The Vertical Master Plan

Abstract

With over half of the world’s population now living in an urban environment, major world cities (especially) will always grow in population over time. To avoid city sprawl, urban densification will be required. This will need to happen at a steadier and more sustainable pace contrary to the “boom and bust” cycle we now take as the accepted model for economic growth.

To maximize vertical efficiencies, a framework for flexible vertical growth within an established and controlled master plan is required – a 3D vertical master plan.

The feasibility of various financial models for this approach would become apparent, making it possible for developers to realize the full plot value over time. Understanding which potential legal conflicts could arise between built and in-progress developments will also inform the outcome.

Once these realities are addressed, the concept of building vertically through long-term phased increments can hopefully be realized.

Keywords: Adaptability; Construction; Cost; Density; Mixed-Use; Vertical Urbanism

In addition to the authors credited, it should be noted that this topic required input from almost every corner of the construction industry. Since its inception, the concept of the Vertical Master Plan has been greeted with a clear understanding of what this study is attempting to unlock and, more importantly, the will to clearly set out just what the current-day issues are that would need to be addressed in order to realize the full potential of this model of building.

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- Jim Shea (Brookfield Multiplex) on overbuild construction feasibility.

Figure 1: Clockwise from top-left, high-profile tall buildings that have been at the mercy of the marketplace: Empire State Building (New York, 1931); Centre Point (London, 1967); Sears Tower (Chicago, 1973); 1 Canada Square (London, 1992); Burj Khalifa (Dubai, 2010); 110 Bishopsgate (London, 2011); The Shard (London, 2012); 22-24 Bishopsgate (London); The Spire (Chicago)

(Source: Grimshaw Architects)
Cecily Davis, Owen Talfan Davies and John Bowman (Field Fisher Waterhouse) on real estate litigation and the impact of incremental building on quiet enjoyment.

Relevance For Today

The timely aspect of this research relates to the recent economic downturn and how this has been a recurring feature of modern-day western society:

The Economic Downturn:

The recent economic downturn meant that developers were cautious in looking for new development opportunities. They were far more likely to look at building a mid-rise building than a high-rise one in the City. With the resulting lack of confidence and willing tenants in the market, a high-rise development was seen as high-risk. A few examples of tall buildings exposed to conditions outside of their control can be seen in figure 1.

Sustainable City Model:

The current strategy for tall building development operates on the principle of “if you build it, they will come”. This is not sustainable – there is a proven history of tall buildings being completed at the beginning of a period of recession, taking years to gain occupancy. Equally, urban sprawl should be prevented — here, a tall building would in theory be valuable by increasing city densification. In reality, the manner of “sudden” provision does not help. A more steady and balanced model of supply and demand is required. The inability to build at a manageable scale prevents on-going growth at a sustainable level. The top graph in Figure 2 highlights boom and bust cycles within a context of a steady GDP growth - ideally modern economies would mirror the steady line of more predictable, lower-risk growth.

Today’s thinking of developing a commercial site to its maximum potential is to proceed with various feasibility studies and concept designs finding ways to unlock a combination of added value, floor plate/core efficiencies and maximizing the permissible height. Once this is done the developer is then subjected to influences beyond their control - namely prospective tenants and project financing.

Based on the impact of these external influences, the development will either have to be scaled back to fit within the available means or risk being cancelled. If there was a way to minimize the risk, and therefore impact, of these external influences developments could be built at a much more financially sustainable rate.

The middle graph in figure 4 illustrates the current-day practices of development feasibility against how incremental overbuilding could work. The assumption which this study is based on is that this incremental expansion would be within a controlled framework - a vertical master plan. Equally, the bottom graph in Figure 6 highlights another potential advantage of how debt financing could be less onerous in shorter phases rather than one sustained commitment over a much longer period of time.

There are examples of phased construction in existence but are either on a much smaller scale or carried out on a specific case by case reason.

The Reason

Grimshaw completed a concept design, achieving planning consent for a commercial tower building which was within the City of London’s commercial district, stood at a height of 217m (50 storeys) with 1,076,390m² of net-lettable space (as shown in figure 3).

During the project, the developer encountered significant difficulties in securing the required amount of pre-let office space to justify the business case in proceeding with a building of this size. The eventual result was that the final building was 75m (15 storeys) tall and had 592,015m² of net-lettable space. If there had been a financial and physical mechanism to allow incremental release of built office space, this might have been a different story.

This experience has been the catalyst in actively seeking to redefine the master plan design process by assuming a 3-dimensional approach. A 2-dimensional plan based study only conveys the most basic design intentions – to illustrate the proposed urban structure and distribution of land-use. With a 3-D, more holistic, approach, qualitative elements like scale, massing and even character can be investigated, allowing the social success of the master plan to be evaluated as well as urban structure and distribution of land use.
The Phased Tall Building Design Process

Design Principles

The design team agreed principles with which to proceed in order to test the feasibility of this concept.

A height of approximately 90-storeys was decided on as the end condition of the phasing process. This was because a building height in the range of 300 - 400m is a common tall building height being constructed around the world. This approximate height of building is also the maximum that apparently can be constructed in London due to airspace/airport restrictions. A building taller than this would have also required a larger footprint, meaning a larger building site. In other words, the building site and footprint dimensions which we used of approximately 45 x 72 m were suitable for a building up to a height of approximately 400 m using a conventional structure and vertical transportation scheme.

In the first instance, the assumed phasing was set at three phases of 30-storeys each as the assumption was that there would be a desire to keep phasing to a minimum - which is true, but the final decision was made to proceed with multiples of 18-storeys (five phases) as this mirrored the St. Botolph case study and was assumed full redundancy of the first phase.

Feasibility Assessment

Two options were developed in order to start quantifying the effort and reward of a phased building as judged against a traditional base case of “build, demolish and rebuild”.

The first iteration of phased construction assumed full redundancy of the first phase which was reduced as the phases progressed. This approach is the most effective in ensuring minimum disruption to phases below but the immediate concern would be how much extra this would cost compared to a traditional building of the same size. This led to the development of a minimum-redundancy option to counter this perceived weakness.

These three building models form the basis of the feasibility assessment of phased construction compared to traditional building.

Use And Amenity

In terms of mix, office, residential and hotel use was allowed for with nominal retail presence at ground floor and possibly with each phase.

Figure 6 shows the basic sequencing of how a mixed-use tower could eventually develop. Commercial office space was seen as the most onerous use to provide for if it did not have dedicated use of the ground floor plane, other uses (residential and hotel) could allow for a relatively nominal presence at ground floor with the main reception level at the base of the relevant phase. The relationship between residential and hotel would still need careful consideration but could still be considered feasible.

Through incremental building, eventually creating a building over time will be “greater than the sum of its parts”. The roof of first-phase building would act as civic/public ground plane of second-phase building and so on. Equally, the provision of separate single-use buildings in a development would create a multi-use building over time making use of non-commercial spaces balanced over a whole day.

Landlord And Tenant Issues

The phased overbuild approach is intended to allow existing tenants of earlier phases to remain in occupation for the duration of the next phase(s) of construction works. As a result, the

Expected Benefits

Short-Term

- Constant growth: instead of building one super-tall building, a vertical master plan allows a range of mid-rise buildings which plug into a vertical framework.
- No letting complexities: instead of creating a mixed-use building (nearly ¾ of the current top 100 tall buildings are single-use), a vertical framework can incorporate a series of different single-use buildings.
- Developer friendly: this approach allows for a low risk approach to developments within the vertical framework.

Long-Term

- Limited urban sprawl: with flexibility in vertical growth, horizontal growth can be minimized (figure 4).
- City growth with minimized risk: much like an airport’s expansion program, incremental growth in three dimensions will ensure steady growth of a city center with associated diversity of uses.
- Provision of public spaces: with each developer constructing their own building and an obligation to provide their own public space at entrance, a series of public spaces could be created rising up a vertical master plan.
following risk factors will need to be considered. Whilst the vertical plan model assumes that there will be no light disruption to any existing demised premises during the construction of the next phase of the development, it is anticipated that there will be noise emanation resultant from the works of construction.

In light of this, the landlord will wish to ensure that the quiet enjoyment covenant is modified, and that it reserves to itself sufficient rights, so as to permit the proposed works of construction without triggering any liability for breach its quiet enjoyment covenant. However, this will always be a case of a balancing exercise of the landlord’s and tenant’s rights (both at the lease negotiation stage and at the construction stage).

Risks of claims could be mitigated by, for example:

- Limiting the hours of works of construction (e.g. outside of business hours);
- Adopting construction practices that minimize noise emanation;
- Leaving the upper floors of the constructed phase vacant during period of construction works (assuming these floor will suffer the greatest noise emanation issues).

These risks could also be managed through good estate management, for example the first phase could be let on shorter term leases without security of tenure, which can be determined easily in readiness for works of construction on the next phase and then re-let on completion of the works.

Plan Design

As this was a theoretical study, the working assumption was that the site was unrestricted on all sides. This was obviously an optimal situation and were this design model to be developed, understanding the site location and setting would be fundamental to the feasibility of the project.

The first plan iteration was to assume an efficient square shape with a central core (sized for the final phase). This worked on the assumption that the central core areas which were unoccupied by MEP or vertical transportation would be used as shafts to move construction materials up during the next phase’s build process.

As the design process moved on, it became clear that minimizing redundancy within the floor plate was more attractive and reinforced a key principle of the vertical master plan - flexibility. Figure 7 illustrates the plan form that was developed going forward. With further engineering input, this plan was rationalized and became the baseline against which to test the two phased build options.

The top floor of each phase would be a permanent crash deck with a temporary fit-out to create a presentable building top while the next phase was still to be realized. Upon commencement of the relevant phase, the temporary arrangement would be removed and used as a work site and upon completion, would act as a dedicated public realm plane for its phase as seen in figure 7.

Technical Feasibility

Optimizing Construction:

Immediately, the main challenge set is of constructing a new building over an existing one or extending the height of an existing building over an extended period of time:

- Providing a permanent building-site to facilitate building without compromising quality of existing built phases.
- Structure and services built to allow for future expansion.
- Differing feasible options on extending vertical circulation.
- Optimizing prefabrication.

In terms of construction sequencing and building feasibility, in order to be viable, significant elements of the building would need to be fully prefabricated. For example, concrete risers through the building would complicate matters as logistical challenges are created at the base by the need for concrete trucks and pumps. Precast columns, walls and slabs to the maximum extent possible, or hybrid systems with steel would be recommended. Figure 8 illustrates how redundant shafts and a permanent crash-deck could aid the overbuild process.

Other items of note are:

- Personnel and materials hoists would need dedicated shafts (redundant shafts for future phases could provide this).
- Loading bays at ground level would need to be provided.
- Centre core to side cores with transfers are ideal and work with lifting.
- Additional phases will require the MEP to be extended vertically, again best done through pre-fabricated risers and kit that can be set from crane / loaded on to the floor
- Logistically this will need to be planned with minimal disruption to building occupants, as already identified and the strategy needs to be proactive for the duration of possible development.
- The reality of urban development means that, in some instances, access will be more of a challenging constraint i.e. single or dual aspect access.
- New technology of 3D printing and pre-fabrication could very much benefit this approach of over building.

Figure 5: From left to right: a. The building designed through the Vertical Master Plan ideology shown fully assembled; b. Exploded to highlight the five phases and relationships of one to the next via the dedicated communal spaces. c. Many city centre sites experience disruption from adjacent construction sites - this is accepted as being inevitable. d. The level of disruption above an existing development may not be as disruptive when compared to today’s accepted idea of disruption. (Source: Grimshaw Architects)
Pioneering Construction Methodology:

This construction methodology would be unique if it were implemented, although there have been instances of flexible vertical construction in the past but never fully capitalized on like, say, the prefabrication process. Advances in construction methodology in sensitive areas now are so commonplace that the idea of building above an existing building seems very much in reach.

Three examples of this thought process are:

- Roanoke Building, Chicago – was 16-storeys (1915), 21-storeys (1922) now 35-storeys (1925)
- Blue Cross Shield Tower, Chicago – was 33-storeys (1997), now 57 (2007-2010)

MEP Provision

There are three fundamental MEP strategies presented each with merits and shortfalls, when considering disruption and redundancy as criteria for constructing a phased tall building (see figure 9), whilst part in occupation.

There are two common concepts which apply to all the options. These are:

- Plant location: To maximize rental income, identify volumetric space for all plant items which can be accommodated in “no/low rental return” basement levels, regardless of the phase being constructed. These will include: utility intakes, HV sub-stations, generators, boilers, chillers, water storage tanks, sprinkler and wet riser tanks.
- Plant capacity: design the shell & core services on a modular principle. Install modules specific to each phase, with space provision for adding further modules as and when the next phase is constructed. Allows capital cost of MEP to track the phased construction cash flow.

Vertical Transportation

In principle each phase is considered as a separate building, self-contained, but served up from grade level by express shuttles to particular sky lobbies. This is a conventional lifting method for tall buildings but by careful positioning of the shuttles and stacking of the local cores it can be achieved in a space efficient manner without interrupting the tenants of existing, occupied phases.

For this study each phase of offices is typically assumed to be 18 floors and 60,000m² NIA over all the floors. The hotel is assumed to be
a 5 or 6 star and a net occupation on each floor of 18 people.

The apartment floors are assumed to have a net occupancy of 10 people per floor. Figures 10 and 11 illustrate the relationship these floors have to their corresponding users both on plan and diagrammatically.

**Cost Comparison**

What now follows over the following pages is a cost comparison of the three building models and summaries comparing capital cost and income.

**Base Case:**

Each phase assumes that the previous phase will be demolished and the new phase will be built anew. There will become a time when the existing basement or foundations can no longer be used. In this case, the existing piles will need to be extracted prior to the scheme progressing which could have an impact of the final height of the scheme. From a financing perspective, the amount of finance charge is in the region of 20% more than a phased approach. This is a result of the finance being charged on a much higher value for the early part of the borrowing.

**Minimum Disruption**

It has been assumed that all foundation/basement and external works costs relating to the 90 story building will be completed in the first phase. However, this option only allows for construction of the structure and cores required for each phase. Therefore as well as an allowance for the cost ofstripping off the existing roof prior to the start of each new phase, the remedial cost for alterations / building out the additional core space to the previous phase to serve the new phase as also been accounted for.

**Debt Financing**

The debt finance graph in Figure 2 showed the relationship of debt financing when comparing single-build against a phased-build model. The amount of overall finance charge calculated for the single-build scheme works out at approximately 40% higher than the overall finance on the scheme carried out in phased-build. This is partly a result of there being less financial risk on a number of smaller schemes and therefore being able to obtain competitive financial rates. Even if one is able to obtain the same finance rate, the overall finance cost of the single-build approach still works out at approximately 20% higher than the overall finance cost of the phased-build approach.

The reason behind this is that the single-build scheme attracts a much greater level of finance charge over the first few years when the greatest portion of the finance charge is calculated whilst

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**Figure 8:** Building material can be passed through core shafts from a materials holding area in the basement. The use of dry building materials and a heavy focus on prefabricated construction process and DIMA would be key to expediting a quick process and minimal disruption. (Source: Grimshaw Architects)

**Figure 9:** MEP options applied on the tall building after the final phase highlighting how the MEP increments have been provided for per stage and a scoring matrix below showing how these options rate when compared to the two build options of minimum disruption and minimum redundancy. (Source: Grimshaw Architects)
models and summaries comparing capital
What now follows over the following pages

COST COMPARISONS

in this instance is a typical commercial office block. (Source: Grimshaw Architects)
Note the colour coding of the lifts corresponds to the lifting strategy (adjacent page) as laid out. The floor plan shown in this instance is a typical commercial office block. (Source: Grimshaw Architects)

For the purposes of comparison as a BASE CASE, BUILDING 54 FLOORS

Three office entrances
Hotel entrance
Apartments entrance

BELOW 18 FLOORS BUILDING

18 FLOORS BUILDING

1a. Existing Case - Demolish and Rebuild

MINIMUM DISRUPTION phased-build option has been the phased-build scheme attracts a number of lesser finance changes.

This graph had been calculated on the basis that the loan period would have been at approximately the midpoint of when the project breaks even at an average rent of £80/ft² per annum of Net Internal Area. The higher value loans are taken out over a longer period and therefore attracted a slightly higher percentage (6% in lieu of 5%) as a result of the finance risk of fixing the rate over the longer period and the larger loan value.

Summary Of Cost Models:

The result of this from a financing point of view is that the intelligent phasing results in a lower capital cost during phase 1 compared to the unintelligent option, but due to the additional remedial works required, results in an overall greater total cost of construction once all phases are complete. Compared to the single-build BASE CASE, it would seem that the more financially effective approach of MINIMUM DISRUPTION is £50M cheaper to build.

With the single build, one is left to the mercy of the marketplace. During a recession, the market is empty and during boom-time, the duration of construction can be a deterrent when so many places are on offer. The phased-build approach secures tenancies in a more low-risk manner.

The phased approach is based on the developer only proceeding with the next phase once the previous phase has broken

Figure 10: A layout of the plan (above) used to develop both incremental build strategies. The external cores deal with vertical master plan’s lifting strategy moving between phases and the centre is dedicated for phase specific use only. Note the colour coding of the lifts corresponds to the lifting strategy (adjacent page) as laid out. The floor plan shown in this instance is a typical commercial office block. (Source: Grimshaw Architects)

Figure 11: (From left to right by column): For the purposes of comparison as a base case, five floor plans of conventional single-phase build at 18 storeys; 36 storeys; 54 storeys; 72 storeys; and 90 storeys. Each showing the plan configuration at ground floor as each additional building use would be added. A single phase building is purpose designed with no redundancy so therefore becomes the benchmark against which the efficiency of phasing options are measured. (Source: Grimshaw Architects)
Figure 12: Each assessment scenario articulated in 3D with their associated cost analysis alongside (From top to bottom): The BASE CASE; Minimum disruption phased-build option; Minimum redundancy phased-build option Notes: Graphs show the total construction cost at current day (2015) fixed prices for each phase, including on costs, fit out costs, and external works. The demolition costs have been shown separately where applicable. Pie chart shows elemental breakdown of costs as a percentage of total construction costs for each phase. The base case is only shown as a means of comparing build costs against the phased options. In practice a build, demolish and rebuild sequence as shown would never happen. (Source: Grimshaw Architects)
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• Obtaining Planning permission for an
ultimate building that intentionally
lacks certainty of phase timings.
• Valuation of the land, which is
driven by the nature and size of the
proposed development(s).
• Construction methodology that eases
logistics whilst minimizing disruption
to occupiers of previous phases.

Addressing these, and other difficulties are a
pre-requisite to making the vertical master plan not only a practical proposition but
also a viable one. And yet the increased
cost of developing the tall building in
increments has the potential to create a
more attractive commercial development,
whilst providing an inherent flexibility that
can be used to counteract the vagaries of
the property market.

Our analysis shows that against the status
quo of building the ultimate 90-storey scheme at the outset (or demolishing
and rebuilding at appropriate points in
the market to eventually get there), the
construction cost premium of phasing
the tower is approximately 5.4% for the
minimum redundancy option or 3.5% for
the minimum disruption option. These
additional costs are associated with:

• The ‘temporary works’ necessary
between phases.
• The up-front investment in elements
put in place for later phases.
• The complications of constructing
above an existing, occupied
building.

However, the premiums can be mitigated or
even balanced by the lower risks of smaller,
more manageable and deliverable chunks of
real estate – this relative comfort revealing
itself in lower finance costs, reduced void
periods – and possibly lower yields.

Like everything to do with high-rise
economics, success will depend on getting
the fundamentals right, and backing this
up with an attention to detail that de-risks
through thorough planning. This theoretical
phased strategy will clearly need such
planning, but it is founded on such logical
financial metrics to make it a compelling
proposition worthy of more detailed work.

Conclusion

The graphs on the previous page are
more a demonstration of exposure to risk
more than anything else. Both methods of
building (single-build and phased-build)
are ultimately the same size and using
similar rental rates they will break even
within a similar period, however the single
build approach carries a lot more risk
than the other. Conversely, once phase 3
is developed, there is very little financial
exposure. Reducing the risk profile of a
development must go some way to a more
stable growth system.

Towers are all about a ‘heightened’ and more
intense risk-reward relationship. The scale
and complexity of the larger, more iconic
endeavors makes them hostages to the
fortunes of time in particular. The greater
the building and the longer the overall
program, the more difficult it is to secure the
services of a supply chain with the necessary
skills / appetite; to accurately forecast price
inflation; to predict occupier demand.

Phasing a tower is a fundamental response
to this dilemma, but is largely (though
not completely) unprecedented, and not
without some obvious challenges, not least:

Figure 13: Graph sequence demonstrating exposure to risk (Above, from top to bottom): Summary assessment of the
three cost models showing both phased options performing similarly and both being marginally cheaper than a single
phased build. An income vs capital expenditure comparison regarding conventional single-build. Three scenarios are
depicted to illustrate the profound influence market conditions have on the construction industry. A similar income
vs capital expenditure comparison for the phased-build approach. No fluctuations regarding market conditions are
shown. (Source: Grimshaw Architects)