

## RE-USABILITY OF HIGH-RISE BUILDINGS: A CASE STUDY OF THE ARTS TOWER IN SHEFFIELD, UNITED KINGDOM

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### Abstract

Undoubtedly the high-rise buildings are phenomena of the new high-tech life style and a symbol of development, power and technology. Today, society is changing at such speed that buildings are faced with new demands where they need to be in a position to adapt the change. There are times when buildings change function during construction or even during the design process, and one of the necessities today is the re-usability of buildings, which would also help to increase their service life. The main aim of this paper is to identify some of the key areas in designing structure of high-rise buildings in order to allow the possibilities for future functional changes by illustrating an ideal framework for general structure of these giants. The paper also reveals an example of a case study building, in which these principles have been considered during its redesign, showing samples of master student projects with an aim to assign new function that considers a new concept of re-usability as a concrete structural design. The study is based on a qualitative method and the data is collected by site visits, with preparation of plans, sections, site photos and information using the internet, and through the use of appropriate literature review of high-rise buildings and their re-usability. The results highlighted a necessity for developing a concept of re-usability in designing of new buildings for future in order to prevent financial losses, also the waste of energy and time in respect of changes in

construction, design and the negative environmental impact of demolition. This in turn leads us to get closer look into the concept of 'Sustainable Development'.

### Keywords:

Re-usability; high-rise buildings; conservative structural design; time-based architecture (TBA); sustainable development

### Introduction

Certainly the result of the expansion of cities is the development of buildings and constructions citywide. Accordingly, high-rise buildings have appeared as phenomena of the new high-tech life style and as symbols of development, power and technology (Collingridge & James, 1989; John & Heather, 2002). They are also the representation of high population of cities and centralisation in official and municipal activities.

Today, society is changing at such a speed that buildings are faced with new demands where they need to be in a position to adapt to the change. There are times when buildings change

function during construction or even during the design process (Reddy, 1996). For example, the current economic crisis has caused many property developers to convert ongoing projects of office buildings into housing. This usually means the plans are needed for redevelopment from scratch. The challenge in accommodating and building time-based architectural design is considered even greater than before and it is to design and build for change and adaptability. "Form follows function" is giving way to concepts like polyvalence, changeability, flexibility, disassembly and semi-permanence.

Lack of re-usability is a principal source of problems in buildings' short service life and early demolition. Hence, the result is both great financial loss and waste of time, energy, and natural resources which are forming unsustainable future for development of the built environment. Therefore the important question here is: 'What are the principal factors in the functional adaptability of high-rise buildings?'

The study is aimed to identify some key points in designing the structure of high-rise buildings in order to prevent the possibilities for future functional changes by presenting an ideal framework for the general structure of these giants. In addition, it reveals an example of a case study building where such principles have been considered during its redesign (Arts Tower, Sheffield, UK), together with some masters student projects with an aim to demonstrate a redesign option with new functionality in terms of the concept of re-usability as a concrete structural design.

In this case, the issue calls for the need of sustainability in design and implementation to

accommodate possible changes in decisions as a result of changing market conditions during the construction period and attempts to reveal the potentials and problems in the case of future possible functional changes becoming a necessity. This study will attempt to find some new architectural solutions, not in other aspects such as psychological, social, etc. but in respect of the re-use of existing high-rise buildings.

The study uses a qualitative method for data gathering and the data is collected by site visits, with preparation of plans, sections, site photos and information using the internet, and through the use of appropriate literature review of high-rise buildings and their re-usability.

### High-Rise Buildings

High-rise buildings are defined as vehicles for utilizing the third dimension of height in city planning. They are characterized by the particular systems of load collection, load transfer, and lateral stabilization. They are not a sequence of stacked up, single-storey systems, nor can they, as to their structural behaviour, be fully explained as a super cantilever turned up. Moreover, they are homogeneous systems with their own unique problems and unique solutions (Engle & Hatge, 1997; John & Heather, 2002).

In order to provide suitable conditions for a flexible floor plan and good possibilities for the later reorganization of individual rooms in each floor layout, the design is of height-active structure systems aimed at the greatest possible reduction of load-transmitting vertical elements in section and number (Satoshi, et al., 2000).

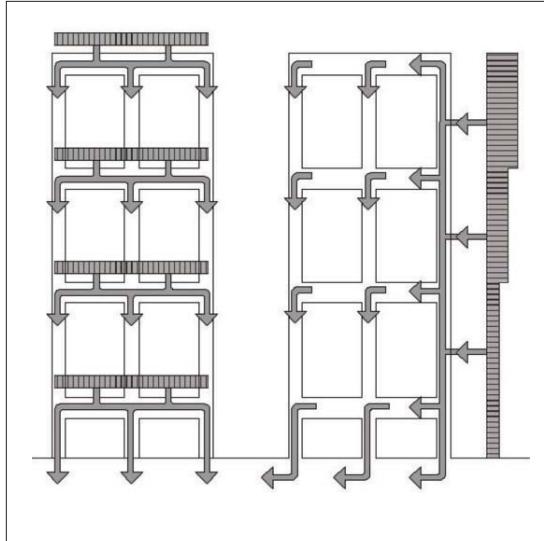


Figure 1: High-Active Structural System; the approach of indirect transmission of vertical forces into the foundation (Source: Engel, H. & Hatje, G. 1997).

In terms of designing high-rise buildings, 'high-active' structural systems are employed to transmit the buildings' vertical forces by using indirect structural elements in the foundations. The 'high-active' structure systems are instrumental and necessary for the construction of high-rise buildings. In this capacity, they are co-determinant in shaping modern buildings and cities (Engel & Hatje, 1997; Satoshi, et al., 2000; Swenson & Chan, 2008).

### Typology in High-Rise Constructions

High-rise buildings can be distinguished by the different systems of storey wise load collection (Ali, 2001; Engel & Hatje, 1997; Swenson &

Chang, 2008). From this point of view, the structural families are as follows:

- 1- Grid high-rise buildings; in which the collecting points are evenly distributed over the whole floor plan, with a number of columns in various but organized distances (see Figure 2);
- 2- Casing high-rise buildings; in which the collecting points are arranged peripherally, and the columns are located in the body of the building (see Figure 2);
- 3- Core high-rise buildings; in which the load collecting zone is located in the central core (Shaft) (see Figure 2);
- 4- Bridge high-rise buildings; in which the collecting points are directed to some superimposed separate structures (see Figure 2).

Moreover, sometimes a high-rise building can be a mixture of the afore-mentioned structural families (Ali & Moon, 2007). Hence, typically they include a core in centre (mostly to prevent the forces of earthquake and wind in top floors), and an exterior body based on Grid, Casing, or Bridge system (Ali & Moon, 2007; Engel & Hatje, 1997; Swenson & Chang, 2008).

### Time-Based Architecture (TBA)

During the 20th century it became increasingly clear that architecture is by no means a timeless medium. Thus, in the late 1960s serious research was carried out into techniques that would enable buildings to be adapted to meet the demands made by time. The desire for flexibility led to the construction of "programmatically natural and characterless" buildings. Hence, flexibility became synonymous with blandness and the word subsequently disappeared from the architect's vocabulary (Leopen, Heijne, & Zwol, 2005)

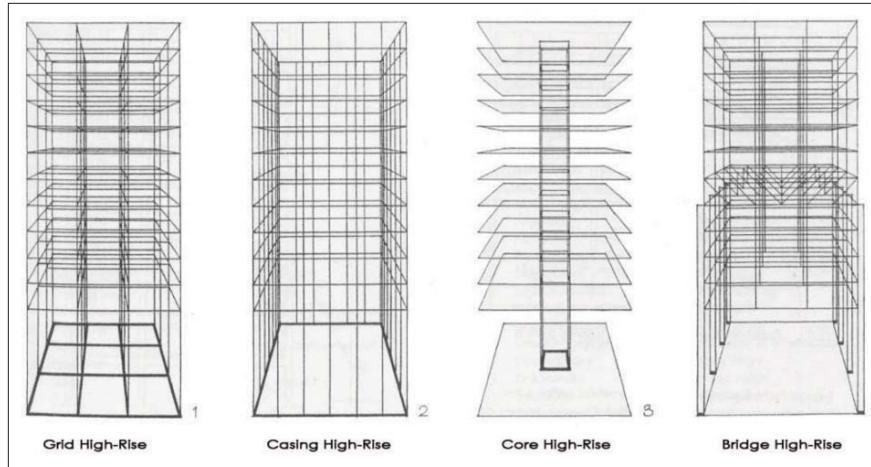


Figure 2: Four major families of high-rise structures (Englel & Hatge, 1997).

Even during the construction procedure, there are times when it is necessary to change the function of a building. Thus, the new approach is to design constructions that are able to accommodate such changes, in other words to create “buildings that respond to the time factor” (Leopen, et al., 2005).

Bernard Leupen (2005), propounded a question, ‘why this interest in time-based buildings and time-based architecture?’ defining the answer to this question, he stated that “time has a significant influence on the design and development of buildings. The concept of ‘time-based’ is derived from video and film art. What the ruler is for the architect, the time-base is for the video artist; it provides the basic measure for his work. Since designers of buildings-those people generally called architects- have to deal with aspects of time, the time- based could also become relevant to architects. But why has time become so important and how should we

deal with time during the design process? [...]”.

### Principles of Time-Based Architecture

As Leupen B. (2005) defined, in principle there are three possible ways to deal with time and uncertainty:

- Make buildings polyvalent; that the building should be proposed to be used in different ways without adjustment to the way it is built. That means there should be always possible to change the function of building. The polyvalence relates primarily to the interchangeability of activities between different rooms and spaces (Leopen, et al., 2005; Spangenberg, 2005).
- Construct buildings that are part permanent and part changeable; This is the origin of what termed the frame concept (Leopen, et al., 2005; Mayhew, 2004). That means to design the building with a completely independent implementation phases.

• Construct semi-permanent buildings, e.g. 'industrial, flexible and demountable' (IFD) buildings; an 'industrial, flexible and demountable' (IFD) building is designed and constructed in a way to be easily unassembled (Leopen, et al., 2005; Spangenberg, 2005).

According to this approach, the building can be categorised into three system levels (like a crate with bottles) (see Figure 3) (Bell, 2008; Geiser, 2005; Walker & Woeste, 2000):

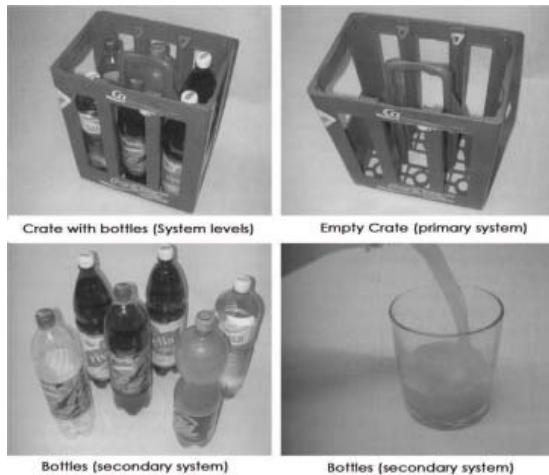


Figure 3: Crate with bottles (Three System levels in building) (Source: Geiser, 2005).

**1-The Primary Support System**-with a service life of approximately 50-150 years-as a long-term investment and unchangeable (see Figure 3). This system must be as open as possible for the different (and unforeseeable) activities in the secondary systems, so the scope of adaptation must be as wide as possible (Bell, 2008). The primary system mainly comprises the following

elements:

- External site conditions (site access, public utilities);
- Load bearing structures (vertical and horizontal support structures);
- Outer building structure (facade, roofs);
- Building services structure (installation structure: concept of the technical access and location of the central control rooms).

**2- The Secondary System**-with a service life of approximately 15-50 years-as a medium-term investment and adaptable (see Figure 3). Subsequent installability, disassembly and reassembly are the key focal points for this level of system (Channabasavaiah, Holley, & Tuggle, 2003). This system consists principally of the following elements:

- Finishing work (interior walls, floors, ceilings);
- Building services installations (central control rooms and technical access);
- Vertical and horizontal access, transport systems.

**3- The Tertiary System**-with a service life of approximately 5-15 years-as a short-term investment which can be changed with out any major structural work (see Figure 3). Accordingly it is subject to rapid change and is the least predictable. The tertiary system mainly involves:

- Technical, mechanical and electrical equipment;
- Fittings and furniture;
- Partitions, doors, metal areas etc.

Consequently, the concept of time-based architecture/re-usability intends mostly on the long-term part of the building (Hoffer, George, & Valacich, 2002; Marakas, 2001; Schatzberg & Schum, 2006), which is Primary Support System

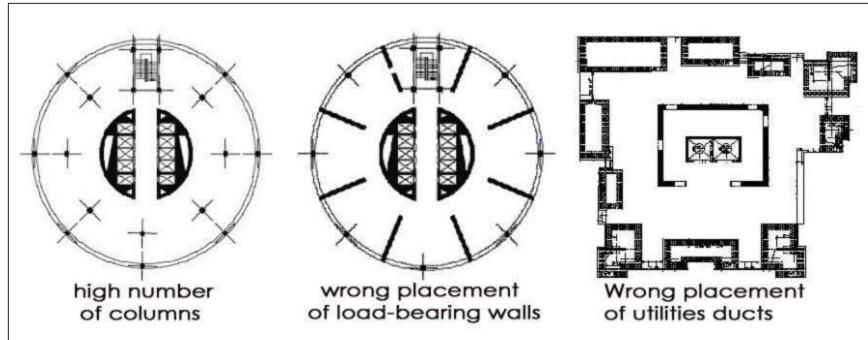


Figure 4: Preventing re-usability by wrong placement of structural elements (Source: Pao & Brzez, 2003).

(see Figure 4). For instance, sometimes high number of columns, wrong placement of load-bearing walls (Satzinger & Orvik, 2001), or even wrong placement of utility ducts, prevent the possibilities for future functional changes in buildings (see Figure 4).

### Factors of Re-Usability in High-Rise Structures

As previously stated in above sections, to achieve re-usability in high-rise structures there is a call for a kind of 'conservative design approach' considering some factors during the design procedure as follows:

- 1.To reduce the number of columns (open planning), by using cantilevers, cantilever girders connected to the main core (shaft), and reinforced armed concrete floors (Bell, 2008; Satzinger & Orvik, 2001).
- 2.To avoid locating the mechanical/electrical utility ducts or the elevator ducts out with the main core (Bell, 2008; Satzinger, Jackson, & Burd, 2002).
- 3.To avoid using the load bearing walls out with the main core (Norman, 1996; Satzinger & Orvik,

2001).

4.To divide the spaces with demountable partitions where possible (He & Beck, 1996; Satzinger & Orvik, 2001).

Hence, to achieve the concept of re-usability a typical and ideal plan can be defined.

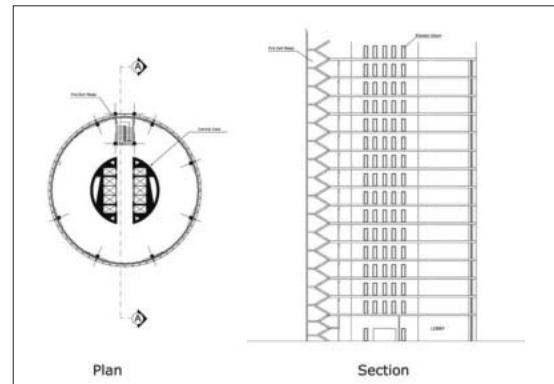


Figure 4-b: An ideal plan of core high-rise systems (Source Authors).

As can be seen in the above figure, all the electrical/mechanical utility ducts and also the elevators are placed in central core. Just the emergency fire exit steps are located out with the central core.

## Re-Usability in Case of Redesign of the Arts Tower, Sheffield, UK

### Location and General Information

The Arts Tower is a building at 12 Bolsover Street in Sheffield, England belonging to the University of Sheffield (see Figure 11). It can be known as one of the most elegant university tower blocks in Britain of its period. At 255 feet (78 m) tall it is the tallest building in the city, although, at 101 m, the 32-floor St. Pauls Tower on Arundel Gate, which was approved in October 2005, will be taller when completed. It is also the tallest university building in the UK (Schneider, 2008).

The building is designed by architects Frank Gollins, James Melvin, Edmond Fisher Ward & Partners, won the first prize in 1953 open competition for master-plan for the central development of the University of Sheffield. Construction of the tower started in 1961 and lasted four years (Schneider, 2008).

The building was officially opened by Queen Elizabeth, The Queen Mother in June 1966; it has 20 stories and a mezzanine level above ground. It involves the Departments of Landscape, Modern Languages, Philosophy, Biblical Studies, and Architecture as well as the library administration. As its name suggests, the building originally housed all the University's arts departments, which had far fewer students in the 1960s (Mathers, 2005).

There are also two floors below ground level that house nine lecture theatres. The building contains a cafe in the basement. It has a student computer room on the 12th floor, and a self-service language teaching centre on the second. Circulation is through two ordinary lifts

and a paternoster lift, at 38 cars.



Figure 5: Arts Tower, the University of Sheffield, Sheffield, United Kingdom (Source Authors).

In December 2007, the University announced plans for a major refurbishment of the Arts Tower. The refurbishment will see a major re-organization of the building's interior, as well as a new façade, and will coincide with the move of the Modern Language departments to the former Jessop Hospital site. The building was vacated in April 2009, with refurbishment taking approximately two years to complete.

### General Structural Information

From a typology view the tower is designed as a mixture of core and casing high-rise families. The structure of the Arts Tower building is based on armed concrete columns and slabs of floors in 23 stories (20 plus Mezzanine and 2 basement floors) .

All the toilets, lifts, paternosters, stairways, and electrical-mechanical utility ducts are located in the central core, established on armed concrete load-bearing walls.

### Conservative Design in Structure

Although the tower has firstly been designed for office spaces, classes, and cafes, the columns are placed in such way not to prevent the future functional changes in buildings functions. This is absolutely a positive point which increases the service life of tower by changing the demands of market and time. This in turn, shows the conservative and futuristic attitude of designers.

The paper deals with some examples of conceptual designs regarding the possibility of re-use of Arts Tower. The design works have been completed by the Taught Master Students of the School of Architecture at the University of

Sheffield, Sheffield, UK, in the module 'Applied Design Project' held during February 2009. The course intended for 're-designing the Sheffield Arts Tower as a sustainable residential community for student use'. Accordingly, the students proposed several new functions for the tower by also establishing its re-usability.

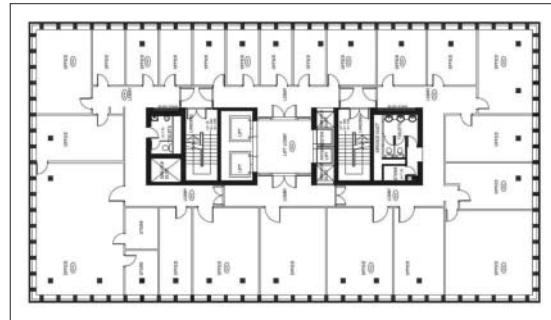


Figure 6: General layout of structure and offices in Arts Tower, Sheffield, UK (Source Authors).

**Example 1:** This example is designed by Anish Sharma. The design includes major changes to the layout of building in both horizontal and vertical sides. Moreover, added five new floors to the Eastern side of the tower.

Double skin facades are recommended as solutions to tackle heat gain and natural ventilation in this design work. Moreover, maximum number of rooms has been provided with balconies in order to promote natural ventilation and also gain indirect heat in the winters.

A double skin on glass along with terrace gardens has been provided towards both southern and northern sides of building to increase warmth



Figure 7: Conceptual design to re-use of Sheffield Arts Tower building by Anish Sharma (2008-09) - Master Student of Architecture at the University of Sheffield (Source: Authors).

during winters as well as venting out the heat in summers. The roofs of both the blocks are recommended to be constructed from steel and be painted in black colour to they save the heat during the day. Green roofs and Terrace gardens are also suggested.

**Example 2:** This example is designed by Xi Wang. The principal intention of this design work was to accommodate students from different backgrounds, with various cultural values and

behaviours. The proposed sections are as follows: Retails shops, student rooms, flat studios, one bedroom apartments, computer rooms, communal spaces, and theatre rooms.

As illustrated some major changes have been recommended for the interior layout of building (e.g. rooms and services). Moreover, four stair ways have been recommended to be added in Eastern and Western sides of building for more access among the units.

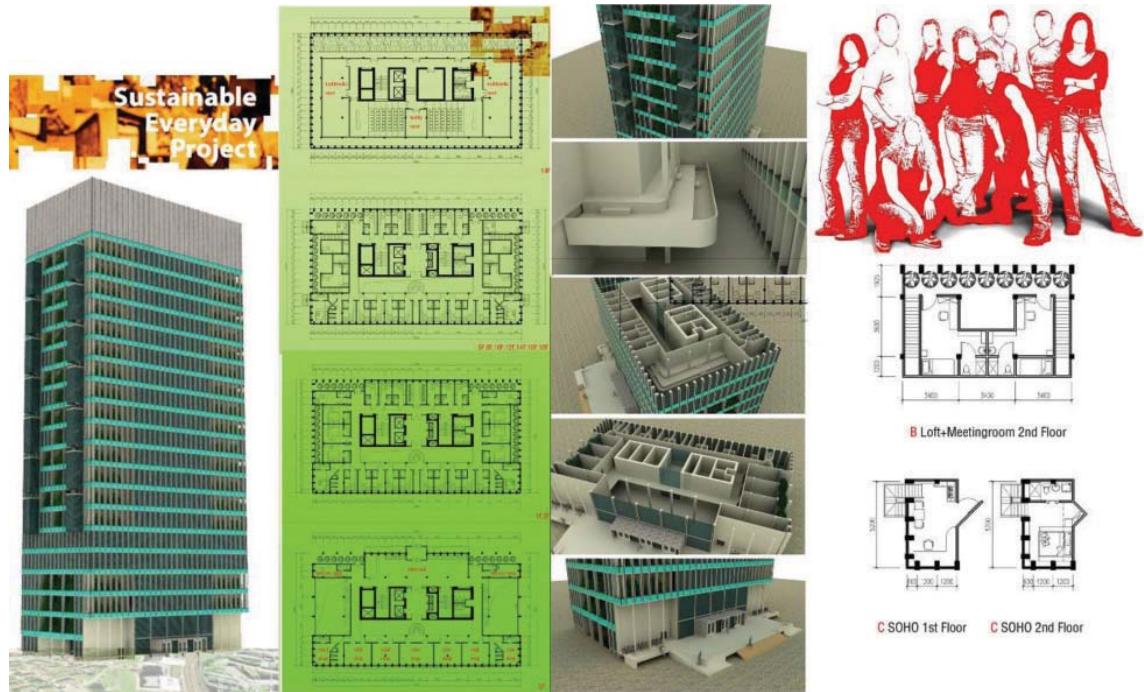


Figure 8: Conceptual design to re-use of Sheffield Arts Tower building by Xi Wang (2007-8) - Master Student of Architecture at the University of Sheffield (Source: Authors).

**Example 3:** This example is designed by Binh Khanh Nguyen. The design includes major changes for layout of the building in horizontal side. Accordingly, it aimed to develop the new model of Arts Tower considering the climatic situation of Sheffield in terms of natural heating and cooling, and to produce energy from renewable resources (e.g. natural ventilation and solar energy cells on the proposed facades). Hence, the building is proposed to operate energy efficiently as well as considering the aesthetic principles. Moreover, the design

intended to provide contact with nature having to two sky gardens in floors 6 and 14. The new functions are as follows: Residential apartments and flat studios, restaurants, educational spaces, gym and leisure spaces, gardens, cinemas, retails, offices, and communal spaces.

**Example 4:** This example is designed by Rohan Shiram. The design proposed major changes for layout of building. It is based on keeping the primary support system of the Tower (columns and central core), and establishing a new

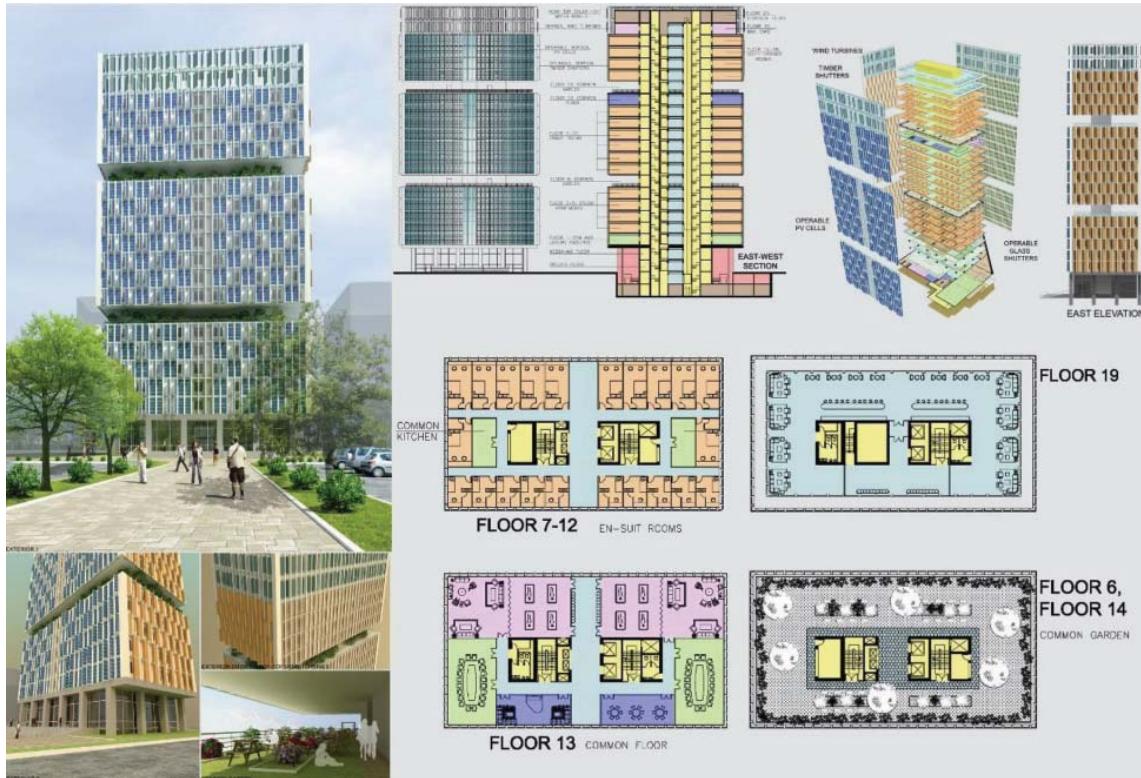


Figure 9: Conceptual design to re-use of Sheffield Arts Tower building by Binh Khanh Nguyen (2008-09) - Master Student of Architecture at the University of Sheffield (Source: Authors).

horizontal and vertical spatial organization based on open spaces used as green roofs and gardens. The dynamic style of building spaces and facade, as well as natural ventilation approaches were considered as significant aspects of this design work.

The new functions are as follows: Residential apartments and flat studios, cafeteria and dining hall, laundries, gym and leisure spaces,

roof gardens, retails, offices, and communal spaces.

As four examples indicated, the provident and conservative design of Tower's structure opens the doors to ideas and possibilities aimed for betterment or re-usability of the building based on new demands of market, culture, and technology. This in turn, increases the service life of the building as new approaches to saving

energy, time, investment, and natural resources, which also provides a more sustainable future for the built environment.



Figure 10: Conceptual design to re-use of Sheffield Arts Tower building by Rohan Shiram (2008-09) - Master Student of Architecture at the University of Sheffield (Source: Authors).

## Conclusion and Recommendations

While the results revealed that in order to achieve satisfactory re-usability in core high-rise building structures, some factors should be given serious consideration in the designing procedure:

1. To reduce the number of columns; as stated

before in the study, the number of columns is one of the significant sources of problem in terms of limitation of re-usability in constructions. Thus, one of the successful ways of achieving increasing the possibility of re-usability and future functional changes in buildings is designing and constructing buildings based on using a lower number of columns.

Designing high-active structural systems is employed as one of the methods of reducing the quantity of columns in buildings (see section 2). Hence, the stresses are transmitting to the foundation in an indirect way through the horizontal and vertical components of the structure.

In addition, the new methods of creating and empowering the armed concrete and the new materials as concrete's additives allow the structural designer to design constructions established on using the cantilevers - cantilever girders connected to the main core (shaft), and reinforced armed concrete floors with out the support of columns.

2.To avoid using load bearing walls out with the main core. Accordingly, load-bearing walls have been underlined as one of the major sources of limitation in the concept of functional re-usability. Again, as previously stated the traditional method of transmitting the forces by shear walls to the foundations can be changed by using cantilevers and cantilever girders, and also employing the new techniques of using reinforced armed concrete.

3.To avoid locating the ducts for the mechanical/ electrical utilities and/or the elevator out with the main core; as previously demonstrated, locating of the ducts for the mechanical/ electrical utilities out with the central core in high-rise buildings places significant limitations on the building in terms of its re-usability limiting the horizontal changes in building space.

4. Trying to divide the spaces through the use of demountable partitions. Thus, in order to achieve the goals of 'time-based architecture'

the adaptable and changeable partitions need to be carried out of the prefabricated and demountable materials suitable for use in the division of spaces in buildings. This in turn, creates the possibilities for all future functional changes. In this case, the isolation against sound, water and humidity, high and low temperatures must be considered.

Therefore, as a result, the study has demonstrated that all high-rise buildings, which are designed out of the defined framework and principles, demonstrate problems in terms of future functional re-usability. This in turn, acts as a motivating factor for architects to consider and take into account the important issue of 're-usability' in designing of high-rise buildings and to respond to the concept of 'time-based architecture'. Hence in the first steps, before the further numerical calculations (by civil engineers) and plans of implementation, architects should provide the concept of appropriate structural supporting systems considering the future functional changes. This action can also form the base for further research by civil engineers in order to identify and incorporate new techniques in structural design based on the concluding points referred to this study.

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