

Towards Green Building: Sustainability Approach in Building Industrialization

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ABSTRACT: Building construction challenge, in recent years, is the reduction of social, economical and environmental impacts along with economical nature and increasing life quality, as here sustainable construction is important. Pre-fabrication and industrialization are referred as a solution of sustainable construction due to some of its main characteristics consisting of many sustainability aspects. Due to this fact, the application of these building systems in most cases, makes achieving to sustainable building more easy. Sustainability aspects in industrialized systems are categorized in four groups of environmental, social, economical and technical issues and in each group some of general characteristics of industrialization in these methods are studied. Today, industrialized construction systems by relying on quality increase idea and blending with the environment and more flexibility, good design and planning and optimization, can fulfill the goals of sustainable construction.

Keywords: Building industrialization, Sustainability, Sustainable construction, Industrialization challenges.

INTRODUCTION

Building construction has important role in sustainable development, it is not only due to participation in national economy, but it is due to the fact that constructed environment has great influence on life quality, comfort, security, health etc. construction, maintenance and updating the constructed environment have potential influence on environment and the building consume most of unrecovered resources and create great amount of waste and the performance of buildings creates half of the total carbon dioxide pollutants (Kamar et al., 2010). Industrialized systems in building in the current era are more used with the aim of increasing quality beside economically. Of potential characteristics of industrial methods due to using high technology and planning is the possibility to fulfill sustainability goals. These methods can fulfill most of sustainability goals namely environmental sustainability.

MATERIALS AND METHODS

The current building construction challenge is creating economical buildings that increasing life quality while reducing social, economical and environmental effects (Kamar et al., 2010). Achieving sustainability in architecture and construction is the goal emphasized more these days. There are many theoretical basics but some of them are not practical. Among practical solutions to provide good housing is industrialization that is sometimes a necessity (Kamar et al., 2010; Mirsaee, 2009). Building industrialization due to some of characteristics has many sustainability aspects and due to this fact, the application of these constructional systems

most of the time facilitate achieving sustainable construction. Thus, the idea of architecture application based on industrial idea thought is as a good solution in linking theoretical basics and constructional realities of sustainable architecture namely in housing issue (Mirsaee, 2009).

Industrialization

Industrialization is social and economical change process as a society is changed from pre-industrialization condition to industrialization case (Tamjidi and Kulabadi, 2003). This fact is mostly a part of extensive process of modernization via development of new methods of production and technology and it means factory production based on concentration and regular activities and atomization of operation by emphasis on mass production (Tamjidi and Kulabadi, 2003; Abdullah et al., 2009). Industrialization based on high capacity is for reducing costs and quality improvement and accessibility to complex product for a wide range of people. But industrialization in building is not executed as a whole in building. If a car is built with the same method as a building is built, rarely people could afford to buy it (Richard, 2005).

In a complete definition, industrialization is general organizing based on quantity presenting a personalized and complete product (Richard, 2005).

In building industrialization, it is possible that the final product is not a standard building, because the demands of user and site are different in each case. Final product is preferably a constructional system. A construction system is similar set of coordinate components or some tools producing buildings with different shapes, sizes and performances. In

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each case construction method is not invented again, but there are a set of drawing activities like the traditional approach the every building is behaved differently. Also, any process should fulfill two demands of production simplicity and proposal of intelligent labor distribution between the factory and the site (Richard, 2005).

Sustainability

International Council of Building (CIB) in 1994 defined the purpose of sustainable architecture creating and innovate an artificial healthy environment based on ecologic design and resources efficiency. A sustainable building is a building with the lowest inadaptability with artificial and natural environment and it is including the building itself, surrounding environment, regional and global environment (Mofidi Shemirani et al., 2008; Soflayi, 2006). On the other hand, four principles of sustainability are defined as equity, futurity, environment, public participation (Ding, 2008) (Table 1). Also Fig. 1 presents another aspect of sustainability principles.

RESULTS AND DISCUSSION

Sustainability Aspects in Industrialization

Perception and interpretation of sustainable development in the building have been changed in recent years. At first the important point was emphasis on resources limitation namely energy and the method of its impact reduction on natural environment. In the past decade, the emphasis was on technical issues of building and construction such as materials, building parts and components, construction techniques and energy. Today, most of non-technical issues

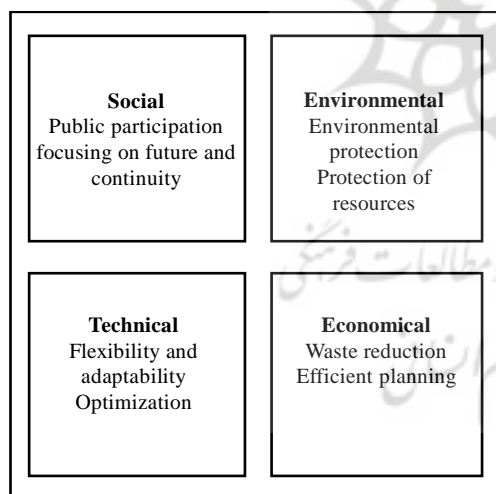


Fig. 1: The main issues in sustainability

were taken into consideration and economical issues and social development were raised as sustainable development indices. Thus, using some solutions such as selection of good construction materials and applying new building engineering methods (Industrial production and pre-construction methods) environmental goals and sustainable development in the industry of building are pursued. Optimized use of construction materials, making the consumption of raw material minimum and recovering them, building industrialized production and maintaining building with the minimum cost are the factors to achieve sustainable development in building industry (Fallah, 2002). One of the most important aspects of sustainable development goals in constructed environment is adaptability with social and economical environmental conditions and one of its important characteristics is efficient planning, consistency facilitation, and design for change, reducing costs and protection and improving natural and environmental values (Bani Masood, 2007).

In previous researches, pre-fabrication and industrialization are one of sustainable building solutions (Kamar et al., 2010; Mirsaedi, 2009; Fallah, 2002; Richard, 2006a; Olia et al., 2010; Ermolli, 2002; Kamar et al., 2009). Generally constructional industrial systems are accountable more than construction methods to sustainability principles and goals (Olia et al., 2010). The industrialized construction systems advantages from sustainability aspects are as the followings: Reducing waste, increasing building life span, increasing quality, simplicity and rapid construction and renovation process, reduction of environmental pollution, reduction of using natural materials and resources, better quality control and reduction of energy consumption (Olia et al., 2010). In another research, linkage points of industrialization and sustainability such as controlled environmental conditions in production, less waste, application of construction materials, transportation conditions and economical sustainability of industrialized systems are mentioned (Kamar et al., 2010) (Table 2).

Using systems of building industrial production due to the speed of building set up can have great influence on creating good environment for building construction and affect the environment of neighbors. These methods make the requirements to storing construction materials and parts in site to the minimum (Fallah, 2002). Among different kinds of industrial methods with sustainability characteristics some methods such as LSF are mentioned (Fallah, 2002; Golabchi and Mazaherian, 2010). In Table3 the characteristics and advantages of some of industrialized systems from the aspect of sustainability are shown.

Generally, industrialization is a force along with sustainability. The points regarding economy, factory production and consistency are as the followings: (Richard, 2006a)

Table 1: Four principles of sustainability (Source: Ding, 2008)

Sustainability principles	Explanation
Equity	Regarding Equity law in local and global aspects in productions.
Futurity	Being assured of fair among generations that keep the minimum environmental asset for future generations.
Environment	Integrity of ecosystem should be kept and its value should be recognized and be respected not only to disturb the required natural process for human being life and protecting environmental variety.
Public participation	The importance of public participation in decisions related to them and sustainable development process.

Table 2: Different Aspects of Industrialization with Sustainability Potentials (Source: Kamar et al., 2010)

Sustainability Potentials	Aspects Of Industrialization
1 Controlled environmental conditions in production	Industrial systems provide controlled production environment with availability to the corners and hard sections that are unavailable in common construction methods.
2 Waste reduction	Industrialization is considered with the minimum waste amount by material recovery capability from one module or product to another product.
3 Construction materials	The used materials have high potential in creating buildings with more saving in consuming energy.
4 Transportation	The capability of presenting big quantities and reduction of the displacements.
5 Economical sustainability	

Table 3: Environmental advantages of some of industrialized building systems (Source: Golabchi and Mazaherian, 2010)

System	Environmental characteristics
LSF system	The capability of preparation outside the construction site and preconstruction.
	Production in controlled environment from technical aspects as pre-fabricated.
	The possibility of control with specialized people in good conditions
	Clean, dry and dustless construction site.
	Requiring less time to set up construction
	Requiring less space to store materials in site.
	Waste reduction in site
	Not having adverse effect on environment due to not using harmful materials for nature.
	Less energy consumption in transportation and operation.
	Increasing recovery of the used materials.
Continuous concrete frames system	The capability of re-installation without extensive destruction operation and the capability of renovation and building development.
	Resistance against corrosion and increasing durability of the building and life service.
	Reduction of construction waste.
	Reduction of environmental pollution of this construction method.
Reinforced concrete system with durable insulated frame	Not using harmful and dangerous materials for environment (Except cement) and the lack of adverse effects of environment.
	Structural life service.
	Reduction of energy loss and good distribution of energy in the environment.
	Reduction of gas production and fuel consumption in production stage in comparison with other common systems.
Pre-fabricated concrete system	Waste reduction.
	Consistency with different climates.
	Reduction of construction waste in production stage.
3-D panels system	Not using harmful materials for environment as raw materials and during construction (Except cement).
	High structural life service.
3-D panels system	Reduction of energy loss in the environment
	Reduction waste of materials

General organizing a product with continuous production of applying similar knowledge and experience instead of new group formation for each project.

Simplicity of process and reduction of the sum of consumed energy in each project.

Working in factory avoids loss of time arising from climate condition.

Dimensional coordination, entire purchase of raw materials and complete purchase of raw materials and final factory product, reduces loss from 40% to 100% in comparison with traditional construction in site.

Factory conditions insure quality control and in this way some of unwanted deficits necessitating next repairs are avoided.

The precision used in factory production, reduces set up operation in site while the construction in the site is done as clean and without waste.

In flexible components or subsystems, dry connection methods are used making possible the non-destructive changes during renovation and changing the shape or location of the building is done without waste arising from destruction. Sustainability aspects in the building are categorized in four groups of environmental, social, economical and technical

issues. In each group some of general aspects of industrializations common in these methods are shown. The mentioned characteristics are some items consistent with sustainability principles and goals and they are effective in fulfilling these goals.

Environmental Aspects in Industrialization

One of the most important aspects in sustainable architecture is interaction between technology and ecology and as precise is technology and environment. The issue of using technology besides establishing good connection with environmental condition (with its general meaning) is raised always and this problem exists in the design based on industrial thought. Today, most of design and construction are innovated. Current industrial methods are directed despite the previous samples.

Using industrial production systems due to high speed of setting up building in site can have great influence on creating good environment to construct building and affect living environment of neighbors. These methods reduce the need to warehouse for constructional materials and parts in site (Fallah, 2002).

One of the most important environmental advantages of industrialization is reduction of waste in different stages of building construction. Usually, industrialization is recognized by capability of material recovery from one product to the other one with the minimum waste. Different aspects of design, management of material and production are ensured to achieve advantages of reducing waste by industrialization (Kamar et al., 2010; Richard, 2006a). The capability of re-assembly fulfills sustainability goals. By re-application of similar components during re-combination or displacement time, any destruction is avoided (Destruction contrary to sustainability) (Richard, 2006a).

Most of pre-fabricated systems such as structural insulated panels and combinational panels have high potential buildings with more saving in energy consumption. However, if good advantages of control and design are not applied, these potential advantages are removed in costly stages on sustainability in site (Fallah, 2002). According to the researches, the most important aspects of environmental sustainability in industrialized construction systems is reducing pollution (voice, environment) environmental impacts reduction, waste reduction of resources, recovery and re-use of materials and components, reducing destruction, saving in energy consumption and using appropriate materials.

Economical Aspects in Industrialization

Making construction and building maintenance minimum by efficient planning and designed process is occurred by constructional system in industrialized architecture. Most of industrialized architecture solutions including installations design, replacing parts etc, make building maintenance less costly. On the other hand, industrialization can have more influence on employment. For example, Malaysia government emphasizes on reducing dependency on foreign labor and industrialization as a good solution with high capability to achieve this goal is taken into consideration (Kamar et al., 2010). The other issues related to economy are reduction of waste in industrialization. Material and energy waste reduction avoid most of extra costs due to full planning. Other

economical aspects observed in most of industrial methods are reduction of maintenance and repair costs, working speed and economical saving in long-term.

Social Aspects in Industrialization

Industrialized Construction systems have high potentials in relation to social sustainability. These items are controlled condition in production, organizing labor, possibility of individualization, mass production, flexibility and public participation.

The characteristics taken into consideration in industrial advanced methods are individualization capability. One of the best characteristics of industrial product is the possibility of using better selection and choice for customer. In industrialized and pre-fabricated construction systems the customers before receiving the product, get its allowance to test it, but in traditional construction, customers based on a series of preliminary designs being understood with difficulty, get financial commitment (Richard, 2006b). Individualization is creating identity and belonging to it as the members of the family have it as a personal space compatible with their interests (Richard, 2006b). This fact that is the most important weakness in previous periods and the reason to put aside industrialized systems is modified in contemporary era. Thus, Individualization of product in industrialized systems paves the way for fulfilling the goal of mass order (Richard, 2006b). Today, in advanced methods of design and building by mechanized industrial production and based on advanced computer systems, mass production of building components are produced variously without including any extra cost (Richard, 2006b). In other words, variety is beside mass production and mass order is possible in this way. Flexibility in advanced methods of building fulfills sustainability goals are possible by creating adaptability with family members' scenario and in this way the main wastes are avoided in relation to innovation. (Kamar et al., 2010). The other dominant characteristic of industrialized systems is participation. This fact in relation to production means participation and multi-dimensional collaboration of production including designers, engineers and manufactures and also it means the involvement of customer in building production process by mass order and personalization. On the other hand, reciprocal reaction of different factors in employment process (Planners, producers, manufactures and customers) and organizing them in industrial methods required public participation in another way.

Technical and Execution Aspects in Industrialization

Adaptability and continuity, modulation and standardization, increasing product quality, simplicity of production process and optimized design are technical characteristics of industrial methods consistent with sustainability.

Industrialization is a process making production simpler, thus repetition of human being activities and required energy are not existing in its traditional man-made methods (Kamar et al., 2010; Richard, 2006b). The other points are creating high quality by industrialized methods. Industrialized systems with availability capability to the corners and hard sections provide controlled environment that is unavailable in common construction methods. By having production tools and fixed and moving tools, controlling human resources is simple in construction and ensure more reliable results in the

construction (Richard, 2006b). Also, due to controlled processes in terms of environmental and climatic conditions avoid materials waste 3 to 5 percent in comparison with common construction workshops and generally reduction of waste is occurred regarding energy and thermal loss in industrialization. (Mohamad Kamar et al., 2010, Richard, 2006b) the most important materials that are based on industrial thought in constructional methods are adaptability with conditions and requirements more emphasized in new methods. Also, continuity is of important principles. Sustainable architecture is consistent architecture with conditions, requirements and continuity. Efficient planning is including easy adaptability and change and accountability in different conditions. New-built technologies take special attention to adaptability, change and accountability in different conditions. They are including Haberaken open building theory that is inclined to create these characteristics besides using pre-fabricated structures (Mirsaeedi, 2009). Also one of the principles of industrial thought is full planning as all design and construction are defined in an efficient and planned system as optimized condition is fulfilled from every aspect (Mirsaeedi, 2009).

Modular coordination is one of the most important principles of industrial thought in architecture being done by optimization and standardization goal. Reducing the used space and optimized design are fulfilling by compatible dimensions and using modulation in industrialization idea. In sustainable architecture, design for change is recognized as one of the principles by simple and modular design (Mirsaeedi, 2009).

Sustainability in architecture is related to the image of future construction. This attention to future is consisting of some solutions fulfilling the idea of using the industrial thought of most of them. These methods due to dimensional coordination of modular structure of advanced technology etc make viable most of other characteristics of design in future.

Industrialization Challenges in Relation to Sustainability

Despite the existence of most of sustainability aspects in constructional industrial methods, some of these methods face with some problems in this regard. Long periods of recovering materials from building wastes, environment pollution in materials recovery process, high material costs, construction machineries, the effect of continuous changes (performance, technological, economical, cultural and ecological) on buildings in their life service, variant and increasing need to buildings and unsuitable extension and flexibility and few existing buildings reducing the expected life of buildings considerable and create main structural changes in short-term (Olia et al., 2010).

Construction systems by application of concrete and polymer materials due to the lack of material recovery and environment pollution are not very sustainable methods (Golabchi and Mazaherian, 2010). But in most of industrial methods, concrete is used and metal materials, soil etc have more priority in sustainability (Fallah, 2002; Golabchi and Mazaherian, 2010).

The important and challenging issues in building industrialization are the necessity of using a method compatible with different conditions (environmental, economical conditions, project characteristics). Sustainable industrial methods are methods with adaptability with project conditions in different aspects (Mirsaeedi, 2009). Thus, in recent researches, methods of constructional and industrial systems selection are studied along with sustainability (Chen et al., 2010a, 2010b). In Table 4 some items of industrialization challenges are proposed in different fields. Industrial methods in the past due to industrial and mass production faced with some challenges namely in social and architecture fields including aesthetics, uniformity, identity and local values etc and nowadays, by applying new and compatible methods, approaches toward personalization and mass order are reduced considerably.

Table 4: Issues and challenges of building industrialization

Issues and challenges of industrialization	
Economical aspects	More costs in comparison with common methods and initial capital in most of industrialized methods
Social aspects	Social acceptance
	Effects on human resources
	Cultural identity
Environmental aspects	Environmental effects of some of the methods
	Blending with environment (natural or artificial)
Design and architecture aspects	Aesthetics and architectural expression
	Identity and local values
	Variation and personalization
	Consistency with requirements
	Flexibility and dynamic nature
Technical aspects	Complex supervision and control
	Complex equipments and tools
	Skillful labor
	Construction methods with high technology

CONCLUSION

According to the study, industrial methods have a lot of characteristics in sustainability. Industrialization is a force along with sustainability. The idea of using industrial idea in architecture is a solution in achieving sustainable architecture. Today, industrial architecture by relying on idea of increasing

the quality and conforming with the environment and more flexibility and by good planning and optimization can be in the range of sustainable architecture definitions. Sustainable aspects in industrialization are presented in Table 5. Also Fig. 2 shows the relation of different characteristics of industrialization with sustainable principles and characteristics.

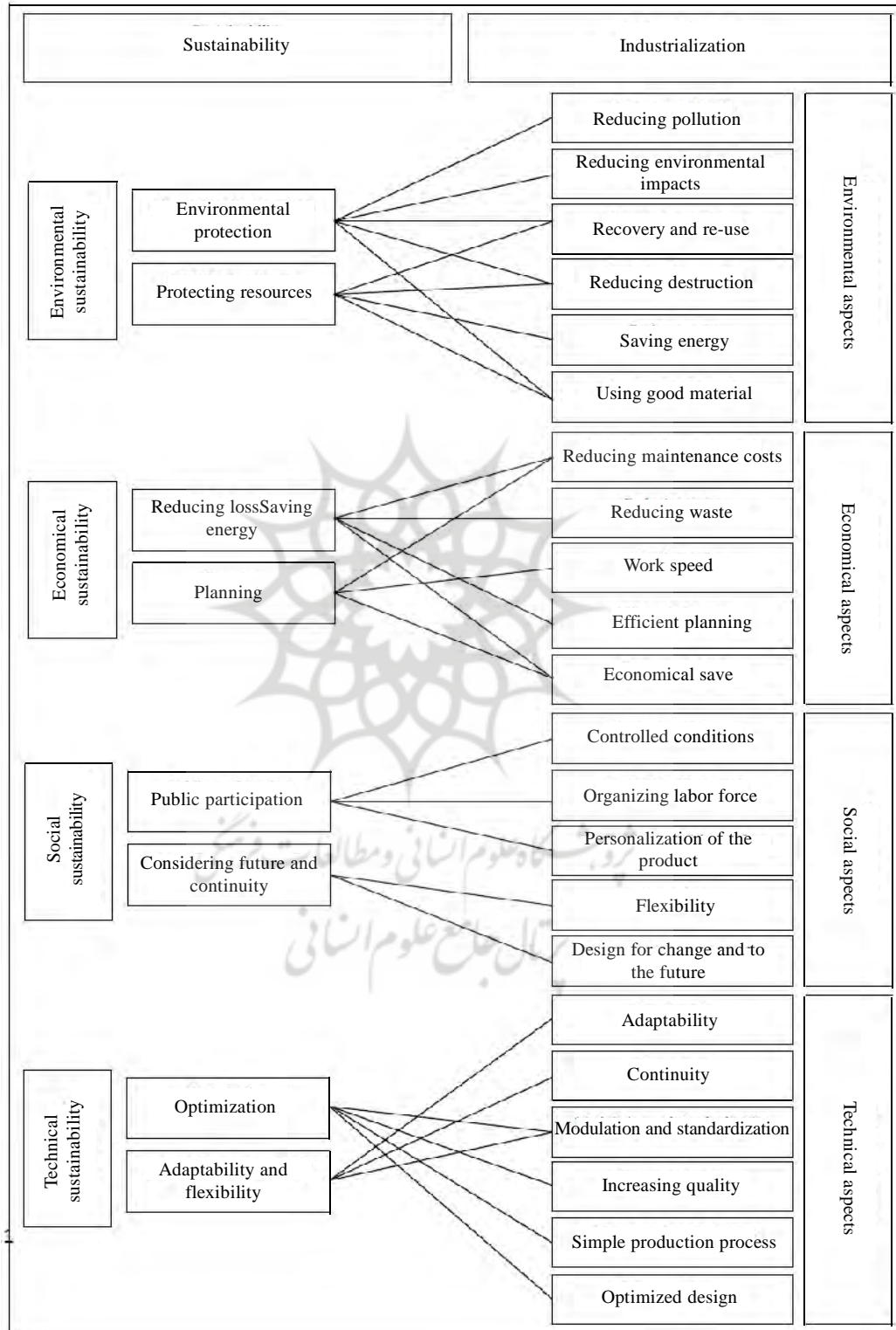


Fig. 2: Sustainability and industrialization relationship

Table 5: Sustainability aspect in building industrialization

Environmental aspects	Reducing pollution (voice and environment)
	Reducing environmental effects
	Recovery and re-use
	Destruction reduction
	Saving in energy consumption
	Using suitable materials
Social aspects	Controlled conditions in the production
	Organizing human resources
	individualization of product and mass customization
	Flexibility (in new systems)
	Participation
Economical aspects	Reducing maintenance costs
	Reducing waste (material, energy, time)
	Work speed
	Efficient and full planning
	Long-term economical saving
Technical aspects	Adaptability and continuity
	Modulation and standardization
	Increasing product quality
	Simplicity of production process
	Optimized design

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