Title:	**Adopting a Program Management Approach to Maximize the Benefit of "Vertical Cities"**
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Subjects:	Construction Economics/Financial Security/Risk
Keywords:	Construction Life Safety Megatall Project Management Risk
Publication Date:	2015
Original Publication:	The Middle East: A Selection of Written Works on Iconic Towers and Global Place-Making
Paper Type:	1. Book chapter/Part chapter 2. Journal paper 3. **Conference proceeding** 4. Unpublished conference paper 5. Magazine article 6. Unpublished

Adopting a Program Management Approach to Maximize the Benefit of "Vertical Cities"

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Tall building construction can benefit from a programmatic approach. By looking at the overall development as a whole program of works, identifying the deliverables required to achieve desired business outcomes, managing the interfaces with the surrounding infrastructure, and establishing robust planning and scheduling the bigger picture becomes clearer, as does the route to benefits realization. Supertall buildings and surrounding developments are unique projects facing unique risks; risk management is at the core of this programmatic approach. Focusing on trends, forecasting, and actively managing and mitigating the risk from the outset will have tangible, measurable, and beneficial impacts on the outcomes for the development and the wider city environment.

Tall buildings are bigger, better, faster, and more prevalent than ever. Driven by rapid growth in Asia and the Middle East, the race among the world's cities to build the tallest, ultimate record-busting skyscraper on the planet is fast and furious. However, once built, these skyscrapers leave a legacy city beneath. Whether in the form of an open landscape for development around the Kingdom Tower in Saudi Arabia, or a city prime for redevelopment in the shadow of the Petronas Towers in Kuala Lumpur, a programmatic approach to design and development can ensure this legacy is overwhelmingly positive.

Well-executed skyscrapers can be a real economic-development driver. The Petronas Twin Towers in Kuala Lumpur, built in 1998, were the world's tallest until it was eclipsed by Taipei 101 just six years later. While they may no longer be the tallest buildings in the world, the towers successfully changed the perception of Kuala Lumpur worldwide (Bremner, 2007). These world class vertical buildings raise the bar for other buildings in the city be they malls, office blocks, or hotels.

There is no doubt that "Supertall" and "Megatall" represent a new vision of vertical urbanization, but as the race for grandeur surges, so does the risk and disruption caused by our increasingly unstable and rapidly changing planet. The unthinkable is no longer unthinkable. Some of these threats remain unforeseeable and outside of our control. The most effective way to ensure successful and safe delivery in

Left: Dubai skyline with Burj Khalifa. (cc-by-sa) Jan Michael Pfeiffer

this unpredictable climate is by taking a commercially led programmatic approach.

By looking at the development as a whole program of works, identifying the deliverables required to achieve desired business outcomes, managing the interfaces with the surrounding infrastructure, and establishing robust planning and scheduling, the bigger pictures becomes clearer. So too does the route to benefits realization. Supertall buildings and surrounding developments are unique projects facing unique risks. Minimal deviations from plan are compounded and can have major implications on the overall performance of the program. Performance management is at the core of this programmatic approach identifying performance KPIs that capture key trends. Enable progress forecasting and the active management of risk from the outset will have tangible, measurable, and beneficial impacts on cost, schedule, quality, and health and safety.

Location

The location of a vertical city can be a challenge and also a key opportunity. When looking at the global landscape of vertical cities, over the past 50-60 years we have seen an eastward shift in the geographical makeup of the world's tallest buildings, corresponding to the economic emergence of these nations. It is evident from the high-rise trends in the Middle East and Asia that these regions use architecture to demonstrate the development and achievement of their nations. These dynamic structures also identify opportunities in the development, or indeed the redevelopment, of the cities surrounding these vertical metropolises.

In countries like China, tall buildings are an effective way of housing large numbers of people, as the population migrates from the countryside to the cities. In the Middle East, tall buildings are more of a statement of intent. The Burj Khalifa represents Dubai's push to become a world city, and the costs of its construction need to be set against that bigger picture (Langton, 2013). On its own the building represents valuable real estate, but the 828-meter-tall structure, which includes apartments and a luxury hotel, is not simply an expensive marketing tool for the Emirates.

The "wow" factor of being in the shadow of the tallest building on Earth has pushed up land values all around the Burj, creating an economic ripple effect that benefits the whole city. Emaar Properties, the developer behind the Burj, have made it the centerpiece of a new business and residential district, charging a premium for properties with clear views of the skyscraper. Even if the Burj Khalifa had failed to turn a profit, its presence has raised the surrounding property value enough to more than offset the difference.

Table 1 shows the average sale and rental rates across selected developments of Dubai. Among the list of developments, highest rates are achieved for properties in the Downtown area.

Conversely, one notable oversight on the Burj development is the public transportation links. In the hot Arabian sunshine, a 1.5-kilometer walk from the nearest metro station to the iconic landmark and adjoining Dubai Mall is a result of poor planning and insufficient interface management. The distance may seem negligible, but in the height of the summer, when temperatures can reach above 50°celsius, the walk is unbearable. The benefit of developing a city in an emerging market that has a relatively flexible landscape with an evolving public transport strategy is to link the two together, promoting the use of the new metro and creating ease of access. Taking a programmatic approach to the whole development would have built this functionality in at an earlier stage.

The Triple Bottom Line

A tall building is not only iconic in design but economically, socially, and environmentally impactful. But can a tall building ever be sustainable? We are no longer in the age of the high-rise urban ghettos of the latter half of the 20th century. Tall buildings can offer unparalleled innovation and exhilaration with a flurry of technological advances that enable skyscrapers to be just as green if not greener than their low-rise counterparts (Ijeh, 2015). There is a balance required between creating a truly iconic development that attracts investment, tourism, and promotes a city brand, ultimately warranting higher rental income, while building sustainably, environmentally, and economically.

The industry is becoming increasingly aware of the costs and benefits of building "green." Knowledge in this area is advancing

	OFFICE - SALE RATES (AED/FT^2)				RESIDENTIAL - SALE RATES (AED/FT^2)				RETAIL - RENTAL RATES (AED/FT^2)			
Development	**Low**		**High**		**Low**		**High**		**Low**		**High**	
Premium Area (Burj Khalifa)					Difference							
Downtown Dubai	1,750		2,350		1,800		4,800		180		325	
Other Dubai Areas		Difference		Difference		Difference		Difference		Difference		Difference
Dubai Marina	1,575	10.0%	1,900	19.1%	1,300	27.8%	2,775	42.2%	130	27.8%	250	23.1%
Dubai International Financial Centre	1,700	2.9%	2,000	14.9%	1,650	8.3%	2,150	55.2%	165	8.3%	210	35.4%
Jumeirah Lakes Towers	1,175	32.9%	1,450	38.3%	1,150	36.1%	1,650	65.6%	120	33.3%	180	44.6%
Palm Jumeirah	NA		NA		1,400	22.2%	2,750	42.7%	NA		NA	

Table 1: Average sale and rental rates across selected developments of Dubai in 2015, sourced from CBRE. Source: ARCADIS

Opposite Top : The five principles of program quality assurance. Source: ARCADIS

Opposite Bottom: The Kingdom Tower approach to health, safety, and environment. Source: ARCADIS

rapidly and the higher visibility, status, and design quality of tall buildings means that they are often the forefront of research and implementation of sustainable strategies. The adoption of LEED-type methods are helping to develop the efficiency of individual buildings as "products", although many of these methods do not go far enough to account for operational use of the building and its impact on the environment.

The U.S. Green Building Council's LEED system ranks buildings on factors such as building materials, water efficiency, and indoor air quality. Based on some of these criteria, many tall buildings have been labelled "green" and some have attained the council's highest rating. Tall towers should have much greater resilience and last long enough to justify their huge cost. However, post-occupancy factors, such as energy consumption, can be less sustainably virtuous. The behavior of residents and tenants of a sustainable facility plays an important role in reducing impact on the environment. These are the factors that are difficult to calculate during construction. By looking at workspace strategy early in the process, systems can be designed that encourage people to engage in conservation and recycling. Defining sustainability and what kinds of behaviors are expected or required of residents in a sustainable skyscraper is essential for their long-term environmental viability.

Many key factors need to be taken into consideration as early as possible to ensure a safe and efficient building is delivered not only within time and to budget, but that also allows benefits to be realized and business outcomes to be achieved. The delivery of major buildings is becoming ever more complex, driven by legislative change (sustainability), technological change (Building Information Modelling - BIM), or the continuous fragmentation of the design/procure/construct process. This complexity is compounded for vertical cities where the systematic analysis, mapping, and management of the interdependence between individual activity and tasks is magnified.

The role of the Program Manager is to create the right 'controls' to inspire the team to deliver the required quality and innovation that tall buildings demand, but within a controlled and risk assured delivery strategy. Five principles of program quality assurance are defined for use on the Kingdom Tower.

Health and Safety Assurance

Building tall represents many risks and as a result health and safety should always be foremost in any construction project. Building a vertical city requires consideration of the risks, as does any other construction project, but there should also be a focus on key areas such as working at height, complex lifting operations, access and egress arrangements, perimeter working, and fire and emergency preparedness. Mitigation measures for these key hazards must constantly be reviewed, updated, and tailored to ensure that the risks of working on a high-rise development are being adequately managed via positive health, safety, and environment (HSE) strategies.

As an example the following eight key fatality risks have been identified on the Kingdom Tower in relation to the construction methodology:

- Lifting operations
- Work at height
- Shaft and riser works
- Building perimeter works
- Edge protection
- Fire
- Electric shock
- Falling materials

For each of these fatality risk areas prescriptive risk control standards are then developed which are incorporated into the safe systems of work. The application of the standards can be audited to assure compliance.

Of specific importance in the Middle East is the need for behavioral leadership. The Behavioral Management of Safety (or BMOS) integrates behavioral strategies and processes into health and safety management systems. Working at all levels of a project or program, BMOS analysis promotes safer behavior and environmental conditions to deliver continuous improvement in health, safety, and business performance. A BMOS program creates a systematic approach that defines a set of behaviours to reduce the risk of work-related injuries. This is achieved by collecting data on the frequency of safety critical behaviours and providing feedback and reinforcement to encourage positive behaviour. The data is also used to identify root causes, facilitate problem solving, and develop recommendations for continuous improvement with particular emphasis on improving communication and awareness at all levels.

Focus on Design Innovation

The viability of any development is dependent on costs verses revenue. These factors get ever more complex when building tall. Typically, as the height of a building increases so does the cost of construction. Many of the challenges faced in the development, design, and construction of tall buildings focus on finding innovative responses to mitigate risks associated with the key cost drivers, these must be identified early.

Buildings like the Kingdom Tower could remain the exception rather than the rule as cost is the major obstacle preventing developers going much beyond the one-mile mark. It isn't the engineering, but the economics that is holding back the development of more tall buildings. The reason that many skyscraper schemes never come to fruition is usually the business

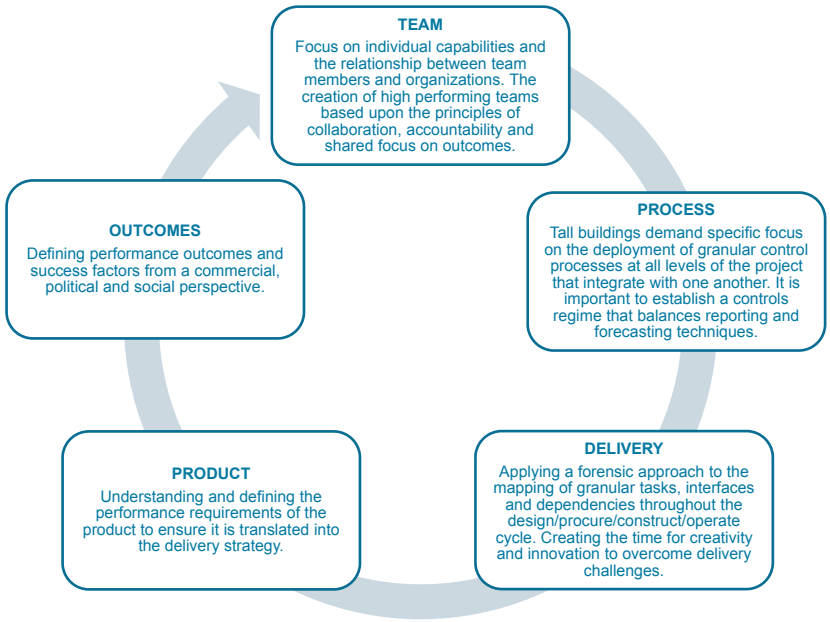
"Supertall buildings and surrounding developments are unique projects facing unique risks. Minimal deviations from plan are compounded and can have major implications on the overall performance of the program. Performance management is at the core of this programmatic approach."

plan. Every time you increase the height, the volume increases by several times more. The Burj Khalifa is a good example of how to mitigate having too much space to sell by keeping the building as slim as possible. This can be measured and monitored throughout the design process by using a programmatic approach and analyzing the building's useable space to keep the design in line with the desired outcomes.

BIM and other virtual construction services are a critical part of executing skyscrapers. Using these techniques means more efficiencies and accuracy in pre-construction planning and strategies, and equally important, during construction. In addition to innovative methods for coordination of structural and mechanical engineering, information can be extracted from the model to facilitate estimating, procurement, clash detection, and field management. The 3D model can be used to identify and avoid safety hazards. The use of this technology can enhance our overall productivity, provide instant clarification, and offer important cost savings in high-rise construction.

Prefabrication is not a new concept, but architects and engineers are tuning their hats to the concept of prefabricated skyscrapers to promote innovation and "lean construction." Due to the repetitive nature of supertall construction, even small improvements can have big effects if integrated early enough. Simplifications of design, details, and construction methods can save a lot of time and money if managed effectively and efficiently at the front-end. However, innovations need to be balanced with reliability. Fully exploring these innovative solutions from the start is fundamental to actively assessing, managing, and mitigating the risks.

On the Kingdom Tower, innovative piling techniques were implemented by using a 110-meter Kelly Bar, manufactured for drilling rigs. This removed the need for extension pieces to be inserted during drilling



Bottom: Computerized drilling rigs used on Kingdom Tower. Source: ARCADIS

Opposite: 3D Logistics Model for the Kingdom Tower. Source: ARCADIS

Regime	KPI	Outcome
Contractor Submittals with specific focus on: Design Drawings Shop Drawings Materials	Duration to complete review Approval status	Engineer performance Contractor quality
Requests for Information	Duration to answer RFI	Engineer performance Consultant performance
Non-Compliance Reports (NCRs)	Number of NCRs issued Number of NCRs closed	Contractor performance Construction quality
Site Productivity	Floor Cycle duration	Contractor performance
Site Inspections	Readiness for Inspection Approval status	Contractor performance Construction quality
Health & Safety	Accident Frequency Rate	Construction safety

Table 2: Kingdom Tower Program Management controls framework. Source: ARCADIS

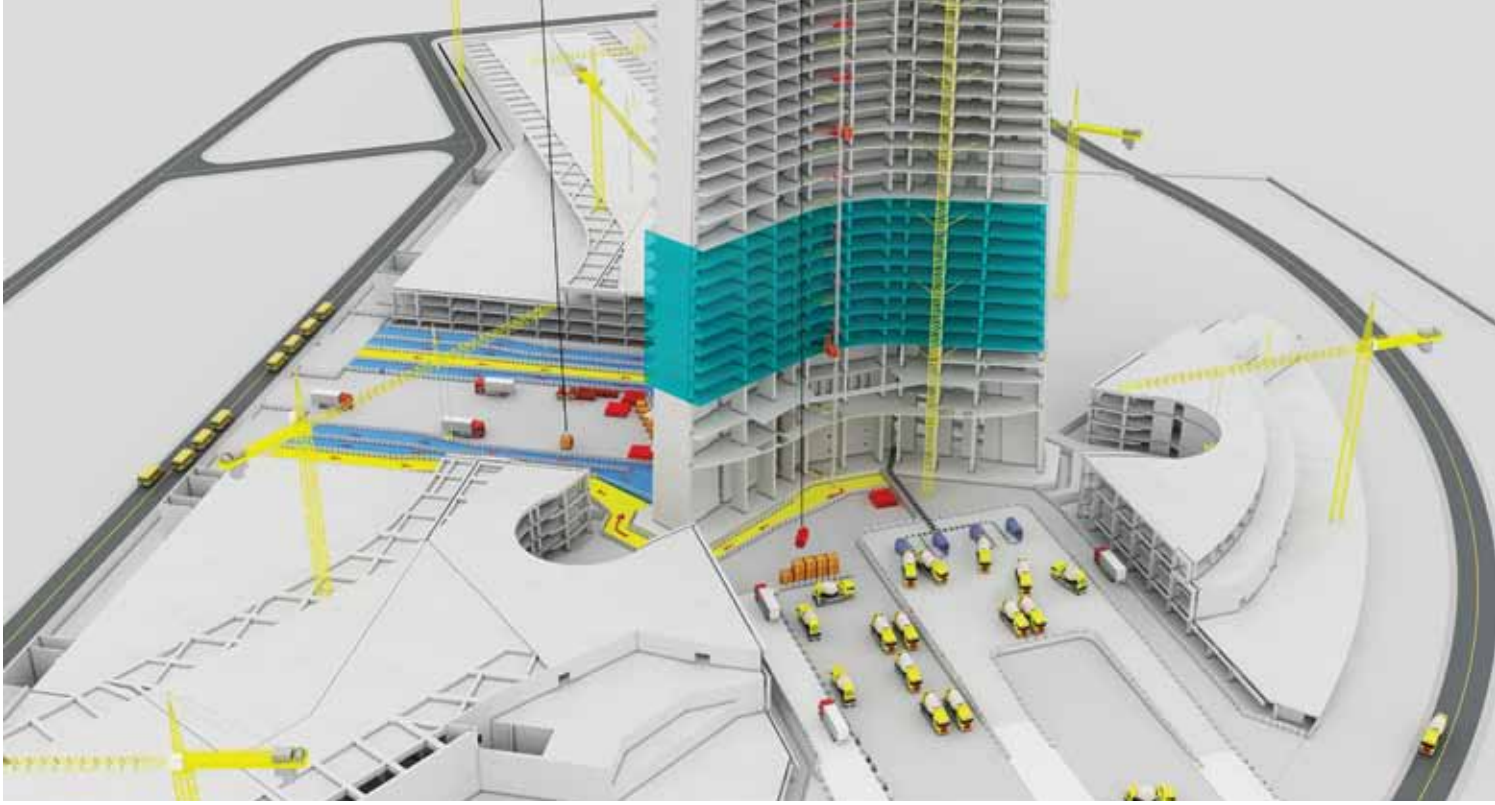
operations, and cut cycle times for depths down to 100-meter, a reduction of 50% – saving approximately 70 working days.

State of the art computerized drilling rigs were used, which bettered tolerance targets by 50%. On-site fabrication of all reinforcement cages ensured quality of fabrication and consistency of supply in order to maintain schedule. Environmental factors were also considered by recovering the drilling fluids, which were then stored in site tanks and recycled using dedicated temporary storage pond.

A key consideration in the design of a vertical transportation system in tall buildings is to reach the optimum balance between the quality and quantity of lift service provided the capital cost of the lifts themselves and the loss of revenue-earning, tenantable space taken up by the provision of lift cores and plant rooms. This becomes even more critical as buildings become taller than 50–60 stories.

The type of vertical transportation system is often linked to the specific use of the building and may facilitate the requirement for sky lobbies. Double decker lifts, a relatively new technology, have been used in many high-rise developments to provide efficient solution to minimize tower core area requirements and meet passenger requirements.

The challenge of moving people up and down such tall buildings is one of the reasons why the prospect of a mile-high building becoming a reality appeared almost impossible until the unveiling of the



Kingdom Tower design. The longest distance it is currently possible to travel in an elevator is 504 meters, up to 638 meters in the Burj Khalifa; however the Kingdom Tower will contain 57 elevators and 10 escalators and the highest elevator will rise 660 meters, with the world's fastest double deck Elevators which ascend at 10.5 m/s from the lobby to the observatory level. This is made possible by using carbon-fiber rope technology (Kone Ultrarope).

It is challenging for elevators to go faster because of the rapid change in air pressure over such a distance. Early appraisal of options and development of a strategy that meets specific requirements of building design is critical to avoid costly late design changes or delays caused by inefficient ways of working.

Performance Management

The adoption of quality controls processes and approaches need to identify and forecast the root issues that may have a negative effect on schedule, cost, quality and overall performance. These could be human, personality or system issues which are slowing things down or preventing quick implementation. If necessary, issues may need to be micro-managed and micro-monitored until they are back on track.

Constant and clear communication of intent throughout the team is essential to create a culture that is focused on the expectations and outcomes. Early identification of the key trends to be monitored and forecasting KPIs will enable the analysis of progress and predict scenarios. On the Kingdom Tower, a specific performance management regime has been adopted to identify trends and forecast outcomes, as seen in Table 2. This is of specific concern for tall buildings, where the compounded effect of delay to an individual task can have exponential consequences.

In addition to traditional schedule and cost reporting, performance data on the Kingdom Tower is captured on a weekly basis and outcomes are presented in weekly and monthly dashboards. Performance issues are further analyzed and appropriate actions identified to reverse negative trends. This micro-management identifies root causes at a more fundamental level and provides key insight into performance.

Construction Logistics and Operational Readiness

Logistics planning is critical for construction speed. There is a bottleneck at the base of every building built where manpower and materials enter and leave the building. This issue is magnified in the construction of tall buildings where peak flows of resource need access to the vertical site. Adequate hoists must be installed and their use must be meticulously managed.

Experience in operational readiness has proven that it is essential to integrate the "opening and operation strategy" into the design and construction schedule. Early stakeholder engagement with the end users and appropriate authorities is required to meet and manage expectations and avoid delays.

For the Kingdom Tower specific areas of focus have been:

Considerations for Permeamble Cladding Systems Analysis

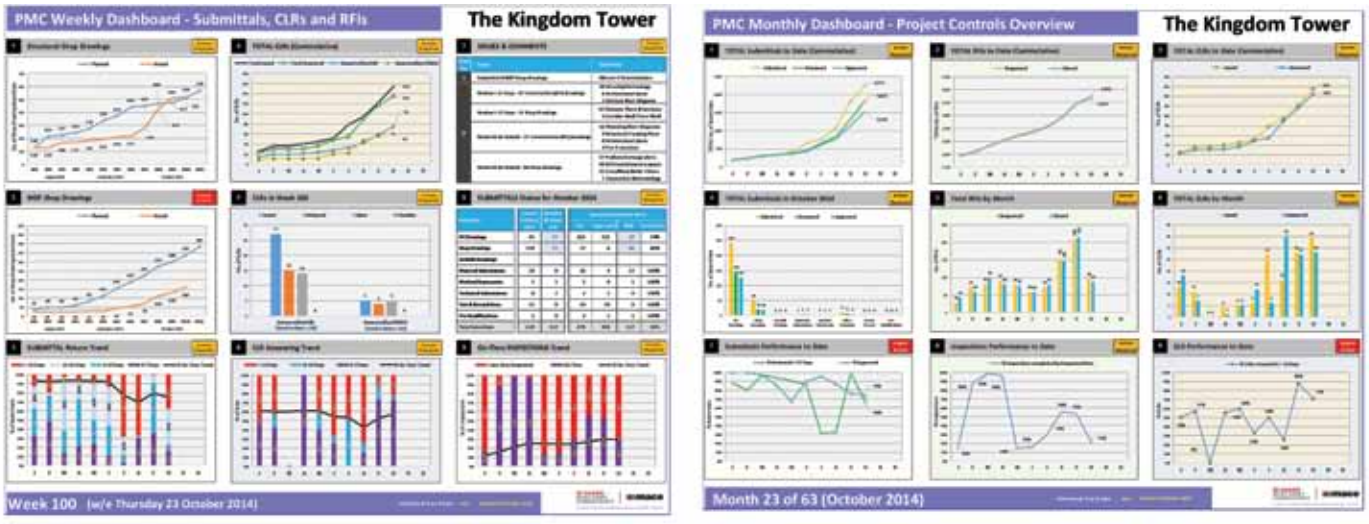
Not all systems are equal when it comes to onsite installation and coordination with other trades. Analysis on tall buildings brings a clear focus on hoisting, stocking and area requirements, all of which have an economic effect to the installed system. Emphasis must be placed on buildability, the management of onsite work area requirements and the simplification of systems. Efficient and effective planning of servicing, repair and replacement must be considered along with appropriate "stack effect" planning.

Site Logistics/Crane and Hoisting Scheme

Logistics planning is key to streamlining material movement to workface and eliminating redundant or inefficient labour. It is critical to engage with the design team very early in the process to identify areas for material deliveries and ensure worker welfare is meticulous planned.

There is a significant cost associated with cranes and lifting strategies. The Kingdom Tower uses "jump lifts" which were invented for the Sears Tower in Chicago. By utilizing this system, hoisting is contained within the core, eliminating the need to close up curtain-wall sections out of sequence. This technique is not only lower in cost, but it also means that the interior hoist is not affected by external weather conditions.

Bottom: An example of the monthly testing done to oversee the project management of the Kingdom Tower. Source: ARCADIS



Procurement Methodology and Timing

Tall buildings are unique, requiring inventive solutions that are at the cutting edge of the industry. Using manufacturers to help deliver these solutions can offer an innovative buildability advantage. This innovation, if properly procured, can be brought in during the design strategy without impacting competitive tendering. This procurement process must be clearly mapped out in advance with a specific emphasis on requirements for design input, proprietary products, phased procurement and site logistics.

Schedule and Trade Sequencing

On tall buildings, there are a number of trades that have to work sequentially and vertically. The most efficient approach is to plan the critical trades from floor to floor, trailing trades at the same pace, creating optimum vertical sequencing. This coordinated approach allows results in improved production rates and better quality control.

Design aspects can often inhibit the optimal pace, identifying this early means that adjustments can be made to improve constructability. For example, the core of the building is the main pacesetting trade, simplifying the core will save time and money by setting a faster leading pace.

Construction Quality Control and Assurance

Quality control and assurance is key to setting expectations, working within tolerances and creating repeatable sequences. Construction quality can be assured by designing these into the details and building in regular schedule checks. It is critical to carry out performance testing as early as possible, ensuring that shop drawings are coordinated and that the right mock-ups are being produced.

Manufacture/Offsite Pre-Assembly

Manufacturing offsite and using techniques for pre-assembly can save money and time and promote quality control. It is critical to assess the site logistic and hoisting plans as this will determine the extent of off-site assembly.

The Kingdom Tower curtain walling design is a high performance system similar in specification to the Burj Khalifa. The complex system, which comprises over 33,000 curtain wall panels, is being manufactured and assembled offsite to simplify and streamline on-site installation.

Material and Tradesmen Availability

Early awareness of market constraints and capacities means these restrictions can be accommodated by adapting design solutions. Designing to promote competition is key and it is critical to secure commitments from trade contractors and material suppliers early.

Tolerance and Movement

Tall buildings are designed for their completed configuration. However, during construction a building may have higher degrees of loading than the finished product. It is more cost effective to design with the construction sequencing known, rather than build in excess capacity at additional expense that may never be utilized. Coordinating cumulative trade tolerances and deflection criteria, accommodating for lateral and thermal movement, and planning for differential movement can help to identify the construction sequence and allow the building to be designed accordingly.

"On the Kingdom Tower, a specific performance management regime has been adopted to identify trends and forecast outcomes. This is of specific concern for tall buildings, where the compounded effect of delay to an individual task can have exponential consequences."

Interior Development Phasing/Tenant Special Requirements

These can have a big impacts on MEP and structural design requirements. Identifying them as early as possible and accommodating for them within the design will eliminate risks to schedule, cost, and quality, removing the need for retrospective structural coordination and other costly changes.

Commissioning and Occupancy

The testing and commissioning strategy must be considered early, so the opening and operation strategy can be integrated into the schedule. The construction schedule must be driven by pre-commissioning and start early with progressive sign offs. The coordination and integration of life safety and shaft pressurization; flushing of chilled water system; and system integration testing, validation, and handover can limit or eliminate the cost of temporary and/or retrofit work. The impact of this is heightened on tall buildings due to the intricate and innovative nature of their designs.

Maximizing Benefits through Program Management

Program Management provides substantial measures of stability, clarity, and certainty. The application of sound Program Management principles when building an iconic tall building provides the discipline, organization, structure, and processes to manage and mitigate risk while also creating the environment to drive design and construction innovation. The result is the creation of exceptional buildings and outcomes, the larger and more complex the challenges, the bigger the benefits.

Tall buildings have challenged technology itself and allowed us to build towers more efficiently and sustainably, and to create internal environments that are comfortable, productive, and energy-efficient. The prevalent green movement has propelled the design of high performing tall buildings to employ intelligent technologies and smart materials. Optimizing a design for efficiencies can shorten the construction schedule, easing the financing costs and reducing the risk of price rises during the construction phase. Greater savings can be made through phasing of works to allow works to be carried out concurrently and allow staggered opening, including the possibility of earlier income streams. Maximizing buildability requires the early, intensive interrogation, planning, and scheduling of the development, with detailed consideration of alternative methodologies.

It is critically important to first understand the business goals and objectives, rather than hastily launching the delivery of technical services. Program Management can deliver these iconic skyscrapers and their surrounding cities safely, efficiently, and at speed by providing a quality control and assurance framework.

Very small deviations from plan can have a significant bottom line impact. It is not enough to manage to time, cost, and scope of work without understanding the critical interdependencies and risks unique to delivering vertical cities. Investing in a Program Management approach from the beginning will undeniably ensure that not only are the outputs achieved, but benefits are realized as well.

References:

Bremner, B. (2007). **"The Race for the Tallest Skyscraper"**, Bloomberg Business Week 01 May. Available from: <http://www.bloomberg.com/bw/stories/2007-05-01/the-race-for-the-tallest-skyscraperbusinessweek-business-news-stock-market-and-financial-advice>.

Ijeh, I. (2015). **"Can Tall Buildings Ever Be Sustainable?"**, Building Design Online 25 February. Available from: <http://www.bdonline.co.uk/can-tall-buildings-ever-be-sustainable?/5074042.article>.

Langton, J. (2013). **"Kingdom Tower, Burj Khalifa and the Era of the Megatall Buildings"**, The National UAE 18 March. Available from: <http://www.thenational.ae/news/uae-news/environment/kingdom-tower-burj-khalifa-and-the-era-of-the-megatall-buildings#page2>.