MMLS: The Future of Vertical Transportation for Tall Buildings

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Abstract. Multiple academic papers and articles point to vertical transportation quickly becoming the "roadblock" to the viable design of super tall and mega tall buildings, despite the development of light weight ropes, high speed drives and advanced control algorithms. The space take of traditional elevators with only one or two cars per shaft is onerous and the obvious solution is to develop a system in which multiple cars can safely travel within a single shaft. The technology required to undertake the construction and delivery of the first MMLS (Multi Mobile Lift System) is now around us and, given the overwhelming business case for such systems, is more than paid for by their space saving capabilities. It is now simply a question of when, not if, these systems become safety certified for public use. This paper looks at rudimentary planning of such systems and reviews some of the practical aspects of how such systems might operate in the coming years.

1 INTRODUCTION

Perhaps the goal of being able to offer the world a Multi-Mobile Lift System, meaning a vertical transportation system with multiple lift cars travelling in one shaft, each car being independently speed controlled, could be described as the "holy grail" of the lift industry today.

An MMLS that can operate achieving:

- Overall system energy efficiency of greater than 90%
- Car capacities of, say, minimum 21 person/1600kg capacity
- Safe deceleration with the removal of power when cars are travelling at high speed, and
- Demonstrate easy emergency release of passengers from cars with no power available

will surely prove very attractive given a reasonably sensible commercial offering.

The author does not propose to review the "business case" for such systems as this has been well covered by previous papers [1, 2]. It should be understood, however, that the reason that so-called mega tall buildings are almost all of a similar tapering shape is because of the inability of today's lift systems to move large numbers of people to extreme heights.

2 COMPARISON OF HANDLING CAPACITY

Some simple comparisons between conventional lift handling capacities and MMLS can act as a reference point for the start of a rudimentary analysis of both approaches.

The current limitation on conventional lifts is of the order of double deck 1800kg/24 person lifts travelling at an average speed of 10m/s up to a maximum of 600m height. The round trip time for such a journey is of the order 180s which means that its theoretical handling capacity per round trip in one way traffic is 38 persons (2 x 80% x 24 persons) or 63 persons per 5 minutes (300 seconds).

Given that we need to achieve an average interval of 30s or less we would need a minimum shuttle group size of six lifts. Therefore with a bank of six shuttle lifts we could move 63 x 6 = 378 persons per 5 minutes. This would mean we can only handle a maximum population of around 2,700 persons at the upper sky lobby based on a 14% 5-minute up peak handling capacity.

A multi-mobile lift system requires a minimum of two lift shafts because, as they say, what goes up must come down!

By comparison a similar car capacity in an MMLS scenario, given similar passenger loading time of 0.9s per person we could, nominally, dispatch a car every 25s. The average interval being controlled by 19 persons loading the car (17s) plus door open and close times (4s) and time for car to move away (4s). In 300s this gives us 12 cars of 19 persons or a 5-minute handling capacity of 228 persons per pair of shafts. With six lift shafts i.e. 3 MML systems we have a handling capacity of 228 x 3 = 684 persons per 5 minutes. This would mean, on a similar basis as above, we could handle a maximum population of around 4,900 persons at the upper sky lobby.

Therefore what we can take from this simple example for a 600m high destination is the following:

1. MMLS can give us a notional 80% increase in 5-minute handling capacity over a conventional lift solution to a destination 600m above ground.
2. Just one MMLS can give us an adequate "quality" of service of around 25s.
3. Conventional shuttle lifts would need to be employed in groups of six or more to address the need for adequate "quality" of service.
4. MMLS can give us the same handling capacity whether the destination is 60, 600 or 1200m above ground.
5. MMLS has no requirement for high speed and, in point of fact, speed will only influence journey time.
6. For destinations involving hotels and/or residential facilities the conventional solution loses handling capacity since time needs to be added for passengers boarding and alighting the cars to travel in the opposite direction albeit at lower flow rates.
7. MMLS has equally high handling capacity in both directions with no degradation in 5-minute handling capacity.
8. MMLS also offers the prospect of finally being able to interconnect between multiple sky lobbies and give the user a seamless and direct route to all key facilities in the building.

3 A 1,000M TALL BUILDING

In 2016 the author embarked upon an ambitious project to look at the potential lift solution for a 250 floor multi-use building standing 1,000m tall.

The purpose of the exercise was to verify if MMLS could provide the building and the design team with a commercially viable solution that would mean that there was a real payback or "Return on Investment" for even the uppermost floors of this proposed 1,000m tall building.

The vertical city proposed would contain everything needed for day to day living, working and leisure activities including:

- Apartments and "villas"
- Office space in various formats with marketing suites, exhibition halls, lecture theatres, meeting rooms and business centres
- Hotels
- Leisure facilities including theatre, cinemas, night clubs, piano bars, pubs, restaurants, museum, 10 pin bowling, fitness centres, spas, gyms and yoga retreats

- Healthcare facilities including GP facilities, dentists, chiropractors, physiotherapists, counselling and day surgery facilities.

The scale of the building would represent a small town of around 32,000 people. It is perhaps of interest to note, as regards the proposed stacking of the various uses and tenancies, that MMLS enables us to “break the rules” of the past with there no longer being the necessity to place the most densely populated floors at the base of the building.

We know that we cannot realistically expect building users to take more than two lifts to travel from the building entrance to any floor in the building. It should be noted, however, that this may not be the case with inter-floor travel since the building user may need to access a sky lobby (one lift journey) then make an inter sky lobby journey (second lift journey) and, finally, a last local lift journey to their ultimate destination.

By arranging, nominally, five 50 floor zones (all stacked one on top of each other) we have a 250 floor building with four upper sky lobbies with a nominal 4m floor to floor distance throughout. Then, by choosing 50 floor zones we know we can organize direct service to any floor from the sky lobby and not need intermediate sky lobbies within the 50 floor zones that, for now, could be all be served by conventional lifts. All floor plates assumed to be 2,500 sq m Net Internal Area.

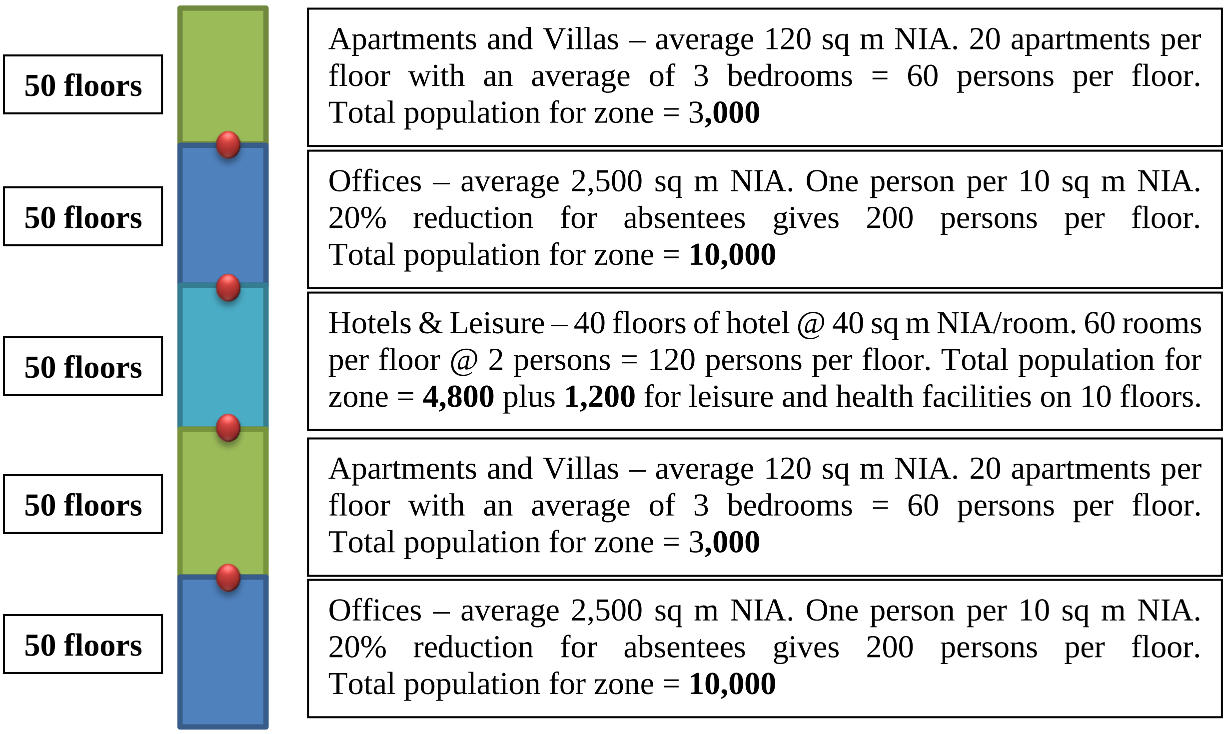

Figure 1 Stacking Use of 1,000m Tall Building

The above shows the notional uses of each sector of the 250 floor building. The idea of delivering 10,000 office users to a sky lobby 600m above ground would be extremely difficult with a conventional lift solution because, as was previously noted, if we wanted a 14% 5-minute handling capacity of 1,400 persons we would need 1400/63 = 22 lift shafts for sky lobby shuttles alone!

4 INITIAL TRAFFIC ANALYSIS

During the typical morning peak the demand for both “up” and “down” lift service in the building could, perhaps, be summarized as follows:

Type of Use	5-Minute "Up" Demand	5-Minute "Down" Demand
Offices	14% x 10,000 = 1,400	
Hotel and Leisure	6% x 6,000 = 360 *	6% x 6,000 = 360
Residential	5% x 6,000 = 300 *	5% x 6,000 = 300

* Likely to be limited "up" demand during morning "up peak".

Table 1 Aggregate Demand for Shuttle Lift Service

Based upon the above we have a theoretical 5-minute "up peak" passenger demand of approximately 2,060 persons but for the hotel and residential sector this is likely to be limited as peak demand for "up" traffic will be in the evening when the office workers are leaving the building.

One MMLS system (comprising two shafts) we indicated earlier would have an approximate handling capacity of 228 persons. Therefore, in aggregate, if we say we require approximately 1,400 plus 400 for the other uses we would need 1,800/228 = 8 systems i.e. 16 shafts for the entire upper building population above the first 50 floors.

5 CIRCULATION CONSIDERATIONS

We know our theoretical traffic simulations and calculations are based upon 5-minute passenger flow rates approximately double the "real world" maximum passenger throughput i.e. 12% plus versus around 6% or so measured in the peak 5 minutes in office buildings.

Planning of circulation spaces and security turnstiles etc is for the most part related to "real world" peak passenger throughput and circulation planning guidance provided by, for example, the CIBSE Guide D 2015.

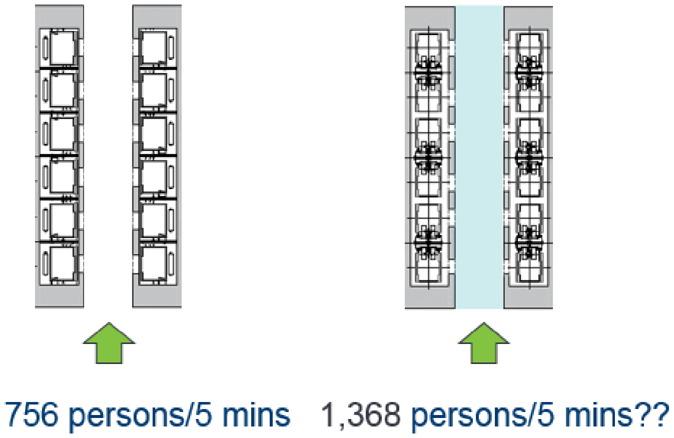

Figure 2 Comparison of Potential Passenger Flow Rates

Conventional System (left) versus MMLS (right)

If we consider we have, on the left in Figure 2, two conventional groups of six shuttle lifts each having an average interval of 30s we know that the theoretical handling capacity equates to approximately 378 passengers per 5 minutes per group per deck. Since "real world" passenger throughput is about half this we can approximate the passenger flow into this lobby space to 189 passengers per 5 minutes. Indeed this flow rate would best be arranged as 95 persons into the lobby at each end.

In Figure 2, on the right, there are six MMLS in one lobby each having a theoretical handling capacity of 228 passengers per 5 minutes then this equates to 1,368 passengers per 5 minutes. The “real world” passenger throughput is about half this so it would equate to 684pax per 5 minutes.

We can see that the lobby throughput is 95/300 = 0.32 persons per second for the conventional system. CIBSE Guide D 2015 page 2-2, section 2.5.1 indicates a maximum throughput for a corridor = vDW. Assuming 1.0m/s pedestrian speed and a density of 1.4 persons per square metre gives a maximum throughput in a 3.2m wide corridor = 1.0 x 1.4 x 3.2 = 4.48 persons/s. Even though the MMLS will see a 180% higher flow rate there may still be enough lobby width for circulation.

The reason, however, the typical lift lobby works is not because of the limitation on the width of the lobby for circulation but on its innate handling capacity and space to handle queueing and for passengers to be able to pass others waiting for lifts to arrive. Figure 3 indicates the comparative queuing in these two lobbies.

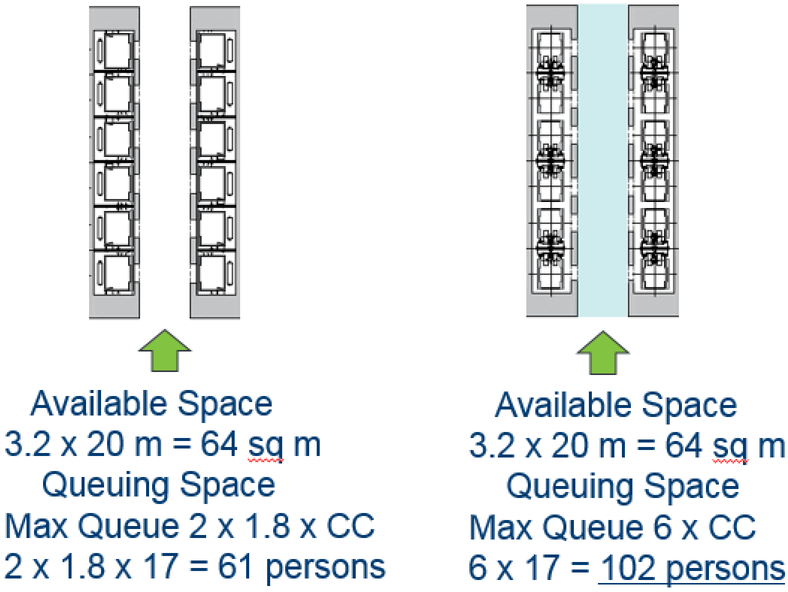

Figure 3 Comparison of Potential Queueing Space

Conventional System (left) versus MMLS (right)

Again, from a simplistic standpoint, the conventional system works as there is approximately the same amount of space in square metres as there are passengers waiting. The MMLS lift lobby is unlikely to be viable in terms of throughput and queuing combined since the lobby space would not even be able to contain the number of potential waiting passengers.

6 CORE PLANNING CONCEPTS

The largest local lift service requirement is for the 10,000 workers at the upper sky lobby and a basic design using double deck lifts would probably look like four groups of eight 1600kg capacity cars with a range of speeds. Again, representationally, shown as something like Figure 4.

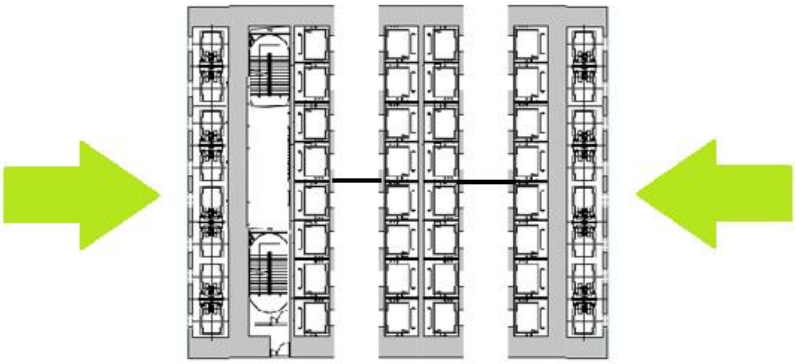

Figure 4 Local Double Deck Passenger Lift Service for 50 Office Floors with MMLS on Outer Sides of Core for Good Circulation

MMLS lobbies are placed to the outside of the core since they only need to stop at the sky lobbies every 50 floors.

The hotel, leisure and residential floors do not require as many local lifts and will easily fit into the space shown above for the local office lifts.

In order to make the circulation and “quality” of service criteria work well it is proposed to use multiple main floor levels for boarding and alighting of all tower users at the main lobby.

Indeed it would probably be useful to consider using an entry floor and an exit floor or entry and exit lobbies on the same floor or on alternative floors to avoid conflicts of circulation with such large flows of intending passengers arriving and others departing from the building.

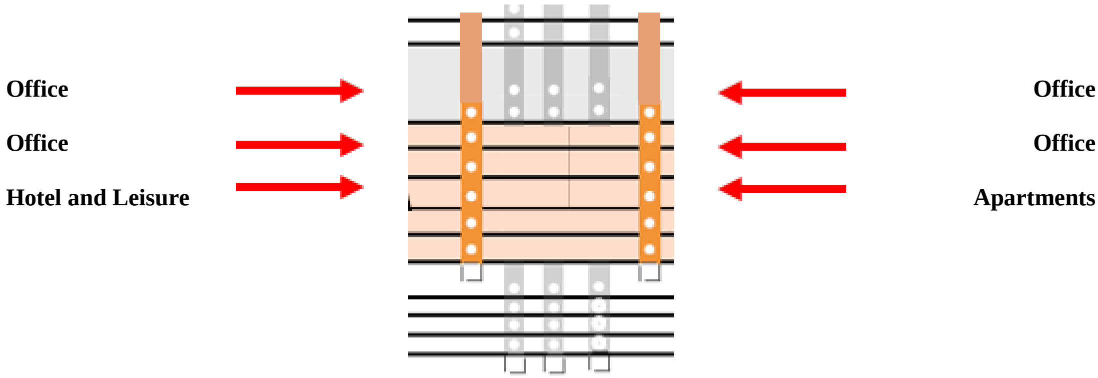

Figure 5 MMLS and “Through” Cars enable Multiple Lobbies to be Generated at the Base of the Building

Another interesting feature of this arrangement is that, dependent upon demand, MMLS cars can be diverted to service the relevant lobby and user group very easily. The building shuttle system is no longer constricted to serving one use in the building. This flexibility is important for a multi-use tower where fluctuations in visitor numbers and peak traffic demands for each tenancy could vary throughout the day.

At the main floor six out of eight of the MMLS would be notionally assigned to moving office workers. These can be arranged such that office workers are split by destination floors into two, three or even four stacked main lobbies on opposite sides of the core. On the floor below can be located the hotel/leisure and residential lobbies. Since each system can exhibit an average interval of around 25s then provided users are split up by destination to enter the correct lobby the requisite handling capacity and average intervals can be delivered. This can include signage to groups or zones of upper floors and the ability to place users travelling to "odd" floors in a different main floor lobby to those travelling to "even" floors. In this way users arrive at the correct upper main floor to board the local double decks directly without the need to move between upper floors using escalators.

7. OVERVIEW OF CORE EFFICIENCY

The core in figure 4 will take up approximately 309 x 24m in plan area = 720 sq m. The net area for each floor plate is 2500 sq m. Therefore in relative terms the gross floor space is approximately 3,220 sq m. This gives an approximate notional net/gross figure of 78% which would be impossible to achieve with conventional lift systems as we have today.

Within the hotel, leisure and residential areas it would be possible to introduce local atriums and reduce gross area. Also within the office zones, by careful design, additional floor area could be clawed back from the core as local lift groups drop off.

Not considered so far is the goods, logistics and waste strategy. On current mega tall buildings the author is advising to move towards shuttle and local goods/service lift arrangements. This is far more efficient than attempting to serve all floors directly from the basement which, in the case of a 1,000m building, would not in any event be possible. Pallet automation techniques are also being studied to "robotise" the solution and automate goods in and waste out movements enabling 24/7 use of the goods lift resource in the building. It is also envisaged that the vast majority of service personnel will use the MMLS system for their "back of house" movements around the building.

8. CONCLUSIONS

This paper has provided a simplistic broad brush overview of what the author believes are some of the essential considerations for the future deployment of MMLS within super and mega tall buildings.

Work is already underway with building traffic simulation capabilities for MMLS to emulate what we can do today for conventional lift systems and traffic analysis.

The author has concluded that MMLS will enable the building of highly efficient multi-use towers within the coming years that are, at last, economically viable.

This is an exciting proposition as building designers search for more sustainable high rise solutions for the buildings of tomorrow.

REFERENCES

[1] Adrian Godwin "Skytrak" – An Elevator System for the 21st Century" Pg255-261 *Asia Ascending: Age of the Sustainable Skyscraper City. Proceedings of the CTBUH 9th World Congress*.

[2] Hans Jappsen "High Rise Elevators for the 21st Century" Pg 172-184 *Elevator Technology 12. Proceedings of Elevcon 2002.*

BIOGRAPHICAL DETAILS

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After graduating with honours in Electrical Engineering & Electronics from Salford University and obtaining a Diploma in Management Studies from UMIST in the early 1980's Adrian worked first for General Electric Co., Hirst Research Centre, one of the UK's premier research laboratories and then for Lift Design Partnership founded by his father, Mike Godwin and Dr George Barney.

Upon his father retiring in 1987 he was responsible for merging LDP with Lerch Bates in 1990 and subsequently developed the firm to include five additional offices in Europe.

His particular areas of interest and expertise are in the development of "smart" elevator control systems, planning of elevator systems for tall, super tall and mega tall buildings and the development of lifts capable of running on a curve. Author of numerous papers and holder of a number of patents in the area of lift systems he has been involved in the design of the lift systems for some of the most prestigious tall buildings in the world working with high profile architects including Norman Foster, Rem Koolhaas and Renzo Piano to produce buildings such as the Shard, the Central China TV HQ building in Beijing and the 90 floor Burj Mohammed bin Rashid Tower in Abu Dhabi. All three buildings winning "Best Building" awards from the CTBUH.

In recent years he has been involved with the first ever application of "destination hall call" control to double deck lifts within the Broadgate and Heron Bishopsgate Towers in the City of London as well as the Shard. He has also been working on the application of linear motors to lifts (a family preoccupation) and is actively engaged in looking at the potential of this technology to solve the challenges of mega tall buildings of the future.

After developing a "world leading" expert system for lift design named AdSimulo he is now exploring new techniques to make vertical transportation in high rise buildings more effective and efficient. Finally, after "demerging" with Lerch Bates in 2014 and rebranding as Movvéo, after more than 30 years, he still heads up the award-winning consultancy founded by his father and Dr Barney.