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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
- Service Science through Automation and Robotics: Mass Customization of performance oriented environments, Automation and Robotic Assisted Living, Service Robotics, Personal Assistance, Demographic change design and management of socio technical systems by human ambient technologies in daily life especially for aging society.
- Automation and Robot Oriented Design: Design and Buildings Structures Enabling efficient use of Automation and Robotics, Modularization, Product Structure, Building Information Modeling
- Automation and Robotics Deployment Strategies: Innovative business processes, automation and robot oriented management, human-machine communication, socio technical aspects, socioeconomic aspects, history of automation and robotics

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Necessity of a Disruptive Change in the Construction Industry – Analysis of Problematic Situation

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The construction industry is going through a phase of stagnation. Its development clearly lacks behind other industries. Deficiencies are experienced that negatively affect the industry by diminishing its performance and outcomes. A comprehensive project is formulated in order to significantly develop and evolve the construction industry. Four aspects are introduced as the main drivers for the successful completion of the project: definition of the problematic situation, relevant available innovations, operational implementation and the guidance towards an envisioned state of the industry. This paper summarizes the methodology and results of a master's thesis that aimed to cope with the first of these drivers. The thesis was developed in the department of building realization and building robotics of the Technical University of Munich and is called *"Restructuring of the Construction Industry for Increased Productivity, Enhanced Efficiency and Optimized Compatibility with the Dynamics of Innovation; Stage 1: Necessity of a Disruptive Change"*. The problematic situation of the construction industry is analyzed through an industry overview, 3 case studies, a literature review and an international sample investigation. Findings reach to a classification of 17 existing root problems, which are ranked by their severity and categorized according to their characteristics. Results show that problems are homogeneous from an international perspective and that they are highly interlinked. Implications are deducted from the results and the drawbacks of traditional approaches are highlighted. Incremental changes are stated as convenient in general situations, but a disruptive change is recommended for the construction industry given the current state of the problematic situation within it.

Keywords*: construction industry, top-down, holistic approach, disruptive change*

INTRODUCTION

Construction projects serve more than just economic reasons, as it is a prerequisite for a well working society. Buildings support people at the purest level of need fulfillment. According to Maslow's "Hierarchy of Needs" shelter is a necessity to protect humans from the elements and thus a physiological need serving as a foundation for other needs[1]. Simply said, societies cannot exist without construction projects. Besides, the whole infrastructure relies on the construction industry. Without infrastructure the modern economy would not be possible. Construction projects are crucial in the lives of humans and in the establishment of modern societies and economies. Therefore a continuous high demand is prevalent.

The current state of construction projects is full of inefficiencies and flaws. In this rapidly evolving world the disorganization causes a tremendous waste of big potentials and leaves all stakeholders with major concerns. Timeframes for project developments are too wide and regularly misconceive the economical dynamics of demand and supply. This results in the emergence of obsolete buildings. The Juglar cycle identifies periodic fluctuations in fixed investments in a cycle of 7-11 years[2]. Research found this theory to hold true in reality and especially in the real estate market; the aftermarket of construction. Large-scale construction projects often have development times above 10 years. Consequently, future cycles have to be forecasted and inaccurate results are likely to cause non-demanded construction projects. Furthermore the lifetime cycle of current constructions is very static. Once plans are settled specifications are complicated and costly to alter. Especially reconstructions are time and money intensive. Therefore demolitions occur often and create waste and new construction efforts. Even softer changes, such as addressing the demand of changing or ageing inhabitants, cannot be easily provided. Thus, the incorporation of changes to the structure or services is hardly possible neglecting many opportunities and failing to address the evolving needs. Forgone innovations cannot only be experienced in the final product but also severely show up during the development of the constructions. It is reasonable to identify these deficiencies as the cause for the flawed outcomes. Methods and plans are depicted during the development of a project and therefore determine the final building.

Ranging from conception to construction the problems on the industry are diverse and multiple. Furthermore they are highly interrelated and share a common result of cost and time overruns, as will be shown on this paper. This collective result aggravates the complex investigation to determine the root of challenges and therefore increases the persistence of problems. In general construction projects are neither contemporary in terms of their execution nor in terms of their outcome. Approaches to provide solutions to the construction industry's complications often comprehend an isolated problem and habitually fail to consider the interrelations among the various components and aspects of the industry. To generate a resolution very comprehensive changes are required. These alterations range from the very first decision of conceiving a project to the installation of the very last light bulb. Therefore the entire value chain has to be evaluated, analyzed and adapted accordingly to the new needs that arise in order to efficiently produce demanded products.

The aim of this paper is to summarize the work of a Master in Science thesis made as a graduation requisite in The Technical University of Munich[3]. The purpose of the aforementioned thesis was to reach a sound understanding of the problematic situation acting within the construction industry. In order to achieve this, it was necessary to find and define the singular problems and their overall individual and collective behavior. This will provide the comprehension needed to formulate the priorities that have to be established to guide the path towards a resolution of the problems.

METHODOLOGY

The problematic situation of the construction industry needs to be properly understood in order to find a way to improve it. A sequence of actions was undertaken to achieve so (see Figure 1).

The input of information was handled by the use of four different approaches, each with an own specific goal. First the importance of the construction industry is shown by the use of an industry. Measurable indicators like percentage of GDP participation and employment data served as tools to determine the industry's significance. Subsequently, the actual existence of a problematic situation needs to be proved. A group of widely known failed projects were used as case studies; their failures serve as evidence of the malfunctioning industry. The next step is the establishment of the specific deficiencies inherent to the current nature of the construction industry. An extensive literature review was performed in a critical way to discern the issues that are most affecting the industry's development. The gathered list was processed in search for tendencies and classifications that provide a better understanding. Finally, the severity of the processed problems was evaluated by analyzing their frequency of occurrence and their impact on real construction projects. Therefore a sample of international projects including the ones described in the case studies were studied in relation to the problematic situation described by the previous stages.

After all this processing of gathered information, a series of results were collected that go in the direction of the focus of the study. Primarily, a well-defined list of root problems was identified and described in relation to their effect and importance on the construction industry's current state. The analysis led to an organization of these problems in two ways. The first one establishes a ranked list that constitutes the order by severity hence giving a perspective of their importance. The second way depicts a categorization that groups the problems with similar characteristics in terms of their impact and their frequency of occurrence in construction projects. As a third important result the locational scope of the problematic situation is introduced. The situation is proven to be homogeneous in a global level. Lastly, an analysis of the interrelationship of the problems is performed based on the existence of influences between them.

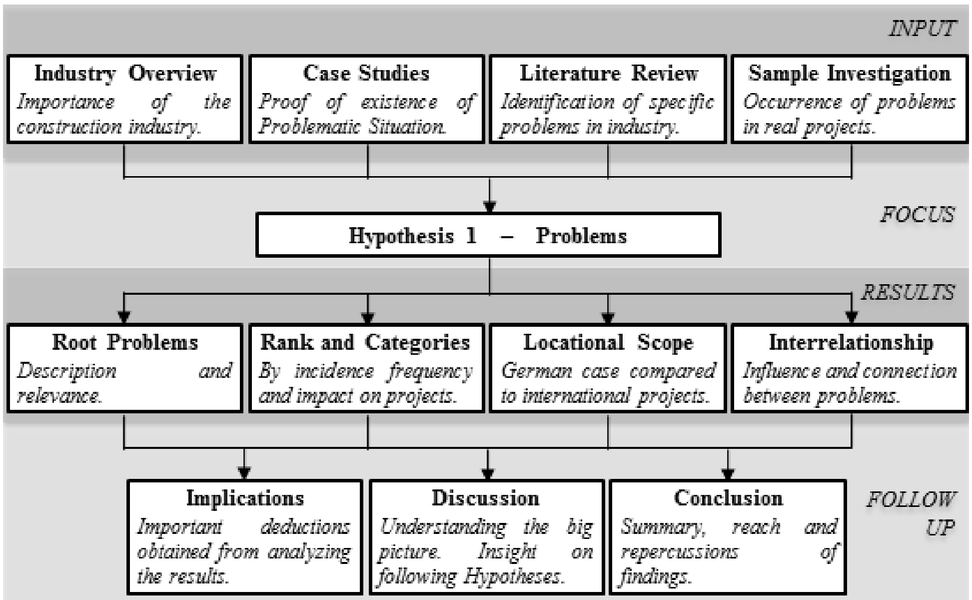

Figure 1. Methodological scheme of the study.

After the methodical gathering of information and its processing towards the finding of results, it is beneficial to analyze the outcomes in order to obtain clarity that allows to discern the convenient directions of subsequent efforts towards problem resolution. Therefore a follow up of the results was needed. With the insight and understanding gathered with the previous steps of the study, some valuable deductions were inferred. They condense the deeper meaning of the findings by having implications that state the approach that should be followed when proposing changes, and the nature of the changes needed. To close, a general conclusion summarizes the intention of the paper and states the reach and repercussions of the findings while discussing possible following steps of investigation.

RESULTS

After following the described methodology to analyze and process the information and data gathered on the input stage, the results described in the subtitles of this section were reached. However, before presenting the results it is important to highlight some intermediate findings that help to establish the importance of this study and its relevance to the current construction industry practice.

The first of these findings sets the importance of the industry from a socio-political angle. This is achieved by a general overview of the construction industry from a wide perspective. It allows to conclude that in average the construction sector is responsible for around 9-10% of the GDP and 7-8% of the total jobs on countries with diverse development levels. The second finding proves the existence of a deep problematic situation that anchors the outcomes of the construction industry. It is accomplished by analyzing the tales of woe of three different renowned failed projects in Germany. The selected projects are the case studies referred to in the methodology and are the Airport of Berlin, the Philharmonic Theater of Hamburg, and the Train Station of Stuttgart. Their examination describes deficiencies in several aspects that lead to severe overruns of cost and time, thus proving the current ill state of the industry.

Root Problems

A meticulous literature review was performed to get a deep insight about the nature of the inefficiencies of the industry. 40 scientific documents were studied to extract deficiencies as seen by academic experts and industry practitioners. It was done in a critical way so as to obtain not only the explicitly stated problems, but also the ones that are slightly inferable from introductory segments and other descriptions. On the reference section at the end of this paper the aforementioned documents are listed from 5 to 44.

Root Problem	Specific Deficiency	Origin
Inaccurate Planning	23, 37, 44, 56, 73, 79, 82, 91, 96, 97, 101, 102, 106, 107, 108, 110.	Owner, Consultant, Contractor, Design, Materials, Equipment, Contract, Relationships, External, Changes, Project Management.
Low Productivity	59, 61.	Equipment, Manpower.
Imprecise Execution	20, 24, 100.	Contractor, Equipment, Changes.
Changing Requirements	6, 14, 47, 94, 95.	Industry, Owner, Design, Materials, Changes.
Context Dependability	5, 49, 51, 54, 58, 66, 67, 68, 69, 90, 98, 99, 113, 114, 116.	Financing, Materials, Equipment, Environment, External, Changes, Government.
Contractual Gaps	28, 29, 34, 48, 71, 72, 86.	Owner, Contractor, Consultant, Materials, Contract, Relationships.
Segregated Efforts	9, 12, 13, 39, 40, 70, 80, 103, 105.	Industry, Owner, Design, Contract, Relationships, Project Management.
Miscommunication	17, 18, 32, 33, 35, 36, 38, 41, 42, 43, 62, 77, 78, 81, 104, 115.	Owner, Contractor, Consultant, Design, Coordination, Manpower, Relationships, Project Management, Government.
Excessive Amount of Trades	27, 83.	Industry, Contractor, Design, Consultant, Relationships.
Information Overload	1, 30, 31.	Financing, Industry, Consultant.
Occupational Hazards	63, 64, 65, 111, 112.	Manpower, Industry, Environment, Project Management.
Exaggerated Use of Materials	45, 46, 50.	Materials, Industry, Government.
High Reliance on Labor Force	10, 21, 57, 60.	Industry, Contractor, Equipment, Manpower.
Reluctance to Implement New Technologies	7, 22, 55, 109.	Industry, Contractor, Equipment, Project Management.
Extensive Construction Periods	53, 93.	Industry, Equipment, Materials, External.
Conflictive and Disloyal Culture	15, 16, 25, 74, 75, 76, 84, 85, 87, 88, 89, 92.	Owner, Contractor, Consultant, Contract, Relationships.
Adverse Financial Conditions	2, 3, 4.	Financing, Government.
Consequences	8, 11, 19, 26, 52.	---

Table 1. Results of the classification of industry's deficiencies into Root Problems.

A list containing 116 deficiencies was gathered after taking care of not considering repetitive ones more than once. Given the big amount of items in the list a classification was required in order to get a better understanding and to allow the finding of logical conclusions. Therefore 17 groups were deduced taking the origin of the deficiency as the classifying criteria as follows: financing, project/industry, owner, contractor, consultant, design, coordination, materials, equipment, manpower, environment, contract, relationships, external factors, changes, project management and government.

After studying and analyzing the gathered list of deficiencies, it was possible to infer common features among them. By grouping these factors together, disregarding the origin classification, it was possible to find resemblances and connections that allowed sorting the extensive list of deficiencies into more tangible root problems. These root problems can have multiple origins and represent substantial flaws in the performance and current nature of the construction industry. Some deficiencies found in the literature were considered in this investigation as consequences rather than actual flaws, consequently they were labeled in an additional category.

The result of the identification of the root problems acting in the construction industry is summarized in Table 1. The table shows the root problems related to the single deficiencies that form part of each one of them and the corresponding origins. For a complete overview of the numbered list of deficiencies related to the reviewed documents, and a detailed description of the root problems, please refer to the thesis document of which this paper is a synthesis[3].

Ranking of Problems

A sample investigation was performed by analyzing the occurrence and impact on real projects of the previously defined root problems. A sample of 15 flawed international projects (including the three from the case studies) was analyzed in depth in order to obtain the required information. The additional 12 projects were: Ryugyong Hotel in North Korea, Mose Project in Italy, Montreal-Mirabel Airport in Canada, Millenium Dome in UK, The Chunnel connecting UK with France, The Big Dig in USA, Sydney Opera in Australia, TCBuen in Colombia, Wembley Stadium in UK, Denver Airport in USA, Berlin Train Station in Germany and Pinakothek der Moderne in Germany.

Having at hand the information of occurrence and impact of each one of the root problems on every single project of the sample, a frequency of occurrence and an average impact can be calculated. This allows to summarize the information of the entire sample in regard of each root problem. Therefore a severity index can be calculated for each problem by multiplying the frequency of its occurrence with its average impact on the projects of the sample. The problems can then be ranked by their severity and the results of this analysis are depicted in Table 2.

Root Problem	Frequency	Average Impact	Severity
1. Inaccurate Planning	100,00%	4,33	**4,33**
2. Changing Requirements	93,33%	4,50	**4,20**
3. Miscommunication	86,67%	4,00	**3,47**
4. Imprecise Execution	73,33%	3,82	**2,80**
5. Context Dependability	100,00%	2,33	**2,33**
6. Reluctance to Implement New Technologies	80,00%	2,42	**1,93**
7. Extensive Construction Periods	66,67%	2,70	**1,80**
8. Adverse Financial Conditions	40,00%	4,17	**1,67**
9. Low Productivity	93,33%	1,71	**1,60**
10. Contractual Gaps	46,67%	3,43	**1,60**
11. High Reliance on Labor force	73,33%	2,09	**1,53**
12. Exaggerated Use of Materials	86,67%	1,69	**1,47**
13. Occupational Hazards	33,33%	4,00	**1,33**
14. Conflictive and Disloyal Culture	60,00%	2,11	**1,27**
15. Excessive Amount of Trades	73,33%	1,73	**1,27**
16. Segregated Efforts	80,00%	1,50	**1,20**
17. Information Overload	66,67%	1,40	**0,93**

Table 2. Problems ranked by severity after sample investigation.

Categorization of Problems

The ranking depicted in the previous subsection fails to give an understanding of the severity setup, thus the constellation of frequency and impact and the meaning for the projects and industry respectively. For example Adverse Financial Conditions (1.67) and Low Productivity (1.60) merely result in the same severity but their setup is completely different.

Adverse Financial Conditions arises rather infrequently but has a severe impact while Low Productivity has the opposite setup since it seems to prevail most of the time without greatly influencing the planned outcome.

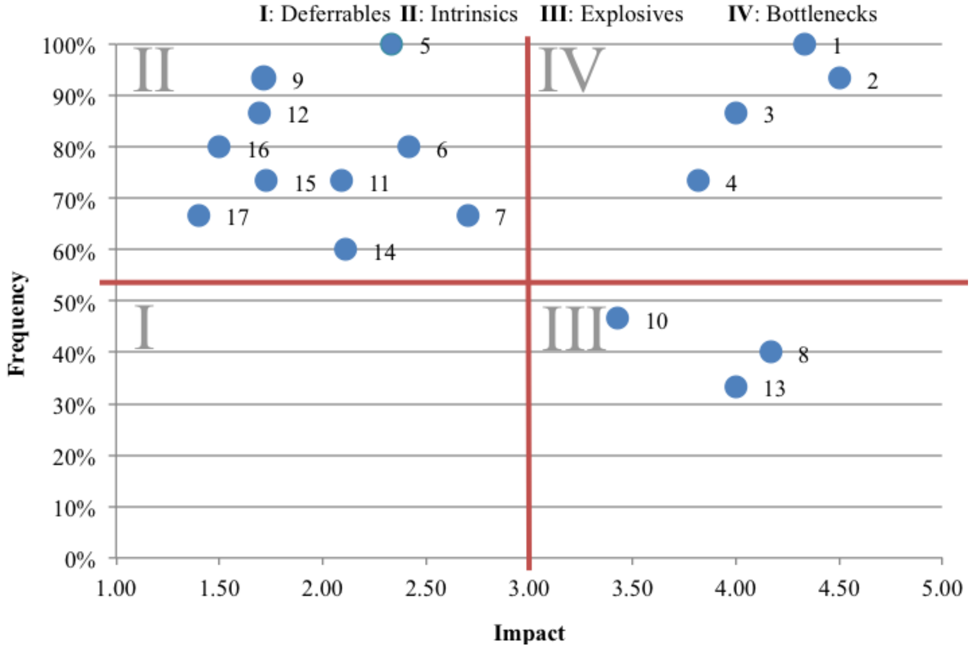

Figure 2. Problem categorization matrix (problems labeled by rank).

A matrix is created using the same data of the sample investigation in order to generate a general understanding of the meaning of the problems. It depicts the problems by their frequency and impact, and divides them into four quadrants that allow a comprehensive categorization (see Figure 2).

Category I: Deferrables

“Deferrables” are characterized by a low impact and a low frequency. Thus, their severity is marginal. As the category name implies these problems are deferrable. Actually it would be an enhancement of the construction industry if all the problems occured in this quadrant, as the sample did not yield any problem with such a low setup. Deferrables are experienced even in the most efficient industries. Nevertheless they should not be neglected. Innovations and enhancements should incorporate these problems in order to further diminish them and to carefully control them to prohibit increases in their severity.

Category II: Intrinsics

“Intrinsics” show high frequency and low impact. Therefore they are industry intrinsic. It seems that all participants in the industry incorporate these problems in all of their assumptions, calculations and considerations. They do not show a large perceived impact on the sample projects, as all stakeholders know from the beginning that they will occur. Nevertheless these occurrences are very crucial problems. Just because they are incorporated does not alter their effect. The perceived impact, thus the deviations from calculations and plans, does not represent the real impact. These problems diminish the overall performance of the construction industry especially as they occur often and are diverse. Stakeholders have to set their mind to create a responsibility to foster an improvement of these industry characteristics.

Category III: Explosives

“Explosives” are setup by large impacts and lower frequency. These problems cause exploding budgets and schedules when they occur. The terminology Explosives is further used, as an increase in frequency can cause dramatic results on the whole industry. Explosives are likely to become Bottlenecks of the industry. This category seems to be the most dynamic. If the problems are not addressed they increase in severity but as their frequency is currently relatively low they can be considered in alterations to shift them to Deferrables. If they are incorporated in the assumptions and planning efforts they are even likely to become Intrinsics. Nevertheless as mentioned before, this would not be an enhancement but merely a deviation of perceived impact from real impact. Cautious but drastic actions are needed to enhance the situation while it is still manageable.

Category IV: Bottlenecks

“Bottlenecks” are associated to high impacts and high frequencies. Thus, they are of highest severity and are experienced in the whole industry. These problems are most likely the main drivers of project failures. It seems that the bottlenecks have diverse impacts over the complete development of projects. These problems are likely to be persistent as they are routed in the industry and even though their impact is large they are not forgone and enhanced by now. It is unlikely that these problems can be diminished with simple alterations. Much effort must be invested to lower their frequency and impact.

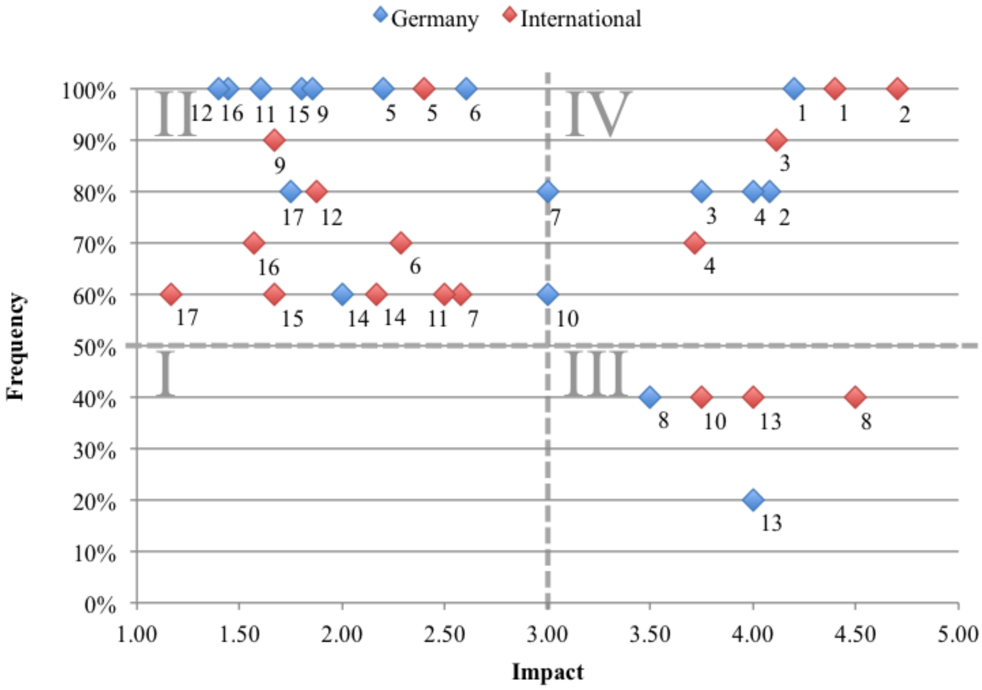

Figure 3. German vs. International problem data comparison (problems labeled by rank).

Locational Scope

From the analysis of the reviewed literature, it was slightly inferable that the problematic situation of the construction industry was very homogeneous on a worldwide scale. The similarity of problems evidenced in the studies from different countries with variable development levels allowed to reach this conclusion. However, this is still somewhat light and lacks meaningful scientific weight. The data gathered on the sample investigation helped to solve this problem by allowing the grasping of further conclusions by comparing the case of Germany with the rest of the world (see Figure 3).

As it can be seen in Figure 3, there is a general tendency that the Problems have a lower impact but higher frequency in Germany. It seems that the problems are deeper rooted within the German Industry. Further the stakeholders seem to incorporate them to a high degree causing a lower perceived impact. Nevertheless the real impact still severely diminishes the outcome of the industry. In addition the highly stable political and economic German situation fosters a lower impact of problems. On the other hand the higher impact and lower frequency of the international samples, especially in the second quadrant, represents awareness and carefulness.

Aside the minor differences, almost all problems remained within the prior found categories. The only problem that clearly swapped sectors is Contractual Gaps in the German sample. It seems that contractual gaps are exploited more often in Germany to acquire a stronger position for negotiation, as the frequency is higher. The lower impact appears to indicate that Germany has a well working legal system that more easily finds consensus in several cases. Extensive Construction Periods is on the verge of becoming part of Bottlenecks in the German industry. There is no real indicator that Germany suffers from longer construction periods, therefore it is believed that this occurrence tends to be a perceived one. Germany's industries in general are highly advanced and perform to highest standards in terms of efficiency and time. As the construction industry lacks behinds stakeholders experience it more strongly.

Although there are differences in parameter values the overall impression remains the same. For the sample investigation it can be shown that the problems occur homogeneously on an international scale and globalism can be inferred.

Interrelationship of Problems

An interconnected network of problems acting together as one dense anchor that does not let the industry move forward is mildly described as conclusions of some of the documents of the literature review. Also the description of each one of the root problems required the use of other problems to accurately state the magnitude and effect of their characteristics showing the existence of influences between them[3]. Additionally, with the sample investigation was observed that none of the problems occur unaccompanied and that many were acting simultaneously adding severity and complexity resulting in the described failures. Therefore the presence of

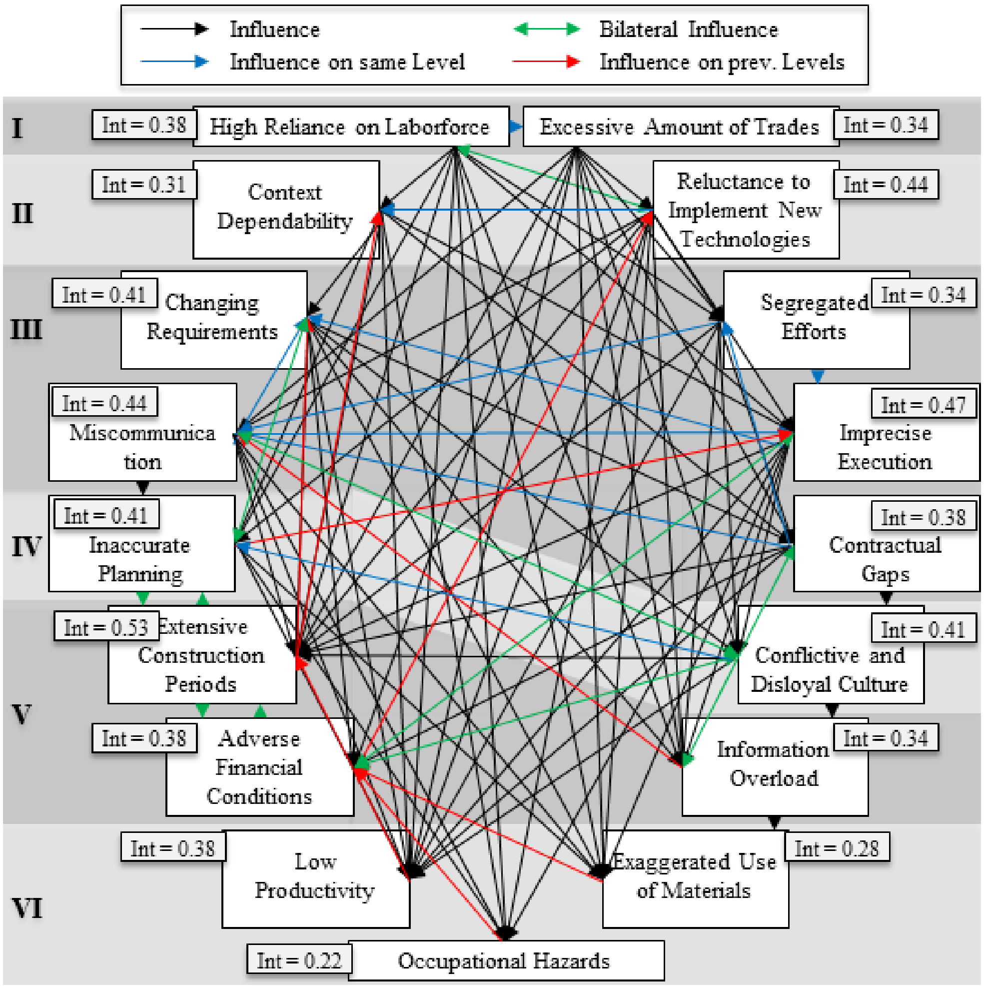

Figure 4. Interrelationship of the ranked problems.

relationships between problems is at this point inferable but not appropriately described. This subsection will go deeper into this subject with the aim of determining the degree of interrelationship of the problems of the construction industry.

From the information gathered in previous stages and the comprehension achieved as a result, it is possible to discern the existence of the influences that each problem has on the others. Once all the influences were established, different types of relationships were discerned: predecessors, successors and bilateralism when two problems directly influence each other. The behavior of each problem in terms of its interrelationship is described with the introduction of the Behavior Index (BI), which is calculated by dividing the amount of predecessors that a problem has by the amount of successors. For BI values higher than 1 the behavior tends to be the one of a successor, while the opposite happens for decimal values.

$$BI_{Problem\ X} = \frac{\sum Predecessors_{Problem\ X}}{\sum Successors_{Problem\ X}}$$

The different values of BI obtained by the root problems allow a comprehensive classification in six different groups that organize the influential characteristics of the problems. These groups are introduced as the. Influence Levels (IL), ranging from level I (the most influential) until level VI (the most influenced). Also an additional indicator is required to observe the degree to which a specific problem is really interlaced with the others. The Interlinkage Index (Int) is established to detect the amount of problems with which a problem a direct relationships. It is defined as the sum of predecessors plus the sum of successors divided by the maximum possible relationships, which for our purpose is 32. The resulting number is nothing more than a fraction representation of the percentage of problems with which a direct influence exists. A Int value of 1 would mean that a problem is simultaneously successor and predecessor of all the remaining problems, which is greatly improbable. Therefore a Int value of 0.50 is already reflecting a high degree of interconnectivity.

$$Int_{Problem\ X} = \frac{\sum Predecessors_{Problem\ X} + \sum Successors_{Problem\ X}}{\sum Problems}$$

The results of the interrelationship analysis are represented graphically in Figure 4. All the problems are organized by their influence level reflecting their behavior. Connections between them are displayed with arrows that represent the direct influences and labeled with their interlinkage index. The existence of influences that bilaterally or individually go back to previous levels or that at least remain in the same one are indicators of the presence of influence loops. Therefore if not directly at least in an indirect manner each problem is influencing most of the other problems in some degree.

The high interlinkage of the problems that act in the construction industry is a fact. There are clear indicators of the veracity of this statement: The high amount of direct influences parting from or converging at any individual problem; the existence of loops that involve indirect influences even from the most consequential to the most causal problems; simply the graphic density of influence arrows on Figure 4. Problems are highly interrelated, direct or indirect influences can be found between every two problems and no individual solution directed to solving one problem will have great impact on the overall behavior of the huge and complex problematic situation of the construction industry.

IMPLICATIONS

The problematic situation harming the construction industry is now very well defined and analyzed. The root problems, their characteristics and their severity are disclosed and accessible for all stakeholders and other interested parties. With the solid understanding gathered from the deep analysis of the industry and its problems it is now possible to withdraw deductions regarding their overall behavior and set the ground for the proposal of possible solutions. Until this point the present investigation gathers and processes data, allowing the reach of results and implications with scientific value that can be used as a starting point for further investigations in search for an overall improvement of the construction industry.

Holistic Approach

Existing literature depicts a high attention towards the construction industry. Traditional approaches that are distinguished in most of the literature documents investigate diverse issues and interfaces. Each topic is analyzed in depth and adequately presents flaws and solutions to individual interface's problems respectively. Nevertheless such degree of specialization fails to consider the effect that a proposal might have in other surrounding interfaces. It is possible that each interface is "improved" without any beneficial impact to the overall performance of the industry. The remaining literature makes an effort to address the problems with a wider perspective. The construction industry's supply chain is taken from a wider perspective and a extended variety of problems are distinguished. However, these wider perspective studies limit themselves to identify the precise factors generating the problems and to assess their severity. This is all done to achieve the goal of having a well argumented ranking that is intended to determine the priority with which the individual deficiencies should be addressed in specific locational and socio-economical contexts (specific approaches again). Nevertheless the interconnectivity of their nature is never taken into account but merely inferred in the best cases.

Current approaches' slender focus is important because a deep and comprehensive understanding of the problems is gathered allowing the examination of various possibilities that may lead to a solution. Also in the existing studies with a general perspective of the problems some degree of interconnection within the construction industry is already perceived throughout the different stages of the process. Problems in a given stage generate more serious problems in later phases. In current approaches experts' specialized knowledge is gathered and a comprehensive analysis of the directly affecting factors is done. All these are valuable efforts that help to comprehend the situation, which is indispensable to serve as guidance in the search for solutions.

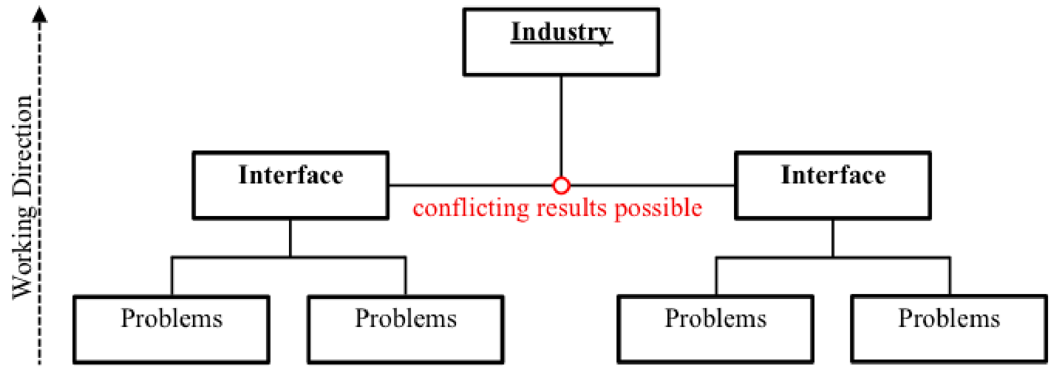

Figure 5. Traditional approaches towards problems in the construction industry: Bottom-Up.

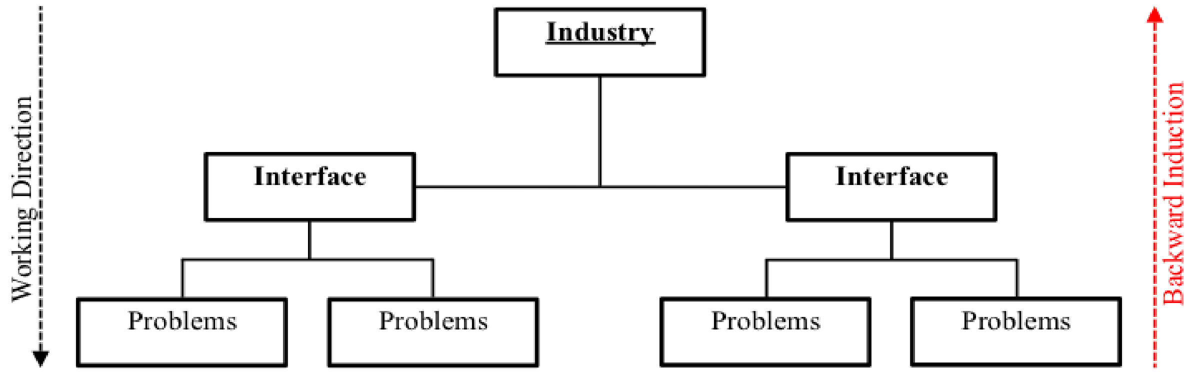

Figure 6. Proposed holistic approach towards problems in the construction industry: Top-Down.

However, the Bottom-Up approach that is traditionally applied leads to neglect the general impact on the industry and the existence of clashes and contradictions between different specialists and among interfaces. Therefore the beneficial individual adjustments proposed by traditional approaches theoretically can even lead to a diminishment of the overall efficiency of the industry by having conflicting results between isolated efforts of improvement in different interfaces (see Figure 5).

These proven interconnections and perceived wasted potential in combination with the previous argumentation of the narrow focus of traditional approaches suggests that further efforts must be spent in studying the relationships among interfaces and how the solution of problems in one affects the performance in the others. This would allow the contemplation of the entire panorama of the industry, the identification of strategic points of action and the assessment of the clashes by tactical trade-offs giving priority to the overall performance of the industry and resulting in enhancements with high positive impact.

The described situation craves for a new angle of action with which the dense interrelationship is considered, the outputs maximized to their potential and the overall performance notoriously enhanced. The required tactic has to be coherent with the best interest of the entire industry and not only for individual interfaces. Therefore a Holistic Approach is introduced as a strategy, in which the construction industry is conceived as a whole, located in a greater perspective level than the linear accumulation of the interfaces that compose it. A Top-Down graphical exemplification is the most exact way to represent this concept since in it the interests of the industry are considered primarily, and from there the focus diverges into the singular interfaces and specific problems (see Figure 6).

The holistic approach considers the interlinkage of problems and interfaces, contemplates the flaws in many sub categories and assesses a fitting solution. This proposal demands a very complex conception and even more complex implementation but is considered to be the only way to generate a drastic positive impact on the entire construction industry allowing it to reach its potential. A leveling in terms of development with other industries could be experienced since compatibility with innovations could be boosted and inefficiencies alleviated. This would give added value to the products of the construction industry by increasing customer's benefits with improved quality and functionality, reduced costs and times of production. In general the Top-Down approach ensures the goal to be comprehensive, as the overall impact on the industry is the starting point. Backward induction exists to include the findings about the problems by including the alterations in the overall goal at the industry level. Therefore the investigation of the problems and their characteristics is highly important, which was addressed in detail with this study. Finally, a solution can be proposed that enhances the industry and does not create clashes.

Disruptive Change

The holistic approach previously described allows to infer the necessity of a different sort of change, one that deals with the interrelationship of the problems and that has a top-down direction of priorities. The traditional attempts to improve the construction industry's performance are highly segregated and attack singular deficiencies with disregard of the general impact that the change might have on the interconnected array of problems. This was evidenced in the individualistic strategy employed by most of the documents analyzed in the literature review. The result of these highly specialized tactics is an *Incremental Change*. This means that enhancements are proposed as a modification of a current state of things advancing small steps at a time. This type of change is very important since every process or method can and should always be improved by attacking the specific ineffectiveness.

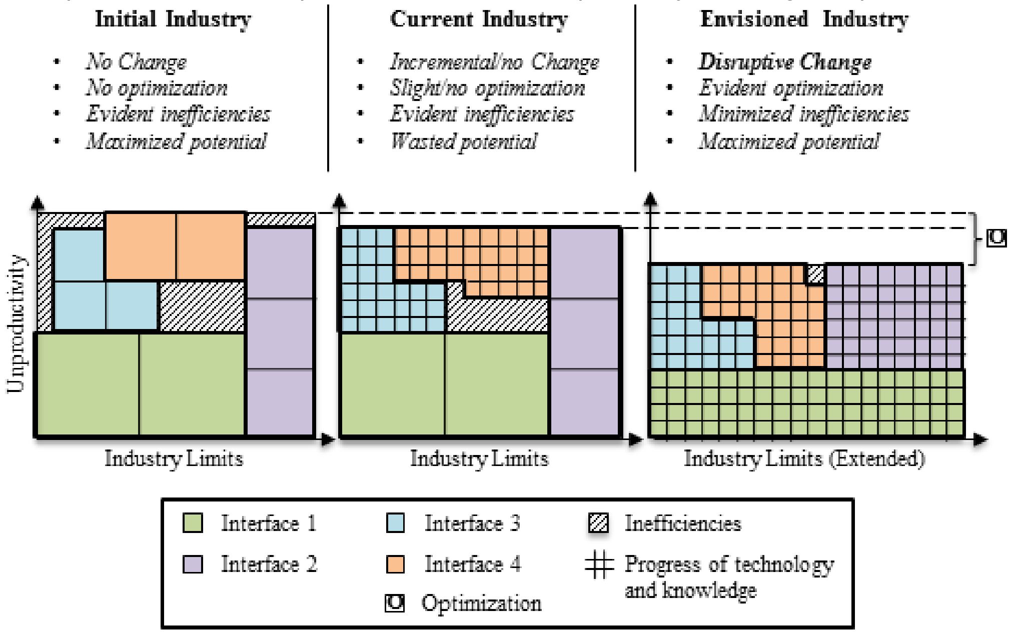

Figure 7. Block Representation of Construction Industry. Benefits of a disruptive change.

However, a time comes when technologies and knowledge develop in such a way that new possibilities are created. These new possibilities may challenge the fundamental organizational concepts on which the current state of the industry and its interfaces are structured. In this case to use the newly developed technologies or knowledge to generate an incremental change parting from this "challenged" state would represent a waste of potential. This is true since the new possibilities may imply that the conceptual foundations can be rearranged in a way that the features of the new technologies can be maximized resulting in a superior derived state than the one that would be achieved with an incremental change by the same technologies. This would mean that all the concepts and organization that support a specific state of the industry must be reconsidered in a deep level to embrace the possibilities that would be brought by the new technologies and knowledge; a *Disruptive Change* would be needed. The act of considering a disruptive change is already adopting a holistic approach towards the enhancement of the construction industry. Hence, these two concepts are highly associated. Thus, if the most adequate approach according to the analysis of this study is the holistic one, consequently the most beneficial type of change is a disruptive one.

An abstract representation of the industry will be introduced with the aim of simplifying the concept and facilitating the comprehension. The dynamics of the construction industry will be represented by the organization of a set of blocks, which stand for the different interfaces that compose the industry (see Figure 7). The representation is framed in a vertical axis that gives information on overall productivity and a horizontal axis that limits the industry due to regulations. It is more accurate to label the vertical axis as Unproductivity because higher values represent a less favorable condition. The horizontal axis sets a boundary that cannot be surpassed within the same state of an industry in terms of regulations like governmental, physical or ethical. Some blocks have contact with other blocks as the interfaces of the industry have relations with each other. Additionally the various interfaces are formed by subdivisions that represent the technological and scientific availability. The more advanced the technology and knowledge the bigger amount of the subdivisions of the respective interface, which increases its possibilities by making it more flexible to adopt different shapes to relate with other blocks. The gaps between interfaces represent inefficiencies since the failure to fill them demands an increase on the unproductivity axis. The aim of industry development efforts is to find the arrangement of interfaces and relations that better fills the inefficiency gaps given the availability of technological and scientific resources. This representation applied to different states of the industry will illustrate the described concepts and provide clarity and understanding on what a disruptive change means for the construction industry and why it is concluded to be the best option.

The first state of the industry showed in Figure 7 represents the configuration of the industry in some previous specific moment in time. In that moment, even though big inefficiencies are depicted, the knowledge and technology did not allow a better configuration of interfaces since no other arrangement would result in a reduction of the unproductivity scale. Therefore the potential is tapped to the maximum for the given conditions of the time. The industry was probably comparable to other industries in terms of performance.

As scientific knowledge and technology developed the industry shifted from the described previous state to the current one. Subdivisions increased in quantity and decreased in size for some interfaces (the ones with priority in research and development investments), which allowed more flexibility to adopt more convenient configurations. However, since the approaches traditionally undertaken lead only to incremental changes the adaptation capacity of the interfaces is small and the inefficiency gaps are not effectively filled. This is regrettable, because the stagnation of the construction industry in comparison with other industries suggests that available technologies and innovations can already cope with these gaps in a more beneficial way. Thus, the possibilities that came with scientific developments are not being exploited at its fullest and an overall waste of the industry's potential is evidenced. With the results and understanding gathered with previous stages of this study it is reasonable to state that the only way to effectively fill the inefficiency gaps is through a disruptive change. This implicates reconsidering every aspect of the industry in a rather profound manner, in a way that not only evaluates how things are done but also the things that are done themselves. In the abstract representation example it is even considered a change of culture and regulations that extend the industry limits, creating even more possibilities for its rearrangement. The comprehensive management of this change would result in the realization of an envisioned industry that is drastically optimized by maximizing its potential and minimizing its inefficiencies.

In general experts seem to cohere with this approach. To create something new or extend limits it is often necessary to disruptively stop old approaches and to rethink the overall goal in order to find strategies to achieve it[4]. Especially with the current problematic situation in mind that influences the outcome of the industry on different stages it is important to assess the big picture. This can only be achieved by a disruptive change that tackles the problems in a holistic manner and captures interrelations on all levels.

CONCLUSION

This investigation gave an overview about the deficiencies faced in construction industries around the globe. These drawbacks relate to a very specific set of 17 root problems that range from the very first conception to the very last installation at the construction site. Root problems represent the direct core from which all the deficiencies and inefficiencies of the industry can be derived and therefore will embody the focus of attack when formulating possible solutions. Adding severity to this range is the high correlation between the problems identified by the complex predecessor/successor relation and the interlinkage index of at least 38%. Therefore the whole value creation in the industry at hand is in question. Current attempts focus merely on single interfaces and fail to consider the range and interlinkage of problems. They are found beneficial when a deep knowledge about individual problems is required but found obsolete when the big picture of the problematic situation needs to be captured. Thus, this study assessed the conditions of the current state of the industry comprehensively to create a foundation and justification for a restructuring. The identified problematic situation with its large range and interrelation requires a holistic approach that follows a Top-Down work flow to achieve an overall goal of enhancement paired with a Backward-Induction to account for the specific problems. By identifying this need the corresponding sort of change is implied. Only a disruptive change can cope with the demand of an industry-wide development. By doing so standards and processes can be altered to guarantee a more flexible and efficient cooperation between interfaces that increases the productivity and shifts the boundaries of the industry beyond the current state.

Stated in the concept of change management, guidance is of highest importance. This leadership derives from role models of the guiding coalition and the communication of visions. Therefore this study can be linked to the broader perspective of a bigger project that takes the results and follow up of this study and further develops concepts that result in a reorganization of the construction industry that addresses the here described problematic situation. This project should serve as guidance to foster the restructuring by introducing visions and strategies to accomplish them. At the current stage of the investigation a guiding team is not at hand. This study strives to ease its creation. It was identified that the problems occur on a global scale and even their characteristics tend to prevail internationally. Therefore the interest concerning the resolution of situation will be common to many countries increasing the importance and interest of projects aiming to provide solutions based on the findings and results of this paper. Hence, joint research & development efforts can be undertaken. The work investigated heavily on the German industry. Germany's strong political and economical condition combined with the highlighted importance and drawbacks of its construction industry is seen as a potential main contributor. The power described can foster the adoptability of the change on an international scale. The study withstands to draw conclusions about the structure of participating organizations. It rather creates urgency and responsibility for all stakeholders to become part of the needed change. From a business perspective the urgency is fostered by the diminishment of viable business opportunities as the problematic situation hurts the most basic principles set up by time, quality and money. From an economic point of view the responsibility is created as the social surplus is reduced by the current market conditions characterized by separation, monopolies and inefficiency.

By applying the efforts described in this study and guided within the overall project a restructuring of the construction industry for increased productivity, enhanced efficiency and optimized compatibility with the dynamics of innovation can be achieved. An international construction market can become reality; a market characterized by supreme efficiency and productivity.

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One Platform-Different Cities: An Automated Plug and Play Modular Building Construction & City Planning System

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It is a 'Platform,' that is designed in a modular approach, which can be used very easily to create new cities as well as to redevelop old cities in different locations throughout the world in any conditions regarding topography, climate, culture etc. It is a standardized universal 'Platform Module' with all the facilities needed for city level planning like infrastructures for Buildings, Transportation and Utilities etc. A flexible Design concept is provided in which Architects, Engineers, Planners can play role to develop their own concepts for city planning. Study revealed the increasing population growth throughout the world and especially rapidly increased population to cities; all the Governments need rapid growing of cities with all the facilities. Problems, Design Principles, Functional requirements, Structural requirements, Technologies, Infrastructures and all the other needed requirements for a city are identified. The experiments performed provided the additional requirements regarding dimensions for the 'Platform' construction. This study led to the initial mock up idea of both Module level and City level which fulfils the requirements for easy approach of city planning, and convenience to all potential Designers. A flexible infill architectural solution is provided for different Planners and Designers to perform their thinking on a simple, easy approachable and convenient module as well as a city planning system. An Automated construction On-site Factory Design for the construction of the 'Platform' is provided. Also an Automated construction Layout for constructing the whole city is provided by the Author. There is possibility of flexible design system for constructing the buildings for the city on the 'Platform' depending on the sizes, shapes and using character of the buildings. The 'Platform' has different sub modules to provide 'Foundation Piles and Slabs,' 'Under-ground Transportation Core,' 'Underground Utility Core,' 'Base Slab for Over-ground Building' and 'Seismic Resistance Technology.' The 'Platform' has the flexibility to customize it depending on the location where it is used for city construction.

Keywords: *platform, advanced construction, integrated cities, architecture, flexibility.*

INTRODUCTION

Motivation The population of the world is around 7 billion and growing very rapidly by the years. So, it is needed to create more cities around the world. Development in each field like industry, construction, education, health, entertainment also makes human life style more interesting and dynamic. All the Governments now are very concerned about to create cities with all facilities for the welfare of their inhabitants. But almost every country faces difficulties to planning and constructing the cities within the needs of the vast population growth; specially undeveloped and developed countries, due to the lack of proper planning, time limitations beyond the population growth, big budgets, and a vast lacking of construction technologies. Almost every country is using conventional city planning systems with different zones like, Residential, Industrial, Educational, Parks, Forests, Playground, etc. But these buildings have diff-errent designs and planning as well as construction process due to heights, sizes etc. Due to the differences between the earth condition, climate, topography, construction material, technology and culture all the countries have different construction systems and building design systems. Now, the housing industries, construction industries are using advantages of technologies for only Single Building Manufacturing system. But, due to globalization, the city plan-ning needs a world-wide standardized Platform thinking of City Planning. This Platform thinking can provide "One Platform" for all types of cities in different locations of the world. It can be customized with all the Utility needs, Transportation (both underground and over ground), Structural needs (foundation works underground and building structures over ground), Infrastructures (playgrounds, ponds, forests etc.). It is like a "Puzzle Board" where we can Plug-in a new building and Plug-out an old one very easily. Mass customization of it can consume lots of times, labors, money, energy, etc. regarding to the conventional way of construction. This "Platform" can be used also for regeneration of existing cities like the Capital city of Bangladesh, Dhaka (case study).

Problem description

African and Asian cities like Lagos, Bombay or Calcutta are growing rapidly and this will probably continue during the next years. About 40 cities around the world have a population of over 5 million. They are called megacities. 80% of them are in poorer countries. [1]

Figure 1: The World's Biggest Cities http://www.english-online.at/geography/world population/urban-areas.htm

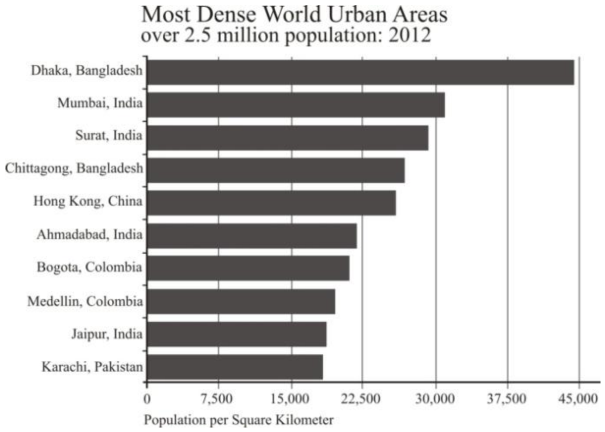


Table 1: Most dense world urban areas over 2.5 million populations in 2012. http://www.newgeography.com /content/002808-world-urban-areas-population-and-density-a-2012

Research objectives (project goal)

A standard system with all the components needed for a city will be provided for all locations of the world having flexibility of customization due to the location, earth condition, topography, culture, material as well as with flexibility of design ideas. A standard production line design and layout for reconstructing the old city as well as new city will be provided. And a customizable architectural city layout plan will also be provided with module manufacturing factory, construction factory and deconstruction factory.

RESEARCH AND SURVEY

Historical references Urban planning is a technical and political process concerned with the control of the use of land and design of the urban environment, including transportation networks, to guide and ensure the orderly development of settlements and communities.[2] **Neolithic period** In this period, agriculture and other techniques facilitated larger populations than the very small communities of the Paleolithic. The pre-Classical and Classical periods saw a number of cities laid out according to fixed plans, though many tended to develop organically. Designed cities were characteristic of the Mesopotamian, Harrapan, and Egyptian civilizations of the third millennium BC. The first recorded description of urban planning is described in the Epic of Gilgamesh for the city of Uruk. **Indus Valley Civilization** Distinct characteristics of urban planning from remains of the cities of Harappa, Lothal, and Mohenjo-daro in this Civilization lead archeologists to conclude that they are the earliest examples of deliberately planned and managed cities.[3][4] **Classical and Medieval Europe** The Greek Hippodamus (c. 407 BC) has been dubbed the "Father of City Planning" for his design of Miletus; Alexander commissioned him to lay out his new city of Alexandria, the grandest example of idealized urban planning of the ancient Mediterranean world, where the city's regularity was facilitated by its level site near a mouth of the Nile. The Hippodamian, or grid plan, was the basis for subsequent Greek and Roman cities.[5] The ancient Romans used a consolidated scheme for city planning, developed for military defense and civil convenience.[6] **Renaissance Europe** Florence was an early model of the new urban planning, which took on a star-shaped layout adap-ted from the new star fort, designed to resist cannon fire. This model was widely imitated, reflecting the enormous cultural power of Florence in this age; "the Renaissance was hypnotized by one city type which for a century and a half-from Filarete to Scamozzi-was impressed upon utopian schemes: this is the star-shaped city".[7] **Americas** Many Central American civilizations also planned their cities, including sewage systems and running water. In Mexico, Tenochtitlan was the capital of the Aztec empire, built on an island in Lake Texcoco in what is now the Federal District in central Mexico. At its height, Tenochtitlan was one of the largest cities in the world, with over 200,000 inhabitants.[8] **Modern planning** In the developed countries of Western Europe, North America, Japan, and Australasia, planning and architecture can be said to have gone through various paradigms or stages of consensus in the last 200 years. **Garden City Movement** The garden city movement is a method of urban planning that was initiated in 1898 by Sir Ebenezer Howard in the Uni-ted Kingdom. Garden cities were intended to be planned, self-contained communities surrounded by "greenbelts" (parks), containing proportionate areas of residences, industry and agriculture.[9]

City planning aspects (1) Aesthetics (2) Safety and security (3) Slums (4) Reconstruction and renewal (5) Transport (6) Suburbanization (7) Environmental factors (8) Light and sound

The city planning systems (1) Rational planning (2) Synoptic planning (3) Incrementalism (4) Mixed scanning model (5) Transactive planning (6) Advocacy planning (7) Bargaining model (8) Communicative approach

History of Construction

People have constructed buildings and other structures since prehistory. Building materials in present use have a long history and some of the structures built thousands of years ago can still be regarded as remarkable. The history of construction overlaps that of structural engineering. History of construction refers a study of; Neolithic construction, Mesopotamian construction, Egyptian construction, Greek construction, Roman construction, Medieval construction, Renaissance construction, Seventeenth century construction, Eighteenth century construction, Nineteenth century: Industrial Revolution, Twentieth century construction.

Technologies

Mass customization in different industries

Mass customization is the method of "effectively postponing the task of differentiating a product for a specific customer until the latest possible point in the supply network." (Chase, Jacobs & Aquilano 2006, p. 419).

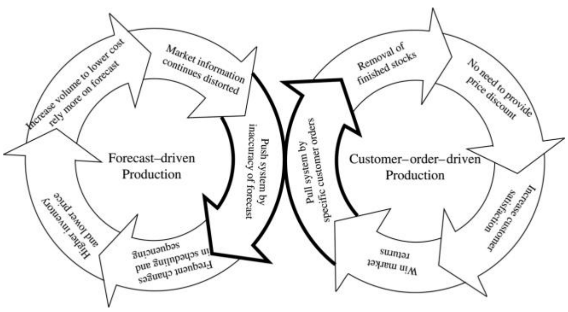


Figure 2: Two different logic cycles: mass production vs mass customization2010. http://www.emeraldinsight.com/content_images/fig/0240260605005.png

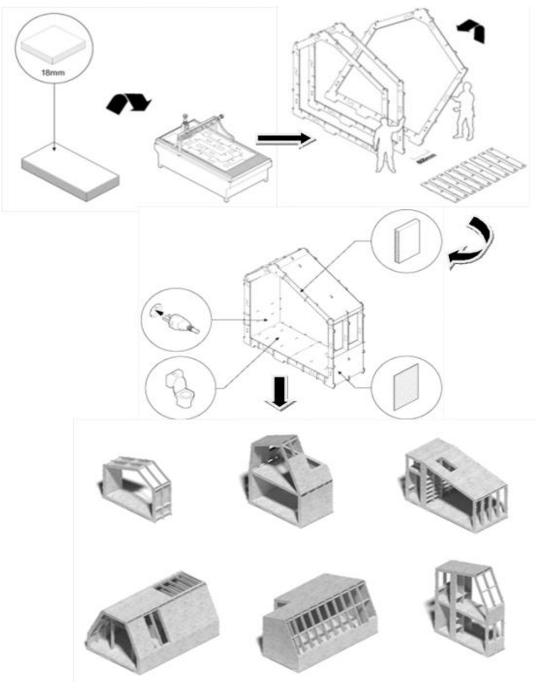


Figure 3: Mass customization of house (Open-Sourced Housing) http://www.architizer.com/blog/wp content/uploads /2011/08/wikihouse-13135269011.png

Construction Factories for building construction (construction &demolish systems): Automated On-Site Factories

A greater degree of automation and integration of robots at the construction site can be very beneficial in many ways, such as cost and time reduction or safety. Systems set up standardized and structured conditions at the construction site (converted and weather unaffected on site factories). Within this structured conditions a multitude of automated and robotic systems operate simultaneously and/or corporate. Single task Robots can be used as Subsystems.

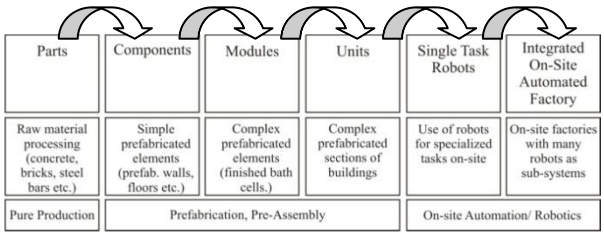


Figure 4: Sub-System Relation (class lecture of master course of Advanced Construction & Building Technology, Prof. Dr.-Ing. (Univ. of Tokyo) Thomas Bock)

Study revealed several Automated On-Site factories of building construction such as, SMART – Shimzu, ABCS – Obayashi, Big Canopy – Obayashi, AMURAD – Kajima, T – Up, Taisei, NCC Komplett, System SKANSKA, etc. Also there have different construction machines used is different industries which the author tried to incorporate in building the whole city. **Production line in different industries** Many products are manufactured and assembled on a production line. Before the introduction of computer control and robots production lines were operated by people. Each person would carry out a limited number of tasks or even just one task and the product would then be passed down the production line to the next person. This would continue until the product was completely assembled. Some modern production lines still operate in the same way whilst others rely on robots and computer control or a combination of people and machines. **Modular Architecture** Refers to the design of any system composed of separate components that can be connected together. The beauty of modular architecture is that we can replace or add any component (module) without affecting the rest of the system. **Plug-in-City, Peter Cook, 1964** In 1965 Archigram envisioned the Plug-in City. Geoff at Bldgblog describes it: Archigram proposed using construction cranes as permanent parts of their buildings. The crane could thus lift new modular rooms into place, add whole new floors to the perpetually incomplete structure, and otherwise act as a kind of functional ornament. [10]

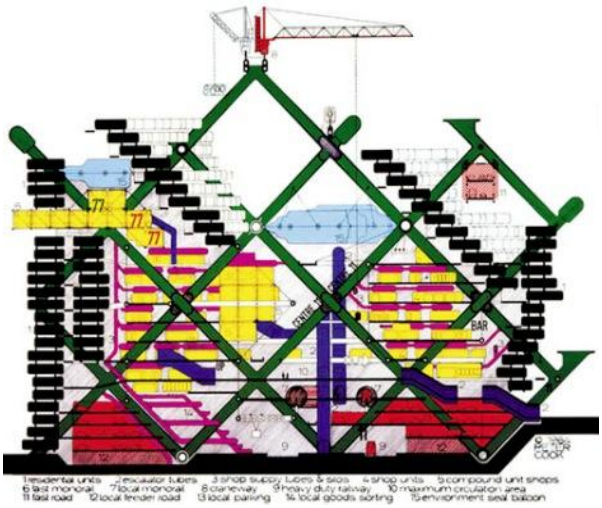


Figure 5: Plug-In City by Archigram/Warren Chalk, Peter Cook, Dennis Crompton; courtesy University of Westminster.

Figure 6: Image of Fujisawa SST, (Fujisawa City Homepage)

Natural disaster protected technologies

Advanced Earthquake Resistance Technology- Passive and Active control systems, Hybrid control systems/ semi active control systems, Damping and Isolation- Tuned Mass Damper (TMD) & Active Mass Damper (AMD), Hybrid Mass Damper (HMD), Viscous Damping Wall (VDW), Active Damping Bridge (ADB), Air floating Floor System, Vibration Control Panel / Prefabricated Steel Panels, Rubber Damping Technology, Base Insulation System (BI), **Damping systems in other industry** Oil industry-Slug Stop, Car industry-variable damping system (Porsche), Bridge- Fluid Damper (TJGZ-FD), High damping rubber bearings (HDR), Railway-Spherical Bearing (TJGZ-LX-Q), High Speed Railway- Pot Bearing.

Current Cities; the Metabolist Movement: Cities of Japan Metabolism was the most important urban architectural, artistic and philosophical movement that Japan produced in the twentieth century.

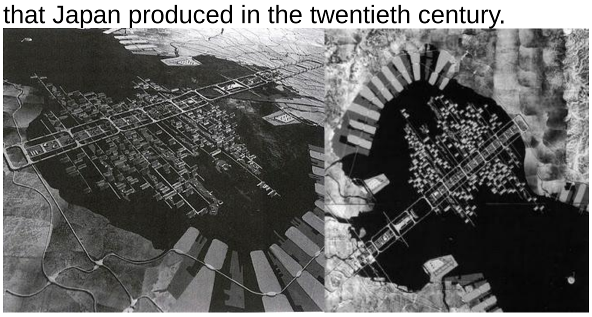


Figure 7: Plan for Tokyo, 1960. Photomontage and model. Kenzo Tange.

Cities of China: Tianfu District Eco-City: car-free vision of the future Adrian Smith + Gordon Gill Architecture's master plan for Tianfu Ecological City is the vision for a self-sustaining, environmentally sensitive 1.3-square-kilometer satellite city outside Chengdu, China.

Figure 8: Tianfu District Eco-City master plan

Metropolitan city of Dhaka, Bangladesh (development idea) Dhaka is the capital of Bangladesh and the principal city of Dhaka Division. It is located on the banks of the Burigonga River. The population of this city in 2007 was 6,737,774 [11]. Dhaka, the capital of Bangladesh grew strongly between 2001 and 2011 and became the most densely populated urban area in the world. Dhaka's density is estimated at 115,000 per square mile or 44,000 per square kilometer, with slum (informal dwelling) densities repor ted report up 4,210 per acre, or 2.7 million per square mile (1 million per square kilometer). All of Dhaka's urban population of 15.4 million fits into a land area equal to that of the city (municipality) of Portland (population less than 600,000) [12].

HYPOTHESIS

A system must be developed to fulfill the scarcity of city as well as the requirements for develop a complete city planning system. That must be followed the philosophy of modularity to a manufactured product. Figure 9 shows how the study takes the project to its extreme goal. There must be a complete clear planning to reach the goal of the project.

Figure 9: Hypothesis flow chart 1

In the Figure: 10 it shows the flow chart of getting the goal of this study; the Platform, the Planning and the automated construction. The main product is the total city. For that the standard platform module has to design which will has the flexibility of mass customization, modularity. For cost efficiency the module must be manufactured. For high quality module manufacturing a production line construction factory must be designed and at last for time consuming, efficiency, cost effective construction of the city an automated on-site construction factory has to design also.

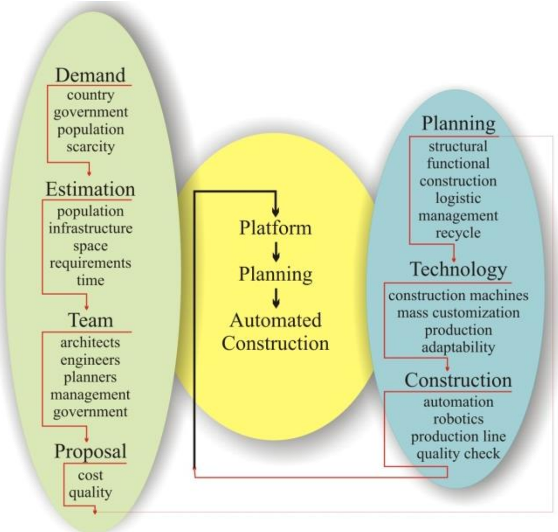


Figure 10: Hypothesis flow chart 2

DESIGN DESCRIPTION

The "Platform" concepts

As the concept is, "A standard system with all the components needed for a city will be provided for all locations of the world having flexibility of customization due to the location, earth condition, topography, culture, material as well as with flexibility of design ideas. A standard production line design and layout for reconstructing the old city as well as new city will be provided. And a customizable architectural city layout plan will also be provided with module manufacturing factory, construction factory and deconstruction factory," the design proposal suggests three analytical parts for the "Platform" for the city planning and construction.

(1) The Module
(2) The Planning and
(3) The Automated construction

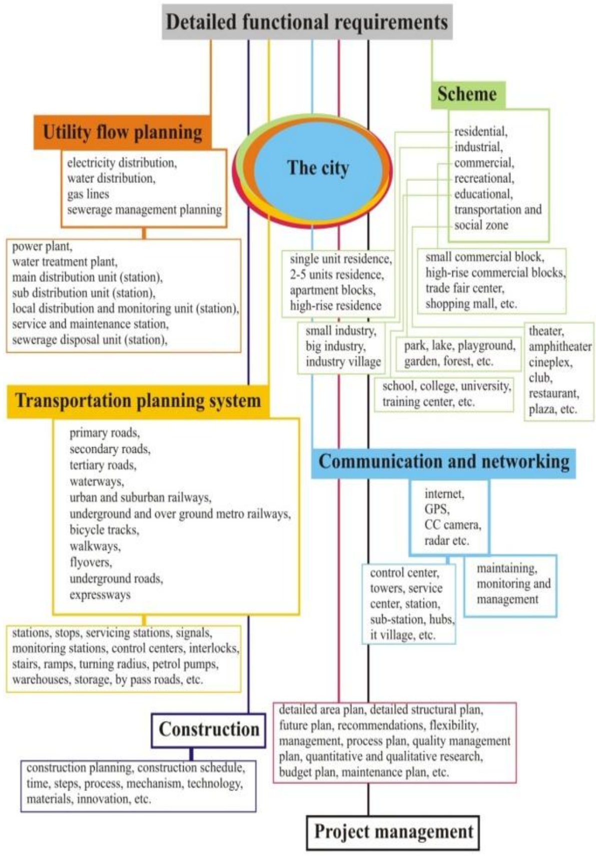


Figure 11: Detailed Functional Requirements for a city.

Figure 12: Detailed Structural Requirements for a city.

The Module

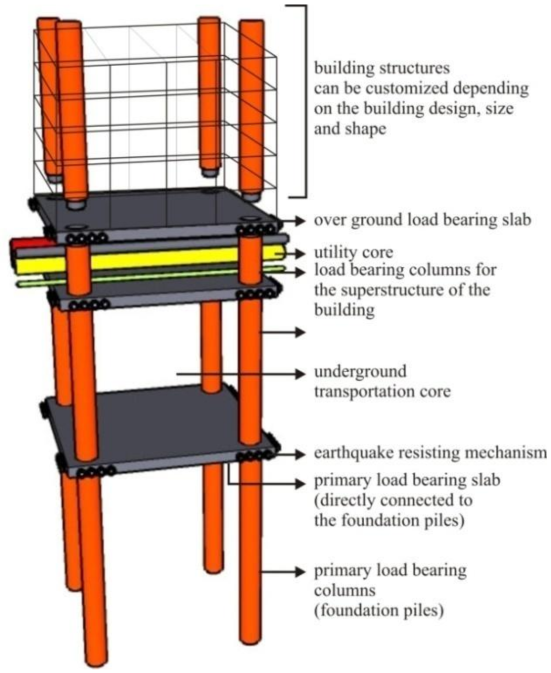


Figure 13: Figure shows the whole module. This should be the one module. Joining more modules together will create the whole city.

Concept analysis part 01: The Module

"The module" is the standard unit for the whole city consists of two basic requirements; (1) The Structural and (2) The functional.

Structural

The structural part consists of primary load bearing columns (foundation piles), primary load bearing slab (directly connected to the foundation piles), superstructure (load bearing column), load bearing columns for the superstructure of the building, over ground load bearing slab.

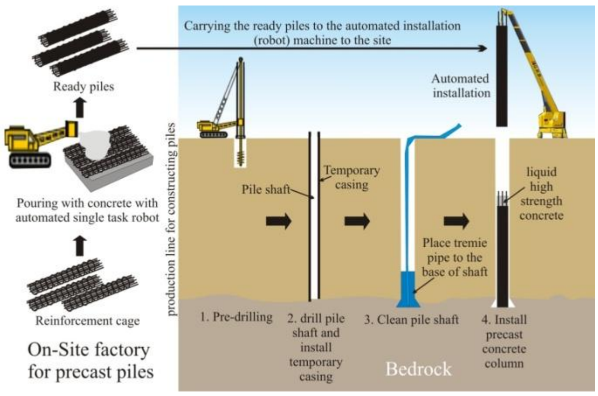


Figure 14: Proposed procedures for constructing large diameter bored piles (automated way).

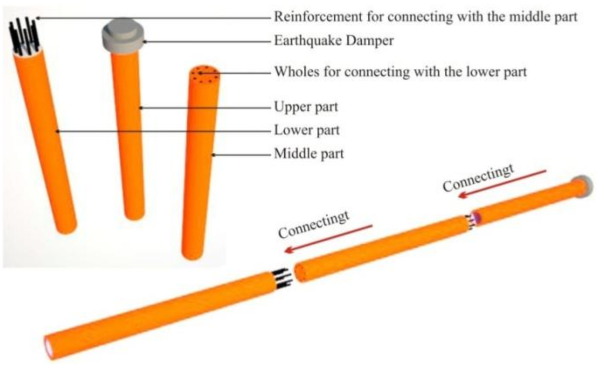


Figure 15: Proposed design for the piles.

Proposed Concrete Piles for the foundation work of the building will be produced at the Production Line Construction On-Site Factory installed on City Site fully automated by computer program base controlling. Basic load bearing capacity calculations, designs of the reinforcement, designs of the piles as well as the raw materials mixing ratio will be evaluated initially before the production process will be started. Piles sizes, load bearing capacity, designs, and installation procedure will be suggested previously. There will be also has the flexibility to use the system for earthquake resistance within the piles. Production line of producing piles for foundation will be full time monitored by the engineers from the central control center.

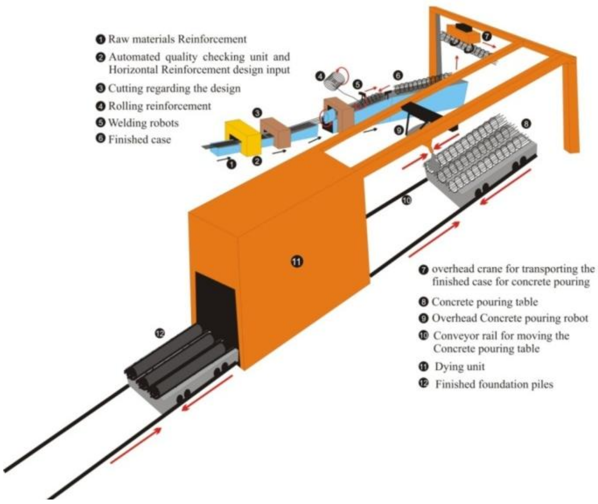


Figure 16: Production line construction process for foundation piles (own concept).

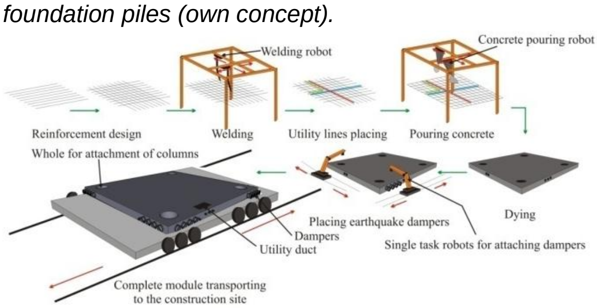


Figure 17: Production line construction process for load bearing slabs (own concept).

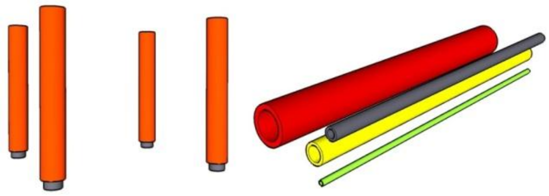
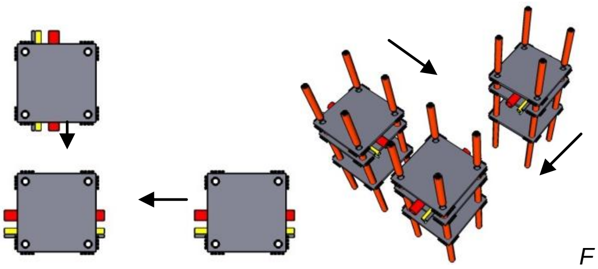


Figure 18: Figure shows the basic components for the module construction, load bearing columns and utility pipes.

Figure 19: Figure shows the earthquake resisting mechanisms and the joining process of columns into the slab (own concept).



F
igure 20: Figure shows how the module connecting with each other. (own concept).

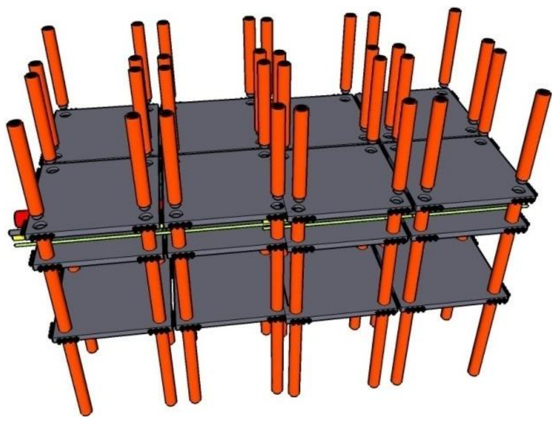


Figure 21: After joining of several basic modules can create a big block and joining more basic modules can create the whole city (own concept).

Functional

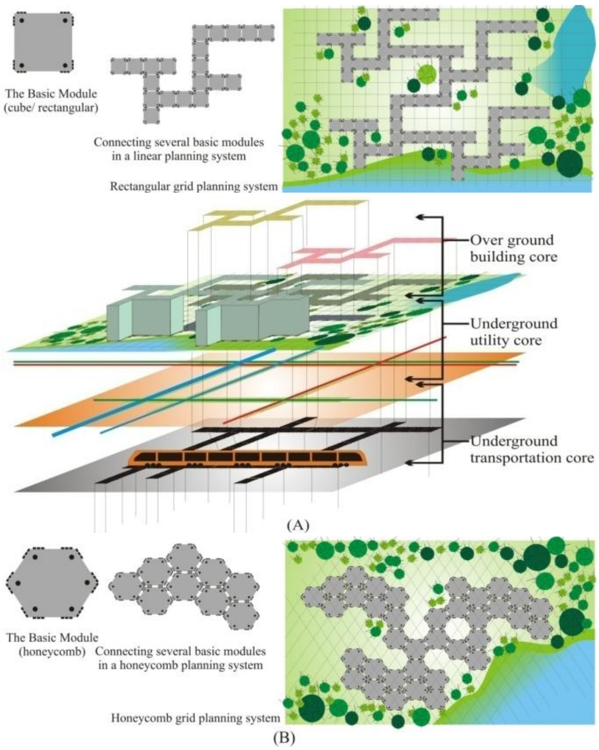
The "Platform" is designed regarding four basic functional requirements. As the platform is designed proposing a standard compact module for constructing the whole city with it anywhere on earth the design must be a very simple but productive one. As the goal of the design to gain a mass production of the module the functional needs of the module strictly followed four functional Core systems. Which are,

(1) The Foundation Core
(2) The Underground Transportation Core
(3) The Utility Core and
(4) The Upper Ground Core

The Foundation Core consists of structures for the foundation; the Under Ground Transportation Core consists of flexibility of constructing underground railway, roads, and pathways. The Utility Core consists of all utility flow lines like, sewerage, electricity, water, gas lines. And the Upper Ground Core consists of all the infrastructures like buildings, roads, etc. (Figure: 13)

Concept analysis part 02: the Planning

The Module (Platform) Planning: Flexibility of designing the city in different zones on the earth is one of the main goals of this study. There have flexibilities for designing the whole city in a very simple way that can help architects, engineers and planners to do it. For reaching that flexibility the planning of the whole city is mainly depends on the Platform module. The size and shape of the module for that must be in a modular way of production. Architects, engineers and planners who will be responsible for designing the whole city will decide the requirements of sizes, shapes and capacity of the module. Before going to the production of the modules they must decided the all requirements needed for the specific zone at which they are going to build the whole city. As the module is the basic unit for the city planning so it must be designed in a way that can easily shows the way to the whole planning of the city. In Figure: 22 several design for the module shown regarding several factors like topography, landscape, etc.



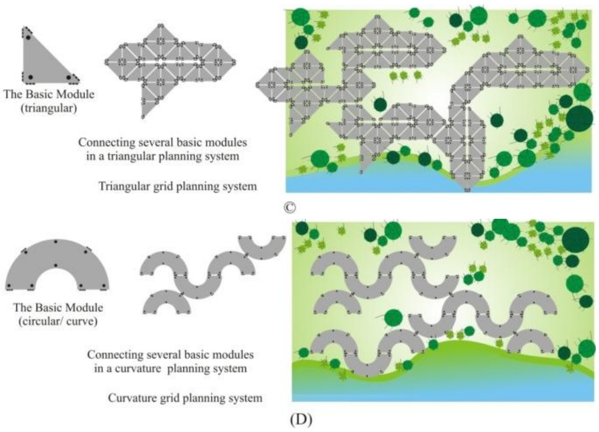


Figure 22: Several Modular approaches for the planning flexibility for a city design; (A) cube/ rectangular planning system, (B) honeycomb/ hexagonal planning system, (C) triangular planning system, (D) planning with curvature system and (E) using different systems at a time achieving flexibility of planning (own concept)..

The Layout (Total City) Planning

Figure 23: Planning flowchart (own concept).

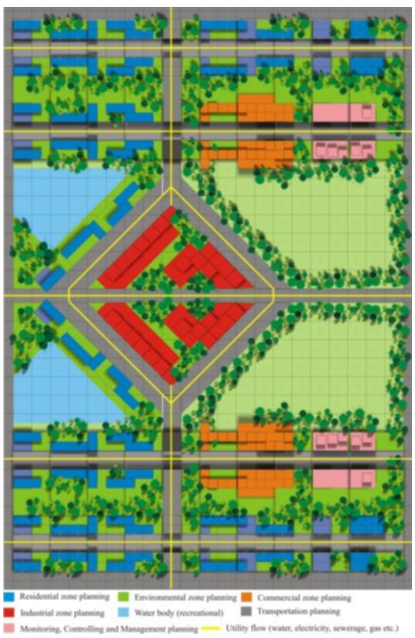


Figure 24: Example (01) of a total city planning in a modular way (own concept).

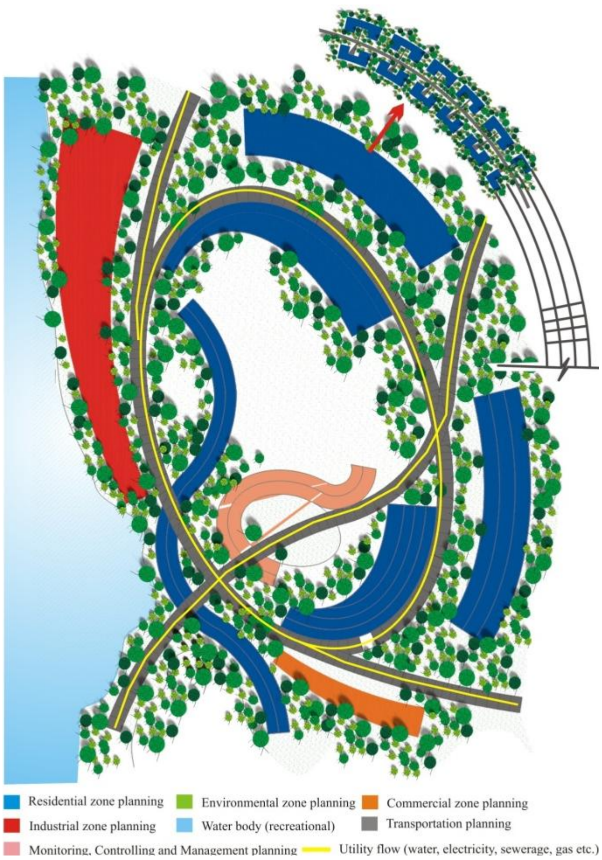


Figure 25: Example (02) of a total city planning in a modular way. (own concept).

Concept analysis part 03: Automated construction

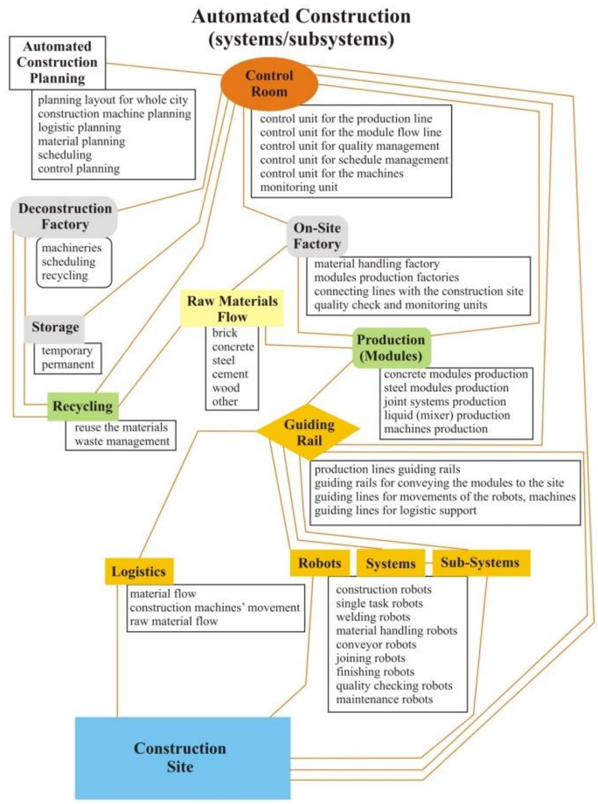


Figure 26: Automated Construction (systems and subsystems) (own concept).

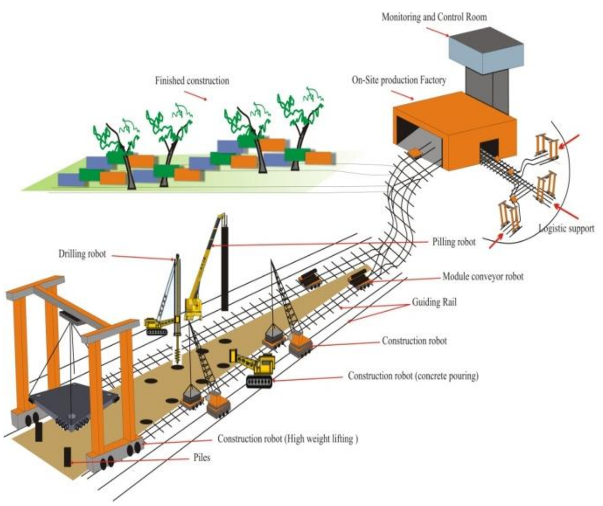


Figure 27: Automated Construction (On-site factory and construction). (own concept).

Mass customization

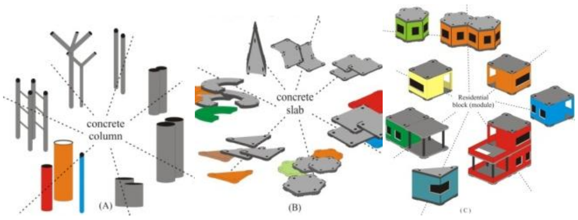


Figure 28: Mass customization of columns(A),slabs (B) and residential block (C). (own concept).

Construction layout

This is one of the most needed thing for constructing a new city and deconstruction of an old city. A proper and clear layout planning must be there for time consume, quality management, cost effectiveness, scheduling. Here in Figure: 30 a complete layout for deconstruction and construction planning has given with all the necessary needs of construction process based on mainly On-site deconstruction factory, On-site production factory, recycling factory, monitoring cell, control cell, logistic flow, design of the city, systems, subsystems and their movements, etc.

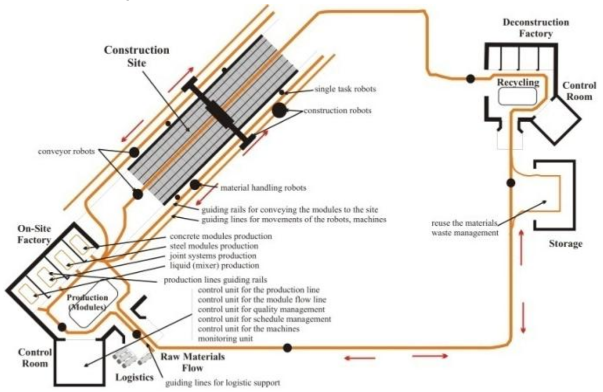


Figure 30: Automated Construction (On-site factory and construction). (own concept).

Construction factories

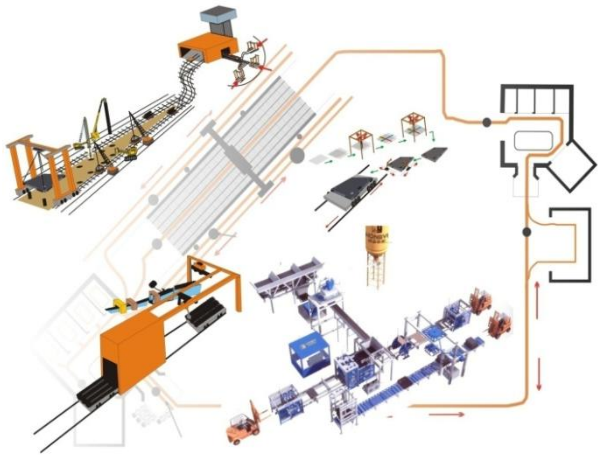


Figure 31: On-Site Automated Construction Factories. (own concept).

Construction Factories are mainly divided into three parts. (1) The On-Site Production Factory, (2) The On-Site Construction Factory and (3) The On-Site Deconstruction Factory. The On-site Production Factory again consists of five major parts; (a) Concrete Column Production Line, (b) Concrete Slab Production Line, (c) Still Elements Production Line (d) Façade Elements Production Line, (e) Joint Element Production Line. The On-Site Construction Factory consists of (a) different Construction Robots, (b) Systems and (c) Subsystems as well as of different guiding rails for the movements of those machines. And the Deconstruction Factory consists of (a) Deconstruction Robots, systems and subsystems and (b) Recycling Unit. All of these have already shown previously. Here in Figure: 31 it shows all the On-Site Factories of the total city construction below.

Modularization

Modularization of every part of the module can consume the construction time, cost effective, easy to handle and easy to maintenance. Here, in Figure: 32 it shows how modularization of each module can help to construct the city in a modular way.

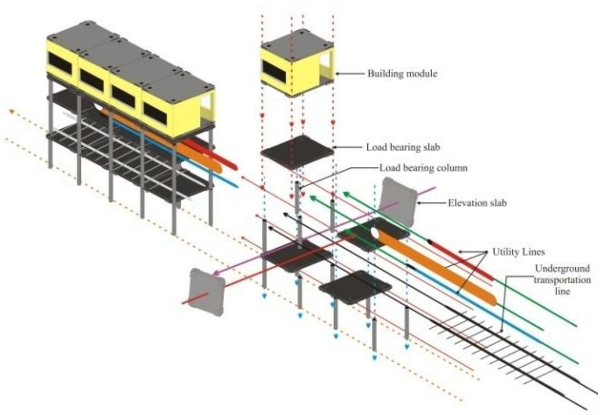


Figure 32: modularization and construction process. (own concept).

IMPLEMENTATION (REDEVELOPMENT OF DHAKA CITY)

The site is located at the south west part of Dhaka city. At one side the river Burigonga and the other side is the old Dhaka city. It is located between Burigonga Bridge 1 and Burigonga Bridge 2.

Figure 33: Selected Site (part of Dhaka City) for reconstruction.

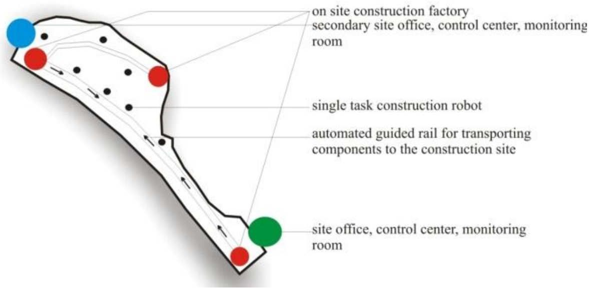


Figure 34: Schematic drawing for Automated on site factory, supply line, control center and automated logistic

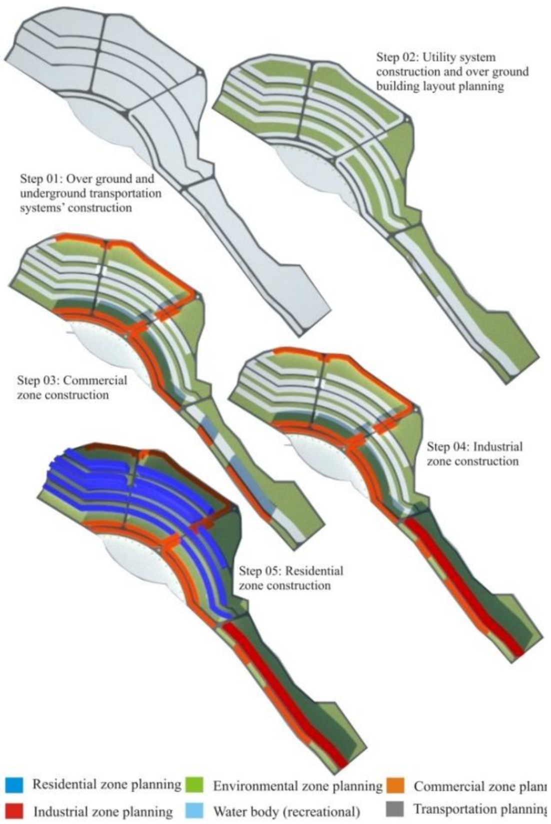


Figure 35: Construction Process (own concept).

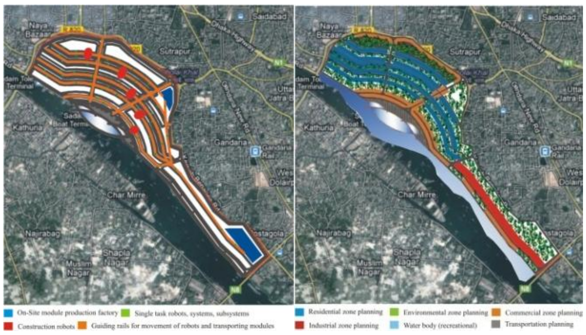


Figure 36: Automated construction layout for redevelopment (left), Redevelopment of Old Dhaka. (own concept).

CONCLUSION

A system like the “One Platform” is a standard modular approach for whole city design. When the demands are big enough and the technologies are appropriate the building industries should make the step forward to provide all the needs for a city in short time with high quality. The housing industry has already adopted modular approach of production of modular apartments. Automated construction systems are also known to the housing industry. But this study provided a production system of a whole city in a factory. Now it is needed for someone to step ahead and take a look at the System. Something like the “One Platform- Different Cities: An Automated Plug and Play Modular Building Construction & City Planning System**”** will be the system for apparent conclusion**.** The “One Platform” approach is an architectural solution, which takes advantage of new technologies and allows many professionals and companies to work together. It allows On-Site Factory-manufactured components to be easily assembled automatically on-site to create a mass customized, adaptable, high quality, high tech, and high value infrastructure for creating a new city.

FUTURE DEVELOPMENT

To bring the “One Platform” system in reality there are many aspects that remain to be examined. An international collaboration of architects, engineers, and other needed professionals as well as the governments must be needed to develop this idea of city construction as a real and effective one. To make it as a standard system it is needed further research of different topography, climate, culture as well as functional and structural need, new technologies of construction, construction materials, cost and time effectence, adaptability and quality research, collaboration of different industries and professional and to study the real life situation of city needs. There must be a précised study of the new adaptable technologies for construction industry and modular approach design for the whole city. Study of related software and computer aided technologies also needed for the production line of the On-Site construction factory. Detailed design researches also needed for the module and its sub modules.

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Universal Construction System (UCS)

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Conventional buildings have a characteristic of being permanent and static. Nowadays, buildings are designed and erected according to the current market demand. They commonly serve a single function and reach the end of their life-cycle in the same location. A building normally faces the fate of demolition once it has become inadequate for various reasons, such as lack of market demand, period of appearance, or simply, requirement of the land for other projects. In some parts of the world, due to the increasing speed of urbanization, new construction projects take place rapidly and many buildings have short life-spans. However, finding the solution to deal with large amounts of construction waste, high energy consumption and low efficiency of construction land use is becoming urgent. This specific "Universal Construction System" (UCS), created by the author, will offer an alternative approach to solving the aforementioned challenges and provide applied concepts in dealing with industrialized building design, production, on-site assembly technology, disassembly technology, interchangeability and efficient land use. UCS emphasizes the idea that buildings should not be erected as a permanent form, but should be flexible or even mobile; they should offer interchangeability throughout their entire life-cycle. Buildings should be designed based on the principle of industrialized building concept, which is highly standardized, but customized. UCS has been developed to adapt to multiple functional purposes. During its lifecycle, the building can be used as residential or commercial depending on the user's requirements. The paper will introduce the concept and design principles of UCS as well as investigate its potential. By analysing the design concept of the industrialized building system, great opportunities would rise for how industrialized construction methods will deal with the issues of promoting construction industrialization and improving building quality. Consequently, UCS has the potential to solve global issues, such as overpopulation, climate change, sustainability and reducing carbon footprints.

Keywords: *universal system, building system, industrialized construction, flexibility*

INTRODUCTION

For decades, the conventional construction industry has been considered a labour-intensive, low-tech industry with low productivity. It seems the construction sector has been left behind by a period of technology innovation and science development that has already reshaped many other industrial sectors. The construction industry is facing challenges to respond to a change in technical, economic and social conditions. There is an increasing need to change construction design, construction technique, production and management strategy within the sector. Industrialized construction methods (modular, panelised, sub-assemblies etc.) played a very important role during the post-war period due to the huge demand in housing. Because of the nature of the concept, there was a potential opportunity to integrate and implement manufacturing technology to enable a revolutionary change in the construction sector.[1]

An industrialized building system can be described as a set of interconnected building elements that act together to form a building that performs many functions. If we consider the structure of the building to be the skeletal system and the skin, then the nervous system and cardiovascular system would be the technological, managerial, production and assembly systems of said building.

UCS reflects the potential of using industrialized building system to solve the aforementioned issues. It can be applied to various types and configurations of construction projects. UCS can be systematically divided into four categories: structural, component, production and construction. In general, structural systems include a series of beams and columns that are interconnected and provide a flexible box-shaped support system. Component systems contain wall elements, floor elements and interior fixtures plus services of the building. Each part can be easily assembled or disassembled to allow the building system to be upgraded regularly. Production systems involve off-site manufacturing of all UCS building elements and can be used as an on-site field factory. Construction systems consist of all on-site technological, managerial and operational assembly activities. A range of construction equipment and single-task construction robots were included by the author in order to increase overall construction efficiency as well as reducing construction waste.[2]

Design scenario

The author constructed a particular scenario that demonstrates how UCS as an industrialized building system will assist both the designer and the engineer. Working together, they will more easily accomplish a project from design to production to construction. This scenario will help the construction industry understated the practicality and potentiality of the design. It aims to impact the current system and to inspire the construction sector to revolutionize its existing methods. Design scenario: design a high-rise residential building with a 100-year lifecycle. UCS will offer a long-term profitable building project that will continually generate assets through its entire life.

STRUCTURAL DESIGN

The load bearing structural system of UCS is designed on the basis of a conventional linear system. It consists of a skeletal structure formed by prestressed concrete beams and columns connected to its foundational system. Four types of prefabricated prestressed structural beams and seven types of prefabricated prestressed structural columns form the boxed shaped skeleton, providing structural support for the building. They also, instead of using welded connection methods, are bolted together to enable the connection joints to be disconnected when required. The flexible connection approach also offers architectural freedom in which the shape of the structural skeleton design can be easily adapted to the requirements of the clients or architects.[3] (Figure 1)

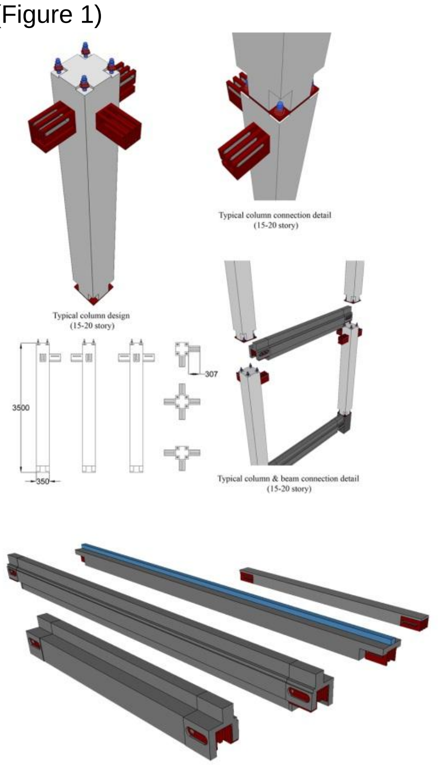

Fig.1. UCS Structural design

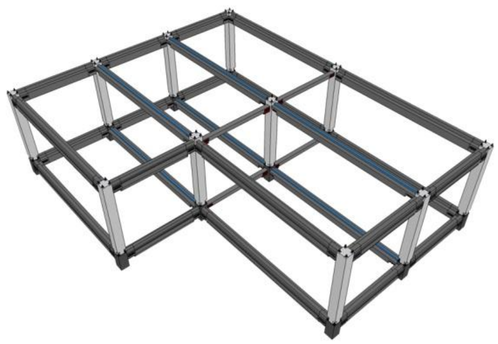

Fig.2. UCS Structural frame design

The flanges of the beams were specifically designed to accommodate wall and floor assembly positions. The beam is prefabricated with high precision. Structurally the beams will take the dead load and live load as well as tension, shear, compression and torsion caused by external forces and the building itself. Then they will evenly transfer most of the forces through the column structures. (Figure 2)

COMPONENT DESIGN

UCS's building components consist of wall systems, floor systems and interior support systems. They are supported by the structural skeleton and each one of them is adjustable, interchangeable and reconfigurable. With the help of flexible components, the operational period of the building can be extended and building maintenance and alteration becomes less complicated.

UCS implemented shear wall designs in the development of exterior wall systems.[4] In this case, the wall panel element is made of precast concrete, yet the material choice can be altered according to design specifications. To maintain property values, the building has to remain productive throughout its life. As a secondary structure, wall components have to be flexibly designed. Wall elements need to be assembled and disassembled easily to adapt with future layout alterations and services need to be easily accessible for upgrading. Therefore, dimensions of the applied wall are relatively smaller than conventional shear wall systems. In general, the wall elements will be sandwiched between the structural beams and floor panels. (Figure 3)

UCS's floor and ceiling system was combined into a single panel design. One side of the panel will be applied as floor and another as ceiling. The floor and ceiling systems have a similar design concept to the wall system: overlapped configuration, connection methods and flexibility. Suspended floors and ceilings, along with embedded services, will be installed shortly after panels are assembled on-site and this will indicate that the construction of the building envelope is complete.

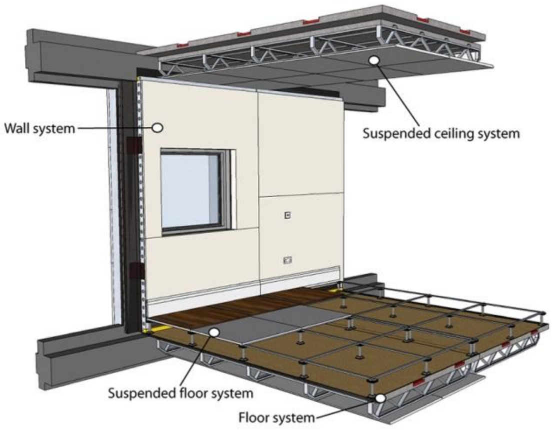

Fig.3. UCS wall, floor components design

A building envelope is a finished structure that includes structure frame, wall, floor, façade, entrance, staircase, elevators and main service supplies such as electricity, communications, water, gas and drainage. At this stage, UCS provides a blank canvas that will allow the designer to configure the layout and fulfill the space's functions using a range of interior support systems. UCS adapted an Open Building (OB) method when designing the interior support system.[2] The interior support system consists of four parts: suspended floor, suspended ceiling, interior wall and service infill layer. Conventionally, services are embedded in the structure of the building causing difficulty to obtain access when upgrading or repairing. The suspended floor and ceiling provide a cavity between the floor panel and the service layer. The cavity is also easily accessible when installing services and during building maintenance. The interior wall system is designed in a way that services and wiring can be accommodated between the steel frame and change direction freely through the floor layout. The system includes: lightweight galvanized steel panel, top and bottom connection slots, insulation, base frame, and wall finish. The design provides a greater flexibility in maintenance and reconfiguration.

PRODUCTION SYSTEM DESIGN

Conventionally, architects and building designers are not familiar with prefabricated building manufacturing methods and technologies applied within the production phase. However, in order to design an industrialized building system, building designers must be aware of the entire construction sequence from design through production to construction and all the way to recycling. After having introduced UCS building components, an analysis of the UCS production system will be detailed reviewing the potential of using automated manufacturing methods within building prefabrication industry.

The UCS production facility starts with an analysis of how the building components are designed and produced. Then material flow and activities involved within production are analysed. Then the detailed planning process is explained and last, interfaces between the arranged equipment in each individual work station are reviewed. (Figure 4)

Initially, precast concrete panels, beams and columns were designed using modeling software based on the specifications required by the client.[5] A variety of designs can be achieved based on a standard approach. During the detailed design stage building elements such as floor panels, wall panels, beams and columns will be designed according to specifications of the design. The output from this stage is the basis for the subsequent detailed design, production, assembly and disassembly plans later on.[1] The previously generated design data will be analyzed along with the mechanical, electrical, plumbing, financial, legal and planning data through the Building Information Model (BIM) system. All this information will coordinate with the project scope to help the designers and clients visualize the actual construction process. In addition, BIM enables designers, clients, engineers and contractors to share data throughout the lifespan of the building.[6]

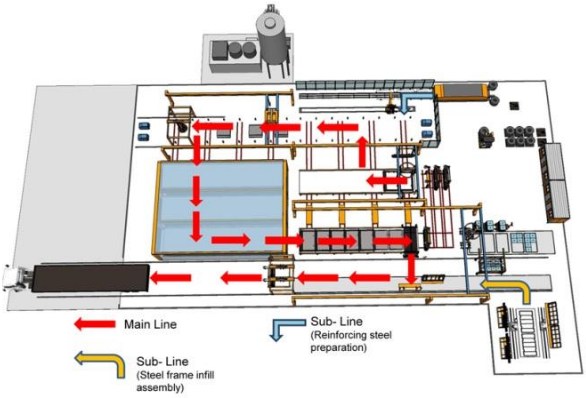

Fig.4. UCS production facility concept

There are three main features of the UCS manufacturing facility: decentralized, compacted and modular. Decentralized production enables production to follow the trend of the market. Compacted design allows the factory to utilize minimum space to achieve maximum productivity. Modularity enables the production facility to be moved from one location to another. Production activities are operated automatically and designed with a formation that goes through a production loop. Production activities include:

- Concrete mixing and transferring
- Mold preparation and plotting

- Preparation and placing of the reinforcement
- Casting and compaction
- Curing
- Demolding and lifting
- Finishing
- Storing, lifting, and transferring

ADVANCED CONSTRUCTION SYSTEM DESIGN

UCS as a prefabricated building system offers great potential to share some of the benefits of manufacturing processes. The building systems are standardized and designed with consideration of stability, reliability, serviceability, maintainability and upgradeability. In order to optimise production and on-site assembly process, the systems were designed based on the concept of Robot-Oriented Design (ROD).[7]

The UCS construction system consists of groups of single-and multi-task construction robots, and a smart crane system (SCS) who work in conjunction with each other to form a synchronized working configuration. (Figure 5) Once a project is completed, the UCS construction system can be quickly disassembled then transported to and re-assembled on a new construction site.[8]

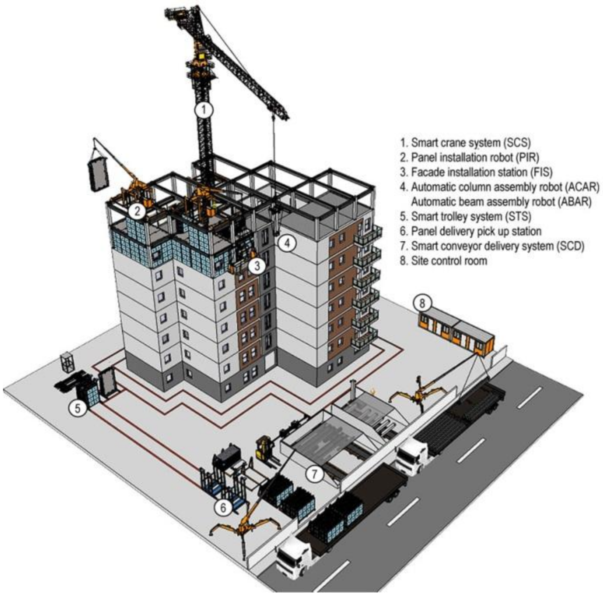

Fig.5. UCS construction system

With the help of the industrialized building design and the utilization of robotic construction technology UCS attempts to transform conventional construction sites into on-site assembly environments. There are six types of construction robots and a number of sub-construction systems that have been used in parallel for the project: Panel installation robot (PIR), the system is designed for installing and disassembling floors, walls and façade panel elements. Automatic column assembly robot (ACAR), Automatic beam assembly robot (ABAR), the robot is to pick-up, deliver, position and assemble and disassemble the UCS prefabricated column and beam components. Façade installation station (FIS), this station is suspended from the PIR's on-board crane and is slung from four suspension points. Smart conveyor delivery system (SCD), this system is designed for transferring column and beam components from the loading bay to the pick-up point automatically. Smart trolley system (STS), this system is designed to load and deliver panel components from the loading bay to a pick up station automatically guided by RFID tracks. Smart crane system (SCS), the system is designed to provide vertical transfers of construction resources, machineries and construction robots.

UCS evolution scheme

The building is divided between the left and right and construction applies a bottom-up approach, working from the ground level up. It consists of four main stages: (Figure 6)
Structural assembly – columns and beams
Wall and floor and ceiling assembly – external wall panels, floor panels and ceiling panels
Façade assembly – exterior façade
Interior fittings after building envelope is complete – interior wall, services, pipes, electric and decoration and preparation tasks such as temporary rail installation and transporting of the PIR system

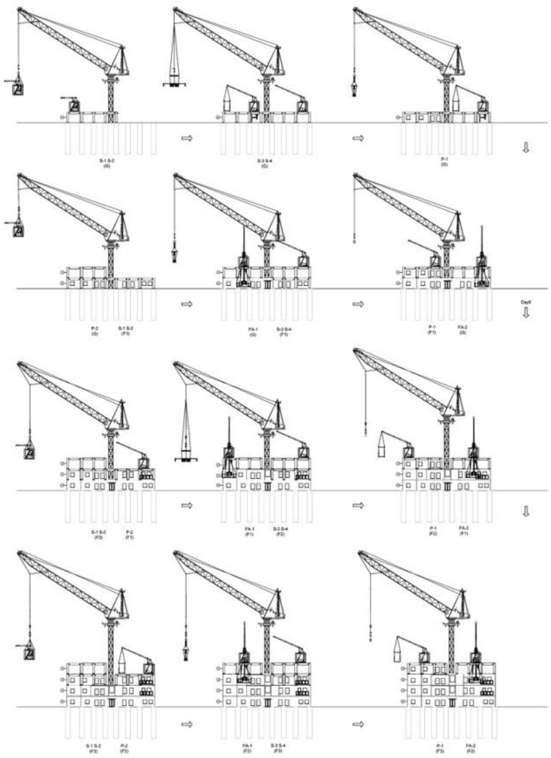

Fig.6. UCS construction evolution scheme

The construction of each floor consists of structural installation, panel installation and external façade installation and internal finishing installation. The layout of the construction site itself is similar to an assembly line. Because conventional construction sites construct everything from scratch, on-site, they are somewhat chaotic and disorganized. Setting up a construction site like an assembly line streamlines all tasks and organizes the chaos.

Deconstruction is normally considered superfluous within the construction industry. UCS, having been designed for flexibility and mobility in construction, aims to prove the importance of deconstruction within a building's lifecycle. When a building requires relocating or repurposing, the construction process, known as deconstruction, will be reversed.[9]

Using this system, the estimated overall construction time will be significantly less than conventional construction times. Building a 20-story building with this method will take approximately four months to complete. According to the sequence analysis, it would take about three days to complete each floor; multiply this by the 20 stories of the building and it would take about 60 days for construction plus about two weeks for initial set-up and final dismantlement. Using a conventional method, this same building would take approximately one year to complete.

CUSTOMIZATION BASED ON STANDARDIZATION

Conventionally, customization and standardization are viewed as two separate concepts. However, UCS defines them as two parts of one concept; they incorporate each other and exist simultaneously.
Based on the product platform concept used in the automobile industry, a large set of parts are connected as a stable component and can be used on different automobile modules. The UCS base building systems are designed to be standardized to allow huge volumes of production out-put and to form a range of product families.[10] The fit-out systems are connected to the base building system. They share a common joining method; nonetheless the design can be individualized based on customer profiles and the targeting of marketing activities.

Flexibility

There is a significant difference between constructing an automobile and a building. Automobiles are unfixed; parts can be upgraded and the auto itself can travel from one place to another. Buildings however, are stationary; renovation is often costly and the building cannot be relocated once erected. UCS has applied the concepts of Skeleton Infill (SI) and OB in order to achieve maximum flexibility and building lifespan.[11]

UCS can be divided into three building levels; each level serves a certain purpose and designed to have a different lifespan:

1. Infrastructure (Urban tissue) – this level consists of the street, public utilities, and urban structures.
2. Base building level – this level consists of the load bearing structure of the building such as beams, columns, floor panels, joining fixtures and building vertical access.
3. Fit-out (infill) level – this level consists of the external-internal wall panels, suspended ceiling-floor structures, kitchen, bathroom, household appliances, and services.

In regards to the coordination and flexibility of UCS, the building can be divided into four levels: (Figure 7)

1. Domestic level coordination – system product is a product can be adapted and altered to suit current demands such as interior walls, kitchen unit and bathroom unit.
2. Unit level coordination – section of the fit-out level of the building can be completely disassembled and assembled in another building.
3. Building level coordination – the entire building can be relocated with various configurations.
4. Urban level coordination – UCS can adapt to fast urban development and maximize building lifespan.

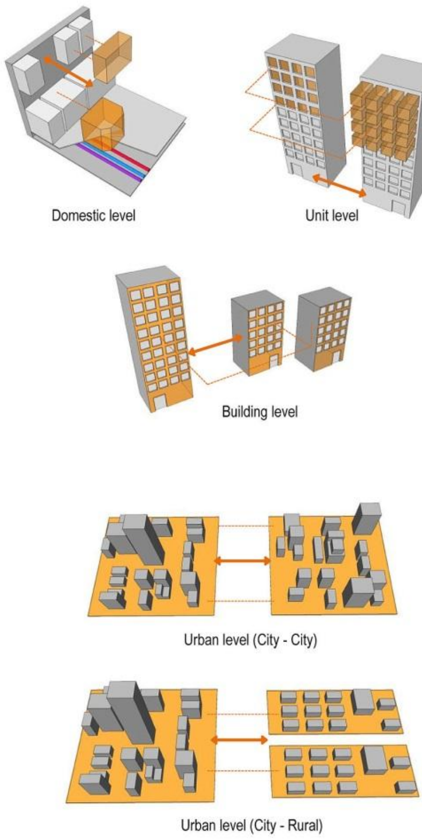

Fig.7. UCS coordination and flexibility

SUMMARY

UCS demonstrates the potential and techniques of implementing construction automation, prefabrication, and lean technology as a whole. It has the potential to solve global issues, such as overpopulation, climate change, sustainability and reducing carbon footprints. Individuals look favorably upon practicality and this system utilizes the most tangible approach available. Regrettably, at the moment the design only made it to a conceptual stage, but with sufficient research and development (R&D) input, UCS could be fully realized, proving its effectiveness in the construction industry.

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An Automated Approach for Installing Building Modules

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Modular building concepts are increasingly becoming most popular construction method due to its less time consumption and ease of construction process. While lack of skilled labor, necessity of providing homing facility for increasing population, increasing growth of commercial institutions, investor's demand for quick return of their investments and on top of all- necessity of constructing buildings in cities where surroundings are packed with busy buildings like offices, homes, supermalls etc. - this sort of building facility is one of the best possible solutions for construction professionals. Usually, building modules are fabricated in off-site factories, then transferred into site and are installed by using cranes. This current approach needs about 5-6 persons to unload the module from truck and another 5-6 persons for placing the module in desired position. The time required is also about 1-2 hours. Safety of workers is also an important factor. However this paper proposes for an automated on-site installation approach for prefabricated modules. At the beginning the objective of the paper is to study the real practices and find out the limitations in conventional modular building construction approaches. The author then focused on some several previous researches for developing the existing modular systems to implement more automation and increase efficiency. Afterwards a new proposal was presented in the form of CAD drawings which attempts to implement existing mechanical and electrical equipment, thus emphasizing not to design new devices but effectively implementing existing devices for construction works. Nevertheless the author looks for the achievable advantages of the proposed system over the conventional processes.

Keywords*: modular buildings, construction, control, crane system, automation*

INTRODUCTION

Modular building concepts are becoming more and more famous due to its less time consumption and ease of construction process. A modular building is a pre-engineered structure which is able to facilitate greater flexibility to satisfy all the requirements for a fully functional building. The obtained output is tougher than standard drywall construction, have greater expandability, relocatable and completely reusable.

Automation technologies came as a blessing to the manufacturing technologies. It provided the industries with great deal of mass productivity, mas customization facility, precision in the final output product, optimum production time etc. Car industries and other daily product manufacturing industries could become hugely benefitted by the effective utilization of automation. Implementing automation in the construction industries also increased in recent year. Yet the development achieved is very limited. This paper envisions for an automated on-site installation approach for modular construction. Instead of developing totally new devices, the proposed method attempts to slightly modify the existing devices and technologies used in different manufacturing processes and thus to enforce them for automatizing modular installation.

CONSTRUCTION: CONVENTIONAL VS. MODULAR

Conventionally the buildings are built piece by piece in the site, takes long time and large workforce, largely affected by the weather conditions etc.

Modular construction is the method of construction which increased the effectiveness and efficiency of the buildings by combining conventional techniques with modern mass production strategies. Instead of building piece by piece, major portion of the construction work is carried out within a high-tech, weather independent factory.

One of the major advantages of modular method over conventional method is- efficient management of the construction process. Since major work of the building is done within the factory assembly line, it is very effectively constructed with real time access to materials, tools and monitoring of the quality. It also enables to have very fast production process. The need for architects, engineers or professionals to be presented on site decreased largely which turns to huge financial benefits for the developers. The on-site work is carried out within a very short period of time, which ensures quick return of the investment, effective scheduling, cost saving, better waste management, better site safety etc.

MOTIVATION

After manufacturing in the factory and transferring the modules to the site are done successfully, it is the job of the site supervisors or developers to finalize the construction work by installing the modules following the design. The modules are stacked by cranes of having the capacity of 80-160 ton depending on the size of the modules and the distance to be covered for transferring the modules from truck to actual building location. The average pace of module installation is 4-6 modules per day[1].

The whole course of the module installation process can take averagely from one to two months to complete depending on the size of the project. Normally the modular construction delivers a product that is about 70-80\% completed, when the rest work is done by the on-site laborers.

The cranes are the most expensive part of the module installation process which can cost up to 2000-2500 EURO per day, not counting the police details or road closures. Therefore, the installation planning has to be done carefully so that the crane is never idle. On the other hand, the cranes are to be provided with proper positioning and operational flexibility - otherwise it might cause negative impact on the number of modules to be installed per day or also can be responsible for accidents.

The existing approaches need about 5-6 persons to unload the module from truck and another 5-6 persons for placing the module in desired position. The time required is also about 1-2 hours. Safety of workers is also an important factor.

PREVIOUS RESEARCHES

Many research projects have been carried out so far for automatizing the installation of prefabricated modules on site. Though it is not an easy task to introduce traditional automation technologies directly into the construction sector for the complexity and varieties of tasks, recently all those traditional automation technologies have been slightly developed and specialized.

Automatic Modular Assembly System

Introducing modularity into both structural components and a means of assembly solves the problem by simplifying the construction task. Based on this idea[2], Yuzuru Terada and Satoshi Murata proposed a novel concept1 of a fully auto-mated construction system called the Automatic Modular Assembly System (AMAS).

The proposed design of a structure module in AMAS has two features. First, every structure module is a regular hexahedron, used as a component of the modular structure. Second, the mechanical connector used to fix the module is implemented on each surface of the module. The connector, which is driven by an assembler robot are genderless and rotation symmetric to give it complete modularity. Built-in power transmission lines are connected automatically when the modules are assembled. Assembler robots use this power network. Structure modules have no actuators but each of them has a microprocessor and sensors for information processing.

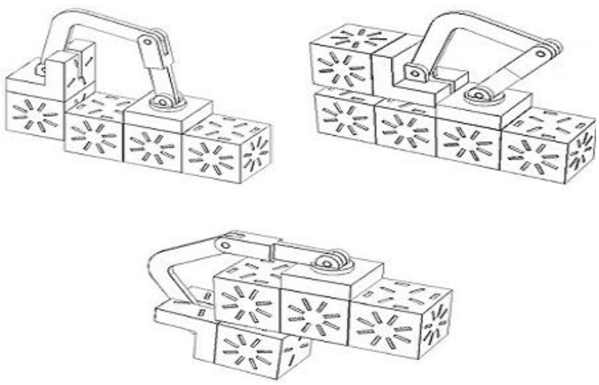

Fig.1. AMAS – structural assembling steps.

Miche: Modular Shape Formation By Self-Disassembly

A group of researchers in MIT Computer Science and Artificial Intelligence Lab proposed an approach[3] in 2008. The approach is to realize programmable matter using self-disassembly as the fundamental operation to achieve shape formation. The function of self-disassembling modular robots can be thought of as analogous to sculpting. They started with a large block made of individual modules. Each module contains the resources necessary for autonomous operation: processing capabilities, actuation mechanisms, communication interfaces and a power supply. The initial structure is transformed into the desired shape by eliminating the unnecessary modules from the structure in a controlled fashion. Much like a sculptor would remove the extra stone from a block of marble to reveal a statue; this self-disassembling system eliminates modules to form the goal structure. The key innovations of the work are:

- The concept of achieving shape formation by self - disassembly.

- The first hardware prototype capable of self-disassembly.
- A suite of provable distributed algorithms capable of planning and controlling self-disassembly in an optimal manner that minimizes information flow.

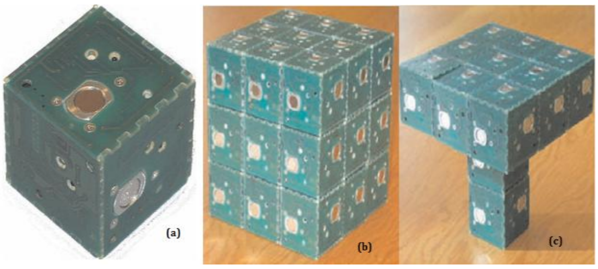

Fig.2. Miche system: (a)Single module (b)Initial uniform assembly of modules (c)Obtained desired assembly.

Conceptual Design of Automatic Footing Device for Modular Housing Construction

This idea[4] actually initiated by the housing method named one-day housing. The basic modules for the independent foundation and the wall foundation were set as shown in Figure 3(a) depicts the concept of combining the independent foundation with a footing beam. The PC independent foundation and the footing beam are combined using Unit Form. Figure 3(b) shows the concept of putting it in one piece by first disassembling the matt and wall of the foundation in order to lessen the weight of a unit, and then putting it in one piece on the site using filling material.

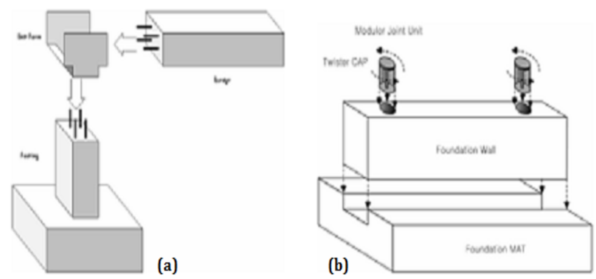

Fig.3. Foundation System - (a) Independent foundation. (b) Wall foundation.

Future Home Project

The main objective of the EU Future Home project[5] is the development of Integrated Construction Automation (ICA) concept and associated to them technologies during all the stages of the house-building construction process:

- Design the buildings in modular way taking in mind their robotic erection.
- Automatic planning and real-time re-planning of the off-site pre-fabrication, transportation and on-site assembly.
- On-site automatic and robotic transportation and assembly of the buildings' pre-fabricated parts.

Fig.4. Future Home Concept - (a)AUTOMOD3 lanner for the on-site processes. (b)Future Home robotic system.

For the On-site installation of the heavy 3D Future Home modules with small positioning tolerance the most adequate crane is the gantry one. The main idea of this project is to use a low cost commercially available gantry crane and then transforms them into robotic system by the following modifications:

- Introducing of the AC brushless servomotors in the entire axis.
- Introducing the vector control drivers for all motors.
- Introducing position sensors (resolvers).
- Introducing the PC control system based on the multi-axis control board.

PROPOSED SYSTEMS

It was the main objective of this research is to find out a time effective and cost effective solution for the modular building construction strategy. The cost and time effectiveness can be obtained by introducing Modular method is already discussed in previous chapters. Previous researches on this particular topic were also discussed. In this chapter the proposed solution and its design details upon specifications will be discussed.

Module

Modules can be designed according to the size limitations discussed in the previous sections. The size limitations can vary depending on the construction site's local authority. Since this paper only focuses on the systems for automatizing the module installation procedures, so the module parameters e.g. length, width, height etc. are kept very much basic.

The materials used in modular buildings are similar as the on-site constructed buildings. Wood-frame floors, walls and roof are the most generally used materials. Some modular homes include brick or stone exteriors, granite counters and steeply pitched roofs. All modular are designed to be set up on a perimeter foundation or basement. In many cases the steel skeleton is the main load-bearing structure and facades are installed on the skeleton in a way that they can be changed later.

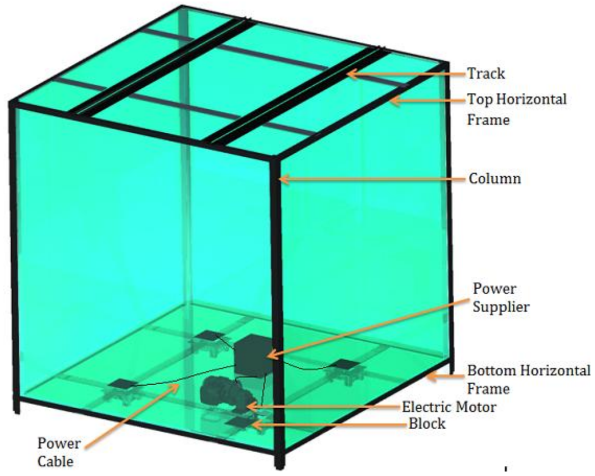

Fig.5. Module System

The module is designed in a way that walls can be built with any materials. Modules can be of any shape depending on the customers demand. For simplicity of the proposal analysis, it has been considered a cube shape. To illustrate the internal systems, Glass is chosen. The module consists of the following features -

- Dimension of the module: 3m X 3m X 3m. It can vary, only for the ease of describing the proposal in this paper- modules are kept in this dimension.
- After setup of modules, there would have a gap of 10 cm. This gap allows the installation of utility lines and pipes.
- The utility lines and pipes would be installed in factory - of course maintaining highest height of 10 cm.
- 2 Frames - 1 in the bottom and 1 in the top of the module. (Picture)
- Each frame consists of 4 Angular beams.
  - Each beam is of length 3 m.
  - Beams are welded together to provide the frame structure.
- 4 columns
  - Each column's length is 3.13 m.
  - At the bottom of each column, the 0.03m or 3 cm is extended internally, which gives the facility to fit into the top of another column. (Picture)
- Bottom of the modules consists of 4 Roller systems. These roller systems allow the modules to have mobility.

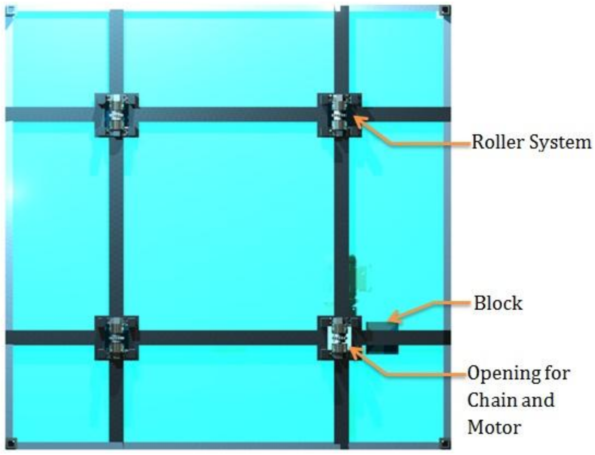

Fig.6. Module - Bottom view

- At the topside of the module - there are 2 rail-guides, supported with 2 beams perpendicularly.
- At the bottom side of the module, there are 4 beams supporters. They carry the loads within the module, e.g. furniture and people.

Roller System

The objective of including a roller system was to provide mobility to the modules. With the help of the roller system, the module to be installed can move through every step of the installation process. Of course it is not possible to implement wheels directly to the modules, because if it is done so- the building originated from many of such modules can become very unstable. That is why there should be some structural support which will not only provide housing for the wheels under the modules, but also provide rigidity to the modules after installation.

Inspired by the Scissor Jackscrew Mechanism, the roller system of the method described in this paper is provided with 2 wheels which can be extended and retracted. Such extension and retraction of the wheels can be possible because of the shaft- where the wheels are connected, and both ends of the shaft is attached with one jack screw in each side. Those jack screws can be functional by electrical power provided from outside.

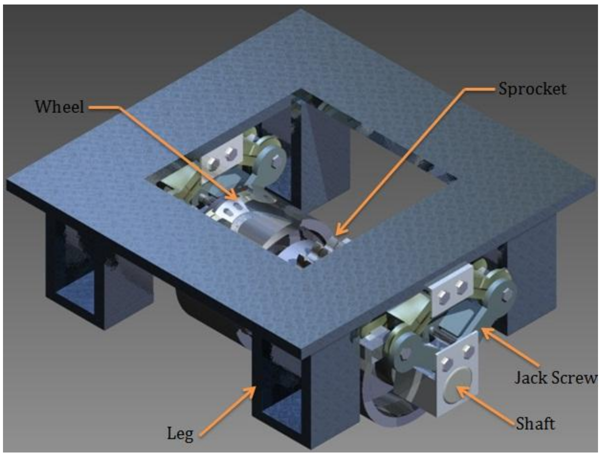

Fig.7. Roller System

Roller Systems are consisted of the following basic features-

- Each roller system consists of 2 wheels.
- 2 Wheels are attached by a shaft.
- In the middle of the shaft, there are 2 sprockets.
- Sprockets can be attached with chains, another side of the chain can be attached with 2 more sprockets which are attached with the shaft provided by the Electric motor.
- Motion of the Electric motor can be controlled by the Arduino microcontroller. After installation of the module in desired place is finished, the motor is supposed to be removed manually. The opening should be closed by the plate, which is made of same material as the building wall material.
- The wheels can be extended and retracted by 2 Jack Screws- both acting together. When the Module needs to run on the wheel, wheels are extended and when the Module needs to be installed on the desired position, wheels can be retracted, thus allowing the Module to be rested on the columns and legs of Roller system.

Crane System

The crane- depending on the openness of transport facility can be fabricated off-site fully or partially and then brought to the site.
This crane consists of the following features-

- To make the crane available for moving, it comes with wheels. Those wheels run by motors which can be controlled automatically. The wheels like in the conventional Gantry cranes, placed on rail guides. So they carry the whole crane through one line, both direction.
- Base for carrying the whole crane facility.
- Vertical columns- all the vertical columns have a specific shape. the uniqueness of the shape allows the column to be used in also the multiple type of cranes.
- A counter-weight to balance and reduce the motor effort to lift the module.
- At top of the crane, the pulley support beams and frames facilitates the motor and pulley housing.

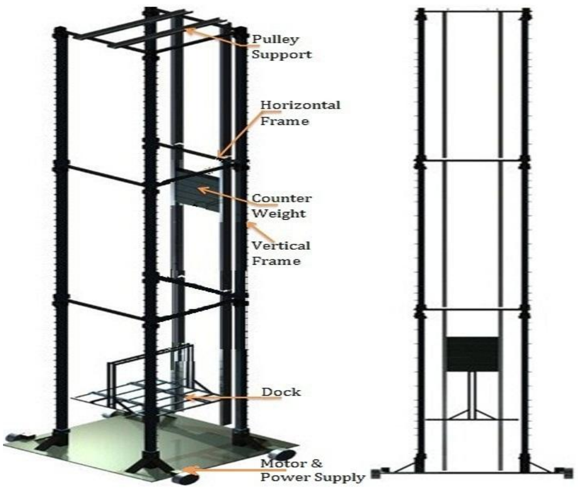

Fig.8. Crane system

- Between two adjacent columns there is one Horizontal frame. These frames actually formulate the shape of the crane.
- The Dock is used to carry the module. It has 2 tracks - which has the same dimension as the tracks on the module.

Process

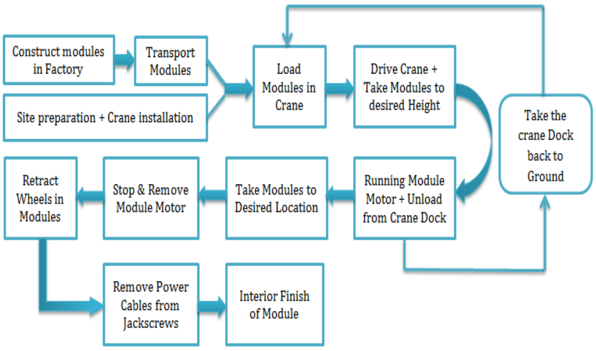

Fig.9.Construction Process

Automation

The system is envisioned to introduce automatic installation of the modules. To make that possible, motors have to be controlled by implementing automation platform like Arduino. These motors can be controlled by potentiometer or sensor.

The concept was - the crane motor will first run by switching on the motor in the crane. As during its travel until reaching desired height, the dock will always face some obstacles which are actually the modules already installed. Then this dock will stop when it detects no obstacle. Instantly the motor in the module will run and will travel until the sensors fitted below it detect specific brightness of light or specific color information sent from the lower module.

The motors and sensors included are -

- Crane running motor
- Crane stopping sensor
- Dock lifting motor
- Dock stopping sensor
- One motor per individual Module.

To control the motors wirelessly, Wi-Fi shield like Xbee shield can deal a great purpose. These Wi-Fi shields can work up to 300m and are less than 1Kg in weight. So these can be easily fitted in the system's electronic parts and serve with high efficiency.

Conclusion

Though the modular construction technology is becoming a more prominent replacement over the conventional method - the lack of trained professionals made this a minutely practiced method. While inclusion of automation and robotics in other manufacturing systems e.g. cars, electronics - are very advanced, but in construction industries the development has gradual scope to be developed.

The automated installation approach proposed in this paper envisioned to subsidize the workforce required by the inclusion of automated system like Arduino platform. The mechanical system presented here also suggests to utilize the existing technologies like Gantry Crane, machine-room-less elevator, Scissor Jack screws to make the whole system more affordable using the state-of-the-art technology.

Since each modules come with some extra sensors and electronic devices, obviously the money to be spent in the building is much higher than the conventional systems. So end users may have to pay slightly more money than conventional products. But author thinks that the budget can be remained same if it is considered that it takes less time, fewer workforces, and no overtime - so money is saved in other way around.

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A Conceptual Framework of Prefabricated Building Construction Management System using Reverse Engineering, BIM, and WSN

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This paper proposes a conceptual framework of prefabricated building construction management system. Latest IT such as BIM is rapidly spreading to architecture, civil engineering, engineering and maintenance with the aim of simplifying complex system in buildings and facilities, minimizing operation cost, providing high value services and advancing facility management. Therefore, the key for the success of AEC/FM is sustainable and innovative design and development using ITC. In this environment, stakeholders are a kind of critical path, which needs a holistic approach. Opportunities for improving efficiency and performance of IT-based building construction through merging both centralization and decentralization of resources such as BIM and computing have increased in the last few decades with maturation of technologies such as BIM, BIM server, 3D Laser scanning, Web of Things, and/or cloud computing recently. The main focus of this paper is the concept of ongoing research in providing the process integration service for holistic construction management which covers whole life cycle using ICT infrastructure. Potentials to support the integration functionalities as a Service by providing functionalities in prefabricated building construction processes are described. The proposed prefabrication building information management system supports stakeholders by giving real-time access to knowledge resources. The proposed conceptual framework has the advantage of availability, efficiency, cost reduction, less time to result, and scalability.

Keywords: *BIM, Cloud Point, WSN, Prefabricated Building, Construction Management, Holistic Approach*

INTRODUCTION

Reverse Engineering using 3D Point Cloud Data

As advanced ICT that have been developed in other areas are seamlessly introduced and adapted into AEC/FM, there are significant challenges in how building are constructed, what kind of methods are used and how stakeholders think, name a few. Of the state of the art technologies, reverse engineering using point cloud that is acquired from 3D Laser scanners is getting popular in construction and its application on AEC domains is widen. Not only for geometric data gathering from building heritage, but for construction, facility management, 3D Laser scanning technology will be common tool in construction domain. In short, 3D Laser Scanners are measuring equipment to measure several thousand points to million points per second by detecting light reflected from targets using laser. Until recently, the technology is utilized to embody and measure city structures, natural scenes, building exterior, and other diverse products. Subjects that are measured through 3D Laser scanners are converted to 3D shape information and the 3D shape information is actively utilized in diverse information-based service. In the construction industry, the development of 3D laser scanner leads to the development of in-situ as-built modeling.

In-situ as-built modeling refers to high degree program acts to reversely analyze and design existing programs to extract ideas and knowhow in order to pursue technical improvement and additional creation. This in-situ as-built modeling aims at inferring the process of design decisions using final products.

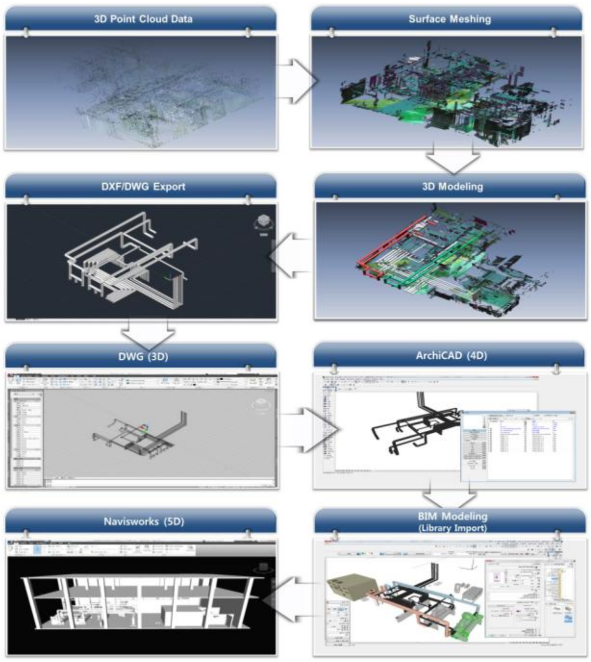

Fig.1. In-situ as-building model acquisition process

In other words, In-situ as-built modeling in the construction industry enables obtaining drawings when there is no drawing of buildings by measuring the buildings through 3D Laser scanners and inferring 3D CAD models through the 3D shape information obtained through the measurement (Bosché, 2010).
Figure 1 shows how 3D building information is acquired from in-situ as-building using point cloud data and BIM authoring tools (Lee el al., 2013). For practical reason, this approach can invigorate IPD method. IPD (Integrated Project Delivery) means the ordering method in which participants in projects such as owner, constructor, designer, and CM (Construction Manager) organize an integrated team at the early stage of projects and implement the projects in order to save resources and costs and improve productivity and responsibility and outcomes are shared among all participants. Currently, the cases of application of IPD are in an increasing trend centering on projects implemented in the sector of public construction (Song, 2011).
The raw data that is acquired from a 3D laser scanner only represents the partial 3D shape information, therefore additional processes are necessary to extract useful information. Several object sensing methods using 3D point cloud data are studied accordingly (e.g. Kim, 2006). Reverse engineering and restoration based on these technologies become active in AEC/FM domains.
3D laser scanning technology leads to the development of reverse engineering in construction engineering industry in parallel (Lee and Park, 2003). Reverse engineering means a process of discovering the technical principal of devices and systems as opposition to the concept of engineering.
Originally used for the analysis of military hardware and commercial hardware, reverse engineering aims at reasoning design determination process without prior knowledge of the production process of original product (Lee and Yun, 2007; Lee and Lee, 2010). While designing of target objects precedes the production of the objects in general engineering, reverse engineering extracts drawing information from existing objects. In particular, reverse engineering in construction industry means the process of extracting CAD drawing data from finished building objects and using it later for design changes and production-related activities, etc. (Han and Kim, 2005; Park and Cho, 2006).
There is a tendency to gather information of pre-constructed buildings, bridges, and tunnels for various purposes during life cycle. Here, point-cloud data from 3D laser scanner is converted to various CAD models such as B-rep, Constructive Solid Geometry (CSG), tessellated surface model, and so on, and the models are utilized for various engineering tasks such as benchmarking, quality control, drawing information management (Lee and Park, 2003). But the reverse engineering is in its infant stage in construction industry and is mainly restricted to the acquisition of drawings of building structures without drawing information and to safety and maintenance management. In these applications of reverse engineering, it is important to enhance the level of precision of the obtained 3D shape information

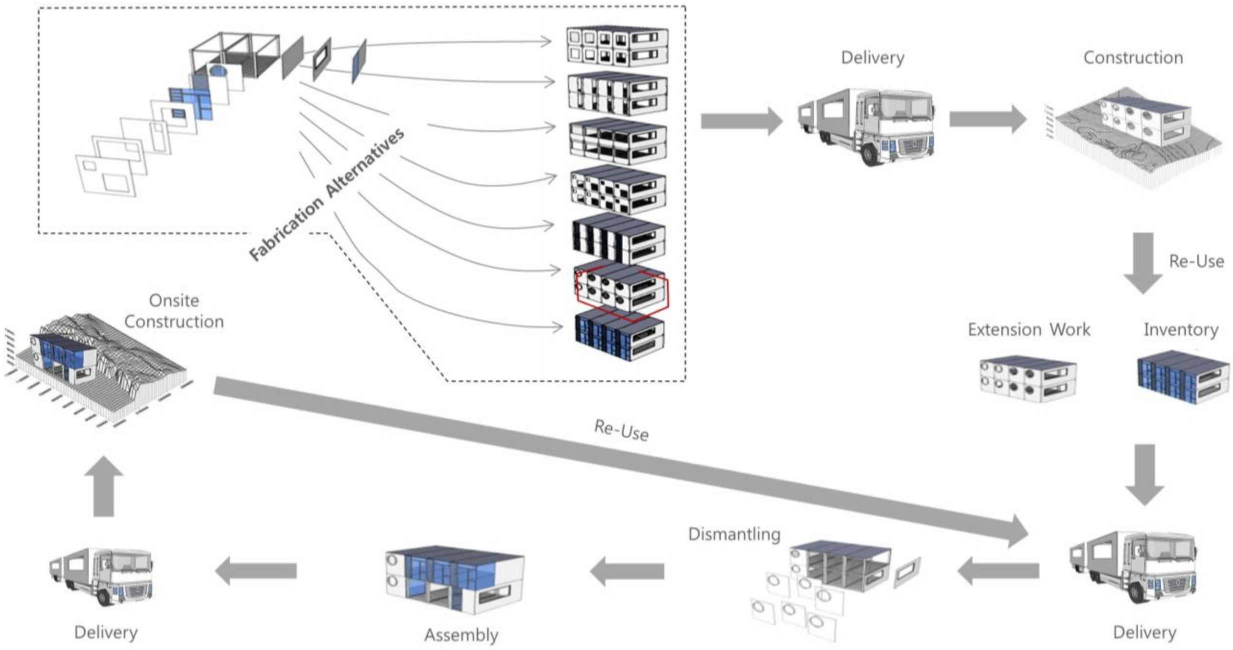

Fig.2. Logistics Flow of Prefabricated Building Component (Image Source: Prof. Kim, S.-A. DMTL SKKU)

Building Information Modeling (BIM)

Once it is believed that processing a bunch of point cloud data is time-consuming and needs overwhelming manual work to use it, as hardware performance outreach and new intelligent approaches are developed, its usage will be near our reach. BIM is defined as modeling technology and a set of processes that enables virtual modeling of facilities in multidimensional virtual spaces for not only planning, design, engineering (structure, equipment, and electricity, etc.) but also maintenance, conveying related information, and analyzing the information (Eastman et al, 2011). Modern design practices use BIM from the beginning of conceptual design because their model

Figure 3 represent prefabricated building life cycle management system. BIM Server and PMIS (Project Management Information System) are linked by the Web Service using cloud computing and most stakeholders can manage and control the whole processes depending on their roles and accessibility to the system. Figure 4 show the functions and subservices that the integrated system defines.

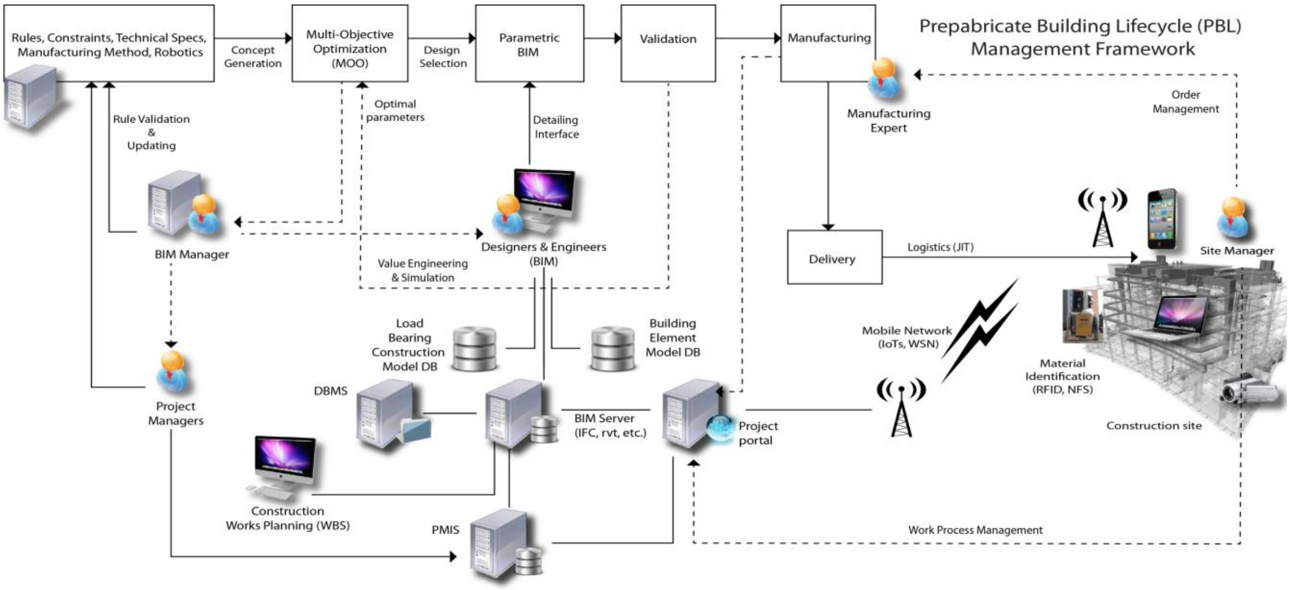

Fig.3. Diagram Model for the Integrated Prefabricated Building Life Cycle Management System

can be easily upgraded to detailing and converted to another format for other engineering services without loss of information. But, its wide usage is in its inchoate stage, which means almost all buildings and facilities are not based on modern BIM model. This is problematic in that BIM is a basic foundation for other new services, which means that buildings designed and built without using 2D drawing and even with 2D drawing cannot use other advanced information process services without BIM.

BIM is a starting point for many of services that it is indispensible to generate BIM file from the scratch. In this aspect, it is necessary to use cloud points from 3D Laser scanner in order to as-built building geometric information onsite. Conventionally designed and built buildings/facilities can be transferred to modern building information modeling system. Target buildings of 3D Laser scanning are not only heritage buildings that is so invaluable that they must be preserved for next generations, but also other shabby building such as apartments, offices, etc. that need rehabilitation in order to cope with diverse functions that dwellers need. Standard BIM such as IFC matures that major construction companies already adapt it to achieve higher productivity. Figure 2 proposed a logistics flow of prefabricated building component for multi-phased reuses. In this process model, component design module is linked to parametric building component design tool. So heterogonous building types and styles can be more adaptive in order to satisfy diverse requirements and needs.

Smart Buildings

Smart buildings accompany a series of technologies that monitor buildings, and improve not only safety but also energy efficiency and user convenience. These technologies range from new materials with higher efficiency and Information Communication Technologies (ICTs). ICTs are used in the system to control heating, lighting and ventilation in smart buildings. It also provides the foundation for automatic package and crime prevention control system that automatically turns off PCs, monitors and other devices as suggested at SMART 2020. Latest study on third-generation smart building system has come as far as learning the building itself through self-learning and optimizing monitoring as well as crime prevention control function (Sharple et al., 1999).

Sensor and sensor network technologies are widely used in smart building applications like HVAC, lights, shading, air conditioning, window/door control, switch, measuring instrument, standard appliances, crime prevention and safety. All contribute to a dramatic energy savings (Czubak and Wojtanowski, 2009). Building management systems in the past mostly relied on wired network, which were costly and suffered from inflexible design. Wireless sensor and actuator network, on the other hand, has many advantages compared to the wired solution (Czubak and Wojtanowski, 2009). It is much easier to install wireless sensor-actuator network since it does not require wired network, therefore it can independently generate energy and can be operated on a segregated module. Wireless solutions like Zigbee, Bluetooth, IEEE 802.15.4 and 6LoWPAN (IPv6 over Low power Wireless Personal Area Networks) are gaining great attention for building automation system (Shelby and Bormann, 2009).

oped. Consequently, replacement of communications and service protocol previously defined by each application domain into WoTs (Web of Things) paradigm boosts interoperability and accessibility. Also time as well as cost put into application service development can be significantly reduced.
Works to standardize WoTs and M2M (Machine to Machine) are active at the moment and CoAP (Constrained Application Protocol) standardization, which

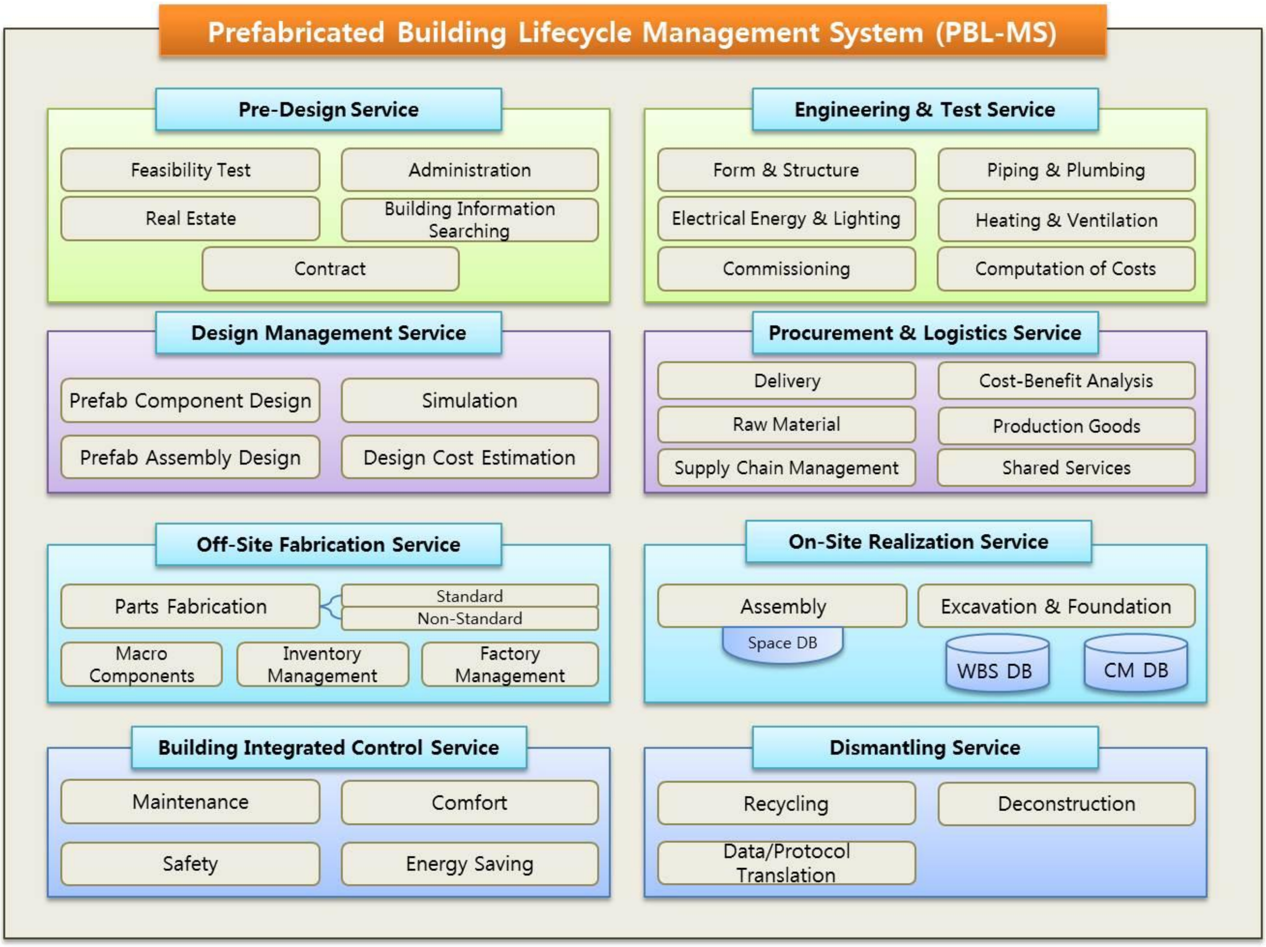

Fig.4. Functions and sub-services of Prefabricate Building Lifecycle Management System

Building management system based on integrated management framework can save the heavy management cost and bring us simplified overall work processes. Lately, a new technology which enables building in or installing lightweight embedded web server into equipment in buildings and integrating with network via IP-based wireless communications to monitor information on equipment through web is under limelight. Development of software tools and system capable of controlling equipment in order to offer the most optimal service to users by converging information measured by each of equipment is also active (Lee et al., 2013).
Information flow in the network model can be put under control by managing scattered data. Web's biggest strength comes from its ability to communicate and link between heterogeneous devices and make service searching and providing easier. Furthermore, application service can be easily devel-

began standardization activity since 2010 as 6LoWPAN's upper application layer protocol, is underway by CoRE working group in IETF (Internet Engineering Task Force) (Shelby and Bormann, 2009). Also, study on RESTful interface and CoAP, which are two key technologies of WoTs, has become highly robust and this is urgently raising the need to secure related technologies since it is expected to expand markets for homes, buildings, cars, grids, RFID and Ubiquitous Sensor Network (USN). Buildings have a lot of different equipment for cooling, heating, ventilation, lighting, disaster prevention and security. And since they all have different communications interface and protocol, a physical interface and protocol converter to ensure a single uniform access to different interfaces is necessary for macroscopic integrated control. This is critical for buildings that have a wide range of equipment for cooling, heating, ventilation, lighting, disaster prevention and security but each equipment group is manually controlled by operator and protocol and communications mode is different by equipment manufacturer.
The lack of interoperability as a result is challenging

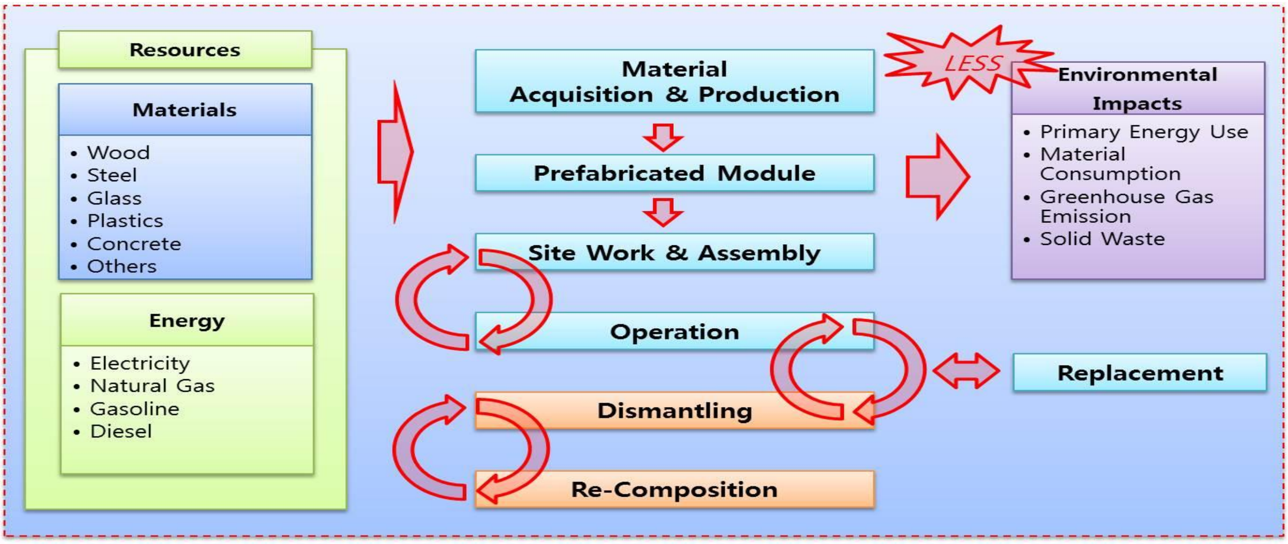

Fig.5. Sustainability by Multi-Phased Reuse Approach of Prefabricate Building Lifecycle Management System

automatic control that is optimized and integrated. Hence, development of an embedded web server/client supporting integrated management of building equipment based on standardized wireless communications and TCP/IP applicable to building equipment and facilities is underway (Shelby and Bormann, 2009). Wireless arrangement of automatic building control system taking advantage of the embedded web server/client not only saves cost by approximately 30% compared to wired arrangement but also cuts installation time by more than 60%.

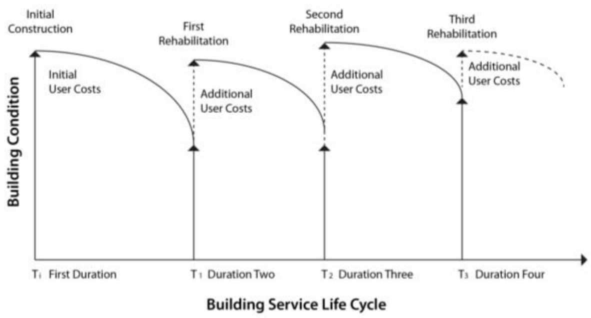

Fig.6. Expected Feasibility Model of Prefabricated Building Construction Management

OUTLOOK

In this article, several technologies which will be incorporated to the prefabricated building construction management system are discussed. 3D Laser scanning technology can be actively used for building data acquisition. Most EU countries and other developed nations that have lots of building refurbishment projects will adapt BIM and the 3D Laser scanning technology, not only for new building construction projects Diverse BIM based services that are developed from the third party vendors will be incorporated to centralized and decentralized management system using state-of-the-art information communication technology. This can suggest feasible construction solutions that are in a sustainable way. As shown in Figure 5, by increasing the rate of reuse, so called, multi-phased reused approach, the system can achieve more economic model as proposed in Figure 6. As all processes are interlinked and mostly the feasibility of construction project is dependent on the poorest performance of a problematic process, holistic approach will be necessitated.

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Ambient robotics for meaningful life of the elderly

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It is innovative if people can be free from aged body and continue their career with assistance of robotics. It is supposed to see the change soon, as smartphone changed life style. This research aims to figure out the direction of this change, development in technique for elders. It also studies various theories to justify various methods for ambient assistance robotic design for elders. In the long life expectancy world, this design will enhance the life quality of elders and encourage young people get pride in their own job, because their career will continue and it deserves to invest their all energy and sincerity in a specific area. As ambient robotics is a design for elders' adjacent assistive design and part of everyday, it is related with quality of life elders. Some theories are cited for the importance of meaningful life. Meaningfulness is regarded as the fundamental goal of design purpose, because meaning stands upon the concept of human being and its consciousness activity, phenomenological background of this research is introduced. It can be suggested in field observation to get real stories containing meanings and essence of life of elders. In conclusion, this study is a beginning of long process to prepare aging society with technique as well as perspective to see elders as valuable work force.

***Keywords**: Aging society, Meaningful life, Phenomenology, Ambient robotics*

INTRODUCTION

Background and purpose of study

There is a case about a retiree: a school principal retired 3 years ago and stays in work without production. His major was for 38 years to teach handicapped students like low intelligence and autism. He can live more 30 years. However there is no way to continue his career. Many great scholars or professors are same cases. It is so undesirable that someday they will be resigned and their career will be stopped. It can be applied to various careers, too. We work for 30 or 40 years and remain as a retiree for almost same years. This work regards the elderly not just beings to care for but ones to live meaningfully and continue their career. It is the matter of self-realization and to keep human dignity, not to exclude important human resources from society.

In other aspect, elders' accumulated experience and wisdom should be used in society. It is regretful to hoard uselessly the talent both for individual and for society.

A controversy about employment competition with the younger generation can be happened. It is another challenge if the elderly still demonstrate their capability in the practical field, therefore, it should be investigated in another paper. In this research, mainly the stance of elderly will get attention.

This study is to investigate the direction of the innovative development ambient robotic design process for the elderly upon phenomenological perspective. Ambient robotics is definitely one of cud-edged technique, which is not only passive reaction to assist the weak physical condition of the elderly, but also to figure out how the technique can contribute to human dignity. With the development of techniques like gene engineering, medical techniques and cut-edged telecommunication like smartphone and internet, life cycle became longer. In addition, ambient robotics for aged people is one of the rising issues for increasing the elderly. It would be hopefully to keep good condition with proper treatment like food and exercise, and health investigation, but it would be so desirable also to get artificial assistance.

Technique should not be developed alone, but it should be a part of whole lifeworld changing. Lifeworld is a concept from phenomenology. Transcendental subjectivity of phenomenology is the base of the concept of meaning as the subject of owner of meaning. Some researches show the importance of meaning in life, not only psychologically but also socially and physically. Therefore, this paper supposes meaningful life as an impetus for technical development. In other words, it is said that life cycle is getting longer and we don't want just longer life, but also valuable one. We need quantitative methods as well as qualitative ones to reach to the balanced methodology of development.

AGING SOCIETY AND RELATED RESEARCHES

For this research, references for aging society, academic journal, statistical analysis report and mass media were reviewed; mass media shows changed attitude of elders who want to realize

themselves, but it is not easy to find academic researches about elders' self-realization and career continuity. Healing environment for the elderly is the main issue for the old. Pathological and sensual research is also one part of assistive space design for the elderly, some cases are introduced here. They insist on preparing for aging-society and study about gerontology or elders' welfare. In short, to the most of experts, elders are weak beings to get care.
To study about healing environment for elders is very important for human right, but it is necessary to go further than suggestions for passive green space, wandering areas for those with dementia and enough residence and community for lonely elders. Ambient robotics for elders is a case of good research to actualize meaningful life. Bock T. et al. have researched and designed robots hidden in the familiar furniture. There are hidden sensors and telecommunication system directed to medical facility.[1]

Fig.1. Evaluation of the robotic furniture system by an age simulation suite [2]

Fig.1 shows the way to design ambient robotics. Because it is hidden in furniture or combined to wall or door, there is no hindrance for everyday but it assists weak physical function of elders. Yellow uniform has sensors in the red line and send behavioral or physical change data to computer.

Fig.2. Functional Transfer Assistant [3]

Fig.2 shows am example of innovative ambient robotics design; without mechanic and artificial occupation in room, elders can get help to move.
Fig.1 and Fig.2 are one of ambient assistance design results. Another ambient assistance research is done or still on progress by various categories like architectural elements, elders' behavior patterns and special instrument development.

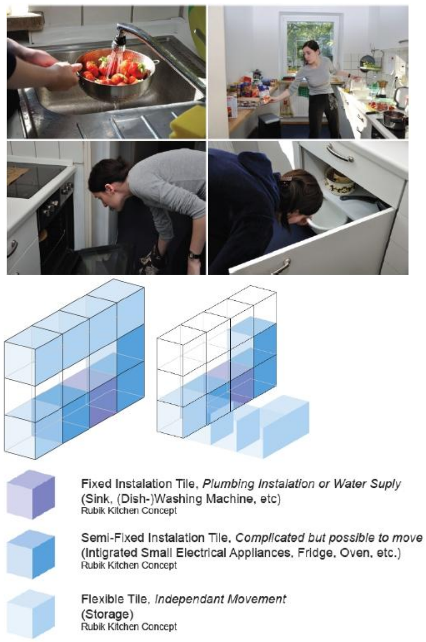

Fig.3 Cooking Process Experiment and Modular Arrangement according to the process[18]

Fig.3 is a kitchen modular design by cooking process. Modular design is flexible and productive. Not only general adaptation with modular, but also special instrument can assist elders' inconvenient actions.

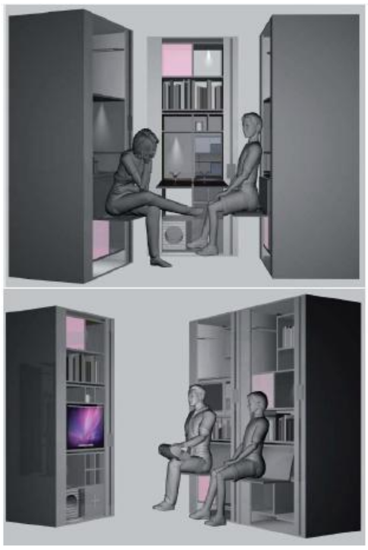

Fig.4. Proposed concept configurations[1]

Fig.4 is another case of modular but different concept from Fig.3. All required functions such as beds, sofas, tables, and chair can be integrated into integrated system, so the old can do various activities easily at one place. Sensors of Fig.1 are also applied in the integrated furniture of Fig.4.

Fig.5. Bathing Assistive Solution[19]

Fig.5 is an image of special bathtub for elders. Even young people can feel dizzy during hot water shower. If a man is slipped on the wet floor, it is so dangerous. This facility has no case of falling down and the old can lean on the bathtub when it is not easy to stand for a while.

Ambient robotics should not be understood as a medium. It should be regarded as not perceptible part of everyday life. We can't perceive the being of the air, but we can't live without it. Ambient robotics also should not get our attention in the lifeworld like air. Because people have spiritual aspect as well as physical, for the real healing environment for the seniors, the balance between function and meaning should be kept and architectural field should be developed based on the growth in technique and humanities. It is necessary not only to think about how develop techniques but also to reflect upon the reason why do we need Ambient robotics and what means to our lives. Reflection before big change by technique will guarantee us to save time and cost.

Healing of elderly housing has objectives like the physical stability and psychological stability. Moon talks that human dignity is the most important healing environment factors in health and welfare facilities. Privacy can be the psychological factor to keep dignity. Environmental and social aspects require intimacy and familiarity. In terms of environmental and hygienic environment, good scenery, including the introduction of audio-visual art is required. After all, these factors are associated with stress.[4]

Recently neurologists also insist that elderly healthcare facility should have healing environment for immunology (psychoneuroimmunology).[5] According to the study, the emotional stress will have an effect on the immune function of patients. Germany's interior architect Antje Monz argued that the positive emotions can lead to improve the health of patients.

A disorder of the elderly individual buildings to complement the building's words to heal the disease state, the ideal design concept can be seen in order to achieve this, Steven Judd (S.Judd) environment of a small, friendly environment for the elderly, the elderly easy to understand the environment, an environment in which employees can easily help you, old man's ego and personality respecting the environment, the staff can easily help the environment, a safe environment, family visits a welcoming environment, stimulation can be adjusted environment and planning needed for nursing homes are described as key concepts.

To design stress-free facility is absolutely important, but it might be possible to go further from passive reaction to active attempt, from not stressful space to self-realizing environment.

The elders are usually long-trained so it would be wasteful to bury their experience. There should be proper research methodology to use latent and skilled professionals. They don't need care facilities, but they need where their activity can gain recognition. This perspective is another perspective to bring elders healthier and dynamic life. It is not only for elders but also for next generation.

People usually measure their working period and regard retirement of their profession, and high earning efficiency is the best condition of a job. Pension is final hope to life peacefully in their old time. However, if their work in young age affects to old age, the career continues and leave records, work efficiency of young people will also rise. Therefore, research to assist for elders' vocational ability should be done.

Another issue about the aged labor force is employment ratio.

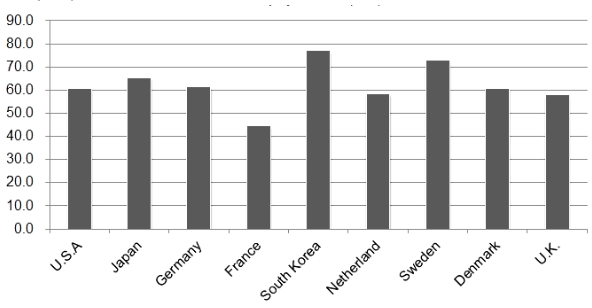

Fig.6.Employment ratio (%) of age between 55-64 [6]

Fig.6 shows that most of seniors between 55-64 are not employed: South Korea and Denmark have over 70% ratio, but other countries except two has 60% or 50% radio of employment. Almost half of them are retired. They do not get income and there is no progress of profession.

THEORETICAL BACKGROUND FOR METHODOLOGY

Lifeworld

We need to know the holistic meaning of a given surrounding. The perspective of aged individuals is essential in what finding out what he holistic meaning of their surrounding is. The goal is to be able to observe a situation without prejudice and develop the most appropriate method for analyzing these types of situations. Individual perspectives could be observed and interviewed.

Quantitative methods are effective in some cases, because individual affairs can be approached closer through qualitative and even non-linguistic observation according to cases. Each person has different ways of remembering and formulating their points of view. By using Husserl's phenomenological epoche and suspending our tendency to form judgments, research can be established more clearly. He or she will compare previous analysis methods and develop various methods for organizing data. Having a flexible procedure based on sound experiential principles is an essential phenomenological idea. Specialists in the humanities as well as medical technicians and nurses will participate in seminar discussions and otherwise provide insightful feedback for the research.

To receive the correct knowledge, a variety of means of communication is desirable. At the research scene, researchers need to be flexible in attitudes. They might be objective researchers as well as they should be daughter or friend of the elderly. This flexible attitude gives us more clear essence. Phenomenological reduction is achieved by stopping the judgment. This is general formulation of the natural attitude to stop the judge. In day-to-day life, we take the natural attitude. Although each individual experience the world to be illusion or hallucination, even if that number is revealed that even while maintaining the unity we believe to exist. The scope of the navigation is reduced through the reduction and exclusion. It does not preclude that determine what the problem is.

In the radical developments of technique, we are in the abundant data. Now, it is time to know the meaning of the change. Theoretical background provides to researchers about the perspective and methodology about how to approach to the problem. This research stands on the theoretical background of phenomenology. In phenomenology, transcendental subjectivity constitutes meaning in the lifeworld. The constitution is not happening of moment, but it has procedure and story. The story is made not only by causal relationship but also by non-casual intentionality.[7] According to Husserl, meaning is noema and intending meaning is noesis. This noesis can be meaningless but intuition adequate the noema. On the epistemological level, lived experience (Erlebnis) is, in phenomenology, the primary source of knowledge, but non-intuitional (e.g., scientific) perspectives as a part of the lifeworld are also taken into account. [8]

Lifeworld is a concept from phenomenology. Technique should not be developed alone, but it should be a part of whole lifeworld changing. Then what can be the driving force for aging society? This paper supposes meaningful life as an impetus for technical development. In other words, it is said that life cycle is getting longer and we don't want just longer life, but also valuable one. It is upon phenomenology and its methodology: qualitative methods like narrative, interview, observation or non-verbal methods like sketches.

The lifeworld is understood by interview and observation. Methodologically, phenomenologist focuses either on a description of human experience as lived or on the interpretation of its meanings.[9] term, lifeworld comes from Husserl.[8] This study begins with researching of current situation, in other word, the state of affairs. Therefore, it is supposed to observe and analyze situation and get knowledge from the state of affairs. It means that it is to observe the process of meaning constitution about ambient robotics for elders, specially retired but still able men.

On the ontological level, phenomenology acknowledges the foundational character of the lifeworld. The concept of lifeworld implies an epistemology in which the question of meaning is most important; the lifeworld is the ultimate horizon for all cognitive activities. As Husserl puts it, "The concrete life-world is the grounding soil of the 'scientifically true' world and at the same time encompasses its own universal concreteness."[8]

Martin Heidegger is a philosopher who tried to understand and explain human being. He analyses the meaning of dwelling in relation to ontology. According to him, to be a human being means to be on the earth; in other words, they dwell in the world.[10]

According to Sirowy, "phenomenology approaches philosophical inquiry from a different perspective, addressing the phenomenon of the world in terms of its being the determinate for the ontological meaning of all the entities within it, and not just something which is determined by them. As Heidegger emphasizes, we always refer to things as being "within-the-world," and this indicates that we have an intuitive understanding of the world, as coming before the notion of the things which are present within it. We understand ourselves and things in terms of the world. The world, however, is not the ultimate frame within which everything is conceived; the world also needs a human existence to perceive it. Phenomenology thus concedes that the "world" is, in fact, also a part of Dasein, human existence. The human world is always a lived-world, a lifeworld. Ontology and epistemology are closely interconnected in the phenomenological framework. As Heidegger maintains, "Ontology and epistemology are not two different disciplines which among others belong to philosophy. Both of them characterize philosophy itself, its object and procedure. [9]

Sirowy cites what Gadamer said:
A building has to emerge from the lifeworld of its users. 'Serve a particular way of life' and at the same time relate meaningfully to the physical surroundings and 'adapt itself to particular architectural circumstances' It should preserve the lifeworld from which it emerges, but also add something important; for instance, it could bring new meanings that would enrich the original context. The creative, innovative aspect of design is here essential. If a building succeeds in unifying those dimensions, it may be called as a work of art.

An essential aspect of the lifeworld is being-with-Others, and an important assumption of phenomenological inquiry is that "the perspective of others is meaningful, knowable, and able to be made explicit."

McAdams found that people tended to construct stories as a way to understand life events. A life story is a way to impose meaning on life thus connecting individuals to the event.[11]

According to Lee, the key to the solution of the problem of truth is not the evidential experience, but the communicative action. It is not the evidential experience, but communicative rationality as the formal pragmatic property of discourse that makes the true claim of a statement acceptable. In addition, Lee also maintains that; since the constitution of a fact by an evidential experience is open to intersubjective investigate the intersubjective dimension of constitution to clarify the condition of the possibility of that constitution. [7]

Transcendental subjectivity [12]

Lifeworld subjectivity can have various attitudes of religious, ethical, linguistic, social, economic, politic and anthropological. Lifeworld subjectivity experiences everyday as well as something various. The experiences include emotional aspects like love, hate, conflicts or cooperate with others. Lifeworld subjectivity takes the general thesis of the natural attitude (Generalthesis der natürlichen Einstellung). This attitude regards the world as the totality of what exists, and therefore there is nothing beyond the limits of the world.

However, there is something beyond lifeworld like atmosphere. Different atmosphere makes person experience something different: if we are depressed, we feel bored everything, or if we are active, we feel excited at everything. It means that the experience is not fixed, but made for special meaning for subjectivity. In other words, world as a meaning is constituted by subjectivity, the transcendental subjectivity.

Lifeworld subjectivity is to be experienced as a part of world, but transcendental subjectivity experience the world as a part of it. Transcendental subjectivity is creative and world as meaning flows endlessly. The experience in youth is different from it when we are grown up, because the meaning of each moment is different.

This transcendental subjectivity is open to future and thrown away to next time. This subjectivity is called as existence in existential philosophy. Existo, the Latin origin of existence is combination of Ex and Sisto: Ex is forward and Sisto is to stand, therefore Existo is to stand forward.

In summary, human being can be exposed as the entire structure of their overall appearance, while at the same time experienced as the lifeworld subjectivity as well as transcendental subjectivity.

Meaningful life

There is no doubt that humans are valuable. Even though they become old, they deserve worthy life. Worthy and meaningful life is one of civil rights. Meaningfulness is different from happiness as Baumeister et al. told in their paper.[13] Happiness is fulfilled when needs are satisfied, but meaningfulness can be made when personal identity and self-expression is possible. According to Husserl, meaning is constituted in the lifeworld by transcendental subject. Meaning can be defined as the connection linking two presumably independent entities together. With the stated goal of positive psychology to foster thriving in individuals and render a more fulfilling life, the interest of positive psychology is not to treat patients but to make a normal person's life more fulfilling and for the non-disordered individual to flourish.[14]

Currently, the meaningfulness theory supposes that meaningfulness is a subjective evaluation. Furthermore, meaningfulness is made through positive action, satisfaction with life, the enjoyment of work, happiness, positive affect and hope.

There are research results that show the importance of meaningfulness in life. Baumeister et al. maintain that meaningfulness is fulfilled through seeking four needs for meaning: sense of purpose, efficacy, value and a sense of positive self-worth.[14]

Meaningful life affects to even sickness. A study done by Stillman et al. (2009) found that social exclusion results in a perceived loss of meaningfulness in life. When a man thinks himself to be socially excluded, one's sense of purpose, efficacy, value, and self-worth are decreased. Bower, Kemeny, Taylor and Fahey found an association between the discovery of meaning and a lower rate of AIDS-related mortality.[16]

A study looked into HIV-seropositive men who had recently witnessed the death of a close friend from AIDS-related death. When confronted with the stress of such a death those men, who were able to find meaning in the loss, were subject to less rapid declines in CD4 T cell levels. Then, the subjects who experienced cognitive processing in response to the bereavement were more likely to find meaning in the death of the close friend. Thus in experiencing a stressful life event if one is able to engage successfully in finding meaning there is a potential link to positive immunological benefits and health outcomes.

As there are benefits to making meaning out of life, there is still not one definitive way in which one can establish such a meaning. Those who were successful in creating a meaningful life enjoyed benefits such as higher levels of positive affect, life satisfaction, etc.[17] When faced with a stressful life situation, finding meaning is shown to help adjustment.[18] Meaningfulness in life is intrinsically related to positive psychology's goal to expand the good life for the normal non-disordered person. It is with a meaningful life that one is able to find connections to people, places, and things.

CONCLUSION

This study is to put up one more perspective on various ones of aging society research. Elders have relatively weak physical condition, need social welfare system and they should not be excluded from social relations. In addition, they are also unchangeable human being they want to realize themselves. The concept of lifeworld and transcendental subjectivity are from phenomenology and become ideal foundation for a perspective. It is to reflect on background of human being. This study understands the self-realization with the theories of meaningfulness. It also introduces technical researches about ambient robotics which are related with ideal value of meaningfulness. Ambient assistance makes everyday activities and even professional works easier and self-esteem higher. Because human beings are understood with quantitative and qualitative methods, it is expected to do more various researches and get balanced analysis.

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Control of Substance Concentrations in Natural and Artificial Aquatic Ecosystems in Problems of Management of Biosphere Compatible Technical Systems

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Purpose Motivated by applications in ecological tasks, this research considers the mathematical problem of the control of the Reaction-Convection-Diffusion Equation System. Such a mathematical problem appears in many engineering applications where as there is a need to describe and control dynamics of the reactants. In this study, two important implementations have been investigated: 1) the control problem of biogen dynamics in a bio-aeration tank and 2) the optimization of pollutant discharge into reservoirs that can be used in the water utilization systems management meeting the requirements of the biosphere-compatibility. **Method** The distinguishing features of our mathematical problem are as follows: the first is non-linearity of direct initial boundary problem for parabolic equations, which makes it difficult to use for operational environmental management; the second is that a control problem includes constraints on the state variables. The numerical solution of such problems is usually difficult and the questions of algorithms for such tasks are still unsolved. To solve problems mentioned above two techniques are suggested. To reduce the task, linearization of an aquatic ecosystem model is used, namely, the substitution of a direct problem by a problem in variations. Further, to escape constraints on the state variables, the method of G. Marchuk[1] based on the adjoint approach is used. **Results & Discussion** Tasks control of substance concentrations in natural and artificial aquatic ecosystems, namely, in a bio-aeration tank Reservoir, are formulated as mathematical models. This paper shows an algorithm to solve control problems of the tasks by reducing those to a linear optimization problem. As a consequence, this study presents the results of computational experiments and shows the efficiency of the algorithm for large-scale problems.

Keywords: *environmental management, optimal control, adjoint equations, reaction-convection-diffusion equations.*

INTRODUCTION

We present an algorithm that might be used as the basis for designing an automated control system of processes governing by the initial boundary value problem for nonlinear Reaction-Convection-Diffusion Equation System:

$$\frac{\partial c_m}{\partial t} + div(\bar{v}c_m) - div(k\ grad(c_m)) + $$
$$+Y_m(c_1,..,c_m) - q_{\Omega\, m} = \sum_{i=1}^{M_{1m}} P_{m_i}\bar{f}_{m_i}, \qquad (1)$$
$$x \in \Omega, \quad t \in (0,T];$$

$$c_m = c_{\Sigma_m}, \quad x \in \Sigma_m, \quad t \in (0,T]\,; \qquad (2)$$

$$-k\frac{\partial c_m}{\partial n} + v_n c_m - q_{\partial\Omega_m} = \sum_{i=M_{1m}+1}^{M_m} P_{m_i}\bar{f}_{m_i}, \quad x \in \Gamma_m, \ t \in (0,T]\,; \qquad (3)$$

$$c_m(x,0) = \Phi_m(x), \quad x \in \Omega\,; \qquad (4)$$

where c_m , $m = 1,...,m'$ are substance concentrations; m' is the number of substances, x is the set of space coordinates containing 1, 2, or 3 coordinates according to the problem type; Ω is the computational domain; t is time; T is the final time; f_{m_i} are powers or power densities of controlled sources; P_{m_i} are functions equal to one in sources areas, and zero – otherwise; q_Ω , $q_{\partial\Omega}$ are terms describing non-controlled sources of substances; $\bar{v}$ is the flow velocity; k is the diffusion coefficient, Y_m are rates of chemical reactions; $\Phi_m(x)$ are initial conditions.

Control problems of such kind of equations have diverse applications in biology, chemistry, and engineering. We apply the method to operative control problems of dynamics of natural and artificial biogen systems.

Mathematical statement of the control problem

The control problem has the following structure:

• Control objective:

$$J=\sum_{m=1}^{m'}\left(\sum_{j=1}^{M_m}\left(J_{1_{mj}}+J_{2_{mj}}\right)+\sum_{j=1}^{K}J_{3_{mj}}\right)\to \min\,; \qquad (5)$$

where $J_{1_{mj}}$ are total expenditures for technology change that are a functional of both function groups: of initial f_{m_i} and optimal $\bar{f}_{m_j}$ source powers; $J_{2_{mj}}$ are costs of ensuring the operation of the substance sources ; K is the number of significant areas where it is necessary to control the amount of a substance; $J_{3_{mj}}$ are functions describing the growth of profit or loss (depending on the technology) on the concentration.

• State Equations:

The state c_m , $m=1,...,m'$ satisfies

◦ the Reaction-Convection-Diffusion Equations (1),

◦ the initial-boundary conditions (2) - (4).

• Linear control bounds:

$$G_m\bar{f}_m\le b_m\,; \qquad (6)$$

where $\bar{f}_m=(\bar{f}_{m_1},...,\bar{f}_{m_{M_m}})$, G_m and b_m are the matrices and the right-hand sides of the inequality systems due to technological limitations.

• State variable constraints:

$$\left\langle p_{m_j},c_m\right\rangle\le\Theta_{m_j}\,,\ j=1,2,...,K\,; \qquad (7)$$

where p_{m_j} are functions equal to one in m_j th significant area, and zero – otherwise; $\langle\ ,\ \rangle$ is the scalar product of a selected function space; Θ_{m_j} are given values.

Reduction to the Linear Programming Problem

Superposition of Solutions of Elementary Problems

We assume that $\bar{f}_{m_j}$ are constants for a period of time $(0,T]$, the functional (5) is linear, and the value of the solution is changed slightly. Consider m^{th} equation of system (1) and calculate the Gâteaux differential[2]. Then the term $Y_m(c_1,..,c_m)$ will be converted to this form $\sigma(c_1^0,c_2^0,...,c_{m'}^0)c$, where c_m^0 is some average value of c_m (e.g., background concentration at zero controlled sources) and $c=\delta c_m$ is the variation of c_m. Further, we use this notation for the sake of brevity, i.e., if there is no need, then we will omit the index m and symbol δ.

Then:

$$c=\sum_{i=1}^{M}\bar{f}_i c_i+c_0\,, \qquad (8)$$

where c_i , $i=1,2,...,M_1$ are solutions of following problems:

$$\frac{\partial c_i}{\partial t}+div(\bar{v}c_i)-div(k\ grad(c_i))+\sigma c_i=P_i,\quad x\in\Omega,\quad t\in(0,T]; \qquad (9)$$

$$c_i=0,\ x\in\Sigma,\ t\in[0,T]; \qquad (10)$$

$$-k\frac{\partial c_i}{\partial n}+v_n c_i=0,\ x\in\Gamma,\ t\in[0,T]; \qquad (11)$$

$$c_i(x,0)=0\,,\ x\in\Omega\,; \qquad (12)$$

and c_i , $i=M_1+1,M_1+2,...,M$ are solutions of problems:

$$\frac{\partial c_i}{\partial t}+div(\bar{v}c_i)-div(k\ grad(c_i))+\sigma c_i=0,\quad x\in\Omega,\quad t\in[0,T]; \qquad (13)$$

$$c_i=0,\ x\in\Sigma,\ t\in[0,T]\,; \qquad (14)$$

$$-k\frac{\partial c_i}{\partial n}+v_n c_i=P_i,\ x\in\Gamma,\ t\in[0,T]; \qquad (15)$$

$$c_i(x,0)=0\,,\ x\in\Omega\,; \qquad (16)$$

where c_0 is a solution of initial boundary value problems only with non-controlled source terms.

Adjoint operator A^* and adjoint equations

Let the linearized problem is written as an operator equation $Ac=F$. We associate each constraint from (7) with adjoint equation

$$A^*c_j^*=p_j\,,\ j=1,2,...K\,. \qquad (17)$$

where A^* is adjoint operator determined with the Lagrange identity $\langle Ah,g\rangle=\langle h,A^*g\rangle$ in order to provide $\left\langle P_i,c_j^*\right\rangle=\left\langle p_j,c_i\right\rangle$.

Namely,

$$\left\langle Ac_i,c_j^*\right\rangle=\left\langle c_i,A^*c_j^*\right\rangle=\left\langle P_i,c_j^*\right\rangle$$

and

$$\left\langle A^*c_j^*,c_i\right\rangle=\left\langle c_j^*,Ac_i\right\rangle=\left\langle p_j,c_i\right\rangle,$$

$$\left\langle P_i,c_j^*\right\rangle=\left\langle p_j,c_i\right\rangle,\ i=1,2,...M\,,\ j=1,2,...K\,.$$

Therefore, the constraint (7) arrive in this form

$$\left\langle p_j, \sum_{i=1}^{M} \bar{f}_i c_i + c_0 \right\rangle \le \Theta_j \ ,$$

$$\sum_{i=1}^{M} \left(a_{ij}^* \bar{f}_i + \left\langle p_j, c_0 \right\rangle \right) \le \Theta_j \ , \ j = 1, 2, ..., K \ , \qquad (18)$$

where $a_{ij}^* = \left\langle P_i, c_j^* \right\rangle$, $i = 1, 2, ...M$, $j = 1, 2, ...K$.

If the objective functional is linear function of $\bar{f}_m$ then the method described above allows us to avoid solving the nonlinear optimization problem (5) - (7) that has constraints in the form of partial differential equations (1) - (4), by replacing with a linear programming problem with constraints (6), (18).

Problem of Determining of Temporary Approved Discharges as Linear Programming Problem

Water pollution control gained a firm legal footing in the USA in 1972, with the passage of the Clean Water Act, which established the requirement that no discharges of pollutants were legal without a permit. A similar evolution began in Europe in 1976[3]. However setting standards discharge is still an acute problem. There are many discussions about reliability of methods that underlie the calculation of maximum permissible discharge [3-5]. Especially debatable question might be setting of temporary approved discharges in case of environmental emergencies, such as a reduction in the level of water or a sudden deterioration of the local ecosystem, etc [6].

One of the main difficulties in determining standards of pollutant discharges is a deficit of forecast information. Formulation of the problem as the control problem of initial boundary problem (1) - (4) solves that question. Using the accurate mathematical model that describes the law of mass conservation as a base for the control of water utilization systems allows making decisions, meeting the requirements of the “biosphere-compatibility”. The term "biosphere compatible economic activity" or “biosphere-compatibility” means an activity that uses technology based on the principles and laws of the functioning of biological systems, and principles of self-ecological communities, and closed circuit units of matter and energy.

Below we give an example where the objective function is selected to compromise economic interests of water consumers who compete for water resource. Also as the competing elements, the aquatic ecosystem stability and enterprises using the water can be chosen.

Statement of the Problem

We consider the reservoir Ω with M objects being of pollutant discharges (agricultural land, industry, etc.). These discharges may be pointwise, or line, or area sources. K objects, which intake the water, are located on the area (for irrigation, as drinking water, fish-farming, etc.). We denote the boundary of the reservoir as $\partial\Omega$, Σ is the connecting line of the reservoir with the other water body, Γ is boundary area containing a source of pollution. The structure of the area is shown in Figure 1.

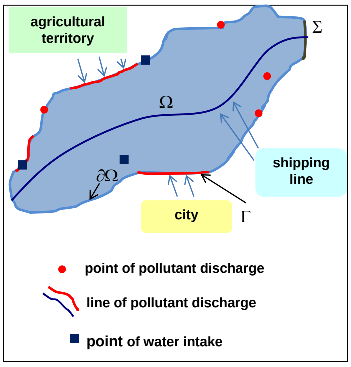

Fig.1. The structure of the computational domain

The task of determining the amount of discharges of substance into a reservoir has the form:

$$\sum_{i=1}^{M} \xi_i (f_i - \bar{f}_i) + K_z \sum_{i=1}^{M} H(\bar{f}_i) \to \min \ ; \qquad (19)$$

$$\sum_{i=1}^{M} \varphi_j \left\langle p_j, c - c_{PDK} \right\rangle \le \Upsilon_j \ , \ j = \overline{1, K_1} \ ; \qquad (20)$$

$$\sum_{i=1}^{M} \eta_j \left\langle p_j, c - c_{PDK}^1 \right\rangle \le \Xi_j \ , \ j = \overline{K_1 + 1, K_2} \ ; \qquad (21)$$

$$\sum_{i=1}^{M} \mu_j \left\langle p_j, c - c_{PDK}^2 \right\rangle \le \Lambda_j \ , \ j = \overline{K_2 + 1, K} \ ; \qquad (22)$$

$$\xi_i (f_i - \bar{f}_i) \le \Psi_i \ , \ i = \overline{1, M} \ ; \qquad (23)$$

$$\alpha f_i \le \bar{f}_i \le f_i \ , \ i = \overline{1, M} \ ; \qquad (24)$$

$$\sum_{i=1}^{M} \bar{f}_i \le \vartheta \ , \ i = \overline{1, M} \ ; \qquad (25)$$

$$\bar{f}_i \ge 0 \ , \ i = \overline{1, M} \ , \qquad (26)$$

where functions $c = \delta c_m$ satisfy the linearized to initial boundary value problem (1) - (4); $\bar{f}_i = f_i - \Delta f_i$ and f_i , $i = \overline{1, M}$ are the future and current discharges; Δf_i , $i = \overline{1, M}$ are decreases of power discharges; K_z is the factor of ecological importance of the water body; ξ_i , $i = \overline{1, M}$ are costs (per unit of discharge power) of improving the technology of each company; $H(\bar{f}_i)$, $i = \overline{1, M}$ are functions of standard fees for the discharge of polluting substance; φ_j , $j = \overline{1, K_1}$ are coefficients of damage costs for agricultural crops from concentration above c_{PDK} ; Υ_j , $j=\overline{1,K_1}$ are the maximum possible costs of damage; η_j , $j=\overline{K_1+1,K_2}$ are cost coefficients of purification of drinking water when the concentration is above the some predetermined value c^1_{PDK} ; Ξ_j, $j=\overline{K_1+1,K_2}$ are maximum possible costs of purification; μ_j , Λ_j , $j=\overline{K_2+1,K}$ are coefficients and the maximum possible costs of damage fisheries from exceeding the concentration of pollutants is above then predetermined value c^2_{PDK} ; Ψ_i , $i=\overline{1,M}$ are investments to improve purification technologies; α is the coefficient whose value corresponds to the existing treatment technologies; ϑ is the limit value of the sum of pollutant discharges into the water body.

After applying techniques described above we obtain the following mathematical problem:

$$\min \quad J=\sum_{i=1}^{M}\xi_i(f_i-\bar{f}_i)+K_z\sum_{i=1}^{M}H(\bar{f}_i)\,; \qquad (27)$$

$$\sum_{i=1}^{M}\varphi_j\left(a^*_{ij}\bar{f}_i+\left\langle p_j, c_0-c_{PDK\ j}\right\rangle\right)\le\Theta_j\ ,\ \ j=1,2,\ldots,K\,; \qquad (28)$$

$$\xi_i(f_i-\bar{f}_i)\le\Psi_i\ ,\quad i=1,2,\ldots M\,; \qquad (29)$$

$$\alpha f_i\le\bar{f}_i\le f_i\ ,\quad i=1,2,\ldots M\,; \qquad (30)$$

$$\sum_{i=1}^{M}\bar{f}_i\le\vartheta\,; \qquad (31)$$

where

$$a^*_{ij}=\left\langle P_i,c^*_j\right\rangle\ ,\ \ i=1,2,\ldots M\ ,\ \ j=1,2,\ldots K\,; \qquad (32)$$

where c^*_j is the solution of the adjoint problem:

$$\begin{aligned}&-\frac{\partial c^*_j}{\partial t}-\frac{\partial(uc^*_j)}{\partial x}-\frac{\partial(vc^*_j)}{\partial y}-div(k\ grad(c^*_j))+\\&+\sigma c^*_j=\begin{cases}p_j, & j=1,2,\ldots,K_1\\ 0, & j=K_1+1,\ldots,K\end{cases},\ \ (\mathrm{x},t)\in\Omega_T,\ t\in(0,T];\end{aligned} \qquad (33)$$

$$\begin{aligned}&k\frac{\partial c^*_j}{\partial n}+\bar{v}_n c^*_j=\\&=\begin{cases}0, & j=1,2,\ldots,K_1\\ p_j, & j=K_1+1,\ldots,K;\end{cases}\qquad \mathrm{x}\in\Gamma,\ \ t\in(0,T]\,;\end{aligned} \qquad (34)$$

$$c^*_j=0\ ,\ \ j=1,2,\ldots,K\ ,\quad \mathrm{x}\in\Sigma,\quad t\in(0,T]\,; \qquad (35)$$

$$c^*_j(\mathrm{x},T)=0\ ,\ \ j=1,2,\ldots,K\ ,\ \ \mathrm{x}\in\Omega\,. \qquad (36)$$

Computational Experiments for Water User Companies of Tsimlyansk Reservoir

Tsimlyansk Reservoir is one of the largest reservoirs in the South of Russia. One of the problems of its exploitation is the presence on its territory of a large number of pollution sources, such as industrial plants, livestock farms, fish factories, water transportation routes, parking small fleet, etc. Figures 2 and 3 show a reservoir satellite image and the computational domain (Rostov part of the reservoir).

We consider a hypothetical situation when due to the prolonged drought, the water level and flow velocity in the reservoir dropped to a critical level. Then, with existing discharges, there is a situation where the limitations on the water quality may not be met in many water intakes.

Fig.2. Tsimlyansk Reservoir

Fig.3. The computational domain (Rostov part of Tsimlyansk Reservoir)

The calculations are performed for phosphates and nitrates on the time interval of 1 month (hypothetical August). The hydrological regime computation is made by the method of equating to zero of the divergence[7]. To describe the ecosystem we use the Astrakhantsev-Rukhovets-Menshutkin-like model[8,9] in form of the problem (1) - (4).

The number of facilities being sources of phosphates and nitrates is $M = 6$ (including shipping line). The number of enterprises intaking water (significant areas) is K = 11.

Information base of the research is resources that are publicly available on the Internet[10 - 15]. Figure 4 shows a graph of the solution of the direct problem.

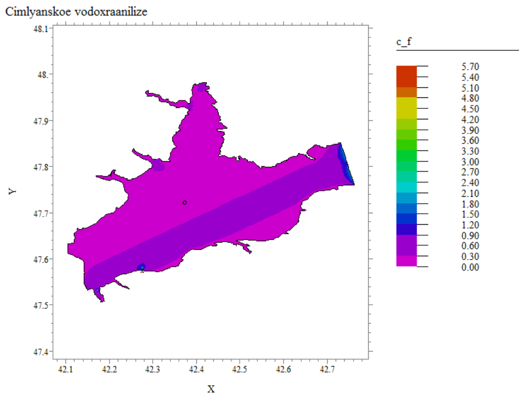

Fig.4. Concentration of phosphate in Rostov part of Tsimlyansk Reservoir

Calculations of the direct problem (1) - (4) show that in some water intake areas the concentration of phosphates and nitrates exceeds the maximum permissible concentration.

Let us define discharge standards by solving a problem similar to (19) - (26) but with stronger constraints:

$$\min \quad J = -\sum_{i=1}^{M} \bar{f}_i \, , \tag{37}$$

$$\left\langle p_j, c - c_{PDK_j} \right\rangle \le 0 \, , \quad j = 1,2,...K \, ; \tag{38}$$

$$\alpha f_i \le \bar{f}_i \le f_i \, , \qquad i = 1,2,...M \, ; \tag{39}$$

$$\sum_{i=1}^{M} \bar{f}_i \le \vartheta \, . \tag{40}$$

where c_{PDK_j} is the maximum permissible concentration in the j^{th} intake area. Unfortunately, the optimization problem does not have a feasible solution.

The next step is to find a solution for an easing constraint (39) replacing it with $0 \le \bar{f}_i \le f_i$, $i = 1,2,...M$. The solution to this problem exists and is shown in Table 1.

Companies	$\bar{f}_i$, $i = \overline{1,6}$, *mg / (L h)*	
	Phosphates,	Nitrites
Volgodonsky branch of "Management Rostovmeliovodhoz"	0	0
MUP "WSS" Volgodonsk	0,0004	0,0016
"Water canal" Tsimlyansk	0,0011	0,0043
MAU "DS and Housing", Volgodonsk	0	0
Volgodonsk NPP	0	0
Shipping line	0,0192	0,0746

Table 1. The calculated powers of allowable discharge

As we can see, unfortunately, it is impossible to comply with the requirements for water quality without closure of enterprises. Then we solve the problem in a more easing statement (19) - (26) and obtain the values of temporary approved discharges. The solution is given in the Table 2 and the concentration distribution of phosphates – in the Figure 5.

Companies	$\bar{f}_i$, $i = \overline{1,6}$, *mg / (L h)*	
	Phosphates	Nitrites
Volgodonsky branch of "Management Rostovmeliovodhoz"	0,1157	0,0448
MUP "WSS" Volgodonsk	0,1161	0,0353
"Water canal" Tsimlyansk	0,3112	0,272
MAU "DS and Housing", Volgodonsk	0,1111	0,07
Volgodonsk NPP	0,1156	0,0288
Shipping line	0,306	0,741

Table 2. The calculated temporary approved discharges

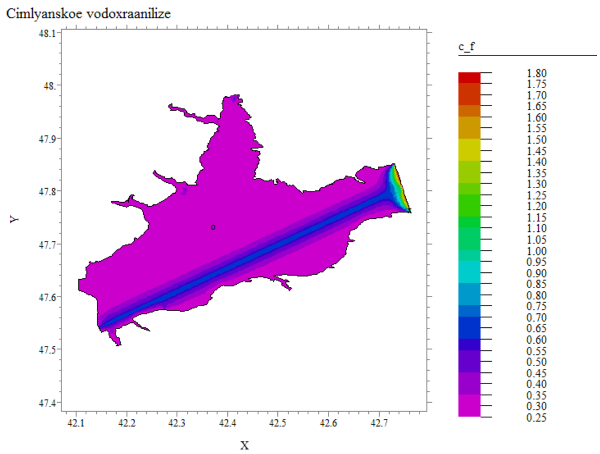

Fig.5. Concentration of phosphate in Rostov part of Tsimlyansk Reservoir (temporary approved discharges)

CONTROL OF SUBSTANCE CONCENTRATIONS INTO A CIRCULAR BIO-AERATION TANK

A bio-aeration tank, which is shown in Figures 6 and 7, is a type of biological treatment facilities where purification occurs due to vital activity of microbial communities.

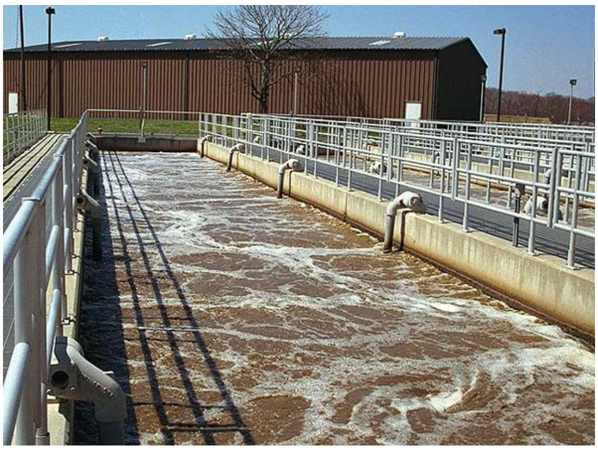

Fig.6. The bio-aeration tank[16]

The physical statement of the problem is formulated as follows: necessary to find the lowest power of an aerator subject to the concentrations of substances do not exceed predetermined values in area of a purified water outflow.

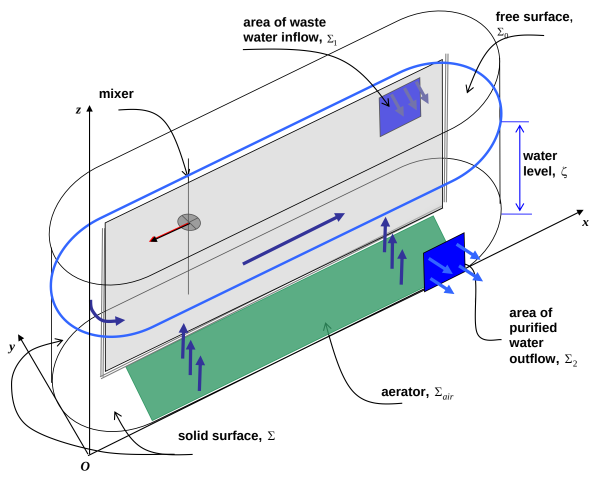

Fig.7. The scheme of circular bio-aeration tank

Dynamic processes in the biochemical reactor can be described as a boundary value problem (1) - (4) for following variables:

• Biogenic element concentrations:

c_1 - BOD, g/m3;

c_3 - ammonia, g/m3;

c_3 - nitrate nitrogen, g/m3;

c_4 - dissolved oxygen, g/m3;

• Strains of microorganism doses:

c_5 - aerobic heterotrophic microorganisms, kg/m3;

c_6 - nitrifying microorganisms, kg/m3;

c_7 - denitrifying microorganisms, kg/m3;

• The substance, source of which is the control parameter:

c_8 - concentration of undissolved air as fine bubbles.

The right-hand side of (1) are equal to zero for all $m = 1, ..., 8$ and also for $m = 1, ..., 7$ in the equation (2). For $m = 8$ the right-hand side of (2) is the unknown control parameter - the aerator power. The term $Y_m(c_1,..,c_m)$ is defined by the expression:

$$Y_i = \sum_{j=1}^{4} N_{i,j} \cdot W_j, \quad i = 1,...,4;$$

$$Y_5 = k_1 W_1, \quad Y_6 = k_2 W_2, \quad Y_7 = k_3 W_3; \quad Y_8 = 0;$$

where $N_{i,j}$, $i = 1,...,4$; $j = 1,...,4$ are stoichiometric coefficients of the *i*-th substrate in the *j*-th biochemical reaction; $W_1(c_1, ..., c_5)$ is speed heterotrophic aerobic conversion, $W_2(c_2, c_4, c_5)$ is nitrification rate, $W_3(c_1, ..., c_5)$ is rate of denitrification, $W_4(c_4, c_8)$ is dissolution rate of oxygen, which are determined in the same way as in the works of Shvetsov et al[17] and Heinz et al[18]. An example of the calculation is shown in Figure 8.

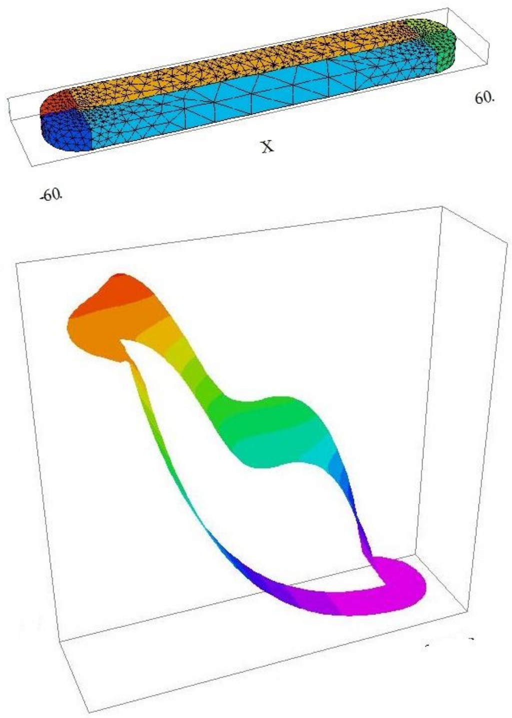

Fig.8. BOD concentration in the bio-aeration tank

The control problem has the form (37) - (40), where $M = 1$, $K = 1$. The function p_1 is not zero in the region purified water outflow. Constraints (38) are set for substances with numbers m = 1, 2, 3.

The series of numerical experiments show that there is compliance between calculations and operating experience of real objects, namely: there is the stability process during aeration nitrifying activated sludge when the system load is less than 200 mg BOD/g a day and the range of oxygen concentrations is from 2,5 to 4 g/m^3. However, by taking into account the complex processes of microorganisms we find regimes when the efficiency of a bio-aeration tank increases to 30%.

Conclusions

We implement an idea of combining a very precise mathematical model to predict substance distribution and an optimization problem of harmonization of economic indicators (such as fines for exceeding the concentration and the cost of a cleaning technology). Next, we reduce the task to linear optimization problem. Thus, we do not neglect the accuracy of the description of the physical processes underlying the life of an ecosystem and, at the same time, our control problem takes the simplest form that lets us calculate large-scale problems efficiently. For example, in computing experiments described above, the most difficult computational part - the solution of an adjoint initial boundary problem, was made only 11 times for the first problem and 1 time for the second task, since the number of such calculations is the number of significant areas.

Another advantage of the method is that if we made one costly calculations of values of the matrix (32) on a predetermined period of time and a hydrological data, then we can solve quite simple optimization problems with any combination of constraints formulated according to economic goals or any other objectives. It is also possible to formulate the original problem in the form of a multi-criteria or game optimization problem.

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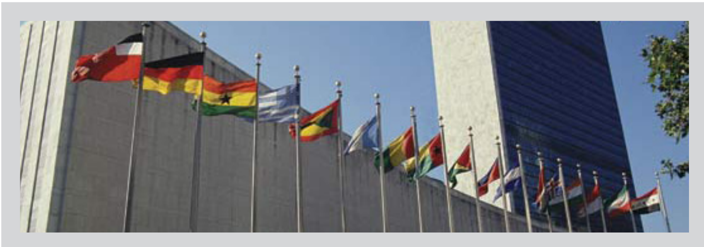

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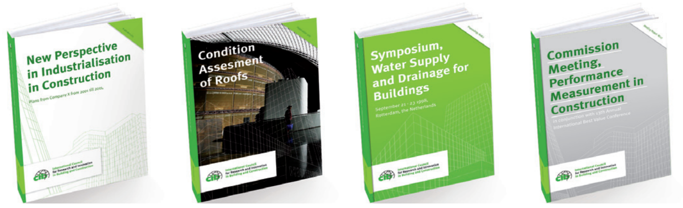

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