An overview and a work breakdown structure (WBS) template for construction planning of mid-rise buildings

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A B S T R A C T

The construction of small houses was started many years before Christ, and the development of this field has led many architects and engineers to a higher level of buildings. Mainly the buildings in terms of height are classified into three types: low-, medium- and high-rise buildings. In this particular study, medium or med-rise buildings are investigated. Reaching the fully finished building stage is not easy, and it requires many steps. Taking into account the step-by-step tasks for proper performance completion, economical point of view, performance period estimation and other considerations, it is essential to organise (plan) the work before it starts accurately; that is why a work breakdown structure (WBS) template is vital in the planning, design and construction of buildings. In this paper, an overview and a WBS template for construction planning of the med-rise buildings are submitted. It was seen that for the successful construction of a mid-rise building, 14 steps are required prior completion, and among all steps, construction step takes more time for completion.

1. INTRODUCTION

1.1. Background

Having a place to live and keep his belongings is one of the most vital things that a human being may have in this world. The global researches were done on the homeless percentage as per the UN, human right and other reports in the year 2017, it was found that 2.5% of the world's population missed a place to dwell and additional 20% missed the adequate housing (United Nations, 2017). At least 75% of the world population had a place to live in 2017. This shows how people give importance to houses, buildings, and so on. Hence to discuss this topic is vital.

In olden days it was difficult for people to deal with environmental issues such as climatic problems: wind, rain, sun, snow and other issues. These issues were affecting their daily living in such a point that protecting themselves as well as their belongings were horrible. These issues were the source of their health, security and freedom problem. So they have started developing ideas such as digging a hole at the face of mountains so that the place may serve them as a shelter. This type of structure is known as a nested structure. The next idea of development was to construct small wooden houses. As the technology keeps on upgrading, those small houses were also upgraded as per the technology up to the period where RC and steel structures came into the picture (Vatan, 2017; Wu et al., 2019).

By definition, a building is a type of structure constructed firmly to serve as a shelter for human and all his belongings or possessions, thereby ensuring his safety (Merritt and Ricketts, 2000).

1.2. Purpose of the study

Lots of buildings projects are subjected to many issues before the completion such as weather, insufficient knowledge of the architect or engineer selected, economic issue leading to lack of materials which also leads to delay in work and so on. To give a solution to all the above problems, the project has to be well planned and designed before it starts. The plan will provide a clear view on what is needed for the completion of the building on time; it will

help to save time as well as the cost (Lines et al., 2014; Serrador, 2012). This plan is not a drawing plan but a general plan of the project in its all aspect, including drawing plans.

In this project, authors proposed a plan also called WBS template required for the successful construction of a mid-rise building. This WBS may also be used for other types of buildings which are low- and high-rise buildings.

1.3. Classification of buildings

To do a proper building work planning, it is crucial to know the following three classifications.

1.3.1. Classification based on height

There exist three main types of buildings which are:

- Low-rise buildings;
- Medium rise or mid-rise buildings; and
- High-rise buildings.

Depending on the research done, it was found that each country or continent has its way of determining the number of stories for the identification of a particular building type. This is due to their zoning, and it is well proved by this memo of west quadrant plan project that:

"There are no universally accepted definitions for these terms". Generally, a low-rise building has around four stories, mid-rise building up to 12 stories and high-rise building more than 12 stories (West quadrant plan project team, 2013).

It is important to note that if for example, the maximum number of stories is 11 for a mid-rise building in a particular area or country, the high-rise building for them starts from story 12.

1.3.2. Classification based on materials

Based on structural materials, there are three main types of buildings which are wooden, reinforced concrete (RC) and steel structures (McGar, 2015). In addition to these, there exist other types of materials used for buildings. Finally, when two or more types of materials are combined to form a structure; the result is called the composite structure (Limbare and Dode, 2018).

1.3.3. Classification based on occupancy

Based on occupancy there exist: Residential, institutional, educational, assembly, factory, mercantile, business, and so on (Biswas, 2017; IBC, 2006).

1.4. Structural systems of a building

Each structure in the construction field consists of 2 central structural systems which are: Sub-structure and super-structure (Merritt and Ricketts, 2000; Mishra, 2019).

1.4.1. Sub-structure

In construction field sub-structure is referred to the part of the building located below the ground level. It is at this level where the foundation is located. Based on the soil condition and the building mass, the foundation may be shallow or deep.

1.4.2. Super-structure

This level is located above the substructure; that is above the ground level. It is at this level where the building is visible to people. The SS is made up of roofs, slabs resting on beams which also rest on columns which transfers their load below to the foundation which finally spread the load to the ground or bedrock below it. The SS may be done at the site itself, or its components may be pre-fabricated in a factory then used at the site.

2. METHODOLOGY

Authors focused on overview and WBS template of buildings in general and med-rise buildings in particular. The selection, principles as well as performance standards of a mid-rise building are discussed in this section.

2.1. Parameters enabling the selection of a mid-rise building with regard to population forecasting

The selection of a building depends upon its uses. For example, in a residential building, the methodology behind the choice of a mid-rise building is explained below.

As per the UN reports about the global growth of population, there will be an increase in population by the expected years, as shown in Table 1 (United Nations, 2017). So each country needs to find a solution on how to accommodate its population. (See also smith, 2018).

Table 1. Population forecasting

No.	Expected year	World population in billion
1	2017	7.6
2	2030	8.6
3	2050	9.8
4	2100	11.2

One of the solutions to this increase in population may be the separate construction of houses or low-rise buildings. This idea is not too good in case the population density is high because it requires a large area for development which may also lead in nature destruction; this is not desirable taking into consideration the environmental point of view. Furthermore, since a large area is required, it may lead to a shortage of land for agricultural purpose, thereby creating an issue regarding the local food supply.

Another solution is the construction of high-rise buildings to accommodate the population. This solution also is not good in terms of comfort of people, especially those living on the upper stories due to the distance from the ground.

Since the two above solutions are reasonable but not the bests, in this case, authors propose the construction of mid-rise buildings because they help to balance these issues to an acceptable range. They use the area but not too large area as in the first suggested solution thereby save the land; additionally, they are more comfortable to people when comparing to high-rise since the distance is not too high from the ground level.

2.2. Principles of a mid-rise building

In construction planning, one of the most critical steps is the building design. Before design, the architect or engineer must know the following principles (Merritt and Ricketts, 2000):

- The building construction shall be as per the client specifications;
- The building designed should be buildable;
- The building should respect its life cycle as indicated by the client;
- The building should be constructed in such a way to be safe and not compromising to the occupants' health throughout its life span;
- The building shall be secure against environmental impacts;
- The interior environment of the building shall not be less than the required for good health and safety of occupants.

The sum of construction costs, repair, maintenance, operation and anticipated future alterations shall be within the specified client limits.

2.3. Performance standards of a mid-rise building

The construction planning of a mid-rise building shall be done as per the regulations or standards provided by the authority in charge at a particular place. These standards are based on best practices and principles guiding the mid-rise building design by ensuring that they are responsive to their existing as well as their planned context. They also give some criteria regarding how the planned and the existing buildings may perform towards each other. The following are the performance standards of a mid-rise building (E.R.A. architects et al., 2010):

- The maximum allowable height of a mid-rise building should be in a ratio of 1:1 with the width of the avenue where it has to be constructed. It means that the maximum height of the building should not be more than the width of the road. This width is called the right of way (ROW), as shown in Fig. 1. Additionally, this height shall not be more than the specified one for a mid-rise building.
- The minimum height of the building at the street frontage should be taken with respect to the adjacent buildings, as shown in Fig. 1 between 5- and 8- story buildings.
- Taking the retail uses at the ground floor into consideration, the minimum height of this story should be 4.5 m.
- In case the front façade of the building is tall, it should be in such a way to permit sun rays to strike on the road for a minimum of 5 hours. This is done by creating a discontinuity in the height of the building, as shown in Fig. 1 at eight-story building. The discontinuity should follow an angle of 45°, and it is called the step back.
- The front wall of the building should start at the specified set back to provide a place for a sidewalk for pedestrians, as shown in Fig. 1 at the long white line beside buildings.
- If the building is to be built at the corner of avenues, the same angular plan and the minimum street frontage is used for both avenues.
- Materials to be used should be durable for an excellent performance of the building throughout its life span.
- Apart from the above-given standards, both architect and engineer have to add other standards as per their experiences for a successful mid-rise building planning and construction.

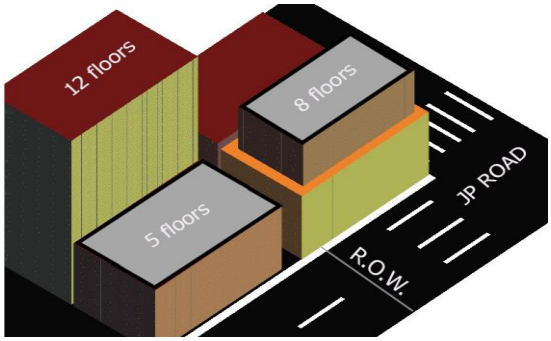

Fig. 1. Performance standards of a mid-rise building

2.4. Advantages and disadvantages of a mid-rise building

2.4.1. Advantages

The following are some of the advantages of a mid-rise building:

- Helps to accommodate a large number of people in an acceptable range.
- It helps to save land since it has more apartments when comparing to a low-rise building.
- It brings movement in the avenue since its ground floor may serve as a retail story.
- Its height is comfortable for people for their movement to markets, offices, etc.
- When comparing one mid-rise to a high-rise building, the mid-rise is economical.

2.4.2. Disadvantages

The following are the disadvantages of a mid-rise building:

- When comparing to a low-rise building in terms of structure itself, this mid-rise is not economical.
- It is not more comfortable to people when comparing to a low-rise building.
- It may have the parking problem in case the area where the building is being constructed is small. In this case, care should be taken to find a solution to this problem.

3. WORK BREAKDOWN STRUCTURE (WBS)

3.1. General knowledge

The construction of a mid-rise building is a significant work and will not finish by only performing one task. Due to this reason, the work has to be subdivided into many tasks or structures, thereby enabling a clear perception of the requirement for the completion of a mid-rise building. In management when the work is divided as said above, we talk about the work breakdown structure (Burghate, 2018; Devi and Reddy, 2012; Office of engineering and construction management, 2003).

This structure will give an idea on different project's elements, how the work is distributed amid the elements of the project and how the most abundant components of the project work are split up into smaller ones. By definition, a WBS is a type of template used to specify different works to be done for the completion of a project by also specifying the schedule required for each work (Devi and Reddy, 2012; Office of engineering and construction management, 2003).

Prior the template, it must be known that the template which is given below is not enough for the whole construction work, so the small tasks which are not going to be mentioned in this paper have to be done according to the experience of the manager, architect or engineer in charge.

3.2. Major titles or steps to be taken

- Initiation of the project
- Project planning
- Project conceptual design
- Building site assessment
- Scope management
- Building basic design
- Time/cost management
- Risk management
- Bidding activity and choice of contractor
- Detail design
- Procurement
- Building construction
- Commissioning
- Close-out and delivery

(Nouban, 2016; Nouban et al., 2017; Sadeghi and Babolian, 2016).

4. WBS TEMPLATE FOR CONSTRUCTION OF A MID-RISE BUILDING

4.1. Initiation of the project work

4.1.1. Definition of the project work
  4.1.1.1. Description of the project work
  4.1.1.2. Preparatory time table of the project work
  4.1.1.3. Technical specifications of the project work
  4.1.1.4. Pre-budget of the project work
4.1.2. Preparative scope of the work
4.1.3. Carry out a feasibility study
4.1.4. Assessment of project needs and list development of major study
4.1.5. Preparatory drawings
4.1.6. Develop and submit project charter
4.1.7. Approval of project charter
4.1.8. Submission of documents approval system

4.2. Project planning

4.2.1. Creating a preparatory scope statement
4.2.2. Project teams determination
4.2.3. Project plan development
  4.2.3.1. Preliminary architectural plan layout
  4.2.3.2. Preliminary structural plan layout

4.2.3.3. Preliminary electrical and piping plan layout
4.2.3.4. Preliminary storage layout
4.2.4. Project plan submission
4.2.5. Milestones and approval of the plan.

4.3. Project conceptual design

4.3.1. Conceptual scope of work
4.3.2. Analysis of mid-rise building
4.3.3. Conceptual calculations
4.3.3.1. Beams calculations and design
4.3.3.2. Slabs calculations and design
4.3.3.3. Staircase calculations and design
4.3.3.4. Columns calculations and design
4.3.3.5. Shear walls calculations and design
4.3.3.6. Foundation calculation and design
4.3.3.7. Formwork calculations
4.3.4. Conceptual drawings
4.3.4.1. Conceptual beams drawings
4.3.4.2. Conceptual slabs drawings
4.3.4.3. Conceptual staircase drawings
4.3.4.4. Conceptual columns drawings
4.3.4.5. Conceptual shear walls drawings
4.3.4.6. Conceptual foundation drawings
4.3.5. Conceptual project budget
4.3.6. Conceptual project performance schedule

4.4. Building site assessment

4.4.1. Identification of potential sites
4.4.2. Assessment of environmental and regulatory impacts
4.4.3. Identification of requirements
4.4.4. Project site identification
4.4.5. Recommendation of the site
4.4.6. Permits' application
4.4.6.1. Get permission from the environmental organisation
4.4.6.2. Get permission from urbanisation department or concerned authorities before construction

4.5. Scope management

4.5.1. Scope management plan development
4.5.2. Development of scope statement
4.5.3. Approval of scope
4.5.4. WBS creation

4.6. Building basic design

4.6.1. Validation of conceptual design documents
4.6.2. Conducting the soil investigation tests
4.6.2.1. Standard penetration
4.6.2.2. Vane shear
4.6.2.3. Cone penetration
4.6.2.4. Permeability
4.6.2.5. Consolidation
4.6.2.6. Direct shear
4.6.2.7. Unconfined compression
4.6.2.8. In-situ pile
4.6.2.9. Tri-axial
4.6.3. Conducting calculations or design
4.6.4. Preparation of drawings
4.6.5. Preparation of procedures
4.6.6. Final alternatives selection
4.6.7. Conducting material checks
4.6.7.1. Steel check
4.6.7.2. Coarse aggregates checks
4.6.7.3. Fine aggregates checks
4.6.7.4. Reinforcements check
4.6.8. The approval of the building basic design

4.7. Time/cost management

4.7.1. Definition of activity
4.7.2. Sequencing of activity
4.7.3. Estimates of activity resources
4.7.4. Estimates of activity duration
4.7.5. Schedule development

4.8. Risk management

4.8.1. Planning of risk management
4.8.2. Identification of risk
4.8.3. Analyses of qualitative and quantitative risks
4.8.4. Risk response plan

4.9. Bidding activity and choice of contractor

4.9.1. Make public the bid through advertisement
4.9.2. Submission of the bid documents to prospective contractors
4.9.3. Evaluating the proposal received
4.9.4. Choice of victorious contractor
4.9.5. Contract award
4.9.5.1. Preparing the contract documents
4.9.5.2. Submitting insurance and bond certificates.
4.9.5.3. Preparation of cost flow estimates
4.9.5.4. Acquire permits for construction
4.9.5.5. Prepare, sign and award the contract

4.10. Detail design

4.10.1. Preparation of subcontractor or consultant for a detailed design
4.10.2. Approval of basic documents
4.10.2.1. Approval of basic drawings
4.10.2.2. Approval of technical statements

4.10.2.3. Approval of reports related to soil investigations
4.10.2.4. Approval of drawings pertaining to topography
4.10.3. Carry out calculations
4.10.3.1. Selection of required codes for analysis and design.
4.10.3.2. Analysis of the building foundation using SAFE, SAP, etc.
4.10.3.3. Building frame (beams, columns) analysis using software such as ETABS, SAP, etc.
4.10.3.3.1. Selection of required codes for analysis and design
4.10.3.3.2. Define span lengths, number of spans, number of stories and floor to floor heights
4.10.3.3.3. Define material property
4.10.3.3.4. Define section property
4.10.3.3.5. Define the load pattern
4.10.3.3.6. Define load cases
4.10.3.3.7. Assign loads to beams and slabs
4.10.3.3.8. Run analysis
4.10.3.4. Analysis result
4.10.3.4.1. Percentage of steel is given
4.10.3.4.2. Bending moment and shear force diagrams are given
4.10.3.4.3. Base reactions are given
4.10.3.4.4. The general behaviour of the frame is provided in the analysis result
4.10.3.5. Frame design
4.10.3.5.1. The frame reinforcement details will be given
4.10.3.5.2. A general report of the design will also be given
4.10.4. Calculation of the parking area
4.10.5. Earthwork calculation
4.10.6. Mechanical calculations
4.10.6.1. Analysis of water pipelines
4.10.6.2. Analysis of sanitary facilities
4.10.7. Electrical calculations
4.10.7.1. Analysis of electrical supply facilities
4.10.7.2. Analysis of lightening facilities
4.10.8. Formwork calculations
4.10.8.1. Nails calculations
4.10.8.2. Shuttering calculations
4.10.8.3. Centring calculations
4.10.8.4. Staging calculations
4.10.9. Scaffolding calculations
4.10.10. Doors calculations
4.10.11. Windows calculation
4.10.12. Floor finish calculations
4.10.13. Painting calculation
4.10.14. Drawing preparation
4.10.14.1. Detailed drawings for foundation
4.10.14.2. Building frame drawings
4.10.14.2.1. Drawings showing details of reinforcements for RC beams
4.10.14.2.2. Drawings showing details of reinforcements for RC columns
4.10.14.3. RC shear walls reinforcement drawings
4.10.14.4. Staircases drawings
4.10.14.5. RC slabs reinforcements drawings
4.10.14.6. Parking area drawings
4.10.14.7. Mechanical facilities drawings
4.10.14.8. Electrical facilities drawings
4.10.15. Preparation of materials
4.10.15.1. Preparation of materials for steel construction
4.10.15.1.1. Steel as per the shape
4.10.15.1.2. Bolts and nuts
4.10.15.1.3. Plates
4.10.15.1.4. Welding facilities
4.10.15.1.5. Anti-corrosive materials
4.10.15.2. Preparation of materials for concrete
4.10.15.2.1. Coarse and fine aggregates
4.10.15.2.2. Cement
4.10.15.2.3. Admixtures
4.10.15.2.4. Reinforcements
4.10.15.3. Preparation of wooden or steel formwork and staging
4.10.16. Preparation of technical specifications

4.11. Procurement

4.11.1. Completion of the vendor list for all the equipment and materials
4.11.2. Send the required documents to the providers
4.11.3. Reception of the providers' proposals
4.11.4. Selection of the victorious providers
4.11.5. Contracting with the victorious providers
4.11.6. Materials testing
4.11.7. Inspection or checking of the shop
4.11.8. Expedition
4.11.9. Customs clearance
4.11.10. Tax payment
4.11.11. Shipping materials
4.11.12. Reception of materials
4.11.13. Storage of materials at the site

4.12. Building construction

4.12.1. Cleaning the site
4.12.2. Marking the site as per drawings
4.12.3. Earthwork excavation
4.12.3.1. Preparation of required equipment
4.12.3.2. Excavation
4.12.3.3. In-situ tests
4.12.3.4. Construction of footings or piles
4.12.3.5. Finishing of foundation

4.12.3.6. Filling back the foundation for the construction of the superstructure
4.12.4. Construction of columns
4.12.4.1. Marking the size of the columns as per drawings
4.12.4.2. Placing reinforcements after tests as per drawings
4.12.4.3. Placing scaffolding and formworks
4.12.4.4. Pouring concrete after tests using the required equipment
4.12.4.5. Removal of formwork
4.12.5. Construction of beams and slabs
4.12.5.1. Placing scaffolding and formworks
4.12.5.2. Placing reinforcements after tests as per drawings
4.12.5.3. Setting electrical pipelines in the slab as per drawings
4.12.5.4. Pouring concrete after tests using the required equipment
4.12.5.5. Removal of formworks
4.12.6. Brickwork
4.12.7. Electrical works as per drawings
4.12.8. Mechanical works as per drawings
4.12.9. Plastering
4.12.10. Painting and finishing the building
4.12.11. Site pavement and finishing work

4.13. Commissioning

4.13.1. Process area pre-commissioning
4.13.2. Safety plans and manuals
4.13.3. Quality levels measurement

4.14. Close-out and delivery

4.14.1. The manuals delivery
4.14.2. Prepare and deliver as-built drawings
4.14.3. Financial issues finalisation
4.14.4. Deliver the project to the client
4.14.5. Close-out

5. CONCLUSIONS

This study included two main topics which are an overview and a WBS template for the construction of a mid-rise building. The overview helped to understand and get an idea about buildings in general and med-rise buildings in particular. The WBS template helped to understand different steps involved in the construction planning of a mid-rise building. It was seen that for the successful construction of a mid-rise building, 14 steps are required prior completion. Additionally, the construction step takes more time for completion than other steps. Finally, the architect and engineer or the chief in charge of the construction are free to add or remove an activity as per their experience referring to the 14 discussed steps.

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