of the manufacturing machine:

a. Laser source: traces out the outlines of every material layer, then sinters and fuses the material parts forming a model layer by layer.

b. Scanner System: collects and focuses the laser beams onto the surface of the material sheet.

c. Material Delivery System: transfers material from the Material Supply Container to the Platform and later to the Material Collection Container.

d. Platform: carries the model being built and moves vertically down with the completion of every section to allow the next new section to be rolled onto the platform and adhered to the previously built parts of the model. A piston under the platform controls the movements.

e. Roller: adds resin to the material being processed as it rolls onto it and applies pressure to adhere each layer to the previous one on the model with each pass. Each new layer is bonded with the previous.

f. Material Supply Container (feeder): contains raw material in either the form of sheets (slices) or powder, according to the type of material being used.

g. Material Collection Container: on completion of each section, the unused excess parts of the material sheet are collected into this container as waste material, which can later be reused.

The process is repeated until the model prototype is done.
According to the user’s abilities or their preferences, the units can be either mounted on walls or free to maneuver about the house using their automated spherical wheels.

Unit 3. Recycle Unit: finished products can be processed back into their raw material in order to be redesigned or reproduced to prevent waste of unused items and useful materials in the house. This creates a balanced constant loop in which the products repeatedly go through.

All three types of units share the same proportions. The Manufacture Unit and the Recycle Unit also share the same foldable mechanism of the legs.

**Advantages and Challenges**

Bringing the technology of personal Home Rapid Prototyping Systems into realization would transform the entire home into a factory and the individuals of the household into fabricators. The advantages a Home Rapid Prototyping System could bring about may vary from the user’s personal advantages to the advantages for the community:

a. Allows the application of individuality in design and function of one’s products and personal customization.

b. Various benefits for the handicapped, the elderly, and people with limitations and difficulties that restrict them from leaving their homes include giving them the opportunity to produce their own goods at home whenever needed. This could also lead to allowing these users to start their own at-home businesses and careers with their personal manufacturing producing goods at home that have a market value, therefore increasing their contributions to their societies and the economy.

c. Allows users who live in distant communities with logistic restraints, or remote environments with difficult or limited access to certain products to easily produce those products locally.

d. The recycling and remanufacturing characteristic of the system significantly eliminates a household’s waste in all its forms, and ensures the contribution and productivity of every material and item in the house. The remanufacturing characteristic also gives the user the ability to constantly change, adjust, edit and modify their items or add new parts to them according their changing needs and preferences.

e. Providing such technologies in homes could contribute to demographic movements through enabling industries and companies to employ the redundant populations in a society, such as the retired, the aging and the disabled by providing them with production work that they are able to accomplish in the convenience of their own homes, thus keeping these individuals contributive, productive to their societies, and their presence valuable throughout their lifetime regardless of their restraints or difficulties.

f. By splitting the whole system into comparable modules, and assigning each single Manufacture Unit module for the production of one specific type of material, gives the user a free choice of choosing their desired modules according to the type of material they plan to use. Regarding mass-production of the system, modularity plays an important factor. This characteristic is also a positive factor when it comes to the financial matters by allowing the user to purchase as many units according to their needs, making the technology more affordable to the general public. Moreover, having several Manufacture Units working simultaneously together, (in appose to having only
one single unit that produces all types of materials in the house), significantly reduces the “build time” of products. Furthermore, modularizing the system increases flexibility and has other advantages such as providing easy access from various positions that is adaptable and configurable to different users at diverse locations inside and outside the house, as well as offering easy solutions for the stacking/storing of units and minimizing the space they occupy. Modularity also makes the system as a whole lighter in weight, providing comfortable logistic solutions by having several separate modules that are convenient for carrying by hand or travelling with while using various means of transportation (car, train, bus, plane, etc.). The user has the option to choose the units they would need during their travel and leave the other unnecessary ones at home.

**Fig. 8. Logistics**

In spite of the endless beneficial opportunities and promising solutions that such a system could provide, there lie challenges that the designers and developers would face. These include:

a. For an invention to be widely spread and be able to make its way to the majority, it would need to be affordable and cost-effective.

b. Concerns related to the availability, as well as affordability of raw materials that go into the production process.

c. Making the technology acceptable, practical and user-friendly to all individuals regardless of their age group or abilities, considering the point that some users may have uncertainty or fear of advanced technologies (Technology Phobia)\(^6\), especially when these technologies are introduced into their homes interfering with their habitual lifestyles that they are accustomed to. Others may have difficulties developing the skills and techniques needed for operating the system, understanding it, familiarizing with the technology and learning.

d. The idea of giving people the ability to produce their own products at home raises matters related to people substituting market products with their own personal “home-made” products, as well as companies’ financials and businesses facing Copyfrauds* and ethical issues of duplicating copyrighted material. *The practice of lodging a false claim on copyright to commercially benefit and gain control over the work or works which do not legally belong to a person or entity.\(^7\)

**CONCLUSION AND FUTURE USES**

The future development of this technology will be confined by the general acceptance and its credibility. Some of the vital foreseeable future uses may be widely seen in remote extreme environments on earth such as habitats in mountains, deserts, the poles, underwater, as well as outer space, where there are transportation restrictions, limited access to resources, and a necessity for independence, self-sufficiency and self-support.

Regardless of the above challenges, over the next decades, it is plausible that Rapid Prototyping will soon transform the way the average person sees their products and 3D printers will, before long, be available in every household printing any item on demand, turning homes into factories.

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Mass Customization in Home Industry

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Abstract: Purpose The house industry is faced with homebuyers demanding houses that reflect their personal and unique style and homes that are individually configured according to their needs. Thus, there is an increasing customer demand for variety (Hofman et al 2006)1. Through Mass Customization (MC) builders can easily provide the houses to customers of their choices. This paper illustrates how MC can be achieved in home industry and design systems of factory build houses for MC. Method Current methods of MC still have limited degree of freedom so this paper also illustrates the strategies and components of MC in general, design systems for MC of factory built timber houses2 and how modularity can affect MC. This paper explains a tool3 for interaction between architect and clients which would assist in MC. Results & Discussion Figure 1 shows proposed process for customized housing unit for MC. By creating a medium (Customization Model) between architect and clients or to take the customers desires during designing phase of houses could improve MC without affecting production efficiency but design technologies which are currently in use in factories are not capable to provide effectively planning and control design systems for MC.

Keywords: Mass customization, Design systems, modularity, technology challenges (cad/cam), Supply chain design.

INTRODUCTION

Before the invention of computer-aided design, most manufacturing processes were limited to one of two options: mass production or customization. Mass production is the production of large amounts of identical parts. Today, societies are heterogeneous in class, race, gender, way of life, and nationality. Income distribution is much more dispersed than a century ago and consequently reflects different needs and wishes1. In the housing industry, homebuyers are demanding houses that reflect their personal and unique style, houses that are individually configured according to their needs. Homebuyers do not want to buy a standard model and sacrifice what they really want in a home, but at the same time builders do not want to sacrifice production efficiencies by deviating from their standard models (NAHB, 2004). Mass customization (MC) is a new business strategy that addresses new ways of running companies to meet challenges. MC is an emerging production paradigm that seeks to design and manufacture customized products at mass production efficiency and speed (Pine, 1993). Demographic trends are forcing homebuilding industries to speed up the industrialization process through MC2. Enhanced productivity, skilled manpower shortages in industrialized countries and growing export markets are general conditions favorable to greater development of prefabricated housing industry. In study of U.S. homebuilding markets, Poliquin ET al. (2001) estimate that factory built roof systems were used in 60 to 70% of housing starts, and floor system were used around 30 to 40%. For the U.S. markets, Robichaud and fell (2002) estimated that prefabricated wall panels were used in 18% of housing starts. The homebuilding sector offers highly customized products and services with an engineering-to-order approach to markets. From MC point of view, prefabrication brings forth the benefits of industrial manufacturing environments. For instance, with prefabrication, a majority of wood frame components are designed, manufactured and delivered to building sites for assembly2.

MC is necessary to be adopted in homebuilding sector to meet the customer satisfaction. An examination of the mass housing process in Nigeria showed that the individual housing unit are built on-site individually hence in order to provide a desired house for the house owner, the design brief for each house has to be generated. This suggestion appears cumbersome but according to Niemeijer & Vries (2007), the use of computer programming will reduce or eliminate the problem3.

MASS CUSTOMIZATION (MC)

Mass customization (van den Thillart 2004, Shin et al. 2008, Benros and Duarte 2009) is a mix between the two systems that attempts to combine the low cost of mass production with the flexibility of custom work.

In general, product design, supply chain design and production system design are components of MC. MC in the housing industry context, refers to the ability to design and build customized houses at mass production efficiency and speed. These houses have been individually configured according to customer specifications. In some cases, builders allow homebuyers to customize their house floor
plan, to add custom features, components and finishes, for a price premium. However, there are restrictions on the choices offered to homebuyers. Apart from the constraints imposed by the size and shape of the plot and building and planning regulation, builders try to limit the level of choice in order to achieve efficiencies in the construction process (Barlow et al. 2003). Furthermore, the type of building system used affects the ability to offer choice.

MC strategies have been categorized primarily by the point of initial customer involvement. Lampel and Mintzberg (1996) define a continuum of five strategies that extend from no involvement (pure standardization) to involvement starting in design (pure customization). The five mass customizing strategies include: Pure Standardization (P.S), Segmented Standardization (S.S), Customized Standardization (C.S), Tailored Customization (T.C), and Pure Customization (P.C). Pure standardization refers to the case in which all products are the same and where the customer does not get involved before taking possession of the product. In segmented standardization, firms respond to the needs of different clusters of buyers, but each cluster remains aggregated and the product produced for the cluster is the same. In customized standardization, products are made to order from standardized components. Tailored customization requires a basic product that can be customized in the fabrication stage. In pure customization, the product is customized from scratch. However, there has to be some initial standard configuration, otherwise this strategy corresponds to prototyping rather than customizing.

In figure 1 line passing through MC strategies shows stages of customization. Barlow et al. (2003) used Lampel and Mintzberg’s continuum approach to categorize the strategies used by five of Japan’s leading homebuilders, all industrialized. For example, Toyota Home manufactures small standard modules that are shipped to the construction site where they are assembled to create a custom home. This strategy was categorized as segmented standardization, since homebuyer involvement does not start until after modules are assembled in the factory. In the homebuilding sector there are different mass customization strategies that are delivering a wide range of custom houses e.g. Sekisui House manufacturer’s standardized components and subassemblies that are shipped to the construction site where they are configured and assembled based on customer’s requirements. This strategy was categorized as tailored customization, since homebuyer involvement starts at the fabrication stage, before the modules are assembled in the factory. This strategy also allows for more design and specification choices to be offered.

MC requires that special products be provided in a cost effective manner. A number of researchers suggest that modularity is the key to achieving low cost customization. Pine (1993) argues that modularity is a key to achieving MC. In the housing industry, modular and panelized homebuilding systems are examples of modular architecture. A modular approach can reduce the variety of components while offering a greater range of end products. Another advantage of modularity is that it allows part of the product to be made in volume as standard modules with product customization achieved through combination or modification of the modules. While modularity has several advantages from a design perspective, it also reduces complexity from a manufacturing perspective. This is evident in industries manufacturing products such as computers and bicycles.

**Design and production in factory built timber frame houses**

A number of companies are surveyed in U.S to explore design systems for MC of factory built timber frame houses. Among manufacturers surveyed, only those producing an estimated 500 or more residential units a year were found to operate integrated and automated systems including (CAD/CAM) mainly for the production of roof and floor trusses. Only one of them used an automated system for walls. For all other surveyed manufactures, the housing component production system was handled manually in most aspects. For floor systems, some companies are selling complete floor systems manufactured their own floor trusses with wooden or steel webs that integrate propriety CAD/CAM systems according
to brand of metal plates and webs used. Engineering software designed for roof and floor trusses have reached a high level of CAD/CAM integration, from drawings to manufacturing, including assembly. They start from architectural profiles, from which structure is automatically generated, taking into account manufacturing parameters and structural design standards. A technical validation is then computed and includes consideration of codes and standards and applicable in the jurisdiction where building is to be erected. Then a cutting bill is generated; part production schedules are optimized and transferred to automated saws for cutting to precise dimensions. The parts are organized into kits and moved to assembly tables, and then a laser system projects the various profiles, numbers and part positions, ready for assembly. Wall manufacturing sector is also using similar trend in automation but to a lesser degree. Only manufacturers using a CAD/CAM software programs combining a specific family of equipment, are able to implement data sharing and interoperability. Such integration applies only to a particular subsystem (roof, floor or walls). None of the manufacturers is using a software solution capable to integrate all of manufacturing units for structural components. The partners in a homebuilding value creating networks face significant challenges in order to be able to manage information and coordinate actions under a MC strategy. Environments where a network of several companies has to integrate the downstream activities of planning, production and delivery with the upstream activities of response to market demand and product design pose a complex problem. The use of product platforms presents a way to manage the complexity by collecting the various assets shared by a set of products such as components, processes knowledge, people and relationships (Robertson and Ulrich, 1998). A well design platform is essential to connect different parts of enterprise including soliciting customer needs from order fulfillment to after-sale service. The integration of MC strategies requires the design process to take into account four basic platform strategies: commonality; modularity; scalability; and postponement (Huang, Simpson and Pine, 2005). As can be observed in catalogues of large builders on internet, some house designs incorporate such options. Sekisui house (of Japan), for example, offers around twenty-two house models, each with about fifty different ground floor plans. These can be built in either steel or timber frame, finished externally in various prefabricated cladding systems, and their interiors can be adapted to three basic design concepts (Japanese, Western or hybrid). Finally, customers can choose between different specifications of interior fixtures and fittings (Barlow and Ozaki, 2005). Maximum repetition is essential in attaining mass production efficiency and effectiveness in sales, marketing production and logistics. This is achieved through maximizing common design features so the modules, knowledge processes, tools equipment, etc., can be reused. Repetition in structural systems and dimensions seen in catalogues of large builders reflects this approach.

The most visible effect of product platforms in home-building is ability to configure variations of models quickly and inexpensively by rearranging the components within a modular design. Modular design creates a clearly defined and relatively stable technical infrastructure as MC strongly relies on ability of the product developer to identify and capture market niches, modular design should subsequently be conducive of a build-to-order configuration to meet the evolving needs of its different customers. Postponement or late configuration is one of the dominant strategies used to address MC issues. The postponement strategy implies that differentiation of products is delayed to the latest possible point in the supply chain (Bowersox and Morash, 1989), locating the decoupling point closer to the customer. A critical decision in any supply chain is determining how production will be linked with actual demand (Fisher, 1997). Decouple point is define as the point in a supply chain where a specific customer’s order is associated with a specific product. The use of the decoupling point in housing supply chains has been suggested by Naim and Barlow (2003), as a way to manage customization. Barlow et al. (2003) explored Japan’s industrialized housing industry approaches to customization, based on Lampel and Mintzberg’s continuum of five MC strategies. They study several Japanese housing companies, including Toyota Home (segmented standardization), Sekisui Heim (customized standardization) and Sekisui House (tailored customization). This exploration demonstrated that MC, in the housing industry, could be supported by several generic supply-chain models. Postponement allows standardization prior to the decoupling point, where customer orders are received. Postponement has been found to be a powerful mean to improve supply chain performance in the production of customized products (Whang and Lee, 1998; Feitzinger and Lee, 1997). This strategy could take different forms. Postponement can take place in the manufacturing by delaying final assembly, labeling and packaging. One postponement strategy proposed for housing construction is Open Building (OB) (Habranken, 1976; Kendall, 2004). OB is an innovative approach to design and construction based on organizing buildings and their technical and decision-making processes according to levels (Kendall and Teicher, 2000). By dismantling the systems and sub-systems from each level opportunities are increased for better organization, increased con-
sistency, quality and more control and flexibility for the homeowner. OB goes beyond simple postpone-
ment, providing continuing benefits for remodeling and retrofitting during the life cycle of the house. While optimizing efficiency and using a systematic production and assembly approach during the construction, OB also allows customization and future changes.

Scale-based product families are developed by scaling one or more variables ‘to’ stretch’ or shrink some of platform elements and create products whose performance varies accordingly to satisfy a variety of market niches (Huang, Simpson and Pine, 2005). Scaling in homebuilding can be found in the work of Freidman (2002), who developed the adaptable house concept responding to such needs as affordability, adaptability, and sustainability linked to various market niches. He uses scaling for wall panel specifications permitting various interior layout and variations on the house elevations.

Supply chain configuration relates to the facility location problem applied across all tiers of the supply chain (Chandra and Grabis, 2004). The primary objective of supply chain configuration is to determine location of suppliers, manufacturing facilities, distribution centers and to establish flows among supply chain members. Since a MC strategy affects the entire enterprise. Therefore, it is imperative that the strategy be reflected in the design of supply chain, from sourcing to final distribution or product (Chandra and Kamrani, 2004). The main factors considered in the supply chain configuration includes costs related to fixed investment in facilities, processing, procurement, transportation and capacity constraints.

The homebuilding supply chain is unusually large and complex (Mullens and Hastak, 2004). Product suppliers provide a wide range of stock materials (e.g., insulation, roofing) and custom components (e.g., trusses, cabinets), with delivery times ranging from hours to months. Managing the product side of the supply chain involves ensuring specified materials are on-site when needed (and not before), staged in the proper location, protected from theft and damage, and, of course, provided at the overall best value to the homebuyer. The services side of the homebuilding supply chain presents an even greater challenge. Most homebuilders who build more than 50 homes per month perform no construction work (Bashford et al., 2003). Instead, they rely on 25-30 independent trade contractors who actually build the house. Difficulties arise in coordinating the numerous independent contractors with a series of complicating factors: multiplicity of interactions between contractors, workflow variability in a long, sequential production system, and repetition of this problem across multiple homes simultaneously under construction. Mullens and Hastak (2004) suggest that the supply chain might be simplified by 1) creating value-added partnerships or simply adding additional value at a supplier or 2) increasing cooperation or better integrating suppliers, perhaps through technology (Bernold, 2005).

Proposed Customization Model for MC

For the generation of a design brief for the personally constructed house the process is simple and straightforward and it involves a face to face contact between the house owner and the architect and it is usually in a discussion format. In other to create this discussion between the architect and the prospective house owner in such a way that it would not be cumbersome, the use of a network of computer was advocated by Niemeijer & Vries (2007) for the purpose of customizing the design. The aspect by which design brief in mass housing would be customized is shown in figure 2, which is from part of the general process proposed for the customization of housing unit which will guarantee a desired house.

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Fig. 2. Proposed Process for Customized Housing Unit for Mass Housing in Nigeria (coloured stage shows involvement of customization model)

The brief for the desired house is expected to be generated by the customization model. It is expected that a programme written and run on a network of computers would serve as the interface for prospective house owner and the architect which will allow for the brief generated to be customized.
Figure 3, 4, 5, 6 are displays of customization model which is supported by programme running on a network of computers. Figure 3 is first display of customization model which shows the registration of the prospective house owner. The intent of this page is ascertaining the identity of the person and also a unique pin number would be generated for the individual. The information required here are personal can only be accessed by the model administrator. The information would also assist in the allocation of plots to the house owners so as to avoid allocating plots close to facilities that might be considered offensive to the prospective house owner based on religious ground. The “User ID” and “Password” will be generated upon successful completion of registration and this can be modified by the prospective house owner and used on subsequent occasions. 

Figure 4.0 is where the customization of the brief begins with the selection of the task that the prospective house owner wants to perform. The choice of editing building plan at the left side of the page will give the opportunity for the individual to select the house type of choice from the various ones in the data base of the housing provider. The client can edit already submitted details and the opportunity to change the password is also available. Similarly figure 5 and 6 shows preview of selected front and side elevation. The elevation of a building is a key aspect of housing design that house owners pay attention to because it often reflects their identity.
The concept of customizing industries, it is difficult to obtain the desired output from the company's viewpoint. However, it is must be noted that this can only be achieved by the specific housing provider where the information within the brief can only be printed out from their database.

Discussion

The model serves as a tool for interaction between the architect and the prospective clients in mass housing schemes. It is to gather information regarding the house type required by the clients so that the architect can adopt the brief which is the final output of the model. The benefits of this model are to the architect and the prospective clients because it allows the architect to meet the needs of the client while for the client it reduces the overall cost of getting a desired house. The benefit of the approach is that housing units developed from the process will address the client’s needs and aspirations and hence reduce post-construction changes resulting from design brief. It will also assist in reducing the overall cost of the house from the owners viewpoint.

The use of computers became the necessary medium for achieving this because of the capacity that a network of computers with the right programme running offers, this is inline with view of Pollard (2008) that stated that MC goes around the concept of “build to order”, which is to make products customer specific. This customized brief should therefore be the foundation of desired house for the house owners in mass housing schemes.

In the context of homebuilding, as in engineer-to-order manufacturing industries, it is difficult to optimize design processes because most of expertise is distributed throughout the company and its network. Moreover, the design technologies in use are not capable to provide effectively planning and control systems over such network. The companies which control well the integration of the decisions from strategy through tactics, down to operational level are in position to develop a competitive advantage. Technologies such as advanced planning and scheduling systems will make it possible for companies to carry out current transactions, to make planning and control decisions and to collaborate to solve problems (Frayer et al.,2005). in order to mass customize prefabricated wood frame components, it is suggested by survey that manufacturing sector has not been provided with proper integration scheme.

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Integrated Work Space Systems for Elderly

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Integrated work space systems for elderly CIB W119 2012 Purpose Regarding aging society mental health, Shultz et al. (2009) demonstrate that people who engaged in career bridge employment are preserving a better mental health condition than those who are continuing their work without retirement and also for those who decides for the full retirement. Nowadays society has invested a lot of effort in creating comfortable climate for the retired elderly but their focus is mainly concentrated upon comfort and health monitoring. The author considers that the absence of the main activity and interest affects seriously the mental state of the elderly, therefore a different approach should be considered: how could ageing society, with good mental shape and acceptable physical state, even if it doesn't allow them to achieve the same quality of work anymore, will be able to continue their professional activities, even they have reached the age for retirement? Of course this question refers only to the persons which clear express the desire to continue their activity and should not be considered as a suggestion to modify the retirement conditions stipulated by laws. This paper claims that the answer is lying in the workspace design strategy. Developing a new workspace environment customized for elderly needs in order to minimize their efforts can be the solution for their reintegration, reducing thus the fast ageing issue. Also, another secondary but important benefit will be that good professionals with a lot of experience will be able to do their work and become advisers or consultants for the new comers into the field. Method To define the method, a complex analysis of all the activities typologies and all the specific problems which derives from these were needed in order to set-up the guidelines for developing the workspace typologies for elderly. The author approach is based on the transfer technology from different industries in order to create the designated environment. For instance, the Japanese company Honda (Honda 2009) has tried to improve the working environment of their employers especially in terms of reducing their physical efforts in the assembly lines developing products such as bodyweight support assist. Having a similar approach but for the benefit of elderly professionals, the workspace designer should be able to resolve specific ageing issues such as: locomotion and mobility, new technology and tools manipulation, collaborative work integration etc. Results & Discussion The research analyzes three types of professional activities in order to understand how complex the requirements for the assistive working space design are: a classic office space, an outdoor open field space and a collaborative space. Each of them has generated the need to rethink elements such as tools, manipulators, instruments, communications and mobility issues in order to make an efficient workspace.

Keywords: work space guidelines, elderly professionals, technology transfer, assistive design

INTRODUCTION Developed countries as Japan, China, Korea, USA, all the Western and Central Europe countries such as: United Kingdom, Germany, Sweden, Netherland, are registering the growth of percentage values for the ageing society (Fig 1).

The new technologies and medicine discoveries and improvements have extended the population life expectancy, thus the elderly society has grown from 8% in 1950 to 10% in 2000 and the expectation for 2050 is 21%. (Fig 2). According to United Nations estimations (2005-2010) life expectancy has exceeded the limit of 80 years in countries as Japan (82,7%), Switzerland, Israel, Italy, Iceland, Australia, Singapore, Spain, Sweden, France, Canada, UK, New Zealand, Norway. Still, these major breakthroughs come also with secondary effects like old
age support ratio regression, retirement politics and plans, working flexibility adjustment, public health, elderly life after retirement, effects which have to be seriously taken into account. According to the Organization for Economic Co-operation and Development (OECD, 2009), the statistic measurements the old-age supporting ratio, which means the report relation between the active working people and the existent retired population, show shrinking values which in terms of social security plans will probably determine the collapse of the now-existing social security and retirement system. OECD also claims for an estimated period of 42 years (2008-2050) countries like China, India or USA, will reduce their support ratio (active working persons per one retired person) from 7.9, 11.2, 4.7 to 2.4, 4.5 respectively 2.6. (Fig 3).

Fig 3 Proportion of population 60 years or older: world, 1950-2050

Another statistic but for Europe estimates that the old-age dependency ratio is expected to increase from its current levels of 25 percent to 50 percent in 2060 (Eurostat 2006). Besides the economical aspect also the matter of elderly life quality after retirement should be discussed. This paper supports the idea that people who engaged in career bridge employment are preserving a better mental health condition than those who are continuing their work without retirement and also for those who decides for the full retirement. According to Shultz et al. (2009), elderly who are involving in bridge employment are better protected from the major health problems, diseases and the decline of daily functions is also delayed. The same authors considers that this is a consequence of the fact that “they are likely to keep their levels of physical activities and mental activities through daily work.” Considering the other option, as retiring completely after their career jobs, Schultz quotes Kim & Feldman (Kim & Feldman, 2000) who observe that would be extremely difficult for elderly to keep an organized lifestyle and the ageing slope will increase drastically, also physical and mental health problems would emerge faster.

PREMISES AND GUIDELINES FOR ELDERLY PROFESSIONALS WORK EXTENSION DEVELOPMENT

Considering all this data above, a pertinent question could be asked: how could elderly, with good mental shape and acceptable physical state, even if it doesn’t allow them to achieve the same quality of work anymore, will be able to continue their professional activities, after they have reached the age for retirement? Of course this question should be pointed only to the persons which clearly express the desire to continue their activity and should not be considered as a suggestion to modify the retirement conditions stipulated by laws. This paper suggests the answer lays in how much the actual work space could be adjusted for the aging society needs in order to permit them to continue their activities.

In order to design a workspace for elderly some special aspects should be analyze: the physical design, the social behavioral climate and the policies and procedures regarding safety and regulations. All these aspects should be corroborate with special elderly changes and alterations. According to Perry, (Perry, L., S., 2011) specific alterations occurs while ageing; in terms of physical changes the strength decrease with 25-30 percent at 65 years, the flexibility with 18-20% (Fig 4).

Also aspects as the body balance, sight, reaction time and speed, hearing, manual dexterity and tactile feedback are decreasing, more or less severe.

Fig 4 Set of guideline of work space design for elderly
terms of physiological alterations, ageing comes with different issues such as oxygen exchange (40 percent decrease at 65 years), respiratory system (25 percent at 65 years), cardio system (15-20 percent less at 65 years), blood pressure (increases) and fatigue which is occurring rapidly. The same author claims that psychosocial aspects occur such as: shift preferences as mornings and less shift work, training and learning structured training and education and also the disengagement is more likely to happen. The designers should also considered the elder job nature in terms of occupational specific description and type is another important aspect in the work space planning. The relation between physical and intellectual effort required, the collaborative level of the job, the outdoor, indoor or mixt space type, are features which have to be considered in the guidelines development.

**WORK SPACE DESIGN PARAMETERS**

In order to obtain an efficient work space design for elderly the developer should take in account a set of designing and engineering control parameters. All these parameters are describing and controlling the complete requirements of a work space for the ageing professionals in terms of the job itself, the tools needed, the environment, in order to adjust the gaps between the old standard work space and the new proposed one, aiming also to reduce specific issues like low performance, injuries and health problems etc. Perry, (Perry, L., S., 2011) defines the main sets of parameters into six main categories: task design, workstation design, environmental design, tools design, manual material handling design and equipment design. Each category controls a set of parameters which characterizes the elderly work space in terms of ergonomics, safety and efficiency.

In terms of task design, parameters such as body specific postures, the level of repetition, boredom versus complex activities, the level of muscular effort, the task duration and the need of the recovery after the task, should be considered. When it comes to workstation design, the developer should consider aspects as sitting versus standing, the height of the working surface, the reachable and visual zones, the chair type, slanted surfaces, sharp edges, storage and shelves, etc. The environmental design has also important parameters which has to be controlled in the design process: lighting, temperature, noise reducing, vibrations, working outfit, office design. The designer has to propose adjustments for the tools and the equipment used by the elderly in many situations. Improvements for grippers, leverages or the complete rethinking of the tools sector in order to reduce weight, vibrations, loss of balance or, on the contrary, to multiply the natural torque force with additional equipment are important points in the work space design. Other important adjustments are required in the equipment design area, like analog versus digital machines, doors and windows knobs and handleings design, controls location, keyboard and mouse etc.

**GENERAL CONCEPTS FOR WORK SPACE DESIGN FOR ELDERLY PROFESSIONALS**

This paper suggests that technology transfer is one of the successful method to implement an existing development in another area or field, in order to achieve the required goal. Companies like Honda are already developing different concepts for their employers to enhance the performance and assure comfortable working spaces, but their researches and developments are aiming employees below the retirement age. Still, for several tasks and job descriptions these technologies could serve the elderly professionals needs. Also, Berkley Bionics and Lockheed, American companies which are activating in another field of innovations, the army industry, are developing special equipment for enhance the soldiers mobility and endurance on the field. So called HULC (Lockeed Martin, 2012)\(^6\), (Fig 5) is a robotic exoskeleton designed to transfer the loads from the soldier’s backpack directly to the ground and not on the back like any other kind of standard carrying equipment.

![Fig 5 Exoskeleton from Berkley Bionics](image)

Transferring this technology to the elderly professionals could help them enhancing their mobility and also would permit them to manipulate and carry additional weights.

**CONCEPT – THE ASSISTIVE MANIPULATOR**

For special tasks which require carrying extra loads a custom assistive manipulation tool must be developed. Taking as reference HULK concept and development the same strategy could be implemented for this assistive tool for the elderly professionals. For the ageing employer the equipment must work as a multiplier of his natural physical strength, enhance his mobility and cope with special muscular and bone problems such as: torsions, special start-
ing and ending positions, legs fatigue. (Fig 6). Of course, a close physical check has to be done before enrolling the person into the job task, to be sure that his health condition still permit him to work and also to adapt the assistive manipulator to his actual state.

**Fig 6 Exoskeleton principle – technology transfer for elderly assistive manipulator**

**CONCEPT – ASSISTIVE UNIT AND TOOLS HOLDER**

Kiva automation system (Fig 7) is a very good example for logistic innovation for factory use (Kiva 2009). The robotic system is carrying out a shelf from the supplier and assist the worker in sorting the components for the client demand. The robot is carrying by itself the shelf going through the special check in points where the employer is making the sorting. After the components are placed the shelf is continuing his path to another check arrives in the final destination distribution to the client point. The robots are organized by operating different paths in parallel and they can meet when different components have to be shift by the human operator. Having a similar approach an assistive unit for ageing employer could be developed. The system should assist the employer as a mobile platform and should also have storage capabilities for the tools. (Fig 8) The equipment has to be designed ergonomically reducing the effort of the elderly by having the picking up tools platform in an easy to reach point, and the storage should be resolve with an additional sorting feature. The assistive unit could handle multiple tasks such as: recommending solution for the employer’s tasks, carry the tools, travel to the tools and components suppliers in the factory, etc. The recommendations could be made in two steps: identifying the issue with camera vision sensors and using the database resource for similar situations to explain the task which has to be. The unit assistant might also has sensors for monitoring the employee health conditions, such as blood pressure control.

**CONCEPT – THE OFFICE DESK FOR ELDERLY USE**

Besides the tasks which are implying more physical effort the research and development should also focus upon the office work which refers more desk tasks, where the intellectual effort is required. Designing an office workstation for elderly professionals (Fig 9) is a very complex task. More elements should be taken into considerations such as the chair and the desk design; also the workstation fitting into the designated environment. The communication with the others via computer, keyboard and mouse adjustment, the desk active workspace configuration, the storage design in order to be reachable, easy to organize, are things which have to resolved. The design of the chair could contain adjustable positions setups such as controllers and mechanisms for helping the elderly raising by his request, sensors for health monitoring, massage options for blood circulation improvements in case of long shift periods. The chair has to have the possibility of moving into the office or to be coupled o the locomotion device of the elderly. Situations like different levels of immobility could happened for elderly professionals but this shouldn’t cause them any constraints or impossibilities to continue to come to the office if they want to carry their tasks. The desk design should be focused on eliminating possible injuries, rounded edges, the reduction of glass as material which can hurt in case of falling or dropping objects by mistake.

**Fig 9 Office desk workstation for elderly**
CONCLUSIONS
Analyzing all the data and having different scenarios for ageing society work integration the author consider that a general set of guidelines is not possible due to the huge level of diversity. Variations in terms of tasks, necessities, environment diversity are doubled by the complex needs of the elders. Yet, taking in consideration different fields different models could be designed in order to have customized guidelines for the respective domain. For instance, an office work space oriented to marketing, architectural designing, advertising agency or other kind of services can have its own setup of guidelines which will permit the research and development of the assistive equipment for the elderly employees in the respective directions.

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Construction Site Automation: guidelines for analyzing its feasibility, benefits and drawbacks

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Purpose Many industries have made smart use of arising innovations which has resulted in great improvements in terms of productivity, functionality and final user's convenience. A good example is the automobile industry; cars only appeared as a product roughly a hundred years ago, but today their fabrication process has a high degree of complexity and efficiency, increasing their productivity exponentially over the years. Construction industry however, does not show this exponential development. With this in mind, the latest trend is to boost the quality, efficiency and productivity in construction processes by having automated construction sites which implement robotics and information modeling. This paper aims to establish a set of guidelines regarding construction site automation and apply them to an academic example that tries to solve specific site (location), technical, economical and logistical issues. Method Because of the high labor cost, some Asian construction companies have found great feasibility in implementing automated construction sites transferring technology and knowhow from other industries like shipyards. By the analysis of some of these existing automated (fully or partially) construction sites and by exploring new ways of conceiving and managing the processes and safety, it is possible to detect and highlight common parameters and the strategies that they have used to overcome the main difficulties. Results & Discussion The resulting guidelines show a set of parameters to consider when thinking about automating the construction process. These parameters are analyzed in three stages: before, during and after construction. After applying the guidelines to the previously mentioned academic exercise, the impacts (benefits and drawbacks) of having automated construction sites are evaluated from economical, technical and logistical perspectives, giving insight on whether or not investing in an automated system is convenient giving the specific conditions of a site and company interests.

Keywords: Automation, integration, prefabrication, robot oriented design, logistics, efficiency.

INTRODUCTION

It is undeniable the importance of the technological development experienced in the last centuries. Many different industries have made smart use of the arising technological innovations which has resulted in great improvements in terms of productivity, functionality, quality and final user’s convenience. A great example is the automobile industry, because even though cars only appeared as a product roughly a hundred years ago, today the processes and technology related to their fabrication has a high degree of complexity and efficiency, increasing their productivity exponentially over the years.

To make of cars the mass product that they are today, many efforts had to be made on continuously seeking a way to reduce the cost of product development, so that the cost of the final product could be as well minimized. The successful implementation of arising innovations in terms of organization (logistics) and technology has played an essential role on this progress. This tendency remains today because of the high competition of the automobile market, with production lines highly integrated with specialized robots.

Construction industry however, does not show this exponential development (Figure 1). With a production process that in general remains to be very close to craft work, buildings and infrastructure remain to be the most expensive and slowly produced goods in our society. This may be considered as unacceptable given the fact that together, buildings and infrastructure conform one of the most important pillars of our society; there would be no civilization without buildings and infrastructure.

Fig.1. Productivity of the construction and automobile industries in the European Union, last decade of previous century.

After realizing these issues, and noting that the construction industry’s contribution to the GDP in industrialized countries is about 7-10%, more importance
has been given to R&D and the latest trend is to boost the quality, efficiency, safety and productivity in construction processes by having automated construction sites which implement robotics and information modeling2.

This paper aims to establish a set of guidelines regarding construction site automation and apply them to an academic example that tries to solve specific site (location), technical, economical, and logistical issues.

**ROBOTICS IN CONSTRUCTION**

The biggest investment on R&D for the construction industry is happening on the Asian construction companies3. They have found great feasibility in implementing robotics into their construction processes, transferring technology and knowhow from other industries like the previously mentioned automobile industry and also ship fabrication (shipyards) 4. This robotics implementation has been done from two very general and wide perspectives: Off-site construction robotics and On-site construction robotics.

Figure 2 shows and explains the different stages in which the construction process can be based on. In the graphic, each step to the right means an improvement in terms of technology and organization applied to the construction process. The interesting part is that except from the “pure production” stage, all the other ones can (or have) to use robots.

The use of robotics demands a series of extra consideration that have to be coped with when intending to implement a robotic based construction system. Some of these additional considerations might be their limited mobility, their weight, their size and even their accuracy. Additional factors also play an important role: dispersion of projects, lack of repetition, dependability among workers, negative attitudes to change, fragmentation of the construction industry, and instability of the market6.

On the other side, after handling these drawbacks, the use of robotics in construction may bring improvement in work quality, reduction of labor costs, savings accrued on safety and health improvements, time savings, improved working conditions and increased productivity7.

The balance between the benefits and drawbacks will determine if the automation solution is feasible depending on the specific economic, technical, political environment that surrounds a company.

**Prefabracion (Off-site Robotics)**

It refers mainly to the use of robots for the prefabrication of the components, modules or units that will be assembled on site. This dimension is the most similar to the production processes performed by other industries (automobile), since they both handle medium size products that can be easily incorporated into a production line that performs the different steps until the completion of the product.

It is clear that many industries have found enormous benefits in the use of robots for the production process. The use of robots for the production of construction prefabricated elements brings all these benefits to the off-site component of a construction project. Depending on the specific needs, the production can be as detailed and complex as required given the controlled environment, taking away all the unfavorable factors that make on-site fabrication hard and variable. This generates a great impact on the productivity, functionality, quality and precision of the prefabricated elements, which directly affects the performance of the on-site activities.

Some Japanese construction companies already apply very advanced techniques of prefabrication, which allows them to provide high quality products at reachable prices, thanks to the optimization of their production process.

**Sekisui House**

This Japanese company is a good example of advanced prefabrication techniques. They sell around 55 000 houses a year using their construction system based on modular panels3. They have panels for
the structure, for the façade, for the interior and for the isolation.

\[
\text{interior} + \text{isolation} + \text{structure} + \text{façade} = \text{wall panel}
\]

**Fig.3. Combination of wall panel of Sekisui House's construction system.**

They have several variations of each of the different types of panels, for example different types of finishing on the interior or exterior, seismic resistant structural panels in case the site’s characteristics create the demand for them, different types of temperature isolation depending on the regional weather conditions, etc.

By different combinations and distributions of the same panels, they manage to provide highly customized products by the use of a few standardized modules. The standardization of their production allows them to implement an automated fabrication line that performs repetitive actions obtaining the benefits of economies of scale.

**Single Task Robots (On-site Robotics)**

Robots designed to perform a specific activity that is typical on construction sites. Some existing robots perform tasks like façade installation, painting, concrete compaction, concrete distribution, concrete leveling, concrete finishing, interior finishing, fireproof coating, positioning systems, steel welding, reinforcement, tile setting…

Big Japanese construction companies are leaders in development and implementation of such robots. Some of these companies are Kajima, Takenaka, Fujita and Tokyu Construction. They mainly focus the development of single task robots to perform activities that fall into the categories of difficult, dirty or dangerous (3k)².

**On-site Automation (On-site Robotics)**

The concept behind it is to install an on-site factory, in which different robots perform specific activities in a synchronized and integrated matter, resulting on the erection of the complete building.

It is important to understand that the performance of the on-site factory is greatly influenced by the previous steps of the construction process. In most cases these previous steps would be the prefabrication and the transportation and storage logistics. The assembly robots of the on-site factory may not be able to cope with inexactitudes and flaws present on the prefabricated elements. Also the time that the automated system is supposed to save might be lost if the logistic organization does not provide the system with the required elements on time. These and many other situations could lead to wasting the capabilities of the automated construction system.

**BIG CANOPY by Obayashi**

The system’s most characteristic feature is the big canopy itself, which is an all-weather temporary roof structure that is supported on four corner posts and is broad enough to overhang on all four sides the entire building under construction. The canopy is raised as construction of the building moves up. When the building reaches its full height, the canopy is dismantled and its perimeter structure jacked down.

**Fig.5. Overview of the BIG CANOPY automated construction factory.**

The Big-Canopy system uses a combination of precast and in situ concrete with modular sub-assemblies. Precast components include columns, beams, slabs and interior wall elements. Additional prefabrication includes vertical and horizontal drain-pipes, air-conditioning ducts, low current indoor cables and wooden interior partitions. The system consists of a gondola-type construction lift for vertical material delivery, automated overhead cranes for horizontal delivery and structural element orientation.
and positioning, and the climbing mechanism for the elevation of the factory when required.

Fig.6. Precast modular construction technique of the BIG CANOPY automated construction system by Obayashi.

After applying several times the system to the construction of different buildings, the results showed that productivity was up at least a third using the BIG CANOPY system. The number of operatives engaged in the erection work was 65% of that used in normal precast construction. Also it was found that 82% of all the high-rise structures authorized by the Building Center for Japan over the period from 1986 to 1995, could have been constructed using the BIG CANOPY system.

The main inconvenient with the system is the limitations of the delivery and logistics system, since the transportation of the precast elements to the top is not very agile. On the other side, the system is very versatile and can grow as high as the structure of the building is designed to grow.

Obayashi Corporation also developed another automated construction on-site factory for steel structure buildings, it was named ABCS. The factory is also on top of the building, but is supported on the already installed structure of the building, instead of the external columns.

Fig.8. Productivity of the BIG CANOPY system compared to more traditional methods.

AMURAD by Kajima
This is also a Japanese automated construction system, but contrary to the previously described system, the on-site factory is located on the bottom of the building. The last floor is constructed first and then pushed up one level, making room for the second last floor to be built. Meanwhile the plumbing works, interior fittings and the cladding of the façade begin on the last floor (that now is second). The process is repeated as many times as necessary until the whole building is completed.

Fig.9. Evolution scheme and pictures of the AMURAD automated construction system by Kajima.

This system uses the three following mechanical subsystems: A system for pushing up the whole building (Z-UP), a transportation- and assembly system for concrete precast elements (Z-HAND), and a material transportation system for the second level of the factory (Z-CARRY).
Kajima also developed a deconstruction system using the same principle of ground factory, it was named DARUMA. With it a recycling rate of 93% was achieved, which is outstandingly better than the 55% of the conventional demolition methods.

GUIDELINES FOR CONSTRUCTION SITE AUTOMATION
Based on the previous analysis (Sekisui House, Obayashi, Kajima) and some additional considerations (Figure 11), it is possible to infer parameters that directly affect the consequences of implementation of an automated construction system.

Fig. 11. Project management triangle: the three parameters that have to be fulfilled to consider a project as successful. Usually the efforts to improve one of the parameters have a negative impact on the others.11

When designing the automated system, and the construction technique that it will use for erecting the building, it is important to consider the following guidelines to determine the systems capabilities to perform successfully in various scenarios, and therefore determine its feasibility.

Guidelines A – Before Construction
• Go as far as possible with the prefabrication: the more details included on the elements since the prefabrication, the fewer activities that will have to be performed on site (plug&play concept). This will help to save time on site, and the complexity of the robots will be reduced because their tasks will be simpler.
• Maximize the modularity of the elements: by doing so, the tasks on site will be more repetitive and the robots will not be as complex.
• Use a platform approach: this has been the key of success of the automobile industry; by designing basic platforms like chassis, engine, tire-breaks that fit many different models, economies of scale bring benefits to productivity and help reduce the production costs. The same can be done with modular elements designed in a way that they can be arranged in different ways or combined freely in order to get more flexibility.
• Allow customization: closely related to the platform approach. By having a modular system, the system may be rearranged in order to cope with specific requirements from a client. This will give flexibility to the system and the range of application will be broader.
• Determine if the revenue that the automated system will generate is worth the investment on the technology: usually the automation of the system will generate revenue by reducing the amount of workers involved in the construction works, and also by reducing the total time of construction some other direct and indirect expenses are reduced. Check if this difference on expenses summed to any loan interests reduction is enough to find the investment in technology feasible, and in how many applications of the system the investment will be returned. Many aspects play an important role in this matter, depending on the location: cost of labor and local regulations for example. If the cost of labor is very high at some place, the saved money will have a bigger role on the decision and probably make it economically feasible; while in the opposite case with cheap labor available the investment could not be the most convenient.
• Give as many additional features as you can to the system: ecological features, quality guarantees, clean construction... the cost of including them will be minimal compared to the total investment, but they can act as a competitive advantage to win projects in several cases.

Guidelines B – During Construction
• Keep in mind that the automated system is supported and depends on the logistics and prefabrication: the automated system could be designed in a marvelous manner, but if the logistics and prefabrication that it demands are impossible to provide for a specific location, then the system will not work at its maximum capabilities and maybe will not be the best option.
• Make the system as non-intrusive as possible: construction works usually have a big impact in the surrounding communities in terms of noise, dust and other inconveniences. By controlling these intrusions the system becomes neighbor friendly giving a better image to the public and maybe making it easier to get construction permissions from local governments.

• Reduce the difficulty of assembly: by carefully designing the connections (always mechanical over chemical) between the elements in a way that inaccuracies of the robots are tolerable, the technical success of the system is more probable. Also by standardizing the connections of different elements, the complexity of the robots is reduced and the investment reduced.

• Try to have as many parallel activities as possible: after a huge investment in machines and robots, you do not want them standing still without performing a productive task.

• Guarantee workers safety and better working conditions

Guidelines C – After Construction

• Make arrangements to make the system as flexible as possible: in this way the system can be reused easier in different projects bringing additional revenue.

• Estimate the approximate time in which the investment will be returned: see if your company is financially capable of waiting this long, also how much productive life has the system after this point to see if the profit fits the interests of the company.

• Give versatility features to the system so that it can function properly under different weather conditions: this will enhance its productivity and application.

• Determine how stable the market for your system is: if the immediate conditions are favorable but there is a big chance of these conditions to change unexpectedly, then the market is unstable and this risk has to be considered.

CONCLUSION - EXAMPLE OF APPLICATION OF AN AUTOMATED CONSTRUCTION SITE

As an academic exercise, Master students of the Technical University of Munich (TUM) were asked to deal with the following problem: Propose a building project for a lot in the center Munich, for which the following conditions must be coped with:

• Location considered being one of the highest land prices in Germany.
• Located in pedestrian area.
• Hard to access.
• Area and surrounding cannot be disturbed during construction.

• Site erection time in less than 10 days (not including preparation and prefabrication).

The following was a very interesting solution to the exercise.

The proposal is an innovative solution that attempts to merge residential and commercial activities in one space, aiming on the direction of achieving a healthy lifestyle, not only for the people, but also for the environment. Ten parameters were considered on the design process of the project, but mainly three keywords (that included some of these parameters) were vital in the development of the concept: Health, Flexibility and Technology. The focus from now on will be on the automated construction site that was proposed to cope with the conditions of the exercise.

The main structure of each one of the three towers is going to be constructed on ground level starting with the top story (roof), where all the prefabricated elements will be installed. Then the building will be pushed up and the next level will be built (AMURAD). This process will be repeated until total completion of the tower. Modules will be plugged on the higher levels in the meantime by parallel processing. Also parallel will be performed the simple installation of modules for the commercial ring located on the lower levels. The energy required for powering the construction period will be provided ecologically by Magenn Technology. All the prefabricated elements were designed in a way that their size is appropriate to be carried by tram and truck.

Logistics

Off-site Logistics

All the elements of the building will be prefabricated, on one or several subcontracted factories with the adequate infrastructure to perform this task, probably out of town. The production will be done in the ade-
quate order so that the elements can be stored properly organized allowing easy access to the required element on the specific moment planned for its installation. This storage will be done on a warehouse located near the construction site.

To avoid any big storage onsite, here is where the critical logistics take place with “just in time” delivery; there will be a continuous flow of trams and trucks transporting the prefabricated elements to the site, 10 minutes by tram and 13 minutes by truck.

On-site Logistics
When arriving to the site, the prefabricated elements will be unloaded from trams and trucks using Richstakers specially adapted to be able to carry the construction elements. The element will be instantly delivered to its specific installation point, where a robot or another installation mechanism will receive it and install it. Richstakers will also install the container shaped modules of the low commercial ring.

Building Information Model (BIM)
From the design phase, we want to integrate a very precise building information model in which every element and module forming the building is precisely defined in terms of function, position and schedule. Every prefabricated element will be installed with a small information carrying device containing data on exact location, installation time, position, etc. In this way, we can have an intelligent construction site and high degree of automation can be achieved. In the case that any unexpected situation occurs, the model should be able to provide the required information on a really short time period, allowing construction managers to implement the necessary corrective measurements. So a high level of real-time control is accomplished.

Building Components
The building is structurally composed mainly by three elements: Core, Metallic Cages and Pluggable Modules. They are all mainly a metallic structure covered with a lightweight esthetical material (not defined).
lifted one story up, the construction of the new level underneath can start following the same process. Apartment Modules can be installed in parallel in the second level of the factory while minor single tasks are performed on the upper levels as well. This cycle continues until the completion of the building. Overall Operation Rate = 1 story every 10.5 hours.

Fig.16. Construction process of the proposed automated construction site

References
Automated Construction – An efficiency analysis and the socio-economic impact

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Purpose The construction industry cannot cope with the increased demand for flexibility and speed. New means are needed to address the issue. Automated Construction is considered as one of them. The paper will analyze the benefits and efficiency of such systems. Further maturing society structures and increasing industrialization alters the labor force available. The impact of Automated Construction Systems in terms of better working conditions and the requirement of highly skilled workers on high labor cost societies will be analyzed. Method First, data about the age and work force structure is gathered in order to give an insight about the recent development and future trends of industrialized societies. Second, the Automated Building Construction System (ABCS) by Obayashi is examined to outline findings about the quantity and required skills of the workers. Additionally the efficiency of such systems is investigated on. Third, the socio-economic impact will be predicted based on the gathered results. Results & Discussion The paper concludes that Automated Construction enhances efficiency but its return on investment is currently too low to generate a broad market for such systems causing obsolescence of the gained efficiency. The paper discusses factors that need to be taken into account to foster the operation of Automated Construction Systems with respect to monetary considerations. For example the operation schedules must be aligned smoothly to generate a fast return on investment. Figure 1 shows the current linear processing that results in low outputs per time interval and thus a slow return. Secondly, it proposes the parallel processing principle for the construction sector. Therefore schedules are aligned in a way that the planning phases are performed in parallel to positively influence the speed of return on investment. Moreover the paper concludes that Automated Construction Systems are likely to reduce the needed work force. Nevertheless highly skilled, well paid workers are needed to operate the systems, thus industrialized countries do not have to substitute the local work force by workers from low-wage countries. Therefore such countries benefit from a social welfare increase.

Keywords: prefabrication, automation, efficiency, labor force, economic impact, social welfare.

INTRODUCTION
To enhance the speed and the efficiency of constructions it is necessary to introduce innovations. When comparing the building and construction sector to other industries the drawbacks become obvious: Innovations nurtured many industries to shift from manufactories to productions. Since Henry Ford introduced the assembly line 100 years ago, cars are produced rather than build. Further these production lines evolved to highly automated and fully integrated high technology production factories. In contrast the construction sector is dominated by stagnation. Bottlenecks as the high reliance on human labor, unstructured on-site and off-site logistics, extensive use of resources and the exposure to hardly predictable environments are still prevalent. A shift to automation, prefabrication and a zero-risk environment is necessary. Thus, a structured production has to be achieved to cope with the demanded speed and efficiency of present and future lives. First, trends in industrialized societies will be outlined in order to get an understanding for the need of automation. Second, the Automated Building Construction System is introduced to generate automated construction systems an understanding of automated sites. Third, the paper points out the requirements for automated construction systems that are needed to enhance efficiency. Last, concerns and advices about the feasibility of automated construction sites will be raised and discussed.

TRENDS IN INDUSTRIALIZED SOCIETIES
Over the last decades many countries evolved to industrialized societies and others consolidated their strong position in the economic world. With all its benefits there are changes that affect the society and economy of these countries respectively. In particular the construction industry will be outlined. The majority of construction workers that contribute to projects in industrialized countries are foreigners. Thus they do not change the employment rate or national income to the better. Moreover the search costs for qualified workers are increased. The most drastic example is Switzerland. 70 % of the construction workers are foreigners who exploit the good working conditions and the high salaries when compared to
their home country, which is perfectly correct and benefits their homelands.\textsuperscript{1}

Nevertheless these low wage workers or in general low wage countries will diminish over time. Figure 1 shows this behavior clearly. When comparing European countries labor costs with the equivalent last year’s data - in this case second quarter 2012 compared to 2 quarter 2011 – the mentioned behavior becomes obvious. The eastern countries that are known for their low wage workers show the highest increase in labor costs. While the European average is really low at about 2\% they are reaching up to an increase of about 8\%. These numbers represent the nominal increase.

The real increase is the increase in buying power thus accounting for the inflation and increase in price level. The eastern countries show a low or even negative real salary development. This indicates an increase in the eastern economies and requires an even higher increase in wages to cope with the development. Thus low labor cost countries will adjust to the western price level as a reason of the socio-economic development. Therefore low wage countries will diminish.

Further industrialized societies are maturing\textsuperscript{3}. The work force becomes scarce which leads to an increase in wages. Industries that offer bad working conditions will suffer the most as they will be required to higher salaries drastically. This development may take a while but the harsh impact can already be predicted by looking at Japan. As Japan severely suffers from an ever aging society and a scarce work force wages are extremely high. Further Japanese companies have to support their workers to the fullest in order to maintain the required labor force. This background has driven Japan to become a high-tech society that fosters automation and robotics. With more than 30\% of all robots in use Japanese companies dominate the development of automated systems.

With the mentioned in mind a development towards automation and robotics can be predicted for industrialized countries. Labor intensive industries such as the construction industry will severely suffer from the ongoing changes. Automated construction sites might help to address these issues. Working conditions can be enhanced to stimulate the attractiveness for the required skilled workers. On the other hand less labor force is required and the efficiency might be enhanced. In the following the ABCS by Obayashi will be explained to demonstrate the development towards automation in the construction industry.

### ABCS BY OBAYASHI

Obayashi has further developed the ABCS continuously since 1980 to automate assembly operations. This is done by building a vertically moving factory site with automated logistics, automated positioning of columns and beams, automated welding technology and digital real-time process monitoring.

A vertically movable so called “Super Construction Factory” (SCF) is located at the highest floor of the building and moves during the construction process upwards. A central element of the SCF is the automated construction logistics system known as the “Parallel Delivery System” (PDS), which ensures an automated, fluent and in-time management of materials and allows an efficient installation in the SCF as materials are delivered to the right floor, right space and in right time and sequence. Figure 2 shows the SCF in use being fed by the vertical lift that is part of the PDS. The security installations to protect works and materials from falling down are also shown.

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure1.png}
\caption{Total nominal hourly labor costs, \% change compared to same quarter of previous year, working day adjusted - 2012 Q2\textsuperscript{2}}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure2.png}
\caption{Super Construction Factory including the vertical lift (part of the PDS) that feeds it with materials\textsuperscript{5}}
\end{figure}
The ABCS strives for highly precise work during the whole construction face. To reach such a level of accuracy new systems were introduced. ABCS uses a system for automated, high-precision installation of structural steel elements. Columns and beams are set by automated traversing cranes mounted at the ceiling of the Super Construction Factory which can be seen in Figure 3.

![Fig.3. An automated traversing crane mounted at the ceiling of the sky factory handles a structural steel element.](image)

Mobile welding robots offer high precision work by welding two sides of the steel elements simultaneously. The welding of multiple sides concurrently guarantees that the linked segments cannot bend during the welding operation.

In the following data gathered by observations of the ABCS will be used to identify achievements and drawbacks of vertical moving construction sites. As the ABCS is in continuous development since many years and it is the most investigated on it serves as role model and performance indicator for other comparable systems such as the Big Canopy by Obayashi, SMART by Shimizu or Akatsuki 21 by Fujita.

**PROJECT SIZE REQUIREMENT**
The size of the project and the associated number of floor levels is positively correlated with the efficiency of the project. Automated building construction sites like the ABCS by Obayashi are based on a core structure, which must be pre-installed manually in order to start the actual automated construction. High time efforts and monetary expenses are needed to start such projects. On average it takes a month to build the core structure and another half a month to dismantle it after finishing the project. This loss of time and money pays off only after a certain size is reached.

![Fig.4. An efficiency comparison between automated (vertical) and conventional constructions with respect to the amount of floors and the required time.](image)

About 20 floors are needed to break even and to achieve cheaper and faster construction by automated sites. Above this floor number the efficiency increases dramatically. Automated systems provide smooth logistics throughout the whole construction process. In addition the workers execute their tasks without danger and without external influences resulting in a positive impact on their work ethic and speed. Studies revealed that the workers are subjected to a so called "learning effect". Once they are familiar with the processes, they can raise the speed of construction regardless of the height of the building. In contrast, the conventional building process slows down with increasing building size. Figure 4 depicts this behavior. Below 20 floors conventional construction outperforms automated sites as a reason of the time required to initially set up the Super Construction factory or it’s equivalents. Above this number the performance of conventional construction diminishes as tasks are getting harder to execute in great heights. Meanwhile automated construction can slightly increase the output as workers and automated machines start to perfectly collaborate. Therefore an efficiency gain and a time reduction is achieved by using automated vertical construction sites if the planned project is higher than 20 floors.
**PROJECT FREQUENCY REQUIREMENT**

If one is looking at the amount of buildings, which are necessary to cover the development costs of an automated high construction, you will end with about ten applications. Company-specific this break-even-point will be reached after more than a decade and diminishes the attractiveness of the systems to be developed at first sight.

But this ratio is not very meaningful if firms increase their frequency, if joint ventures for the exploitation and development are established, if companies are formed, who rent such systems, as it is common with other large equipment. All this allows the full utilization of automated systems and enables a more accurate clarification of the efficiency gained.

In the age of automated building construction sites, the term “Parallel Processing” wins a certain ambiguity. For the purpose of Henry Ford, these systems used the production and prefabrication capability of factories, which can be set more cost- and time efficient by the use of parallel operations and are, in addition, independent of external influences.

In this context the term “Parallel Processing” can also be used for the parallel designing of multiple projects. Automated construction sites are based on computer-driven processes that go back up to the designing phase. This allows the overall planning of projects in parallel conduct and to vote only the construction phase with the availability of the systems.

With a possible building-time of up to three levels per month and an assumed average of 20 levels, the overall building-time can be limited to 6 months. Since automated construction sites work independent from the environment, are logistically perfected and minimize the human margin of error, time sequences can be planned and coordinated precisely. Thus, at full capacity, automated systems pay for themselves in just 5 years. The mentioned considerations are depicted in Figure 5.

Table 1: Break-even point of the investment

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<th>Year</th>
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*Fig.5. Reaching the break-even point of the investment in a shorter time period by scheduling the operations sharply.*

One of the key features of automated construction sites is the so-called “Super Construction Factory”.

This demonstrates the systems working area. Separated by weatherproof insulation and protection materials, it enables a continuous and weather-independent work. By reducing the decibel-factor and enhancing the systems level of automation, a continuous operation of the plant is possible, without violating legal or technical work directives. This would halve the time expenditure for constructions and enable profitability for the automated construction sites after only 2.5 years.

**IMPACT ON LABOR FORCE**

Rising labor costs and skills shortages strive for automated solutions. Such systems allow large projects to be carried out cost-effective and with least planning efforts. Many steps can be taken over by machines and robots, thus reducing labor costs. In addition only a much reduced number of professionals is required, who - in the best case - oversees all possible projects. Figure 6 shows the results of two projects that have been executed using the ABCS by Obayashi. Compared to estimated numbers of conventional construction the ABCS required approximately 50% less working hours. Especially security and floor finishing tasks (concrete distribution and leveling) were reduced to a minimum as the former is guaranteed by the SCF and the letter can be highly automated. The mentioned de- and installation efforts are also depicted but the overall decrease compensates for it. This reduces the accumulated labor costs but increases per capita income as higher skills are required.

![Fig.6. Labor reduction by automated construction shown by two projects executed with the ABCS and compared to estimated conventional construction requirements](image)

This development could benefit the construction industry in a high-wage country like Germany as the local economy can be stimulated. For decades most
construction workers that operate in industrialized and thus high wage countries are foreigners. They offer their labor force at dumping wages compared to the prevalent national level. Therefore the employment rate of those countries stays unaffected even though huge projects with high cash flows are conducted. Changing the construction work force from low income jobs to high wage professions can alter the situation. Automated construction sites require those skills and combined with much better working conditions than conventional construction attractive works become available.

DISCUSSION
Major socio-economic changes are going to take place over the next decades. These developments need to be addressed by high-tech solutions that ease to occurring problems. In the construction industry automated solutions might take over. The question arises why these solutions are still rarely used even though such beneficial outcomes might be achieved.

Theory works better than reality. In a volatile economy with major crises huge capital investments such as developing an automated site are highly bounded by risk. With a monetary return that set in after years of usage such systems do not seem to be the right choice for investor even if they are social welfare enhancing in the long run.

Further the construction industry is a very volatile market with more extreme amplitudes than any other. Investments require an even faster return and can hardly rely on future time and money savings.

Additionally current automated systems bound size and shape heavily. Not many companies can assure to be consistently building above 20 floor projects and not many companies want to be relying on easy geometric forms sacrificing architectural freedom for construction ease.

Nevertheless the inefficiency and scarce labor force will require the construction industry to change.

“Form follows function” – the Bauhaus showed that such thinking can predominate and create time-less icons. Systems like the ABCS are rather prototypes that try to maximize the automation. With a better ratio of human and robotic tasks such systems can reach a real time applicable level. The possibility to run these sites 24/7 can be the key point to success as it sets automated systems apart from conventional construction and benefits the efficiency a lot. It still needs a lot of thoughts and changes to introduce automated construction sites to a broad market but it can be partly used already and will benefit companies and people in the future.

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Demographic Change Design: Integration of Human Ambient Technologies in Kitchen for Aging Society

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Abstract:
The rising life expectancy has a big impact on demographic change. It highly demands smart designs and ambient assistive technologies to perform their task independently for the aging society. The ratio of elderly people living individually or in a shared environment with different age groups and abilities is statistically in continuous growth. Therefore it compels that kitchen solutions are ought to be compliant and adaptable to all members of a home especially for disables or aging people. It gives opportunity to participate and integrate themselves into common environments. This paper presents a proposed integrated system concept for a smart kitchen 'Adaptable Kitchen' that is appropriate for all kinds of people. In this paper, the state-of-art review of technologies and standard ergonomic has been accomplished for daily activities of aging society. In addition, it executes real experiments and problems analysis for one of the daily activities; cooking. Moreover the feasible solution has been purposed to perform the particular task as efficient as possible. Contemporary kitchens offer the possibility to modifications and alterations of height, width or general structure by containing adjustable elements. However, these alterations require complicated and time-consuming efforts that cannot be done by an unaided individual. The other deficiency with these designs is unacceptable aesthetic changes that impose on normal kitchen scenes and exterior visual appearance. People with disabilities do not favor to live in an environment that boldly discriminates them from common and “normal-looking” environments. Therefore, present demographic change demand highly proficient design with the integration of human ambient technologies in kitchen for the users of all kind with a common solution without any discrimination.

Keywords: demographic change; ageing society; ambient assistive technology; adaptable kitchen.

INTRODUCTION
Current trend of demography shows that the rate of aging people is in continuous growth. The remarkable change in demography demands modification on smart technologies that participate and integrate themselves into common environments with normal people. The changing reality of ageing is providing both challenge and opportunity for new innovations. Societies are innovating better ways for living longer and providing support. This paper explores the role that social innovation can play in ageing societies.

Our life has become easier and smarter with integration of advanced technologies in daily items like furniture, fixtures, tools, clothing, and households. In present context, WLAN, GPRS and RFID for sensing and localization of the environment have become most popular and acceptable technology. Such smart technologies are integrated with the environment and respond intelligently of human behaviour and activities, which is termed as “ambient intelligence”. The concept of ambient intelligence and smart environment has been taking over the world of technology. They provide wide range of simplicity, flexibility and competence to perform any task in relation to surrounding environment. The daily activities of age-

ing and disabled people may include mobility, sanitation, eating, cooking, clothing and washing. Among these daily activities, cooking is also an important task that seeks special attention for them.

"Universal Design", a term conceived by the architect Ronald L. Mace as “concepts of designing all products and the built environment to be aesthetic and usable to the greatest extent possible by everyone, regardless of their age, ability, or status in life”. The analytical evaluations of inadequate aspects of existing kitchen show the requirement of new concept for kitchen which could addresses both functional and visual aspects. Therefore this paper will propose a solution for kitchen termed as “Adaptable Kitchen”. It is focused for all kind of users including ageing and disabled people.

STATE OF ART
In the present context, there are a lot of research projects and scientific experiments focusing on the development of ambient assisted living (AAL) technologies specially for ageing society. Ambient technologies basically integrate sensors and actuators on different items of households and other daily activities which enhance the speed of work. Sensors
are portable and reliable for fall and other vulnerable moment detection as well as also guarantee privacy and security and thus has high user acceptance. Sensors in combination with actuators, using available methods of home automation and service robots, are the approaching method for ambient assistive living of elderly and disabled people.

Fig. 1. Ambient Socio-Technical Support for Assisted Autonomous Living

There are number of frameworks developed in EU and other research programs e.g. a middleware platform in “PERSONA”-project can be used for implementation of AAL services. Furthermore, many social projects have been promoted, which deal with social structures, residential quarter neighborhoods and care structures.

RESEARCH AND SURVEY
The comparison of basic types of mobility devices: Manual Wheelchairs, Electric (power) Wheelchairs, and Mobility Scooters has been reviewed to provide a common solution for all kind of people. The main purpose of consideration is to create more comprehensive understanding of the variation of users’ portions. In addition it is important to analyze their components, way of function, and their standard dimension. The standard sizes of these mobility devices are shown in fig. 2:

Fig. 2. Reference wheelchair proportions and dimensions

The findings help to create a list of guidelines after conducting research on normal kitchen standards, handicap kitchen standards, and performing experiments related to kitchen activities and food preparation processes. There are several points (also referred to Neufert architectural data and ergonomic) that are to be considered during the design of common kitchen. Wheelchair users face difficulty reaching the bottom of a sink that is deeper than 6 inches, which demands shallow sink for the users. It prevents them from bending excessively.

Standard counter height increments are 28 inches, 32 inches and 36 inches (36 as standard). Toe space is 10 inches high and 8 inches deep under the cabinet for clearance of wheelchair footrest. Bottom shelf of wall cabinets should not be lower than 48 inches above floor. Lower cabinets are to be installed with a 10 inch recessed toe-kick. It is difficult for wheelchair users to reach the back of counter top or the back of a cabinet shelf when the footrest of the wheelchair bumps into the lower parts of the cabinet. A recessed toe-kick allows user to pull closer to cabinets to increase reaching distance. Counter top should be between 29 inches and 36 inches in height and up to 19 inches in depth for knee space.

Fig. 3. Reference wheelchair reach ability

Common Problem of Ageing Society
The demographic change and development pattern of the ageing people will direct to increasing number of older people living alone. The need of intensive care and support and on the other hand decreasing workforce due to ageing and an increase of budgets for health care and social care are rising in the present context. The rapidly growing number of persons with physical and mental disabilities such as: hearing and sight loss, memory loss and especially chronic conditions are the most common problems of ageing society. Whereas, health concerns, economic issues and loneliness are some additional problems the aging population has to face that must be carefully addressed. Likewise, the elderly person’s income and economic welfare is also a problem since they become physically and mentally passive in compare to normal people.

However, today’s elderly person is considerably healthier than those of previous generations but still
need health plans like Medicare and Medicaid. The care and assistance to these persons are becoming more and more important both from the social and economic point of view. This will bring dramatic challenges for healthcare and care systems, service providers, designers, and state retirement fund schemes as well. All these growing trends and challenges affect the economy and finance of the state, mainly on the public resources.

Limitations in kitchen for wheelchair users
The design of kitchen has great impact on a wheelchair user to live independently at home. The requirements of the user vary individually. Some of the most common requirements for an adaptable kitchen are large enough space sufficient between the furniture units for the free and safe mobility. The low depth of sink, enough space in front of legs to accommodate the legs of wheelchair users, reachable height of cabinets, practical kitchen layout are some universal requirements of wheelchair users.

CONCEPT
The diverse kitchen activities such as kitchen area and utensils preparation, cooking and food preparation, serving and dining, washing, cleaning and storing are covered in this project. The creation of a universally designed supportive system that accommodates all of the above mentioned activities within units of modular compartments. It can be situated in variations of spaces/rooms which allow users to have access to all kitchen facilities as desired. Installation of the unit does not require structural changes or changes in infrastructure supply such as electrical connections, water supply and drainage. This solution provides a wholesome and independent design that flexibly accommodates itself to the user. It allows them to add their own preferences, adjust its dimensions and have the ability to easily move the kitchen units within the house.

CONCEPT IMPLEMENTATION
Compact modular units which are easy to move from one place to another are implemented. This provides flexibility on space as well as for their use. A design that reduces work effort and time during food preparation is implemented to make the user’s experience more comfortable and pleasant. Ergonomic, safe technical solutions are designed to be accessible by user of all kind with a common solution. The need to modify or change the existing architecture of a kitchen or space is excluded as the concept is adjustable easily in any space without any disturbance. This advantage can make the assembly of kitchen more convenient and acceptable.

With the consideration of the work efficiency, the flow of activities in the kitchen should not be neglected. The work flow is also responsible for the space occupation as well as efficiency in use. More work space, and storing food / utensils / appliances close to the food preparation areas are provided to minimize the mobility of user. Easy access to all kitchen facilities without the need to approach the stations on the wheelchair is also taken into consideration. The body movement: parallel, twisting sideways, rotating is minimized by making things operable with minimum movements.

Beside the efficient use and space, furniture design and its layout is also equally significant. Cupboards with pull-down / pull-out baskets and rise and fall units are implemented for the easy accessibility and application. Ambient technologies like sensor application, robot assistance, electronic touches; simple touch to turn on/off, or move, are included in order to simplify the activities. A functional food preparation area: a front and side approach to the work area counter (pull-out cutting boards) with a small dining or breakfast table, (pull-out surface) deals with the
function of space. Heat-resistant countertops allow users to slide hot utensils without the risk of trying to lift them which reduces an effort to perform such task. A tap that can be maneuvered to different orientations for washing dishes or hands is taken into consideration. Thus, the solution of ‘adaptable kitchen’ is designed to suit both the space available and the specific needs of the user, being fully adaptable to meet individual needs.

**Experimental Results & Evaluation**

Based upon the projected outcome from the concept, the advantages of developed products are: work flow, flexible space, adaptable for all people, assistive environment, plug and play connectors for infrastructures, mobile modules and user friendly interface.

Approach 1: The first approach is for the wheelchair users with the special flexible arrangement and mobility along with the implementation of ambient assistive technology. In fig. 6a and 6b, a wheel chair user is using the proposed modular kitchen ‘Adaptable Kitchen’ with assistive robots, making the work performance easier and comfortable. In this case, the kitchen moves for the user instead of user. The reach ability is enhanced with different mechanism like sliding, rolling and folding. Kiva robot \(^{15}\) under the module is helping for the mobility of modules, which can be easily controlled by the users. In addition, a robot arm is supporting the disabled person to relocate essential materials to perform the task. There is a monitor, with tactile sensors as a user interface, which controls the robot arm as well as other supportive activities. The circular floor is rotating for the orientation of the disabled person so that the user can access with minimum effort.

**Approach 2:** The second approach is for the normal or mixed users without application of assistive services. In fig. 7, a normal user is using the proposed modular kitchen with different configuration of working space adjusting the working height and it makes reachable to perform the task more efficiently. The height of the counters and components are adjustable with folding legs which make the normal user’s functions comfortable. The robots are at the corner and not used at the moment since a normal person can perform the activity independently without any support. The space needed for robots to perform task is now free for the normal people so that the user’s movements are undisturbed. The person will be moving instead of kitchen in this case.

**Approach 3:** The third approach is for the unused time period. In fig. 8, the working space is completely open when the kitchen is not in use. All the modules...
and other elements are stacked at corner since every element is foldable in itself. This open space can be used for other room’s purpose like bedroom with folding bed when the kitchen is free. The concept of multi-use of the room space hence saves spaces which is very costly in most of the cities.

MECHANISMS
As per the design of the proposed kitchen, different mechanisms are applied for the kitchen furnitures as well as for floor. The working mechanism of such furniture should be simple and effortless to use so that the person can handle it without any support and supervision. On the other hand, the price of fittings and installations should also be feasible so that the disabled and ageing people can commonly afford it.

Some of the important mechanisms such as folding mechanism for cabinates to pull it down to the desired height of disabled as shown in fig. 9a. This pull down mechanism not only helps to reach the necessary items but also provide free space for other activities when the cabinates are not in use. The second type of mechanism is a rolling cabinate which has working mechanism like a folding knife as shown in fig. 9b. Along the circular pole, the cabinets are supported and folded in adjacent angle which brings the cabinets closer to the user.

Besides the furnitures, floor has also mechanism of rotation to orient wheel chair users that works as mechanism of spinning disk shown in fig. 9d.

These mechanisms integrated in furnitures and building element help ageing as well as disabled people to perform their daily activities with minimum effort in addition with multi-functional use spaces. Plug and play connectors either fitted to the wall or to the floor as per the desire of users is best suited for the connection point of main module to the infrastructure point.

CONCLUSIONS
With the fast growing development and integration of ambient assistive technology, the smart environment with context awareness, user friendly and flexibility to perform daily tasks for the users of all kinds is fostering day by day. In addition, life expectancies are getting higher, and people with disabilities are
expected to contribute, grow more active and productive in the daily life than they could before. It presents more challenges for architects and designers to endorse these demands and progresses through the products or the environments they create. In addition, it is usually much more expensive to install a specially adapted kitchen in an existing home, than to stipulate one at the construction stage in a new home. Consequently, this paper has proposed a flexible and efficient approach for the design of a kitchen for the different user’s type without any discrimination. This makes the living environment more acceptable for all age groups of a family with different requirements. The concept implemented is modifiable easily in any kind of space without any interruption, hence, doesn’t need to modify or change the existing architecture of a kitchen or space. The assembly of kitchen is more convenient and acceptable.

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Prefabrication and Automation in Rammed Earth Building Construction

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Purpose Rammed earth construction (REC) is an ancient building technique. It has been wildly used globally for thousands of years. However, it has been abandoned and neglected by the mainstream construction industry after the industrial revolution, due to the availability and affordability of mass produced construction material such as bricks and concrete. REC has not been further developed since, meanwhile the potential of this ancient technique has been forgotten, until recently there is an increasing trend among construction industry, which attempts to reduce its carbon footprint and explore new ways of sustainable construction. The purpose of this paper is to examine and explore the existing techniques, materials, and strength, limitation of REC and evaluate the potential of implementation of new technologies throughout the design and build phase. Identify how technology implementation and cross disciplinary strategies would eventually upgrade this ancient building technique to its 21st century standard. Method For instance, in China, the government aim to carry out one of the biggest regeneration program in its vast rural areas. The main scheme is to improve rural housing condition and provide adequate new dwellings. In terms of sustainability, REC technique seems the best candidate for this role. Traditional REC has the reputations of labour intensive, time consuming and easily affected by external environment such as rain and wind. This paper will describe possible solutions to overcome those difficulties by examining various on-site and off-site construction technologies that have been adopted by mainstream construction industry, and also emphasis how technology implementation, innovation and alteration would influence REC in terms of efficiency and quality. Additionally, the potential of use rammed earth technique in different terrain, social and economy circumstances. Results & Discussion By analysing the differences between traditional REC methods and advanced methods, the author demonstrates the opportunity of optimizing existing techniques in other sectors such as manufacturing and automotive industries (Figure 1). Consequently, this could enhance the productivity and sustainability of advanced REC in the future. However, industrialized production methods might overshadow the nature of rammed earth building technique. Therefore, preserving yet enhancing the traditional techniques is vital.

Keywords: Rammed earth construction, automation, prefabrication.

INTRODUCTION REC has been widely used throughout the globe for thousands of years, from the ancient Great Wall of China 4000 years ago to the 250 year old Fortified City in the Draa Valley in Morocco. Archaeologist’s founding has proven that earth as a building material and technique has inspired our ancestors, and has influenced the way we build. However, after the industrial revolution due to the availability of cheap building materials such as brick, rammed earth has become less popular. After the invention of cermet, concrete became the primary material in modern construction. Rammed earth has slowly abandoned by the industrialized world. Fortunately, this historic building technique still been widely applied in many developing countries today. More than one third of human population still reside in earthen houses. Under the current trend of seeking sustainable construction methods, rammed earth has been rediscovered due to its unique characteristic. Firstly, soil is an ecofriendly natural building material and vastly available. Secondly, it is cost effective; building with rammed earth can dramatically decrease building cost. Last but not least, REC has very small energy consumption. However, there are still indicated many weaknesses, and potential for improvement. Commonly earth will be compacted with manual rammers layer by layer. This is an extremely nerve racking building process. It is not only time consuming, labour intensive but also effected by many external elements such as weather and terrain. Research has

Fig.1. Proposed method
shown that in the private housing sector mechanic tool have been developed and adopted into rammed earth construction, such as flexible design of formworks and pneumatically powered dynamic rammers. This has improved efficiency of the building process. Furthermore, newly developed, advanced earth building techniques demonstrate the value of earth building not only in self-built sectors, but also for construction contractors\(^1\). Future development and improvement on existing technology is essential, which covers various aspects, as well as challenges, the author will discuss these issues in later stages of the paper. Furthermore, the paper will mainly focuses on REC of single or double storey family dwellings.

**CONVENTIONAL REC TECHNIQUE**

REC technique is used predominantly for building load bearing walls which require moist earth unloaded into a temporary formwork in layers. Each layer approximately 10-15cm thick and then well compacted by means of ramming. Traditionally, the formwork consisted of two wooden panels on either side of the work space acting as a retaining wall which enable the panel to firmly hold up the soil while ramming is in operation (Figure 2). The formwork will then be disassembled, moved forward and reassembled in the direction of the construction. It will be interlocked by series of spacers which enable the formwork to lock into place and stop the form work expanding outward caused by the force. Compared with adobe masonry construction, rammed earth construction offers more stable ability because of the nature of monolithic structure.

Earth-based materials have shown many sustainable characteristics such as low carbon emissions minimising construction pollution and waste. In many countries, construction industry is one of the major producers of carbon emissions. Within the context of sustainable strategies for reduction of the environmental impact of construction, earth materials have the potential to make a significant contribution. The market for conventional rammed earth buildings is growing rapidly in many parts of the world, especially in Australia where in certain regions it accounts for approximately 20% of the new-build market. The same trend can be also found in the UK, USA, and other Latin America countries\(^3\). Especially in Australia, REC technology has been improved by many construction firms. Formworks and tools are been upgraded and customized to optimise efficiency. Building codes have been issued to overlook the building standard by local authority. Subsequently, there are specialized firms and skilled workers which would deliver high quality standard building projects. In contrast, in developing nations such as China who are behind the glorious economic growth, there are still many undeveloped regions where people are still suffering from inadequate accommodation.

**CHINA RURAL AREA REGENERATION**

Recently the Chinese government has introduced an ambitious national programme which aims to regenerate its vast rural area. The main challenge of the programme is to improve and upgrade the rural housing standard but not to compromise with the local environment. In China rural areas are predominately occupied by agriculture land. In many provinces local authority have issued tough regulations to control the use of farm land. As a result, limited sub-soil can be excavated. On the other hand there are many remote areas that are not accessible by any means of transportation. Tools and building material can only be delivered by human labour or by animals. It is unfeasible to use heavy machineries and modern construction techniques. This might be one of the reasons why the local construction sector was undeveloped. In addition, more and more young people decide to migrate to larger cities in search of economic opportunities; this has led to major demographic shift in Chinese rural population. According to a national report, in the year 2011 China's urban population has exceeded the number of rural dwellers for first time in its history. Less labour is available in its rural region and skilled craftsmen are even in shorter supply. To be able to achieve the goal of regeneration of such vast area, selection of building method choice of building method is essential. REC is inexpensive and relatively low-tech, which has demonstrated many advantages and potentials of fulfill this task.

**MATERIAL SELECTION & TREATMENT**

Sub-Soil, clay, sand, silt and gravel are the primary materials for REC. Material section and mixing is the first step and the most important step of preparation. But not all soils are suitable for rammed earth construction, only sub-soils. Because top soil consisted of soil mixed with organic remains of plants and animals, structural performance can be affected

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*Fig.2. Traditional formwork*
when it starts to decay. Soil needs to be mixed with right amount of gravel, sand and clay to form desired mixture for wall construction. Each project is different depending on its geological characteristics of the local area; local geological survey and collection of soil sample is recommended. Poor performance of the soil mixture can be optimised by adding stabilizers, such as Portland cement and lime which are commonly used. Yet this method was controversial as the nature of sustainability of rammed earth construction is compromised as the building cannot be recycled when cement stabilizer is added. According to research from Energy & Environmental Research Center University of North Dakota alternatively coal combustion, fly ash and bottom ash have excellent potential for use in REC. They are more cost effective and environmental friendly. There are no well-established engineering standards available for soil–fly ash or soil–bottom ash mixes. The fly ash industry has established many tests to evaluate the product. There are also numerous standardized tests to evaluate soil characteristics. Although these tests provide a starting point for rammed earth evaluation, many of the tests that are used for soil or fly ash as individual components are not applicable to rammed earth because the nature of the composite is different from that of either component. Standardized tests to evaluate soil–fly ash mixes do exist, but the tests are merely performed to establish appropriateness for roadbeds and fill, not for REC. Consequently, establishing engineering standards for rammed earth is necessary.

Conventionally, REC contractors tend to repeatedly use their soil source from the same quarry due to lack of trust of local soil source. Logistic can be costly if materials have to travel across long distance. Time spent during transportation is non-productive and could cost delay on a project. Therefore gathering soil locally can be cost effective, that a local soil database could hold record of local soil data and guideline of local excavation. This solution could be realized by incorporation with local geologists as well as university and research institutes. Data collected can be shared as guide line for local building control authority and local construction contractors. Using evacuated sub-soil from a conventional construction site can be reused rather than landfilled. Removal cost could be split by the construction firm and rammed earth soil provider. The soil will be treated and mixed under the guideline and distributed to REC industry. Reuse evacuated soil could offer minimal construction waste to landfill.

**In-situ Construction & Prefabrication**

Panning is the key strategy for in-situ type of construction such as REC which most of construction activities are conducted on-site. Materials and components need to be protected from external influence before assembly. Firstly, material storage can be problematic in an on-site situation as a result of changing characteristics of the weather. For instance in cold climates will produce frost due to the moisture level left in the soil mixture and by contrast in dry climates moisture will quickly evacuate. As a result soil mixture is damaged and can cause delays on-site. Despite the course of climate and location, a fundamental part of in-situ construction is to have prefabricated component materials on site ready for assembly. In REC, structural components can be prefabricated on-site to reduce initial investment. Secondary elements such as internal wall or roof structure can be prefabricated either on or off-site depending on the project. Weatherproof shelters can be used to protect finished components and workers from external elements. In addition, on-site quality control, in terms of controlling soil moisture content and precision of the assembly it is essential to ensure construction quality.

**Design Flexibility & Standardization**

Industrialisation in building is not new and many buildings are now industrially manufactured. Characteristics of industrial production are mass production, repetition and standardisation, off-site production and machine made production. Post-war housing shows some the characteristic of mass production. Also in Japan there are many examples regards to off-site building production such as Toyota Housing, Sekisu Heim which has demonstrated the advantages of factory made buildings; high precision, high quality, highly customized, and brilliant customer relationship. To be able to adopt the principle of industrial building method, traditional REC technique has to be reconsidered regards the way it has been designed produced and assembled.

**Formwork design**

Traditionally, formwork for rammed earth construction is similar to formwork used in concrete production; it offers temporary support during compaction process. It must provide strength and stability. Normally formwork will be dismantled and reconnected almost immediately after compaction. It is labour intensive and requires coordination between all site personnel. This assembly of formwork costs a significant part of overall construction time; therefore an efficient formwork system is essential to improve productivity of REC. There are many choices of formworks available on the market. However, to apply those in an extreme terrain became a difficult task due to their weight and size. The suggested solution is that formwork needs to be designed modular, light weight, easy to be cleaned and transport, potentially without using crane or other heavy lifting device. Furthermore due to increased cost of formwork, attempts have been made to develop
permanent formwork techniques. Permanent formwork made from thin masonry or brickwork or alternatively timber frame formwork, which became part of the structure after use.

Implication for components design
Wall is one of the primary parts of the rammed earth construction which offers load bearing structure of a building. Commonly formwork is used to construct walls. However, it is time consuming and takes experience to manage. Instead of producing entire wall section on foundation slabs, alternatively wall modules can be designed as interlocking parts with special connecting point designs, which smaller or individual formwork can be used. Each module has to offer sufficient stability as monolithic structure so mortar might be used as stabilizer. Size and weight of each module is important issue. Preferably it will be easily carried and assembled by 4-5 people on-site with basic construction equipment. On the other hand, smaller size means building module along with formwork can be transported by trains, trucks, van, or even by a family car (Figure 3).

Standardization
Another core challenge is standardization of REC. Building design requirements need to be regulated, for example, Australia, New Zealand, and USA (New Mexico) have already issued full national building codes regards to construction of rammed earth building. Standardization of the design will allow prefabrication to take place, which can dramatically improve productivity of rammed earth modules and optimise its quality. For example standard component design allows mass production of the component therefore reducing the cost. Implementing the principle of the open-building approach by John Habraken, the base building such as the wall can be constructed with standard modular element to offer a rigid outer shell. In contrast internal walls and fit out of the building need to be designed to be more flexible; prefabricated by timber frame or light steel frame structure, which can be easily disassembled when internal alteration is needed. An open-building approach could offer individuality to a standardized design as the end user is engaged into the design process, therefore the finished building should appear with a high degree of customization but offer a mass produced price, which is in common with automotive industry today.

Fig.3. Smaller components design allow easy transportation

Fig.4. Proposed on-site factory

TECHNOLOGY IMPLEMENTATION & FLOW OF WORK
The methods and tools already available to help industrialisation in the construction sector to be a step forward are numerous. They vary from robotizing of traditional craftwork to completely new techniques especially designed for application in industrialised construction. Implementations of the correct technologies or methods are essential. In Japan they have developed huge numbers of single task robots and automated construction systems. These have demonstrated increased productivity and improved quality of construction. However, this cannot be achieved without the cost of heavy research investment and facilities. The similar approach seems unfeasible to develop REC in developing nations. Subsequently, use low-tech approach seems practical, which will keep the cost low and offer an affordable product. Although it might be low-tech, it does not mean to follow a conventional approach. The attention is to use limited man power, tools with minimal energy consumption to achieve optimised result. An efficient, well organized on-site construction facility will ensure the quality and safety of production. Similar to off-site factory production, distribution of different types of materials and storage of different types of prefabricated components as well as managing division of work forces has to be stressed (Figure 4). If necessary, work tasks can be divided into sequential stages and different level of priority. For instance, Sekisui Heim has established sophisticated production facility. To keep a smooth
production flow, the company adopted production sequence which is very close to automotive industry. Tasks and workstations are well divided; components are prefabricated on a sub-line, which running simultaneously with the main line to reduce time losses of the entire production line. Another approach is from Sekisui House, which is a smaller family business who relies on Sekisui Heim’s powerful production capability. The company purchase bespoke building design from Sekisui Heim, so no production facility is needed. This is prefect solution for smaller firms. A unique bottom up approach is used to erect the roof, “J-up” jacking system to lift up the roof structure one storey high at once. When the wall frames are secured the jack will repeat the same action again. This not only saves on-site space but also provide a weather proof shelter for the ground work force. These approaches can be modified and implemented for REC.

Mobile factory is a construction concept developed by Manu Build. The concept is container based with the ability to “link” containers together on-site to produce a variable and extendable factory. The container-based factory can be moved by lorry from one site to another whenever and wherever it is needed. The factory has autonomy in energy, management and operational senses. In addition the factory is flexible and provides safe working environments and is reconfigurable for multipurpose on-site activities and materials. Alternatively, the concept can be implemented into REC, which soil can be transported by containers together with formwork and construction equipment. A mobile rammed earth factory can be very flexible despite the influence of the weather and location (Figure 5). Prefabrication of the wall components can even start during the transportation period by using on-board automated system similar to the concept of cement mixer lorry, thus the normally wasted delivery time is now productive. Preservation of local work force and local business has to be taken into account at an early stage of any project. Rammed earth component prefabrication does not necessarily be off-site factory based. Because of this, most building components can be prefabricated on-site or sub-contracted to a local firm. The building needs to be designed in a way that non-skilled workers could erect after short training and guidance by professionals. Because in many cases, especially in China, a rural building site is where villagers come together and work as a team. It offers senses of community and belonging, outsiders normally are not invited. Hence social impact and local custom need to be addressed before construction to ensure all stakeholders can benefit from the development.

SUMMARY

Rammed earth is not currently treated as a standard form of construction method used in the construction industry today. However, it has the potential to be accepted as mainstream construction due to its features of sustainability, customizability and flexibility. To be able to complete with other types of construction, rammed earth construction must preserve its strength and overcome its weakness by technology integration and implementation. The author has mentioned some possibilities of improvement, but there are still many issues unaccounted for, which require more extensive studies and research to accomplish.

References


Fig.5. Prefabricated modules are transported by containers
A Flexible Automated Working Space Module (FAWSM): A Development Approach for Activities of daily living

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Purpose The purpose of FAWSM is to develop a working space module which will be installed in the building over any stage of its lifecycle and will assist the all user groups through automated systems to have a work space based on daily activities as flexible as every individual user’s needs. It is a standardized universal work space module having advantages of flexibility in transportation, modularization and usage. Method Demographic change studies, dealing with elderly population growth, reveal a relatively rapid increase and it is expected that in the next half century the proportion of elderly people will increase from 7% in 2000 to 16% in 20501. Europe and Asia countries have almost passed the closing stages of the demographic transition process while Latin American and Africa are only at the beginning3,4. In this study, Activities of Daily Living (ADLs)2 and the needs of different age groups and professions are identified. The experiments performed provided the additional requirements regarding dimensions for the module construction. This study led to the initial mock up idea which fulfils the requirements for easy approach, personal height requirements for grabbing something from the shelves, and convenience to all potential users. Results & Discussion A flexible infill architectural solution is provided for different age groups to perform their works on a simple, easy approachable and convenient module. There is still need to integrate the pervasive technologies to cope up with the upcoming challenges of our society. There is possibility of flexible control, manual and automatic, to use the module depending on the needs and health status of the user. The module has wheels fixed at base to provide transportation mobility within an apartment as well as to another location. The module has foldable table to provide work space, one height adjustable cabinets sub-module for easy accessibility and another bottom sub-module with a drawer and easy accessible cabinet.

Keywords: demographic change design, architecture, ageing society, working space

INTRODUCTION Rising life expectancy and/or declining birth rate are causing population ageing. It is most advanced in the highly developed countries, and it is less developed countries that are experiencing the dramatic change. The speed of population ageing is anticipated to increase in coming decades, this emphasize on the study whether elderly will be able to live the extra years of the life in good or poor health, and what technology development can offer in this regard.

Figure 1: Ageing is accelerating worldwide
Source: UN World Population Prospects: (2010 Revision)

Figure 2: Major developing countries will start converging with developed one
Source: UN World Population Prospects: (2010 Revision)

This demographic change need to be accommodated into our society at different levels and area. A recent survey in the United States showed that it was only a small minority who wanted to retire at the traditional age. Around 80% wanted to continue to participate- but not in the same way. They want to work part time or start a new career, or launch a small business. They wanted flexibility5.
**Research and Survey**

In developing countries, 75% of the elderly persons are living with their children/grandchildren. On the contrary to this, there are only 27% elderly people in developed countries who live with their children. The elderly living alone need an independent living solution. Activities of daily living (ADLs) is a term used in healthcare to refer to daily self-care activities within an individual’s place of residence, in outdoor environment, or both. To fulfill the need of elderly disabled people, the idea is to make a smart working space module. We conducted the experiments to find the dimension requirement, and found that easily grabbing height for an average height person is 160cm. We compared our requirements with the UN’s design manual for barrier free environment.

![Vertical reaching zones of a wheelchair user](image)

Figure 3: Vertical reaching of a wheelchair user

![Vertical reaching zone of a normal person.](image)

Figure 4: (Left) Vertical reaching zone of a normal person. (Right) Horizontal forward reach of a wheelchair user

We identified the following activities for our smart working space module construction as per different user age group.

<table>
<thead>
<tr>
<th>Age group</th>
<th>Activities</th>
</tr>
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<tr>
<td></td>
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<tr>
<td>5-10</td>
<td>x</td>
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<tr>
<td>11-25</td>
<td>x↑</td>
</tr>
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<td>x↓</td>
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<td>46-65</td>
<td>x↓</td>
</tr>
<tr>
<td>Over 65</td>
<td>x</td>
</tr>
</tbody>
</table>

Table 1: Analysis of activities regarding the age group of the users X= average, X↑= highly required, X↓= less required

**Experiment Observations**

![Extended Table](image)

Figure 5: Extended Table

![Controlled drawing table](image)

Figure 6: Controlled drawing table

![Flexible drawing board](image)

Figure 7: Flexible drawing board

![Revolving cabinet](image)

Figure 8: Revolving cabinet

![Other ideas](image)

Figure 9: Other ideas

![Limitation](image)

Figure 10: Limitation

**Results**

![Dimensions requirement for the working table for both disable and normal person.](image)

Figure 11: Dimensions requirement for the working table for both disable and normal person.
CONCEPT
The basic idea was to develop different automated modules based on daily activities of a person is placed in different locations of the Room. The room is divided in a simple grid both in ceiling and floor. These grids are used as the guiding rail for automatically movable Modules based on Activities and need of the person. The modules are hanged from guiding rails from ceiling. The modules can also move vertically due to the ergonomics needed for the user. There is an observer Robot hanged from ceiling that can also move with those rails for keeping its eyes to the user all the time and transfer data to the Communication Module and other Modules. The Communication Module Placed at the room which can be controlled by the user from his/her sleeping bed or even from his/her wheel chair. All the service lines are hidden in the surrounding walls which can be attached with the Modules after using them. The special wheel chair will be as a part of the sleeping bed of the user. It can be vertically movable regarding the height (ergonomics) of the modules and the user. But finally only one working space module was chosen for the mock up.

Figure 12: Initial idea of developing different module for a room

Concept Implementation
After choosing the working space module implementation, the activities to be performed on this module were analysed for different age groups, and was tried to accommodate those for elderly, disable and as well as normal persons. A working space module with three submodules M1, M2 and M3 was chosen emphasizing on modularity, convenience and movability.

Figure 13: Concept Implementation Process

Figure 14: Flexible Automated Working Space Module
IMPLEMENTATION TO THE MOCK-UP (PROTOTYPE)

A scaled prototype model is developed in the lab regarding the ADL of working space as well as on basis of the ergonomics needed for different age groups of both able and disabled person. The dimension of the space module was kept strict to that size for easy movability, transportation and modularization. It was also observed how to integrate both manual and automatic control system for using the module as flexible as we can.

Figure 15: diagrams showing the Plan view and the Front elevations opened and closed of the MOCK UP

Figure 16: diagrams showing the movements both in horizontal and vertical directions of the modules and sub modules of the MOCK UP
The Prototype

After having mock up (scaled prototype) developed as an architectural infill solution, it is observed that it can easily be implemented on the full scale. The all three sub-modules are movable providing more flexibility. The top sub-module (shelves) moves over the rail vertically providing better and convenient grabbing approach for different user. The rotating function of the drawers provides an extra flexibility specially for disabled persons. The middle sub-module (folding table) is used successfully for telephonic, study, computing and other similar working task. The bottom sub-module is also movable, and convenient to use the cabinet as everything placed inside comes out when the cabinet door is opened.

Secondly, there is a need of standardizing this module, so that new sub-modules could be added as plug-ins with ever changing needs. The more modular approach shall also be adopted.

CONCLUSIONS AND FUTURE DEVELOPMENT

It is feasible to provide this as an architectural infill solution which can be added at any stage of building lifecycle. A combination of mechanical and pervasive technologies (Ubiquitous computing and the use of actuators) will be ideal to provide a modern solution for the elderly's independent life.

References

5. Dr. Margaret Chan, a keynote at “Global Population Ageing: Peril or Promise”, World Economic Forum 2012.
**INTRODUCTION**

Derivation of new applications for ubiquitous technologies in architectural environment always calls for acute observation and understanding as to what, where and how certain types of technology could be seamlessly integrated into the infrastructure of built environment in order to address specific problems which are faced by people in the activities of daily living (ADLs). Further, with the advancement in ubiquitous and embedded computing technologies, the technical solutions that could be taken up to improve the standard of living are huge in variety. This paper focuses on how integrated, networked and intelligent assistive technologies could aid the process of personal hygiene and grooming which is one of the self-care tasks included in the ADLs. To develop a new application in this regard, an explorative investigation approach will be taken. The aim of such investigation is to firstly develop theoretical and conceptual assumptions that might eventually lead to the formulation of propositions. Then take this initial hunch to the next level by using qualitative research methods such as reviewing of existing applications or workshop. Subsequently, designs, prototypes and technical implementations can be made to the idea based on the research. Eventually a set of guidelines arises from the whole development process.

**RESEARCH AND SURVEY**

Due to medical conditions or accidents, there are currently a significant number of people who has to use a wheelchair in their daily lives. For example in the alone USA there are 3.3 million people relying on wheelchairs to mobilize. This figure is generally high especially in industrial countries, and not negligible in various aspects. These people will always find themselves having a hard time adapting themselves to home environments that are only designed for healthy person. On the other hand, since the high prices of professional care, most of them simply have to manage some of their activities of daily living at home by themselves. Personal hygiene and grooming is usually the first activity that a person will engage when starting one’s daily activities. More specifically, it would involve sub-activities as follows:

- Washing hands
- Washing face
- Brushing teeth
- Shaving
- Hair styling
- Make up

These events most likely take place in front of the bathroom washbasin unit with mirror and storages.
In regular households, the facilities that accommodate such activities are often times in simple and rigid configurations. Users have to adapt themselves to the fixture to perform hygiene related tasks, such as bending and stretching their body parts.

This might be of little discomforts for an average person, but it could cause a lot of inconveniences and sufferings for people with certain kinds of constraints, for example an elderly person who has to depend on a wheelchair to move around. In this case, the design of the facility would concern a complex mixture of geriatric requirements. There are some existing bathroom washbasins that are somewhat convenient for wheelchair users to adapt. These facilities are mostly seen in hospitals, nursing homes, high-end hotels and so on.

In hotels and hospitals, there are extra handles attached in the bathroom to provide more support for users in wheelchair. But these designs are only considered for the practical use and neglecting the aesthetic standards and psychological effects on users. Moreover these facilities are too simple and lack customizability, wheelchair users still find it hard to orientate and adjust to a comfortable state when performing activities in front of them. Figure 2 shows some examples of such wheelchair-friendly bathrooms in hotels and hospitals.

In Nursing homes, the bathroom facilities are much better in terms of both practice and appearance. But since they are still public environment, customization cannot be brought to the fullest. And some functionalities are simply omitted because of the presence of professional care givers.

Through reviewing of several other studies, it should also be noted that the hierarchical modularity and platform strategies are also very important aspects of the feasibility of the product. Various assistive technologies can be customized to facilitate certain user needs, and also extended or exchanged at a later time to cope with the changes. Individual modules have to be pre-configurable, easy to install. Easy maintenance by both care givers and takers has to be addressed in the early design phase.

RESULTS

With some investigation and comparison mentioned above, now it’s fairly clear what the basic requirements for bathroom sink units dedicated for users in wheelchair are.

- Horizontally and vertically adjustable washbasin
- Angle-adjustable mirror
- Ergonomic design
- Storage cabinets for easy reach

Beyond all these most basic needs, the hypothetical unit can also be equipped with value-added functions and attributes such as

- User recognition
- Automatic configuration
- Health monitoring
- Entertainment
- Modularity

Some requirements are met with more efficient architectural designs, others can be accommodated by applying technologies such as sensor-actuator feedback systems, ambient intelligence and mechatronics. Creating an environment that is friendly for people with disabilities to carry out daily living tasks will require integration of many sensors and actuators. As envisioned by ubiquitous computing, communication can be added between these distributed electrical devices, thus making it possible to combine distributed information, analyze data and efficiently support users during their tasks.

CONCEPT

After identifying the activities taking place in front of the washbasin and subsequently determining the functions and attributes of a hypothetical washbasin
unit, it is possible to define a concept for an intelligent bathroom sink unit that is friendly to all types of demographic especially the disabled. The everyday hygiene keeping and grooming activities are no more than simply a formality for all, but with an intelligent, ergonomically designed and entertaining multifunctional washbasin unit, the experiences can be much more pleasant and enjoyable, not only for people in wheelchair but also ordinary people.

![Image of the proposed intelligent bathroom sink unit.](image)

**Fig.4.** Overview of the proposed intelligent bathroom sink unit.

The proposed unit consists of following modules:
- an ergonomically designed ceramic sink
- a multi-functional angle-adjustable mirror

The sink unit not only has a shape that provides convenience for people who depend on wheelchairs, but also provide both vertical and horizontal adjustment so that every member in the household can use it in a most comfortable way.

- a multi-functional angle-adjustable mirror

It provides different angular positions to cope with the special need for users in wheelchair. A touchscreen tablet is also integrated into the mirror module at a reachable position to provide various functionalities such as radio broadcasting, music playback, user preset for mirror angle and sink position, face recognition for automatic configuration and etc.

- multi-functional storage closets

They are positioned on two sides of the ceramic sink in order to be easily accessed. The drawers from top to bottom are dedicated for different hygienic tools, and the distribution of the drawers are arranged according to the usage frequency of specific tools. Certain drawers should also have sterilization devices implemented so that the frequently used tools are in a constantly bacteria-free state. Loudspeakers could also be integrated into the module, with connection to the tablet mentioned above. Additionally, automatic air-freshening tool is attached in order to maintain a pleasant atmosphere in the bathroom environment.

Modules can be easily assembled into a whole unit, and unit works in a plug and play manner. It functions as long as it's supplied with water pipe and electricity.

Sensors and actuators work in a closed-loop feedback control with the control of the central system. Tablet device attached on the mirror will provide a graphical user interface to allow user easily configure the system according to own preferences. The whole system as a platform also allows other value-added extensions to be hooked onto the system.

![Image of the simplified structure of the control system.](image)

**Fig.6.** Simplified structure of the control system
**Solution Approach**

There are various technical solutions to be implemented to the proposed system. Linear actuators and angular actuators can facilitate the functionalities associated with mechanical motion. A wide range of affordable products could be easily found in the market. Sensing devices include position sensors, proximity sensors, angular sensors, temperature sensors and so on. All the sensors can be connected to the central system and interconnected to each other as wireless sensor network by technologies such as ZigBee. Thus reducing the cabling work had to be done. Mechanisms such as lifting columns can be used to support the washbasin and allowing vertical movement. Physical buttons can be placed on the unit to adjust system configurations. To test the feasibility of the proposed system, a prototype has been made using primarily MDF wooden plates. Some mechanisms are replaced by simple connections and railings without actuators just to mimic the effects. The scale is 1:2 in the prototype.

**Fig. 7. Dimensions of the system**

The dimensions of the system are set according to the standardized measurements in Architect's Data, where wheelchair dimensions and the person's reachability and comfortable viewing angles in the wheelchair are given as references.

**Fig. 8. Some references from Architect’s Data.**

**Fig. 9a. Front and top view of the prototype**

**Fig. 9b. Side views of the prototype**

During the building of the mock-up, there are several points to be concluded. Modularity is one of the key attributes for this system to be easy to implement. The adjustable washbasin also needs to have a strong support in order to guarantee the user safety.

**Conclusions**

An explorative investigation approach is taken in the proposed research. When performing personal hygiene and grooming activities from ADLs, people in wheelchairs tend to require more flexible bathroom setup. Due to the large number of people who rely on wheelchairs to mobilize, the potential market for this system is promising. Even for ordinary healthy people, this intelligent bathroom sink unit also could bring a new level of ease and comfort in daily life. In other words, the system can also be seen as a universal home appliance that aims at all demographics.
The proposed approach dealt with identifying the needs and requirements by conducting quantitative research. The research is loosely guided by Verplank’s Spiral\(^1\), which supports the explorative approach. The project starts with a hunch, which is a vague idea of what to do. This leads to a hack, a first technical implementation, and makes it possible to try if the hunch actually works. If it does, it is further developed into ideas that lead to multiple designs, which can be implemented as prototypes and subsequently tested\(^4\) (Figure 8). This approach is very practical and efficient in developing ubiquitous computing applications in built environment.

Fig.10. Verplank’s Spiral\(^1\)

References

Dealing with mobility issues in home environment: Proposal for vertical moving storage system

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**Purpose** Demographic changes like rapid increase in the elderly population\(^1\) and the percentage of single-person households\(^2\) have created new needs in the home environments. Members of the ageing society face increasing mobility limitations\(^3\) which have a noticeable effect on their Activities of Daily Living\(^4\) (ADLs). As an answer to those problems, a system within a household that assists people with mobility issues is proposed. The proposed solution focuses on providing accessible storage space, for people of different height, age, sex and degree of mobility ability. **Method** The steps of the development approach were: i) Preliminary research on matters of ADLs, ii) Experiments in real environment and collection of relevant data, iii) Evaluation of experimental results, iv) Identification of technologies and mechanisms, v) Concept development and test models, vi) Final concept and evaluation. **Results and discussion** A Vertical Carousel Storage System is proposed, rotating individual compartments towards an access point, adjusted each time according to the user’s needs. This adjustment is made possible by the proposed access opening, which can be moved and lock in different positions of the front surface, allowing access to people of various heights, in standing positions or in wheelchair. Further modifications of the initial concept need to be done in order to achieve more efficient use of space.

**Keywords**: mobility, furniture, automation, storage system

**INTRODUCTION**

Current trends in the consistency on the world’s population indicate significant challenges that will have to be faced in the following decades. Not only is there a rapid increase in the elderly population which will only grow in the next half century, but the percentage of single-person households worldwide is increasing as well. The needs of the ageing society that have to be addressed are closely linked to limitations of mobility, which, in turn, have an immediate effect on Activities of Daily Living (ADLs).

In order to confront these issues, modification of the home environment is essential for supporting the future individuals in their Activities of Daily Living. Several efforts toward this goal feature the implementation of technologies and the redesign of home spaces and furniture\(^5\).

The aim of this project was the development of a storage solution, within a household, that could meet the demands of a mobility impaired individual.

Before any attempt of designing a system helping people with mobility problems, testing must be done in order to obtain the relevant data results, evaluate them and later use them to get the most optimum results. The highest number of the samples one takes, the more reliable the results become.

**RESEARCH AND SURVEY**

The first step of the testing process is to set some standards in order to obtain more accurate measurements. A point \(x\) in front of each piece of furniture used was marked, 18 cm away from the front surface of the furniture, and every possible user used for the experiments was measured from the exact same point. Each of the individuals participating in the experiment was measured under the same conditions, performing the same predefined set of movements (Fig.1). A set of constants was used as a basis for the measurements: the point \(x\) on ground level in front of the furniture, a vertical plane on point \(x\) parallel to the front furniture surface, and the horizontal plane of the ground level. Also, a swivel chair with properly adjusted height and size was used to simulate the movements performed by wheelchair users (Fig.2).

**Fig.1. Measurement of reachability in standing position**
The sample group included a variety of individuals of different height, weight, sex, and reaching ability. The movements measured were: upward reach, downward reach (Fig.4,6), forward reach and sideways reach (Fig.5,7), both from a standing and from a sitting position. The subject was on point X when standing, and had their feet on point X when sitting. All test subjects performed the movements with a minimum effort (without stretching or bending). This procedure essentially demonstrated the range of arm movement in a relation to a three-dimensional object, but internal partitions were not taken into account at this point.

Fig.2. Measurement of reachability in sitting position

Fig.4. Field of reach in vertical plane, in standing position

Fig.5. Field of reach in horizontal plane (forward and sideways), in standing position

Fig.6. Field of reach in vertical plane, in sitting position.
Measurements also took place with the individuals in a sitting position to simulate the accessibility options of wheelchair users. During testing it became evident that wheelchair users face more limitations than just the height of the storage spaces. Even storage space at their shoulder height is not accessible when they try to access it by leaning forward, because of the dimensions of the wheelchair. Approaching the furniture in a parallel movement and reaching sideways allows them to reach a significantly larger area, though it may not be the only viable solution (Fig. 3).

The range of movement is even more limited when the user needs to access an internal storage compartment, for example a shelf. The issue in this case is not only in matters of accessibility (bending of the arm is usually required), but also in matters of limited visibility.

**CONCEPT**

The purpose of the measuring procedure was to aid as a guideline during further steps towards coming up with a storage solution for users with mobility problems. The design stage should be preceded by the evaluation of the results obtained from the experiments and of the data gathered from other sources (for example, furniture sizes) (Table 1). This evaluation allowed us to define the optimum solutions in terms of the following: size of storage compartment, position of storage compartment (within the user’s reachable area), way and direction of approaching storage compartment (standing and/or wheelchair users).

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**STORAGE FURNITURE SIZES**

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<thead>
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<th>type of furniture</th>
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<tr>
<td>Wall mounted cabinet</td>
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<td>70/92/40</td>
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<td>60 (incl. door)</td>
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</tr>
<tr>
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<tr>
<td>Wardrobe frame (type b)</td>
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<td>203</td>
<td>58</td>
<td>-</td>
</tr>
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</table>

**Table 1. Standardized storage furniture dimensions**

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Based on the experimental results, it was defined that the suitability of a storage compartment is directly linked to its position relative to the user, so that it is within the user's field of reach and vision. The optimum position is at the center of the user’s reachable area, due to the fact that compartments positioned closer to the edges of the reachable area lack visibility, thus making them practically unusable.

There are variations of this optimum position according to the individual's height and moving ability. The evaluation of the experiments resulted in a series of characteristics that should be implemented in the final product and define its design process:

- The final product should correspond to standardized dimensions in order to be able to be combined in a multitude of room sizes and layouts (Table 1).
- Standardization is also essential for the individual storage compartments in order to produce efficient storage space.
- Due to the fact that there is a specific position for each person where a storage compartment is most efficiently used, all storage compartments should be able to be placed to that position. Therefore, the final product should contain a mechanism that brings the compartment to a specific position, the storage access point.
- The storage access point differs for each person. It should be adjustable, in order to respond to different needs dictated by the user’s dimensions and mobility skills.

4. **Concept Implementation**

The proposed solution is a vertical carousel storage system, which is a cabinet containing individual compartments, intended to be used as shelves (Fig.8).

![Fig.8. Axonometric drawing of the inside of the cabinet](image)

A mechanism consisting of gears and belts is responsible for the movement of the compartments. Two gears connected with an axis are placed on the lower part of the sides of the cabinet. This mechanism transmits movement to two belts, which in turn rotate two more gears on the upper part of the cabinet. Evenly spaced individual storage compartments are hanging from these two belts. This coordinated movement of the two belts is responsible for the aligned transfer of each compartment to the desired position (Fig.9).

![Fig.9. Two-dimensional drawings of product's interior](image)

As mentioned previously, the desired position is unique for each individual; a static solution would not suffice. Therefore, on the front surface of the cabinet, a sliding panel containing a flap-down door can be adjusted to different heights within a certain range (Fig.10). This range was calculated using the experimental results, specifically the average height of reachable area of all users in standing and sitting position (Fig.4,6). In this way, it can respond to the needs of multiple users of different height and mobility skills. The flap-down door and the opening it covers make up the Storage Access Point.

![Fig.10. Vertical adjustment of the flap-down door in various positions](image)

An example showcasing the cabinet’s function is the following:
The user approaches the cabinet and requests a specific object within the piece of furniture. The Storage Access Point, if not located in the appropriate height for that user, can be adjusted at that time. In the interior, the mechanism rotates the compartments, imitating the movement of a vertical carousel. The mechanism stops when the requested compartment aligns with the Storage Access Point. The Access Point door can now open and be used as an assistive surface while the user collects the needed objects from within the storage compartment.

Before using the cabinet for the first time, it should be programmed to adjust the opening according to each user’s reachability.

**Automated movement and alignment of the selected shelf at the access point.**

The movement of the mechanism could only be achieved using a motor, since the force needed is significant when considering the weight of the compartments and their contents. To reduce possible risks, the alignment of each compartment with the Storage Access Point should be automated, in order to eliminate human errors.

**Automated selection of the shelf according to the object selected**

RFID tags should be embedded in all the objects contained in the cabinet, as well as a screen on the exterior of the cabinet demonstrating the list of objects included inside it. In that case, the user would request specific objects, rather than a complete shelf, minimizing unnecessary movements and the time required to find an object. In case of clothes, washable RFID tags could be implemented. The same procedure applies also to the placement of an object in the cabinet.

The implementation of a fully automated system would be beneficial in the long term, as a person’s mobility limitations grow more severe. Although a fully automated solution would increase the cost, this could be balanced by standardizing all the parts of the product, and decreasing the total production cost.

In a fully automated solution, the age of the users should be taken into consideration due to the fact that elderly people are not familiar with modern technology. Thus, the proposed solution should be as simple as possible to them.

The application of the storage solution proposed and the dimensions are not exclusive. In correspondence with the standardized dimensions (Table 1), the product can be produced in several sizes and for different uses, such as in kitchens, bathrooms, bedrooms and all sorts of rooms needing storage compartments.

Beside the innovative features embedded in the system, the mechanism used in the final product is rather simple, and easy to be applied in alterations. Apart from installing it in a vertical way, it could be also applied in a perpendicular plane performing horizontal movement.

Moving one step forward, this idea could allow the connection of many cabinets in the same room, able
to work individually or linked to each other and constituting a three dimensional automated space.

References
Visualization and Simulation Approaches In Construction

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Purpose As robotics and automation technologies are integrated in building construction processes, it is also necessary to visualize and simulate the construction work with the help of augmented reality. Model simulation and visualization can help project engineers to estimate construction schedule, workforce necessity, proper utilization of resources and to meet the client’s demand precisely before the beginning of real construction work. Engineers can also monitor detailed construction work during realization and simulate on-site activities with the table-work. Method This paper is aimed to analyze some projects, identify the common project failures and common reasons behind the failures of those projects. Analysis of research papers for some proposed visualization systems for pre-project estimation was done throughout the paper. Results & Discussion in addition the author proposes visualization and project monitoring approaches encouraged by indoor navigation systems. Workflow with augmented reality during construction lifecycle was discussed in this paper. However, author aims for demonstrating the achievable degree of efficiency by augmented reality before and during construction process. Nevertheless a comparative study was done for evidencing the advantages of visualization approach.

Keywords: visualization; construction-visualization; construction-simulation.

INTRODUCTION
The conventional building construction process is replaced by more efficient industrialized form and the increasing globalization demands for short time consuming projects with quick return of investments but containing high degree of accuracy. Due to the continuous degradation of quality, productivity, skilled manpower and working environment, to compete with other products in the market – the investors in construction sector looked for revolutionary change. The inclusion of automation and robotics aimed to accomplish the demand and can be said that could attain the goal into a satisfactory level.

In beginning of the research for automated and robotized construction process, the majority of the researches focused on hardware and software development which are obvious in areas such as concreting, steelwork lifting and positioning, finishing works and planning software prior to the real construction works. Little attention has been given to investigating the factors that affect the infiltration of these technologies into the construction work site and processes. Previously, researchers predicted that construction sites will gradually become “intelligent and integrated” as materials, components, tools, equipment and people will become components of a fully sensed and monitored environment. Automations of construction processes is considered to replace manual hazardous labour and labour-intensive tasks such as welding and high-steel work by wirelessly networked with sensors and communications technology based construction sites. This automated construction sites will ensure highly efficient, risk free, less time consuming tasks performed by the construction workers who are well trained with the work they are performing.

Upon the findings of different real construction works, researchers sorted out some common project failures and the reasons behind those failures. Visualization of projects before going to the action is supposed to be an important solution to avoid the project failures. Visualization approach can also help to run the construction work on schedule, because detailed works are closely monitored by the supervisor. Simulation technologies can enable planning and analyzing construction operations performed in advance anticipating problems of efficiencies that would occur in the implementation phase. Therefore, simulation systems are used to design optimal resources to supply in a construction operation and analyze an ongoing operation to be evaluated and refined.

Navigation technologies also can serve a great purpose to ensure the best possible outcome in a construction work. Proper utilization of usual navigation and indoor navigational approach can come out in handy to avoid project failures.
SOME BIG PROJECTS ANALYSIS AND THEIR FAILURES

Sydney Opera House

The Sydney Opera House is considered as one of the canonical examples of project failures with major budget overruns accompanying significant delays. The reported failures are—

- The judges put in place a 'stage gate' process to evaluate entries, but then they were disappointed. The beautiful ‘sail’ design, the one which is ultimately selected actually could not meet the selection criteria but anyway the judges liked and selected the design throwing all the selection process aside.
- At the beginning of the real construction work, actually there was no clear concept of how it is possible to construct the roof. It’s not that all the estimates were wrong, it’s that there was nothing to base the estimates on in the first place. The roof was designed and built many times which caused much of the delay and cost overrun. After continuous repeating of the same task, engineers come out with the solution to construct the roof out of interlocking tiles.
- Though Opera house is one of the greatest architectural masterpieces from last century, but it failed on cost and field estimation.

Scottish Parliament

Regardless of winning many national and international rewards for its architectural excellency, the Scottish Parliament is also criticized by experts for certain reasons.

- It overran initial costs by a factor of ten and was delayed by 3 years. The design was not finalized before construction work took place like the Sydney Opera House. The budget of the whole building was not according to credible cost estimation process. Among five selected finalists, none of them adhered either to the user brief, an area of 20,740 metres squared, or the budget of £50 million.
- The architects changed the design few times which caused them to add 4,000 square meters more with the initial design. The additional land caused to increase the land consumption about 14% to the original design area.
- There was complexity to balance between the sponsors’ desire to have the parliament ready as soon as possible and the architects’ desire for a “gestation period” to really flesh out his design together with a need to be engaged in all decision making.

Toshka Project

The New Valley Project or Toshka Project is one of the biggest projects in middle east ideated by the Egyptian government in 1997. This project consists of building a system of canals to guide water from Lake Nasser to irrigate the sandy wastes of the Western Desert of Egypt, which is part of the Sahara Desert. The objective of this project is to facilitate the local communities who live on agriculture and industries by developing a new valley in addition to the existing Nile Valley. It is viewed as a highly ambitious project by the experts which was meant to help Egypt deal with its rapidly growing population. But so far the advancements achieved and prospects of the project indicates that it was ill-conceived and it looks set to be a grandiose failure. The failures so far observed are—

- Toshka’s total budget has been estimated from as low as US$83 million (according to numbers from the Egyptian government) to a whopping US$87 billion (according to the US State Department). less than 25 percent of the original budget has been spent already, but the results are piecemeal. The only objective met so far, is the diversion of water from Lake Nasser into what little of the Sheikh Zayed Canal was built. The canal is currently 60 kilometers short of the first of the oases through which it was supposed to run, Baris.
- Toshka’s original objectives were set in two phases: in the first one, the Sheikh Zayed Canal would be completed and 550,000 feddans (an Egyptian unit of area equal to 1,038 acres) would be reclaimed. At the end of the second phase in 2017, a total of two million feddans would have been recovered from the Western Desert. On the contrary, In 2005, the government announced that it was abandoning the second phase entirely and that the deadline for the project’s completion was extended to 2022.

From the analytical study of the projects stated above, when anyone start looking at major delays and extreme cost overruns, these culprits emerge:
1. The Teleport
   No one disputes that teleporting is a phenomenal idea. Yet, no one has any idea how to implement it. A lot of failed projects are like this. These sorts of projects often arise when the stakeholders get more excited with the ideas than considering the budgets and feasibility. Resource based forecasting isn’t possible because there’s no precedent and the feasibility of the idea is only understood very late in the execution phase of the project.
2. The Winner’s Curse
   A bidding process would seem like a sensible way to find the lowest cost provider for a project. In practice it doesn’t always work that way and the winner’s curse means you may often end up selecting not the cheapest vendor, but the one with the least reliable estimates. They appear
cheapest, but only because they haven’t effectively gauged what it will actually cost to do the work. Once they are selected as a vendor, they then have leverage to increase costs and things unravel from there.

3. The Camel

Just as a camel is a horse designed by committee, so camel projects lack one person in command, and typically have large groups of people calling the shots. All projects have large numbers of requirements, but because of the large number of stakeholders these requirements cannot be scoped down to a level that will enable the project to be completed within expected time and budget.

COMMON REASONS FOR PROJECT FAILURES

In general, all the project failures occur due to the following reasons:

1. Failing to plan is planning to fail.

24% of projects fail outright, but given a new project people typically like to get stuck in believing they’ll be successful. Perhaps they will but stats suggest that you should spend 20% of the duration of the project planning it. Seems counter-intuitive, but many mistakes are avoidable by thinking things through in advance. For a 3 month project, that means the necessary planning time is 12 days, that might feel like an unwelcome delay, but the impact on project effectiveness will be dramatic. Poor planning by not taking into account risks involved in projects, sequential transmittal of drawings, expected arrival of materials, poor controlling of delayed activities and cost overrun activities, poor project review and poor team development or no development are also some important reasons behind project failure.

2. Pre-mortems

People love to be optimistic, a pre-mortem does the opposite. A post-mortem is looking at things after they have happened for success and failure. A pre-mortem considers that the project has failed (an assumption) and invites participants to look at why that’s the case. The assumption of failure frees people up to poke holes in the plan and think about a better outcome.

3. Communication

Most project failures are due to lack of communication, people don’t communicate. The project manager must have a strong base of communication to ensure the project’s success. Poor management can shoot up the cost be it material or labour and the contractor has to bear the additional charges. Also reviewing the project management time to time and reallocation of funds and changing the critical path can be resulted into major failures.

PROJECT VISUALIZATION AND SIMULATION

Construction projects have many unique configurations and the unique nature of projects is very crucial to make planning decisions. Visualization and simulation systems allow the planners to overview the existing model and at the same time to make a quick glance into the real construction processes. When models accurately represent the construction operations, the model complexity increases significantly. Consequently, the effort required to create and maintain these models increases. Planners continuously add features and necessary equipment to overcome the constraints they experience during the simulation of the model. The planners can experience all kinds of constraints in their simulation system which they are supposed to experience when the real construction work goes on.

Because of the complexities found during the simulation and visualization process, construction managers can develop plans that may simplify the effect of the project’s geometric configuration on the construction process. Instead of accurate and in depth process analysis early in the project, the common practice is keeping the process plan at a macro level and creating a detailed plan for shorter intervals as the project proceeds. This prevents earlier consideration of problems on site and evaluation of alternatives.

Can the modeling effort be simplified with reasonable assumptions while maintaining or increasing the power of the resulting models? Intuitively the modeling of operations can be simplified by basing models on the spatial configuration and making effective use of geometry. By managing spatial effects effectively, allowing various manipulations, transformations and analysis on geometry, construction operations can better utilize process modeling and simulation approaches for other man-made systems, such as manufacturing, communication, electrical systems.

2D drawings are the predominant representation of the finished facility which can provide minimum idea of the real construction work. The availability of 3D geometric models for project management can open the door of new possibilities. Effective use of the 3D geometric models provide better understanding of the construction processes with geometry in mind.

VISUALIZATION AND SIMULATION SYSTEMS

Construction operations are visualized and simulated in many ways. The choice for implementing a proper system depends on the degree of visualizing the construction site, degree of complexity in construction works, information available and information necessary and insights to be visualized.
Dynamic construction visualizer

Dynamic construction visualizer or DCV is intended to be used in conjunction with a wide variety of simulation tools using 3D models created in an equally wide variety of CAD modeling programs. It is neither a simulation tool nor a CAD modeling tool. It can be implemented as a Microsoft Windows application and can operate files which are written in DCV language. The DCV graphically illustrates the specific modeled construction operation (Fig.1) based on the data taken from logged on simulation model. Simulation model creates DCV animation when they run. Simulation language has to be simple enough to generate model trace file easily but at the same time it has to be strong enough to illustrate the dynamic operation of complex construction tasks.

![Fig.1. Schematic model diagram for earth moving operation.](image)

DCV is implemented as a “post-simulation” visualization tool which can provide the following services to the operator:

- It maintains a simulation clock whose speed can be controlled by the operator.
- The operator can put himself in any vantage point of a 3D virtual workspace so he can navigate the place like actually he can do in real world construction site.
- User can jump into forward or backward to any desired position by specifying a past or future time value in the clock.
- The operator can observe specific construction tasks through the animation, can pause anytime and make static observation to find out disparity or constraints on the task.

Although the DCV system can depict the real dynamic motion of construction equipment e.g. dump trucks, excavators, cranes, backhoes etc. but it cannot depict the transformation states of simulation objects during visualization. It illustrates the visualization based on certain completion stages e.g. assembling, loading, unloading etc. but it does not support the visualization of physical deformations of simulation object or its environments. For instance, when an excavator digs the earth, DCV cannot depict the concrete deformation, concrete flow into the concrete pump, bending of rebar or cutting of blocks.

Augmented Reality Applications

The recent development of computer technology and miniaturization of computer hardware allow for the integration of augmented reality in construction works. This system consists of a see-through head worn display which is capable of overlaying graphics and sound of real world activities. It can track users and objects in space and sends visual information. This system is written by C, C++ and CLIPS programming language and can run in Unix operating system.

It shows the users portions of a building which are hidden behind structural obstacles and enabling users to see additional information of the hidden objects. The user can stand on a position within a room and can see the graphical representation of a model prototype and tracks the orientation data by an ultrasonic tracking system.

![Fig.2. Computer graphics by head mounted augmented reality system.](image)

The graphical object of the research lab is represented by the augmented reality technology (Fig.2).

The augmented reality technology can improve the condition of construction, monitoring and renovation work in many ways. By the X-ray vision of such technologies can help maintenance workers to see through obstacle and thus avoiding hidden features, electrical wiring and structural elements. The speed of the construction and maintenance work will increase rapidly.

Navigational Approaches

There are many systems for outdoor navigation systems already being used globally. These systems are categorized into two – Network Based and Handset Based.

In network based system also known as network dependent system signals are taken by mobile
devices from mobile network covering its area of presence. Handset based which is network independent can provide location identification information even if the network is not available in that particular location. This form is very advantageous and most frequent used method from this category is Global Positioning System (GPS). GPS can achieve cm-level kinematic positioning accuracy, but with some major constraints. First and foremost the use of GPS signals for indoor positioning poses difficult challenges, due to the very weak signal levels. Indoor positioning using high sensitivity GPS receivers cannot be guaranteed in all situations, and accuracies are typically of the order of tens to hundreds of meters at best. Indoor positioning technologies set the constraint of a limited coverage range, such as a building or other confined spatial area (for example, a stadium or an exhibition).

A system developed based on GPS is Locata\textsuperscript{11} by Locata Corporation. Locata is a positioning technology that is designed to overcome the limitations of GPS and other indoor positioning systems currently available. It has invented a time-synchronized pseudolite transceiver called a LocataLite. A network (Fig. 3) of LocataLites forms a LocataNet, which transmits GPS-like signals that have the potential to allow point positioning with sub-cm precision (using carrier-phase) for a mobile unit (a Locata).

Another system to overcome GPS’s constraint in indoor navigation is Active Badges (Fig. 4) developed at AT&T Cambridge. A small infrared beacon is worn by every person or elements and the badge emits a globally unique identifier every 10 seconds. A central sever collects this data from fixed IR sensors around the building, aggregates the data into a central repository, and provides an API for applications to take advantage of the data. An extension to this work used by the Xerox ParcTAB system implemented a 360-degree infrared “deathstar” to address the problem of IR directionality.\textsuperscript{12}

**PROPOSED SYSTEM FOR VISUALIZATION AND SIMULATION**

Navigation based visualization and simulation technologies can be possible solutions for avoiding construction project failures due to poor communication, poor planning and poor estimation. The whole process of the construction with such technologies can be summarized (Fig. 5) as follows -

1. **Planning stage**

   In this stage project planners and decision makers along with the customer will survey the project site and make necessary and optimum planning for the construction design. Augmented reality system can be fruitful in this stage. Customers will make their demand and the designers will justify the feasibility of the demand according to the resources available. Designers can use the site’s GPS data to observe along with the on-site physical visit. After getting raw data from site and customer and processing the data they can finalize the project estimation and propose the final design.

2. **Ongoing project monitoring stage**

   In this stage project supervisors and other observers can closely monitor all real time construction work with minute level details. Indoor positioning system with pseudolite and active badge system can help in this stage. Pseudolite based navigation can be used to locating the cm-level accurate positioning of elements, fittings, joints etc. and active badges can help the project supervisors to monitor if the equipment are reaching and available at the desired location in correct quantity. Individual construction tasks can be simulated by the DCV system when existing DCV models limitations can be overcome by using data from pseudolite activity. This phase also allow efficient real time data extraction, execution and recording of the construction activities.

3. **Correction stage**

   The data found in project monitoring stage can be used to find out any irregularity in the construction work instantly and enable the supervisors to make immediate correction of the problems. This removes the time delay and cost overrun due to the pause in construction task.
Fig. 5. Workflow with augmentation during construction lifecycle

CONCLUSION
In general the practice of visualization and simulation systems in construction works are very limited by the practitioners and the adoption of these systems are very slow in the construction industries. This can be said happens due to the lack of enough number of researches in construction simulation systems, complexity of the construction works and lack of much effort to prepare models for simulation systems. However to avoid the common failures occurring repeatedly in big construction projects, it is obvious that proper visualization and simulation tools should be implemented. The positive side is, like other production industries like car manufacturing or beverage productions, construction works also consist of common and repetitive tasks. So, systems should be developed to visualize and simulate these common tasks. The paper reviewed and intended to combine few technologies and to suggest a possible system to make the construction task more efficient. Successful implementation of the suggested method can be practiced and more researches can be carried out to investigate more deeply into the utilization of the systems with highly autonomous, intelligent construction and manufacturing systems.

References
A new vision for Bauschiff Neufert: System evaluation and opportunities for evolution and current use

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Purpose Mehanising and automating construction processes has significant benefits, such as reduction of production times and costs, improved working conditions and increased performance. In Japan, the development of cohesive building production systems was an answer to problems such as the aging of workers and dwindling workforce. The Bauschiff system of E. Neufert was innovative at the time of its inception in the first half of the 20th century, drawing inspiration from shipyard technology. Its main ideas and work processes can be implemented towards a new automated construction site concept. Current tools and technologies, for example robotic devices, site automation and Building Information Modelling can enhance the highly structured process of the system. Method Study of the original Bauschiff Neufert system, as well as current examples of automated construction sites and innovative construction technologies. Assessment of the material towards an effort to implement current technologies and innovations in an evolved model of the Bauschiff system that is suitable for current applications. Results & Discussion The main ideas of the Bauschiff system could form the basis for an automated construction site today. The redesign process involves automation of processes and options for higher individualization of buildings. The clearly structured process found in the Bauschiff system could benefit from the application of Building Information Modelling (BIM). A less automated approach could find application in developing countries, where there is no shortage of labor force.

Keywords: automation, construction, on-site production, concrete building

INTRODUCTION
The recent development and application of advanced building systems has not only been an answer to problems in the construction industry, but has also shown significant benefits. However, building systems have existed for a long time.

Ernst Neufert's Bauschiff system, designed in the 1940's, has elements in common with and draws inspiration from Adolf Sommerfeld's Bauhellings System, which was applied in the 1920's. Elements in common between the two systems include the transport of formwork, the production of concrete buildings, and an on-site factory that moves on tracks. In both cases, the buildings produced were highly repetitive in nature.

The more evolved Bauschiff system will be analyzed in the following pages. Features such as the clearly structured construction process make this system a good candidate for examination, in order to propose improvements that would make its use beneficial today. Finally, a proposal for improvements and possible applications is made.

THE BAUSCHIFF NEUFERT BUILDING SYSTEM
Neufert's Bauschiff building system, as described in his book "Baurordnungslehre", is an on-site linear production building system for the production of concrete structures. Its basis is a clearly defined construction process, utilizing several subsystems.

The following text describes the construction process, as well as subsystems and important features of this system.

Construction process
The construction process can be described as having seven distinct stages, repeating in a loop during the production of the building. These stages are in order the following:

Preparation
The first stage is the preparation of the site, which starts with the excavation of the site. The soil, which will be stored for later use, is pushed aside by bulldozers and then removed by an excavator. Once the soil has been removed, premade formwork for the foundations of all bearing walls is placed, which is then measured and aligned with great accuracy.

Conveyor belts are placed around the excavation point in the necessary arrangement to accelerate the excavation process. After the laying of the sewage pipes, the concreting of the basement foundations starts, again using the conveyor belts for the transport of the concrete.

On-site factory
Construction of the on-site factory starts with the laying of the rails, on which the construction hall will be assembled and rolled later. The construction hall consists of steel scaffolding frames, which are as-
Assembled horizontally one by one on top of the rails. Each one is lifted in a vertical position with the use of cables pulled by the workers, thus avoiding the use of tower cranes. Once all frames are lifted into position and are safely connected to each other, the building hall is completed and the next stage is about to begin. During the building hall assembly, the formwork that will be used in the next stage of the process is placed in appropriate positions further down the tracks. The formwork parts have been laid there in the exact order they will be needed. This demonstrates a just-in-time, just-in-sequence element of the Bauschiff process.

Fig. 1. Process stages and flow in the Bauschiff System

Formwork assembly
Assembly of the formwork starts from the basement. After the assembly of the basement formwork, it is measured with devices with millimeter accuracy, and it is realigned exactly by adjustments of the screws. This aids in the avoidance of further mistakes, as Neufert states that “The more accurate the beginning, the more accurate the end”. In the following floors, the process changes and the distinction between interior and exterior formwork is necessary here for a more clear description. In the floor above the basement, the exterior formwork is assembled first, and at the same time a team of workers places preassembled steel reinforcement on top of the basement ceiling formwork. Shuttering chairs are then placed into position, and the reinforcement runs through under them. They serve as support for the rails, on which the interior formwork will be rolled. They can also be removed easily later, thanks to the conical shape of their legs. After all interior and exterior formwork is fully assembled, and reinforcement is in place, this process is repeated on the following floor. At the open end of the construction hall, the structure of the building material elevator is erected, and connected to the work platform of every level.

Concreting
The concreting process is facilitated by concrete tanks, which are filled on ground level by a concrete mixer vehicle, and are then transported through the building material elevator. They stop in the appropriate floor, where a worker pulls them on the work platform. All transport is performed on overhead rails, from which the concrete tanks hang. Once pulled from the elevator, a tank moves to an overhead connector rail, which rotates on a turntable. This way, it can be rolled to the different processing places. On each work level, concrete is first poured for the walls of the floor below. Concreting boxes facilitate the insertion of the concrete into the wall formwork. The newly concreted wall is then vibrated and calibrated. The ceiling concrete is poured next. This marks the completion of one level, and the concreting process is repeated this way on each following level, until the roof level is reached. There, the formwork is sloped, not only to ensure the distribution of concrete, but also to assist in the drainage of rainwater later.
The concreting of the first section of the building is completed, and the construction hall, exterior and interior formwork, will all move towards the direction of building and the next construction point.

Fig. 2. Shuttering chair, rails, reinforcement

**Exterior formwork transport**
Before the concreting of the next building section starts, the exterior formwork is rolled first, along with the construction hall on which it is mounted. Workers on all floors clean the formwork surfaces from clinging concrete and apply formwork oil. When the structure of the construction hall and exterior formwork reaches its next position, it is fastened to the completed part of the building. At the same time, the interior formwork remains stationary. The exterior formwork has plain openings for the windows, which will serve an additional purpose in the following stage of the process.

**Interior formwork transport**
In contrast to the exterior formwork, the interior formwork is moved on each level separately. The transport starts from the basement level. In this case, the formwork surfaces are cleaned through the window openings of the exterior formwork. The interior formwork structures are not moved simultaneously on all levels, but are moved in the lower levels first, followed by the upper levels sequentially. Concreting and reinforcement placing take place as described previously. Transverse interior walls are cast using manually placed formwork, which is transported internally in the building.

**Finishing**
The above process of formwork transport and concreting is repeated, until all concrete work is finished for a particular building except the final vertical wall. Then, the construction hall and all formwork is rolled away from the building, at a distance of 1.5 m, and the final vertical wall is cast. The entire on-site factory (construction hall and all formwork) rolls on tracks to the next destination, where the next structure will be built.

For a number of buildings on a site, the process stages are repeated. The preparation stage takes place for all structures, however the on-site factory and formwork assembly stages are only performed once. The construction hall and formwork are simply

Fig. 3. Section, interior formwork transport and cleaning of exterior formwork
rolled to the next point, where the concreting process and accompanying formwork is performed again.

Subsystems and process details
To adequately describe the Bauschiff Neufert system, some subsystems and details of the building process need to be mentioned.

Construction hall
The construction hall structure itself is an important element of this system. Its purpose was not only to serve as a scaffold for the placement of the exterior formwork, but it also provided a weather-independent environment for the workers in its interior. It was covered by a corrugated metal roof. Further modifications could be made, with additional coverings for the winter season. Moreover, air heaters could be used to ensure the interior environment had the desired temperature of 15-18 °C.

Fig. 4. Section, construction hall, interior formwork, concrete tanks. The concreted walls are shaded.

Interior formwork element and window formwork
In contrast to the exterior formwork, where the window openings were plain gaps on the formwork surface, the interior formwork was more complex. On the interior formwork element, at the position of the window opening, hinged formwork could fold and unfold, providing the necessary boundary in the wall during the concrete pouring process. This sub-element was moved into place when interior and exterior formwork were aligned.

Fig. 5. Concrete tank and concrete pouring of wall

Material elevator and concrete logistics
As mentioned before, concrete transport was achieved through moving concrete tanks that ran on overhead rails, and reached each floor through the material elevator. These tanks would be returned on ground level when empty and would be refilled. According to Neufert’s intentions, the tanks would stop automatically on each floor in the materials elevator, though no mention of how this is achieved exists in his text.

Fig. 6. Section and plan displaying the position of material elevator and the route of the concrete tanks. Materi-
al elevator is indicated with the dashed border.

Connection bolts
The interior and exterior formwork was fastened with a number of connection bolts. These bolts ensured the proper distance and position of the formwork, as well as the necessary pressure after the concrete was poured. The holes could be easily sealed after the removal of the bolts. Before the transport of the formwork, all bolts were unfastened by the workers manually, and then fastened again when the formwork was in place.

Evaluation of the Bauschiff Neufert System
The Bauschiff Neufert system's main idea was the on-site, linear, moving production of concrete buildings. The produced buildings were rectangular in shape. Several rows of buildings could be constructed using this system, not necessarily parallel to each other, since the on-site factory could change orientation in plan as long as the appropriate tracks allowing this motion existed.

![Fig. 7. Plan, possible variations in positioning of the construction hall](image)

A crucial element of the system is the moving formwork (interior and exterior), as well as the integrated window formwork sub-elements. According to Neufert's design, all windows produced were identical, repeated in all the length of the building. Architecturally, the highly repetitive nature of this design would not be desirable today, since nowadays individuality and variation are important concerns.

Neufert also focused on avoiding the use of heavy machinery and designing his system in such a way that it could be assembled and transported manually by the workers, and that each task could be performed by as few workers as possible. However, in some cases such as the example of the connection bolts, it is not clear how time consuming the manual process is.

A limitation of this system is that the structures produced are comprised of load bearing walls. The system is designed in such a way that walls, as linear elements are easy to cast and produce with this system, but the same cannot be said for columns, which would necessitate a different approach.

Another feature of the Bauschiff system is the parallel process of building. Following the concreting process, the completed building sections are then ready for the next stages of interior work and finishing, which proceed at the same time as the concreting of the following sections of the building.

Current building systems
Several building systems exist today, which have elements in common with Neufert's system. The moving formwork, for example, is an essential element in the systems of Slipform Engineering (H.K.) Limited and PERI GmbH. Slipform Engineering's slipform technology features vertically moving formwork, which is best utilized in the construction of circle concrete walls. PERI GmbH offers the ACS P Self Climbing System, a self-climbing formwork scaffold with integrated working platforms. This is suitable for advancing cores in highrise buildings, and tower-like structures. The formwork in both examples moves, although in a vertical direction in contrast to Neufert's horizontally moving system.

The parallel processing of finishing work performed in completed sections of the building, as major construction continues in the next sections, is evident in other systems as well, for example in AMURAD by Kajima Corporation. In the last decades there has been an observable shift from the earlier use of single task robots towards total automated building construction systems, best displayed in the systems developed in Japan since the late 1980's.

Proposals for redesign and applications of the Bauschiff Neufert System
The author believes that the most important consideration in the redesign of this system is a greater flexibility in the produced designs. The importance of customization today and the existing strategies for Mass Customization make it imperative for the redesigned system to produce more complex designs than the highly repetitive products of the original. A first suggestion is the introduction of modular formwork, where parts can be exchanged to produce exterior surfaces with a variety in the design of the openings.

Another consideration is the original system's production mainly of long structural walls. Further evolution of the hinged formwork could allow the appropriate encasements for the pouring of concrete columns or structural walls of shorter length, which would allow greater flexibility in the design.

Another modification necessary would be the redesign of the connection bolts, in order to achieve a more efficient solution. Since the fastening of the
bolts was done manually in the original system, a large number of bolts fastened and unfastened repeatedly would lead to a time consuming process, and a different solution could reduce the time necessary for this task.

The clearly defined and structured tasks of the Bauschiff construction process are ideal for applying Building Information Modeling\(^1\) (BIM) technology. Not only will it lead to significant cost benefits, but the improved information management and exchange will optimize the construction process and logistics, especially in the case of using modular formwork components. This way, errors can be minimized or even eliminated.

The original reliance of the system on workers performing manual task can also be changed. Several of the original processes can be modified and performed by machinery, and can also be automated. First of all, the transport of the interior formwork can be performed by machinery instead of manual force. But more importantly, the concrete logistics process could be automated for greater efficiency. Possible solutions include the modification of the concrete tanks transport system and the handling of their transport performed by actuators, or even replacement of the concrete tanks by concrete pumps, where a centralized system could replace the concrete transport concept with a centralized concrete distribution system.

The original Bauschiff system did manage to lower the requirements of manual labor for many of its tasks, but the redesigned solution should achieve to minimize them even further. The new system would be applicable in environments where the numbers of skilled workers are especially low. The good conditions of the construction site would also make it an attractive working environment. Even in cases where there is no shortage of workers, a non-automated version could still be used. The first improvements mentioned here could still be applied to produce attractive buildings with a variety in design.

Finally, the horizontal linear production concept at the heart of this system is meant for the construction of long buildings or rows of buildings, up to a certain height. It would be more successfully used in areas and environments where this is architecturally desirable. In locations where high-rise development or low-lying detached housing of individual design are preferred, this system would not succeed.

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Prefabrication and Automation in Concrete Building Construction

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Purpose One of the most urgent issues faced by human being nowadays is the gradually decreased space for living. Especially the growing number of people on one hand creates the demand for higher quality house, on the other hand the decline trend of workers drive up a sore need of highly advanced methodology in building technology. Concrete building as a main form of houses in some densely populated developing country such as China calls for a fundamental reformation for both the ideology and technology in this field. Method 1. The paper will sum up and analyze the most advanced automation technologies for both the production and information management of concrete prefabrication. 2. Solutions will be provided to overcome the shortage of labor, because of the demographic change. 3. To find ways of solving the house shortage issue especially in developing country by means of an advanced building technology. It is defined as the technology that increases production efficiency when compares to the traditional concrete house building technology. 4. To find methodology of making the concrete house supply chain more efficient. 5. Comparison will be made in the level of automation development for industries between automobile, consuming goods and house nowadays. Trend of the building automation in house will analyze in article. 6. Introduce a prototype by means of using DLR LRW III robot in realizing on site building automation (Fig 1 is the photo took by author in his DLR human friendly robot application in building bricks, type of robot in use: DLR LWR lightweight robot). Results & Discussion By enumerating and analyzing the most advanced automation technologies and creating a prototype, the author demonstrates the technologies in concrete house production and on site building. Currently, because of a high labor cost in developed country is existed ahead of developing country, many experiences of construction automation can be learnt by developing country which the issue of high cost labor is gradually appearing. However, the ideologies introduced could increase the productivity and quality of house building in the developing country in the future. In the context of demographic change, automation and information technologies will no doubt facilitate to drive up the whole standard of construction industry nowadays after the main technological hurdles are conquered.

Keywords: Precast concrete, Automation, BIM, Standardization, Human friendly robot,

INTRODUCTION

The advantage of automation technology in using construction industry reflects in the making prefabrication in a short period of time. A standardized prefabricated product can be defined as a product with discrete solid parts. In this paper, analyses will make on the topics of off-site precast concrete production, standardization, the impact on construction industry caused by demographic change, a human friendly robot application on precast concrete manufacture and onsite assembling. Moreover, precast concrete industry is not only entwined with the use of highly advanced equipment, but handing down from the essence of history and culture.

METHOD

Precast concrete technology past and present

Ancient Romans are documented as the first user of precast technology. They considered concrete as a sustainable material to carry out their infrastructure plan. In last century, precast construction is quite popular in the republic of the former Soviet Union and Eastern European country. Afterwards, this style of building became welcoming by some Communist countries as well. By seeing the history of precast concrete, precast supplier plays a crucial role in prefabrication concrete building industry. Nowadays, besides a widely application in civil engineering, precast concrete is also a good solution for building high quality Residential construction. The demand of diversity of house hastens the development of advanced production system for precast concrete. Both the reasonable designing of factory layout and the robotized equipment supported a high productivity and the possibility of producing diverse elements. Concrete precast supplier plays a crucial role in prefabrication concrete building industry.

Fig. 1. Evolution of precast concrete
**Pallet Circle**

“The skill is built into the tool” is one of the descriptions of mass production. The tool in assembly line plays a crucial role in precast production as well. A faster production is always containing state of the art ideologies in mind. This pallet circulation system can be regarded as the most advanced production system of precast concrete. All the automatic equipment concentrate on providing services for “Pallet” which is the standardized mould made for precast concrete. Most equipment in this circulation system can be defined as robotized manipulator which means that they are highly automated and can be operated in autonomy. Five tasks in the flow are corresponding to cleaning robot, formwork robot, bar feeding robot, concrete spreading machine and automatic storage machine respectively. Meanwhile, a lean manufacture site presents that a new building information management facilitates a high efficiency of production. So as to increase the turning over rate, BIM (Building information modeling) is a potential method to work hand in hand with highly automated equipment. Nowadays, the diversity of precast is constrained by the size and shape of the pallet itself. It seems less room for the application of BIM in off-site side. However, the tendency of diversity augmentation will doubtless lead a wider and more organic application of BIM. Vice versa, the process of manufacture will be optimized by using BIM as well. Factory as the incubator of precast is the start point of the whole precast building lifecycle. It should be a most important link of the building process.

![Fig. 2. Producing loop of precast concrete](image)

**Pallet circulation system**

Despite the less steps of producing a final product when compares to produce an Auto, the variety of precast concrete products makes the design of flow and factory layout the critical factor that effects on the efficiency. The experiences such as the moving and continuous assembly line, learnt from auto industry, consist and complete interchangeability of parts, the designing simplicity of factory layout makes the manufacture innovation on precast concrete assembly line possible. Pallet circulation system requires a highly efficient supply chain as well, because of the different kinds of material and processing time demanded by the final products. Moreover, tasks in pallet circulation system are mostly finished by automated machine and robot. Human errors are largely avoided.

![Fig. 3. Core role of pallet circulation system](image)

Lean production principle raised by Toyota is another thing can be learnt by precast concrete industry. Two pillar concepts, JIT (Just in time) and smart automation can fully apply on pallet circulation system which brings the zero waste, the highest quality and the efficiency.

**A new prototype of accessory placing robot and onsite building robot**

Besides the formwork shuttering, accessories such as socket, pipe which are light weighted are installed manually, the workers pre-knew the types of accessories from job card. This process is the bottleneck of the whole flow. Man made mistakes are easy to happen in the step. Inaccuracy will bring about connection failure between the precast elements in the later stage. A human friendly robot called LRW III robot invented by DLR (German Aerospace center) can play the role to assist the worker to finish this task quickly, or finish this step itself. Safety is con-
considered as a top priority in precast concrete producing site, the human friendly robot is designed under this principle. The flexible joint will not cause a violent contact when it has a collision with human who are working around. And this collision detection effects when the gripped accessories reach the final goal position as well. In prototype, the robot works with vision system, to select the accessories from warehouse, and then find the right way to grip them. By a 7 degree of freedom manipulator, end effector can reach the goal position easily. The module design of this robot (module joint, module link) makes the user easy to build their robot with special aims. For instance, in the case of precast concrete, more joints and longer links are needed for reaching a wider workspace. The blocks in below picture represent accessories, bricks or other material, tools with various shapes. Robot is able to recognize them by the assistant of vision system and find the goal position on pallet or final precast concrete without failure.

![Fig.5. Prototype of DLR LRWIII human friendly robot in the application of building technology](image)

Left side: The point cloud graphic simulated by vision system.
Right side: End effector grips one of the blocks

When flexible joint robot works on site, it is endowed with more ability to help the precast builder to finish the tasks, such as welding connection, inspecting gap, handling heavy stuffs and so on. Nowadays, this type of robot will firstly apply in car industry to help worker for screwing. It can not only operate as a stationary one like in Fig, but a movable model when sitting on a mobile chassis. To be sure, the prospective application on construction industry will have a larger potential in off site, on site as well.

**Labor shortage raised by demographic change in developing country**

Demographic change is a global issue. The shrinking proportion of young people leads to a labor shortage which is more apparent in construction industry. In this paper, take the situation in China for instance to research on. Construction industry in China has long since been regarded as a labor intensive industry. However, because of one child policy and the end of baby boom generation, in according to the statistic data from United nation’s world population prospects, after 2016, the amount of working population will have a downside. In the year of 2050, the workers who are with the physical condition for the constructing job will go down to an even less level. (Fig.6)

![Fig.6. Data as at May11, 2011 Source: United Nations World Population Prospects for the people within working age in China](image)

Nowadays, construction workers who are familiar with traditional manual building technology in China are uneasy to find the successor to inherit the skill. There are two reasons for this. On one hand, manual working on concrete construction building is in the tendency of dying out. On the other hand, there are very few of younger who are able to bear the suffering of traditional concrete building site. Based on macro reason from statistics and status analysis, precast and automatic, robotic machine being applied are two necessary way of solving both issues of improving the quality of concrete building and labor shortage in construction industry. After the cast-in-situ being gradually replaced by precast concrete in the big consuming nation of concrete building such as China, the pallet circulation system as a mature technology in developed country such as Germany will have great market potential. Advanced building technology means not only the automatic machine being used but a scientific mass production methodology. The re-planning of the resource distribution and re-scheduling of the process are assisted by software such as BIM. Besides the building information, manpower resources should be considered in schedule as well. Analysis for proportion of using manpower and machines will assist the decision maker to balance the rate of progress and cost control. Over time, a database built on empirical data will make suggestions on whole supply chain so as to optimize the whole lifecycle of concrete building. All in all, demographic change should be seen as a positive factor to push the industrial transformation from the long term point of view.
By the Standardization of construction process and precast elements to resolve the house shortage issue

The high price caused by malignant real estate speculation that gives rise to a man-made house shortage. Besides this improper reason, a natural fundamental human necessity is to have a roof over their heads. How to make this roof reliable and of a reasonable price is the dream of everyone. When it comes to concrete made house, standard deficiency is the question of questions needed to solve. It is interesting to note that the standard was quite developed during the ancient time of both the east and west. Both in ancient Rome and ancient China, the concept of modules (Latin: Modulus) is that use a unit to scale a building component. In Song dynasty of ancient China, Ying zao Fa shi (Treatise on architectural methods of state building standards) is a technical treatise on architecture and craftsmanship. In Qing dynasty, the engineer practices are summed as examples to refer the standardized engineering. The standard was made all around the delicate wood made house. Fig 7 is the evolution of the order structure in wood construction, mostly are for building the temples.

![Fig 7. Evolution of the Chinese order](http://www.ikuku.cn/38971/zhutao_yueduliangsichen_g.html)

In Fig 8, Romans standardized the ancient Greek columns, which enriched and normalized architecture style.

![Fig 8. A standardized ancient Greek columns](http://leizi-stons.blog.sohu.com/46659594.html)

When it comes to concrete precast researched nowadays, the architecture form takes place a great change. The demand of consumer urges more innovative reform on construction field. First issue of precast modularization is considered on the confliction against to the individuation. Take the car industry for instance, Alfred Sloan (General motors) thought to resolve the contradiction between the individuation required by consumers and the need for standardization. He introduced a series of "hang-on features" to provide wider choices for customers without changing the basic mechanical structure. Meanwhile, in architecture, Skeleton and infill system (SI) is a design concept that already executes in Japan residential building that result in a diversity of house without losing standard. In terms of precast concrete manufacture, the characters such as heavy weight, high stiffness make it uneasy to indiscriminately imitate SI. However, it is wise for the standard maker to set the standard flexible enough that in harmony with the house designer and precast concrete supplier. When combined and constrained by equipment, a heuristic loop between the housing developers and precast concrete suppliers will gradually expand the diversity of both the final house and precast elements based on a module standard. Therefore, more choices of equipment and manufacture methods are the vital part of the whole industry.

**CONCLUSION**

Construction industry is entwined with information and automation technology when it should gear to a sustainable development. Ever-accelerated updating of precast concrete equipment provides a wider choice of products for housing developer.
Meanwhile, this process poses major technological hurdles on supplier due to the standard deficiency. Prefabrication is not a new concept. Many experiences can learn from the history of architecture. However, a new shift in the concept of information exchange will make the builder and producer to coexist well and to supplement each other. To conclude, in the case of concrete building construction, prefabrication and automation will dominate his future.

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Assistant Bed - Solution to Patients in Bed

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Purpose Pressure ulcer (PU) is a common skin disease when patients or the elderly stay in bed for long. Although it is a tradition that children look after their old parents in China, and in some western countries, nursing home takes charge of that, the situation of nursing is still a big problem. The assistant bed is aiming at making the nursing easier or even make the elderly living independently possible. Method The concept of the bed is: two units, one for living, one for service. Two boards make up the prototype. The service board is mostly used for toileting, washing, and offers smart tablet entertainment to users. The living board is divided into head zone, upper zone, lower zone. To meet the ergonomics needs better, the upper and lower zone are divided into more semi-zones. In-between two adjacent zones, pivot connects the two parts to offer rotational flexibility. The living board is covered with a kind of mattress “Wechseldruckmatratze” to prevent from PU (Figure 1). A prefabricated platform is assembled in the room in advance. It is consisted of one strong central pivot which is fixed onto the wall and two strong "arms". With the help of these two arms and the cooperation of two units, a tough problem in nursing: turning-over can be solved. The arm for living unit locates on an half-envelop structure which is designed for hiding the equipments for the whole system. The mechanisms under the living board for moving the zones have the potential for transforming the bed to a wheelchair through a special docking method. Results & Discussion On living unit, user can sleep, take exercises, and realise other basic daily activities; on service unit, washing, toileting can be achieved. Regarding the exercises on the bed, the bed offers three modes: (1)passive (2)active (3) smart tablet exercises. The system CPU records the states of muscles and bones to adjust the amount of exercise automatically at the best level. The “Wechseldruckmatratze” air chambers are inflated and deflated at different time point, so it is not necessary to turn the user every two hours, hence, staying long in bed is no longer a problem. Through the cooperation of two units, user can turn over easily to free the skin and do some cleaning. With the equipment under the lower zone, the bed can be transformed into a wheelchair, so the bed works as if a ship docking upon the platform. The bed can be driven by both motors and operated mechanically by hand cranking. The assistant bed has the potential to integrate with kinds of sensors to measure the user’s basic physical status and provide the best posture to user based on ergonomics, and the potential to work with other equipments in a room or in a house, to form a ubiquitous intelligent space. With this assistant bed, nursing is not necessary. User can live independently like a normal person. If nursing is provided, it can give hands to help turn over, sit up, take exercises... It will be a useful assistant in aging society.

Keywords: assistant bed, wheelchair, pressure ulcer, living and service, aging society

INTRODUCTION

A pressure ulcer (PU) is a localized injury to the skin and/or underlying tissue usually over a bony prominence, as a result of pressure, or pressure in combination with shear. So it is a common skin disease when patients or the elderly stay in bed for long. To these people, there also exists another severe healthy problem: after staying in bed long, the function of muscles and bones degenerates gradually. That means, the muscles cannot provide enough strength and the bones become soft and fragile. Besides, they usually suffer from less curable, mental disease, such as autism, senile dementia. Thus, it is not an easy task to nurse those patients, no matter for their family or professional nursing service. As cultural background, there is a typical difference between Chinese and some western countries. In China, children need to look after their old parents, however, in western countries, nursing homes usually take over this task. The assistant bed in this paper is aiming at making the nursing easier, or even, making the elderly living independently possible.

METHOD

Influenced by a famous architectural concept raised by Louis Kahn: served and servant, the assistant bed is mainly consisted of two units: living unit and service unit.
The basic function of service unit is for toileting, washing, and some other user individualized service to realize more basic daily activities. This board is divided into upper zone, hip zone and lower zone. In hip zone, there locates a device works as a toilet and in upper zone provides smart tablet entertainment for users. The basic function of living unit is for sleeping, relaxing as bed, sitting as chair and taking exercises. The living board is divided into head zone, upper zone, lower zone. To meet the ergonomics needs better, the upper and lower zone are divided into more semi-zones. In-between two adjacent zones, pivot connects the two parts to offer rotational flexibility. Lower zone is bisected so that either of these can also move out of sync.

In order to solve the PU problem, the living board is covered with a kind of mattress "Alternating Pressure Air Mattress (APAM in English & Wechseldruckmatratze in German)" (Figure 3). The basic principal of it is to inflate different air chambers at different time point, so that the skin contacting the bed surface can be free of pressure and ventilated by turns. So it is not necessary to turn the user every two hours.

To realize the exercise function, here we raise two methods in this paper: 1. hydraulic jacks (Figure 5) 2. motor embedded pivot. In the hydraulic method, at least 6 jacks are used under the unit. Through adjusting the height of stroke, the live board performs different configurations.

With the mechanisms under the lower zone of living unit, the bed can transform to a wheelchair. If hydraulic jacks are utilized, a practical docking system is necessary to connect unit with jack mechanisms. If motor pivots are utilized, it is simpler and a specially
designed wheeled base is necessary. The detail of the transformation from bed to wheelchair is still in research.

**Bed Mode**

**Transferring and Turning over**

In order to realize turning-over and transferring in a relatively simple way, the best condition is user leaning to his side on one unit(either of two). For example(Figure 6), if the user wants to be transferred from living unit to service unit, he leans on his right side, and the living board starts to rotate about the central pivot to a predetermined angle, the service board welcomes the user forming a 90 degree angle with living board. According to force analysis, when the frictional force equals the component of gravity along the board, the user can slide slowly and smoothly to the service board. At last, the two boards rotate back to initial position and the user lies on service board. During the transferring and turning over process, the whole system should be controlled not only by motors but also by sensors, e.g. gyroscope. The system functions positively and the user feels good.

**Fig.6. Experiment on Turning to One Side**

**Washing and Toileting**

If the user wants to use the toilet, he doesn't need to call a nurse there. He moves to the service unit, and sets the bed to toileting mode, so that he sits up, and the switch of toilet opens. Nowadays, technology is mature enough to develop a small device, just like "Blue-collar Robot"(Figure 8) to transport the toilet bucket, or the toilet zone can link directly to municipal pipes through a vacuum toilet\(^1\), ensuring cleaning, odorless, healthy environment.

**Fig.8. Blue-collar Robot in Warehouse**

(\[http://singularityhub.com/2009/05/08/kiva-robots-continue-to-conquer-warehouses/\])

In sitting mode, user is able to wash feet and carry on some other basic daily activities.

**Fig.9. Left: Sitting Mode; Right: Toileting Mode**

**Exercises and Entertainment**

As to popular exercise methods nowadays, we want to embed these functions into the assistant bed as well. The bed offers two kinds of exercises: active and passive.

**Active Exercises**

Active here is same as the definition of active assistive exercise in medical field, which refers to voluntary contraction of muscles controlling a part, assisted by a therapist or by some other means\(^2\). Of course, if the user had the ability to move actively, the definition also covers active exercise (motion imparted to a part by voluntary contraction and relaxation of its controlling muscles\(^3\). In this exercise mode, about the pivot, the lower zone rises up or falls down, and the user on the bed has to follow the action. In this way, user practices leg muscles.

**Passive Exercises**

In contrast, passive exercise refers to motion imparted to a segment of the body by another individual, machine, or other outside force, or produced by voluntary effort of another segment of the patient's own body\(^4\). That is to say, in passive exercise mode, the bed offers a relatively elastic force, and what the
user needs to do is to overcome this force, just like arm wrestling. User is involved in passive exercise.

![Fig.10. Sit-ups and Lower Limb Exercises on Assistant Bed](image)

**Mental Exercise and Entertainment**
User can play with the smart tablet PC when he leans on his left. Some apps that can be downloaded from online store are also valid for patient recovery, not only the physical, but also the mental. So assistant bed producer can cooperate with app developers and nursing department to develop new apps based on treatment requirements. Since tablet PC is a popular entertainment device as well, user can enjoy nice movies or has video chat with relatives and friends. Doctors and nurses can also perform simple diagnosis through HD video camera. In this way, nursing staffs don't need to see one patient too frequently, so that one staff is able to take care of more patient at the same time.

![Fig.11. Modeling of Tablet PC Use](image)

**Wheelchair Mode**
Inspired by the inventions^{15–21}, the assistant bed has the potential for transforming to a wheelchair. As if a ship, the living unit docks at the platform as a bed. And if user wants to go outside, he can pilot the ship to where he wants. As mentioned before, the wheelchair needs a mobile base and a brilliant docking system which connects the unit board tightly with the base. The details about them are still in research.

![Fig.12. Modeling of Wheelchair](image)

**DISCUSSIONS**
So far, the function of the assistant bed is relatively complete. It is still able to improve and be better.

Regarding the turning-over process, in order to make it more smoothly and more comfortable, the mechanism can be improved. The passive board, which is the goal board to the user, can be more active: it slides under the active board to 300mm, and slides slowly back to initial position when turning-over is finished, in this way, user stays in the center part of passive board. The US Patent “Inflatable Patient Transfer Roller Mattress”^{22} can be integrated in the alternating pressure air mattress, because they have similar principals and similar components. If so, the transferring process is much easier and turning-over is more comfortable.

Nursing is still a labor intensive work in hospital now, but in this concept, nursing staffs don't need to go to every patient too frequently. Besides user controlling the system by himself, nursing staffs can also control it remotely. So workload is further cut down. It is very efficient in some developing and low population countries, where professional nursing staff is not sufficient.

As to the exercise function, there is a solution to achieve 12 most common recovery methods^{23}. We can optimize the platform and introduce more equipments and devices upon ceiling and walls. The exercise function is sensor-based, that means, the all physical status of user are real time sensed, and the CPU of the system records the states of muscles and bones to adjust the amount of exercise automatically and operates the function according to the feedback gathered by the sensors. Integrated therapy into the program, the assistant bed gives best effect to user.

The final vision of the concept should not be an individual bed system, but a ubiquitous space. The assistant bed can work with other smart equipments
Conclusions
No matter in a nursing home, or in a private house, with the assistant bed, nursing is not necessary. It provides functions, such as turning-over, transferring, exercises, and wheelchair. We want to give the ability to live independently back to immobilized patients, so they can live just like normal people. To nursing staffs, the assistant bed is a brilliant tool to work with, because it can be operated easily and it reduces the workload sharply. It will be a useful assistant in aging society.

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