DEVELOPMENT OF A BUILDING SYSTEM

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ABSTRACT

The universal principle of architecture can be defined as follows: “The architectural product is the synthesis of the different man-made physical environments that are formed by locating the series of building components in different ways”. Within this context; it is necessary to determine the principle of building assembly and the assembly of ‘material components’ in order to produce the building. The material components are the elements of sub systems (such as; structural, envelope, services, partitions, circulation, and finishing systems) which form the building system of an architectural product. Every building is an integrated product. Integration defines the relations of sub systems with the whole. Therefore, it is necessary to define the sub systems and their relations in realizing the architectural product. This paper presents the analysis principles of the sub-systems, relationship between the analyzed systems and components, integration principles and possibilities of them, and the future conditions.

1 INTRODUCTION

On the verge of 21 St. century, one of the widely popular subject in the field of all disciplines and architecture is technological changes and innovations that affect on social life. The advanced technology finds its origins in the developed countries, it is , today, a technology that is expanding its presence throughout the world with significantly larger numbers of such building being constructed in developing countries than in either Europe, The United States, or Japan. Regardless of location, however, practicing professionals within any geographic area use their experience of the past as means of achieving the perceived goals of the present. Beyond that, the technological transfer of design, production/construction techniques and methodology from various parts of the world is an ongoing process that is of value to all professionals regardless of location. Therefore, such realities need to be discussed in universal level.

A general characteristics of each new technology compared with the previous one it replaces, is that, it aims to provide more suitable life conditions. Thus, current

experiences demonstrate that it is inevitable for the new technologies to affect the architecture defined as ‘an art of design and construction of long lasting, comfortable **building** with space or spaces as a whole, that meet the various requirements of the human, provide appropriate living conditions and improve the level of life standards’.

As it is stated in the definition; Architecture is a profession which exists and becomes concrete with the **building.** The success of the architectural product mainly depends on its structural organization, the level of technology that realizes this organization, and the performance of the man-made environment. In such an approach, the principal of the building assembly and construction system, relation between the building and building process, and the effort in realization the levels of comfort determine the border of the interest of architecture in technological aspect.

As it is known, in order to design, construct and produce a space and/or spaces as a whole, the elements which form the building system should be defined, and the relations among them should be determined. This depends mainly on decision of the duration which has specific steps that is called **‘the construction process’**

In the manufacturing of the components, such materials and tools are used; such production and construction techniques and methods are applied. All the techniques used along with the civilization form a “whole” and an accumulation turns into a “science”. Generally the whole of these techniques can be defined under the headings of **“building technology”,** or **“manufacturing and production technology”.** When it is thought chronologically in the history of technology, it is understood that also the primitive shelters, constructed to have more comfortable environments, were built with the building system and construction technology reflecting accumulation of time. Carving the rocks, constructing the branches of trees, putting small rocks and bricks on top of each other, then the production techniques related to concrete have been used as a common technology for a long time and has affected the design process and the relations among building components. These techniques with different construction methods and with fewer building components founded the base of today’s technological innovations.

Today, the buildings that are constructed with new building systems and construction techniques are improving along with the opportunities provided by technology and industrialization, add new dimensions to architecture. Especially the buildings constructed in the light of systematic design approaches in which the integration principles -according to the predetermined aim- of the components have the priority and the building system formed by sub-systems with different functions, are important improvements in this field.

In the light of this introduction, the analysis principles of the building systems which form man-made environment, relationships between analyzed systems and components and the integration possibilities of them need to be discussed.

2 ANALYSIS PRINCIPLES OF THE BUILDING SYSTEM

A building can be viewed as a system that consists of certain sub-systems with different functions in the building. A building, consisting of space or spaces, can not be achieved if the building system is not defined in concrete terminology's.

The building system is formed by the contribution of a great deal of complex knowledge and components along with today's technological possibilities. In addition to this, many other disciplines take part in the system with their own components. To achieve a building with successful performance; the coordination, organization and supervision of these components need to be carried out by an architect.

These components are the elements of sub-systems which form the building system of an architectural product. The definition characteristics of the sub-systems components in concrete terminology's, prevent the building system from important complexities and contradictions even if different integration principles and different architectural approaches are followed.

Especially in the 1960's and '70's innumerable studies were realized about the analysis of the sub-systems which form the building system. It is useful to mention some of these studies that help today's system analysis.

In the model improved by the "Building Performance Research Unit (BPRU)", the system is defined under three main sub-systems;

- Constructional System
- Contents System
- Services System (Markus 1972)

Broadbent who takes care of BPRU's model as a base presents four sub-systems as in the following:

- Structural System
- Space Separating Systems
- Services Systems
- Fitting Systems (Broadbent 1982)

Bovill, in his study analyzing the components required by function in a more detailed way, as follows:

- Structural System
- Acoustic System
- Vertical Transportation System
- Plumbing System
- Electrical System
- Lighting System
- HVAC System (Heating, Ventilating, Air-Conditioning System (Bovill 1991)

In his project, "School Construction Systems Development (SCSD)", Ehrenkrantz, who evaluates the choice of the building system providing the maximum constructional performance in the education centers, deals with the sub-systems, the relations between them and integration possibilities of sub-systems, introduces the basic systems as in the following:

- Structure
- Partitions
- HVAC and Lighting Systems (Ehrenkrantz 1986)

Along with the approaches of these researchers; depending on their functions and tasks within the building; and dealing with the current approaches, followings are the basic sub-systems that can be analyzed:

- Structural System
- Building Envelope System
- Services Systems
- Space Separating Systems
- Circulation Systems
- Finishing Systems (Çelebi 1994)

The sub-sub-systems of these basic sub-systems can be determined depending on their function and task asked.

Within this context, it is important to determine the general characteristics of the sub-systems of the building system and the related sub-sub-systems in order to produce the architectural product.

3 THE GENERAL CHARACTERISTICS OF SUB-SYSTEMS

3.1 Structural System

It is a system that supports the building system. Its components as foundations, columns, beams, and slabs are designed according to its power to hold the dynamic

and static loads. From the point of practice it is permanent, bounded to the soil, and it is the most long lasting basic system among the sub-systems.

Because of the fact that it realizes the space and/or spaces as a whole, structural system either determines the space or supports the components that determines the space. Within this context, in tall buildings, depending on the dimensional performance and multi-use of the space, the structural system can provide "**a space uninterrupted by vertical structural components", "a space the least interrupted"** and **"an interrupted space"** in each flat (Çelebi 1994).

It is important to determine the sub-sub-systems of structural system depending on this performance, and sub-systems can be categorized as followings:

- Massive and Solid Systems (Load bearing wall structures, etc.)
- Skeletal Systems (Grid systems, suspended structures, etc.)
- Composite Systems (Consists of massive and skeletal systems together, as skeletal system shell dome on it or structures like this)

Such a categorization and the analysis of the sub-sub-systems and components of every system in terms of this categorization is an appropriate approach from the point of an architect.

3.2 The Building Envelope System

It is a sub-system, separating the internal environment from external one that have different environmental conditions. The building envelope system has an important role in the creation of the physical ambiance in consistency with the function and external environment of the building. Especially today, as a result of wide utilization of the contemporary construction and production technologies and new materials, the issue is gaining increasing importance.

However, in the light of this article, it is very important to select the sub-sub-systems of this sub-system. According to the aim of this study, its sub-sub-systems can be defined as follows:

- Non-load bearing systems (Independent from structural system), or
- Load bearing systems

In the whole building system, non-load bearing system controls the atmospheric effects by supporting no load other than its own weight, and provides comfort conditions in the internal environment. It is essential that its components should be deal with in terms of systematizing, the changeability and increasing the capacity (as in curtain wall systems) (Brookes 1985).

In other alternative, when it is an element of structural system, we can talk about two kinds of functions; depending on its capacity of controlling the atmospheric conditions and supporting the loads. However, in this situation, it is not a system thought as an independent sub-system but it is one that is thought as a capacity added to the component playing a part as a structural system, and its characteristics and components are dealt with this point of view.

Especially today this system thought as basic and independent from the structural system; in terms of minimizing the load on the artificial heating, ventilating, climatization, and lighting.

3.3 Services Systems

They are systems consisting of the ones that gather the spaces with many different functions and the ones necessary for the comfort. In addition, they are usually used when the building envelope is insufficient. In terms of their functions and tasks, their sub-sub- systems can be categorized as followings:

- Heating System
- Ventilation System
- Climatization System
- Lighting System
- Electrical, Electronic and Communication Systems
- Plumbing System

The services systems seen as an applicated component in the building years ago, but it is now seen as a separate basic sub-system because of the improvement in technology of these systems.

Although the technical characteristics of these systems are not in the content; it is important to consider that their location is permanent, and they occupy a specific volume within the building by standing in their own zones. Along with the technological innovations they renew constantly, they affect the organization of the spaces and the possibilities of integration of sub-systems.

3.4 Space Separating Systems

While bordering the spaces located within the building (and surrounded by the envelope), these systems at the same time, determine the qualities (such as visual and audial insulation, color and form) and quantities (such as dimensions) of the space. The most important factor to determine the sub-sub-systems is to realize whether to take into consideration the flexibility of the spaces or not. For this reason, it has been

accepted and applied as a classic approach to classify and divide them into sub-sub-systems in terms of;

- Demontable Systems or,
- Permanent Systems, and to determine the following systems accordingly.

With the help of the opportunities provided by today's construction technologies, the use of demontable components have made possible to realize long life buildings from the point of function.

3.5 Circulation Systems

The order of circulation, and the permanent location of some of the components providing the circulation (especially in tall buildings or in buildings with complicated function), affect the organization of the space directly, and requires this system to be taken into consideration as a basic sub-system.

Circulation systems include the sub-sub-systems that establish the relation between the exterior and interior spaces, and provide the transportation between the spaces on the same flat or different flats. Within this sense, they can be devided as;

- Corridors
- Entrance Hall
- Stairs
- Elevators
- Mobile Bands or Movable Bands

3.6 Finishing Systems

Every other system, except the basic sub-systems mentioned above, is included in this particular system. It is possible to analyze the sub-sub-systems of this system in the following way:

- Finishing Systems (claddings/coatings, suspended ceilings, suspended flooring with service ducts below, carpentry, paints, etc.)
- Furnishing System
- Equipment's System stand by activities (mobile lighting fixtures, TVs, PCs, etc.)

The greatest characteristic of these systems is that their components can be changed and renewed easily.

At this point, the basic characteristics of sub-systems and components are clearly defined in general level. However, the building system can not be achieved without

carefully investigating the interaction between sub-systems. Organization and coordination of the buildings today depend strongly on the research and development of the innovative technologies for construction and on integration of sub-systems.

4 INTEGRATION

Although all the sub-systems are considered as a “whole”, they actually are integrated to form a “greater whole” (Angyal 1970). That is to say, they all, form the “wholeness of the building system”.

Generally, **“integration”** can be defined as: Incorporation of diverse parts or groups into well-ordered whole. In other words, integration defines the relation of parts with the whole (Barton 1983).

In architecture, term of integration is used in order to combine several sub-systems and form a completely functional building. Integration is widely accepted for the purpose of reaching the required performance criteria expected from the building. A number of criteria come into scene here;

- To maintain the wholeness of the building, in the face of the decrease in the mechanical and physical qualities,
- To increase the level of comfort of the occupants,
- Health care,
- Safety issues,
- Volumetric performance,
- Thermal performance,
- Indoor air quality,
- Acoustics performance,
- Visual performance,
- Functional performance,
- and more.

According to these criteria, the wholeness of the building should always be reliable not only for a short term but for a long time.

Therefore, the aim of integration is to integrate the building sub-systems functioning in a harmonious way appropriately, in such a way that they achieve the maximum building performance criteria (Rush 1986), contributed to the efficiency of energy, time and material.

5 FACTORS THAT AFFECT THE INTEGRATION PRINCIPLES OF THE SUB-SYSTEMS & ASSEMBLY OF THE BUILDING SYSTEM

According to the contemporary approaches, there are **four main factors** displaying in a holistic wholeness with another that affect the principle of the assembly of building system and the possibilities of integration.

- One of these factors is the **"form of relations between sub-systems".** In a building system, the forms of relations between sub-systems directly effect the principle of a building system assembly. The **"tightly"** or **"loosely"** joints between sub-systems make a building system **"permanent"** or **"flexible".**

Tightly-jointed relations and permanent building systems define the types of buildings with the conventional construction methods, forms and ideas. Although buildings with permanent components supply opportunities for the integration of sub-systems, they mostly do not apply the advanced and high technology.

It is a challenge to modern architecture to develop a building system that offers a large degree of flexibility. Flexibility can be admitted as the possibility to include additional demands concerning use and lay-out; or the possibility to combine similar building components into different end products.

When it is applied as a use of space, some systems (as structural system and permanent space separating system) become practically permanent hindering a complete flexibility in the space, and the occupant cannot change the location of the components of these systems and dimensions of the space according to his/her own wishes/pleasure.

For this reason, while coordinating, organizing, and forming the relations between the sub-systems, it seems to be an important strategy of design to devide them into two different groups according to their being permanent or flexible ones, and to seek the solutions for the integration problem of the complex sub-systems in this way.

Whereas spatial organization may be described without referring to a particular technical solution, character cannot be possibly separated from the building process. This flexibility in the building process, is in the interest of production. We can speak of an industrial production if the components of sub-systems are made for the projects before their specific function or use is known. They are made before the design is finished.

Therefore, the building system which is constructed by the components produced in flexible, independent and in an industrial way, always necessitate advanced technology, and finds its reflections in the quality of production and erection process. The components of the sub-systems operate many functions, have the quality of an

integrated single component with a composite characteristic. However the process is related to erection and jointing processes.

As it is seen, the first factor that is called **“form of relations between sub-systems”** is directly related to “production technology” which is the second factor affecting the possibilities of construction and integration.

- Within this context, second factor concerns directly with the manufacturing technique of the sub-systems’ components, the qualities of the materials and construction techniques; in other words, it is related to **“the production technology”.**

The qualities and issues of the components in the building system, the choice of materials, the relations between the components of sub-systems varieties depending on the production technology of the building whether it is conventional or advanced. So, the integration possibilities of sub-systems and components chosen in terms of these production technologies are different from one another.

It has already been mentioned above that the building can be considered as a permanent in the milieus where the conventional technologies and architectural approaches are dominant. Due to the inclination of the production processes toward the factory production and site erection, the use of advanced technology is essential. Turning the components manufactured by the advanced technology into a single component with multi-function in composite character, and causing the use of artificial materials, make it easier to reach the required level of performance in the man-made physical environment. At the same time, this brings the development of the erection equipment and the level of knowledge necessary to improve them.

For a long time industrialization of the building process was understood to be a mechanization, a rationalization of the manufacturing process. The application of system formwork, climbing cranes, slipforms are aid, but not industrial process. They are only measures to simplify the activities on building sites.

An industrial product, however, is a building component that fits in with an organized building process for a potential market, in which building components are offered that provide a complete end-product through coordinated assembly.

Industrial Process also affects development of the erection processes. Improvements in erection processes obtain the integration of space separating systems and building envelope system with the services and finishing systems. Here, the integration takes place firstly between space separating panels and claddings. When the level of comfort performance isn’t enough, the components of the services systems take part in the integration.

Especially in intelligent buildings, it is necessary to think these components along with the integration consisting of information and communication systems as well.

Within this context, erection processes are limited with the articulation of equipment to the vertical and horizontal space separating components; and with junction and filling the joints.

- The third factor that affects the integration possibilities is **"the arrangement of sub-systems according to their importance".**

The "aim", mentioned in the sub title of structural system, that affects the choice of structural system dramatically, determines the sub-system or the sub-systems that are more important than the others. For example, in the building where the environmental comfort conditions are controlled by services systems and where the flexibility is aimed; the structural system and services systems gain more importance than the other sub-systems. So it is inevitable to design a building system determined by the guiding of structural system and services system.

These systems, in the architectural approaches whose main themes are founded on "technology" are emphasized and are legible as in mass of building as well; we also follow and notice the advanced level of technology existing within these systems.

- **"The life-spans"** of sub-systems and related components are also the fourth factor which is an effective factor in integration. A modern building can be separated into following independent life-spans:

• **Long Life**	• *Structural System*	• *Foundations* • *Columns, Beams* • *Floor Slabs* • *Load Bearing Space Separating Panels*
	• *Circulation Systems*	• *Stairs* • *Elevators* • *etc.*
• **Medium Life**	• *Building Envelope System*	• *Long Life Envelopes* • *Medium Life Envelopes* • *Short Life Envelopes*
	• *Space Separating Systems*	• *Non-load Bearing Interior Partitions* • *Non-load Bearing Exterior Partitions*
	• *Finishing Systems*	• *Coatings, Suspended Ceilings, Carpentry, Paints etc.* • *Furniture* • *Equipment such as TVs, PCs, etc.*
• **Short Life**	• *Services System*	• *Climatization Equipment* • *Lighting* • *Plumbing* • *Cables of electrical and communication systems* • *etc.*

This kind of methodically subdivision allows for the construction and erection of components in shorter times and replacements of the various components allowing a more flexible use of space (Colomban 1995).

Setting up a building system by taking into consideration the life-span of the sub-systems and components in integration, means having the opportunity to easily replace just the components that deteriorate or that are subject to change for different reason.

6 CONCLUSION

Within the terms of technological development and innovations, the number of sub-systems forming the building system decreases due to the integration possibilities.

Some sub-systems turn into a single component which has many functions in order to perform many tasks together and which is produced in an industrial way.

Services systems that display an independent and applicated feature in the type of production in conventional sense, today their function, frequency and weight increased constantly and they also became complicated. They are caused to form relations with the sub-systems and they play an important role in determining the relations of integration between sub-systems. This fact leads to the necessity to examine the weight of sub-systems in the general building system and / or the possibilities of integration.

Today, at this point of high technology, the buildings which have been designed with components and sub-systems have advanced technological possibilities and on which the various integration alternatives of sub-systems that have been practiced, add new dimensions to the field of architecture.

Due to the use of materials made of steel, concrete, aluminium, plastics and glass in the manufacturing of systems components, it becomes inevitable to construct buildings which reflect the technology as an image.

In the near future, it is widely accepted that the strong need for improvement the productivity, to reduce the waste of materials, to realize working conditions unaffected by the adverse weather in the site, and so on, will propel automation and robotics in the construction industry. And an automated building construction system will be the major feature of construction industry, rather than single purpose construction robots.

In the future; also, computer integrated buildings will be a standard feature of the real property industry throughout the world. The intelligent buildings in this line, will allow occupants to view and control aspects of their physical environment by logically linking and integrating their workstation PCs to buildings services systems (especially heating, air-conditioning, ventilation controls, lighting controls, local power bars/smartbar, security, and fire alarm systems).

It seems likely that a number of advanced buildings, regardless of location, will be constructed with the help of technology dominated by the integrated components and robotics erection principles, depending on artificial materials. So it is obvious that the building systems with different images and different form approaches will become wide spread in the near future than today’s High-Tech buildings.

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