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A TECHNICAL PRIMER: THE OTIS ODYSSEY* SYSTEM

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Abstract

Fundamental aspects of the ODYSSEY* integrated building transportation system are described as they apply to tall and wide buildings. Included are many of the system's quantitative aspects, such as passenger handling capacity and core space efficiency; and qualitative aspects, such as pedestrian circulation and traffic mix. Equipment and other aspects are described generally. Overall, this paper provides some of the bases for our announcement in July 1996 that building height and circulation limits that were based on available transportation systems have been broken. The words "our" and "we" in this paper usually refer to the Otis Elevator Company.

Introduction

In the ODYSSEY system, a cab is moved off the car frame of an elevator or off the bogie of an automated people mover (APM). For an elevator, this is done while the car frame remains attached to the elevator's wire ropes and is held at the floor, thereby using conventional elevator components and maintaining safety. Cabs are moved off and on car frames smoothly using the

latest linear induction motor controls and other designs to provide passengers with a level of comfort they have come to expect from elevators. Configured in a transportation system, cabs move efficiently among combinations of elevators and APM's. For example, when one cab is moved off an elevator car frame another is moved on simultaneously. In tall buildings, the system applies generally to shuttle elevators that transport people to skylobbies. The moveable cabs in this new "vertizontal" mode of transport by Otis have been named TRANSITOR* cabs.

Motivations

Initially we were seeking ways to handle "hyper-building" concepts, such as those suggested several years ago. We wanted to be able to provide a transportation system that was efficient in terms of building core space and overall costs; comfortable to ride in terms of noise, vibration, and passenger ear comfort considering the speeds involved; and convenient to use in terms of pedestrian circulation and user-friendliness.

We knew that fully electric "ropeless" elevators could one day increase the number of cabs in a hoistway, thereby reducing the number of hoistways and core space, but they are not available today. The capital and operating costs of ropeless would take decades to pay back through rents gained on the space they would save. Without a counterweight, individual elevator energy consumption will increase by a factor of seven or more — not a very "green" solution. New safety designs also will be required to keep ropeless cabs from colliding. Equipment costs will also be high due, in part, to the need for full-height linear motors. In our entire evaluation of ropeless, it was assumed that structural engineers would not have a problem extending building height if there were fewer hoistways in the core.

We also looked at other ways to get more cabs in a hoistway without the energy drawbacks of ropeless. One was to use detachable rope grips like those we now use on some of our people movers. These could provide a means of obtaining counterbalance with "down" traveling cars. However, most of the ideas were shelved because of their complexity. We also looked at "wall climbers" or cabs that are propelled by placing the rotating powertrain on the cab itself. However, these would have increased noise and vibration substantially at any of the speeds required.

Within limits, we could have extended travels for traction elevators by building even larger machines, stronger and lighter ropes, and more advanced sway designs. However, even with our double deck elevators, this would have compounded the core space problem, as will be shown later. We can

provide single-deck elevators traveling much faster than 10 m/s, but these would not even come close to double-deck in terms of core space efficiency. Also, descending direct from more than +/- 100 stories at speeds above 10 m/s would cause ear discomfort for many passengers. We could seal the cabs, but the delays at the ground to recompress gradually to atmospheric pressure would negate much of time the speed had gained.

While the initial motivation for the ODYSSEY system was very tall buildings, we quickly recognized the merits for super-wide buildings and mega-complexes, and "shorter" tall buildings. The overwhelmingly positive reaction to the ODYSSEY system that we received worldwide also suggested we had tapped a desire for something more than reduced core space and improved circulation in transportation.

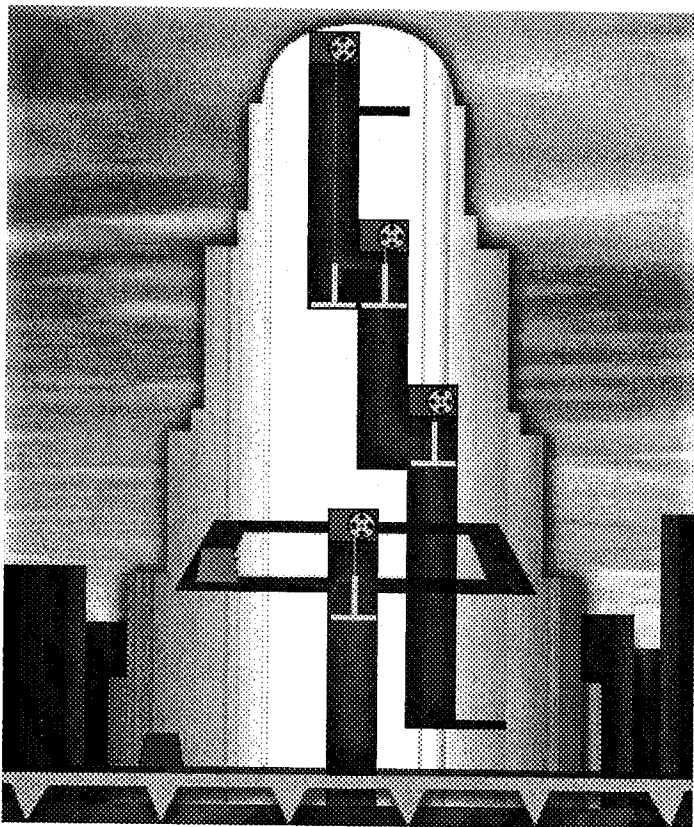


Figure 1

Fundamental Advantages

Referring to Figure 1, several advantages of the ODYSSEY can be seen or envisioned:

- Horizontal and vertical transportation are uniquely integrated.
- Direct “vertizontal” circulation can be provided without changing cabs.
- Traffic can be separated using different types of cabs in the same system.
- The car frame remains attached to the ropes at all times to maintain safety.
- Standard roped elevator equipment is used for cost effectiveness and availability.
- With roped equipment, energy efficiency and ride comfort are maintained.
- With shorter legs of travel, rope weight and sway issues are minimized.
- With shorter legs of travel, descents are gradual for passenger ear comfort.

The latter two items refer to skylobby shuttle elevators in tall buildings. This technique may be reviewed by referring to Figures 4 and 5 herein. Referring to Figure 2 below, some basic traffic advantages start to emerge:

With shorter legs of travel, cabs can return in less time to a main lobby or skylobby for another load. Reducing this time, while carrying a footprint-efficient load (e.g., double-deck elevators), is the key to increasing handling capacity and reducing the number of shuttle elevator hoistways. This advantage can also be extended to people movers in horizontal transportation.

Transferring the cab instead of the people also reduces the time to return cabs to the main lobby or skylobby. A shuttle cab can be moved smoothly off/on a car frame in about half the time it takes a load of people to enter/exit and to cycle the doors, with delays. When the cab is moved to an off-line loading area, people can enter/exit comfortably while the system keeps working.

The following analogy compares the advantage of shorter legs of travel for handling capacity: If one person runs up a large hill to put out a large fire

with one or two buckets of water (the “two” buckets representing double-deck elevators), a certain amount of water will be put on the fire over time. Yet, if several people worked together passing one or two water buckets to each other, much more water will be put on the fire over time, and the buckets can be passed smoothly and methodically.

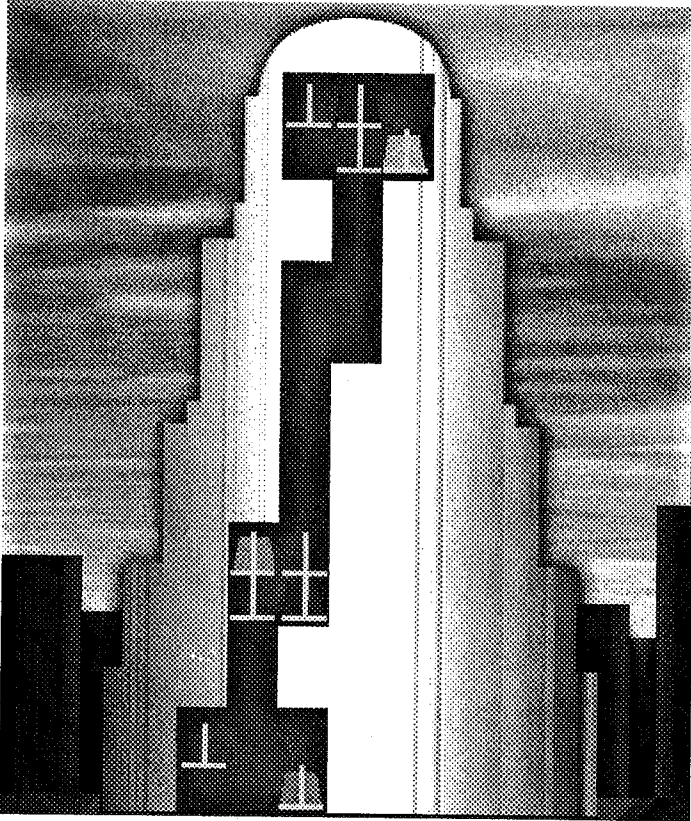


Figure 2

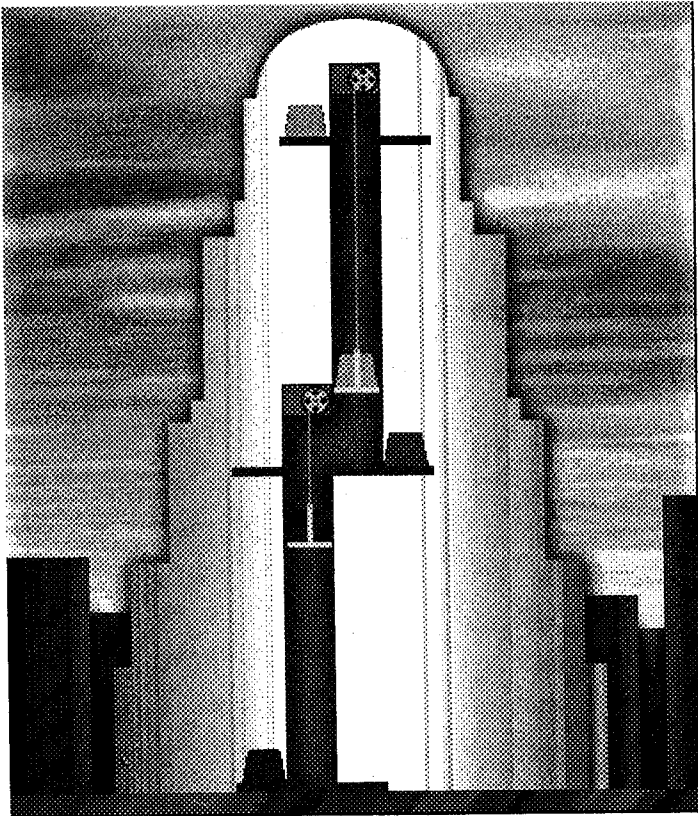


Figure 3

Versions of Odyssey System for Tall Buildings

For skylobby shuttle elevators in tall buildings, we usually talk about two categories of the ODYSSEY system. We nicknamed these the “switch” and the “shuffle”:

Figure 2 shows the “switch”. Car frames trade their cabs at hoistway offsets, then move the transferred cabs to progressively higher and lower

levels. Off-line loading occurs only at the main lobby and skylobby. A single-cab version is shown in Figure 2. A dual-cab version is used later in the 100- and 200-story examples that follow. The "switch" is used generally to move traffic between a main lobby and one skylobby.

Figure 3 shows the "shuffle". Car frames trade cabs at a hoistway offset, which also is a skylobby, then move the transferred cabs to a higher and lower level. Off-line loading occurs at the two skylobbies and the main lobby. A single-cab version is shown in Figure 3. A dual-cab version is used later in a 50- to 60-story example that follows. The "shuffle" is used generally to move traffic between a main lobby and two skylobbies, and between the two skylobbies.

Many combinations and variations are possible. Hoistway offsets can be added between the main lobby and skylobbies in the "shuffle" to increase handling capacity and/or rise. The "switch" can be designed to handle some of the inter-skylobby traffic of the "shuffle". Off-line loading can be omitted from the "switch," where cars simply stop at the terminals and the doors open. With another car frame bay, the auxiliary elevators shown at the terminals in Figure 2 can be omitted (a variation which is used in the 100- and 200-story examples herein). Still another approach is to provide just off-line loading, forming an "I" shaped hoistway with no offsets. Off-line loading alone could have reduced by one the quantity of shuttle elevators to the skylobby in each of the Petronas Towers in Kuala Lumpur, Malaysia.

Skylobby Shuttle Elevating and a 100-Story Example

The first large-scale example of skylobby shuttle elevating was New York's World Trade Center in the early 1970's. To reduce core space, local groups of elevators were stacked on top of each other, creating three building zones. Shuttle elevators then transported people to skylobbies where the zones were joined. All elevators were single deck, including the skylobby shuttles which are 4,500 kg. in capacity (10,000 lbs.). Unfortunately, the latter require about twice the footprint and time to load as double deck. If the towers had been built more recently, they probably would have been built using double-decks to add to the space the skylobby technique saved.

Even with double-deck and skylobbies, carrying the same amount of people to higher skylobbies requires more shuttle elevators than the skylobbies

below, due to the extra travel distance and time. Consequently, disproportionately more core space is required by elevators as building height is increased, which becomes an economic barrier to building higher. Figures 4 and 5 below show a possible design evolution of the system in the North or South Tower of the World Trade Center: Shown in comparison are today's single-deck skylobby elevating, double deck skylobby elevating, the double-deck shuttles replaced by a double cab ODYSSEY "switch", and the latter two if building height was extended a full zone.

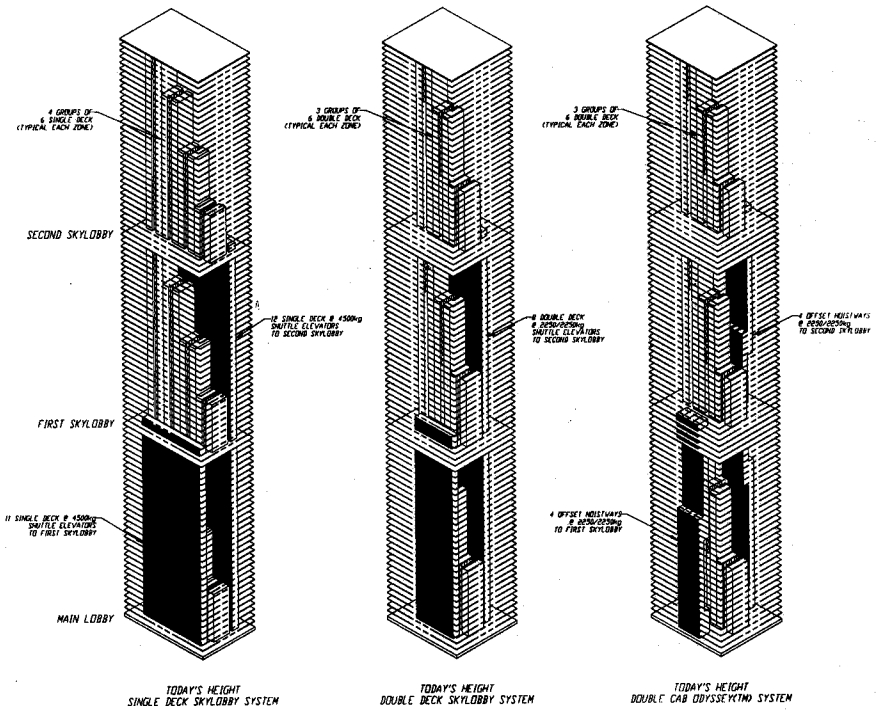


Figure 4

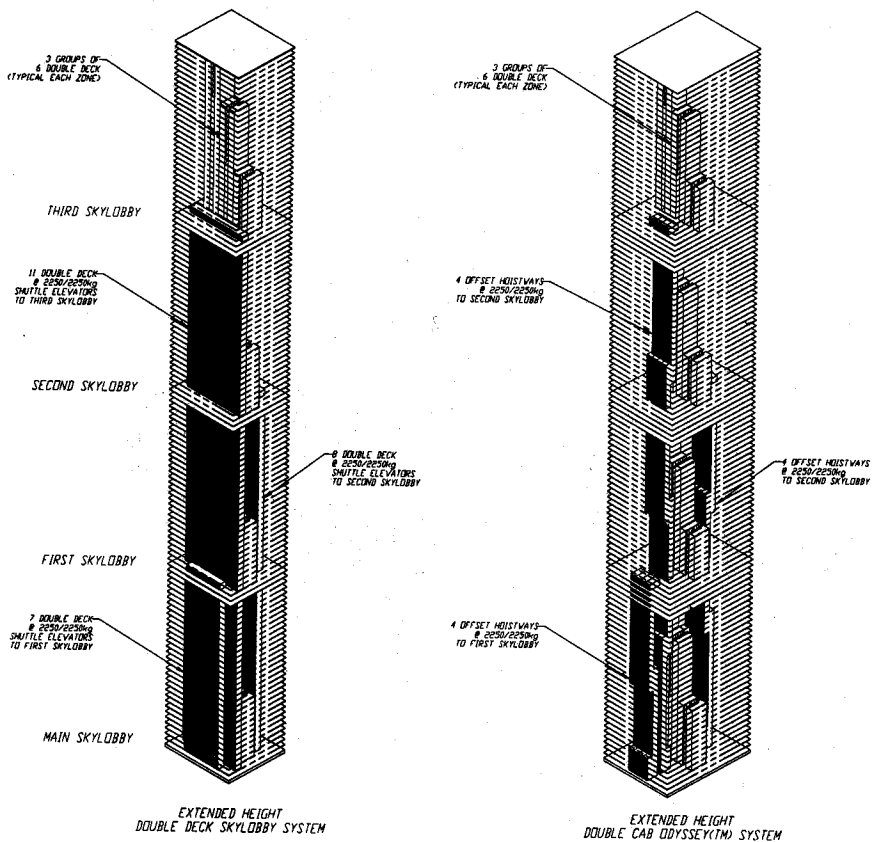


Figure 5

The space saved with double-deck locals is usually ~30% compared to single deck locals. For the shuttle elevators in Figures 4 and 5, the ODYSSEY system could have reduced core space over deck by ~25 to 30% at today's height (~70% over single-deck) and by ~40% at the extended height.

To extend building height prior to the ODYSSEY system, considering 11 shuttle elevators would have to travel through so much of the building, the architect might have reduced the size of the floors and population in the upper zone to reduce the number of shuttles. With the ODYSSEY system, if rent

was \$400US/SM/YR, and the space saved in shuttle elevators alone was ~8,000 m², a 10-year straight return of \$32 million US might encourage the owner to build higher and “straight up”.

The preceding analysis assumes the same number of skylobbies or zones. With a 200-story example later it will be suggested that increasing the number of skylobbies or zones can add to the space saved.

Basic Traffic Estimating Methods - Tall Buildings

The following compare the basic methods of estimating “up-peak” traffic for the double deck vs. ODYSSEY shuttles for the upper skylobby in Figure 5. The criteria is to carry 14% of a population of 7000 people to the 400-meter level in five minutes and keep the estimated ear pressure differential below 2000 Pa going “down”.

Double Deck Shuttle Elevators:

- 2 cabs per elevator carrying 25 people each
- 400 meters travel
- 10 m/s UP and 8.5 m/s DN @ 1.0 m/s² @ 2.0 m/s³
- Ear pressure differential DN@1960 Pa (10 m/s DN would @ 2150 Pa)

Time for empty cab to return to main lobby, per hoistway:

Load both cabs*	24.7 sec.
Close doors*	3.4 sec.
Run UP 400 meters	50.5 sec.
Open doors	1.7 sec.
Unload both cabs*	24.7 sec.
Close doors*	3.1 sec.
Run DN 400 meters	56.1 sec.
Open doors	<u>1.7 sec.</u>
Total time	165.9 sec.

(*both cabs loaded simultaneously, minimum 10% delay factor)

Five minute handling capacity per hoistway:

$$25+25 \text{ people UP} \times 300 \text{ sec.} \div 165.9 \text{ sec.} = 90 \text{ people/5 min.}$$

Quantity of hoistways to handle traffic:

$$7000 \text{ people} \times 0.14 \div 90 \text{ people/5 min.} = \mathbf{10.9 \text{ hoistways}}$$

Double TRANSITOR Cab ODYSSEY "Switch" Shuttles

- 2 cabs per car frame carrying 25 people each
- 4 travel legs @ 100 m. = 400 meters total
- 10 m/s @ 1.0 m/s² @ 2.0 m/s³ (ear pressure differential DN @ 835 Pa)

Time for empty cab to return to main lobby, per hoistway:

Run UP 100 meters	20.5 sec.
Transfer or "switch" cabs	12.0 sec.
Run DN 100 meters	20.5 sec.
Transfer or "switch" cabs	<u>12.0</u> sec.
Total time	65.0 sec.

Five minute handling capacity per hoistway:

$$25+25 \text{ people "UP"} \times 300 \text{ sec.} \div 65.0 \text{ sec.} = 231 \text{ people/5 min.}$$

Quantity of hoistways to handle traffic:

$$7000 \text{ people} \times 0.14. \div 230 \text{ people/5 min.} = \mathbf{4.2 \text{ hoistways}}$$

The preceding estimates are based on commonly-used methods. The effect of the shorter legs of travel are shown in the ODYSSEY case. Also note that passenger transfer and door times are taken out of the equation. This is because the system keeps working while passengers are entering and exiting the cabs at the off-line loading areas.

In practice, a review of the upper zone population would most likely result in rounding to four hoistways in the ODYSSEY case. A reduced speed of 8 m/s would have also given the same end result in the ODYSSEY case. On the other hand, the speed or acceleration rate going "down" might have been reduced in the conventional case to improve passenger ear comfort.

Points for Skylobbies and a 200-Story Example

Figures 6 and 7 below show the previous version of the ODYSSEY system applied to an office tower at least twice the area and height of a World Trade Center Tower. In studying and comparing these diagrams to the 100-story example, note that increasing the number of multi-level skylobbies can have several advantages:

- Skylobbies may be grand spaces taking entire floors or take just enough space for passengers to transfer from shuttle to local elevators.
- Express zones can be eliminated from the double-deck local elevators. This helps save additional space and minimizes the quantity of local elevators.
- Since local elevators do not have to handle population resident to the skylobbies, this also helps minimize the quantity of local elevators.
- To reach most floors, passengers only have to change cabs once. All others who have their offices on a skylobby level do not have to change cabs at all.
- Since shuttle elevators “keep moving” and do not stop for local traffic, the space at skylobby levels can generate higher rents.
- Skylobby levels provide excellent locations for common spaces such as tenant restaurants or conference rooms, or a hotel reception lobby.
- Spaces above or below skylobbies provide locations for zoned mechanical equipment or intervals of lateral structural bracing to exterior supercolumns.
- Considering the volume of traffic that must pass at the bottom of the building, manageable-size groups of elevators and a multi-level main lobby improve circulation by dividing traffic both horizontally and vertically.

Prior to the ODYSSEY system, a three-zone scheme of double-deck skylobby elevating had been proposed for this 200-story “hyper” tower. People in the top 1/3 of the building would transfer from shuttle-to-shuttle-to-local elevator to reach their floor. We have not revisited this scheme in detail to see if it was the most space-efficient system of its day, but for these purposes we will assume it was generally efficient. Figure 6 compares its main lobby footprint to an ODYSSEY system for passenger elevators only (no service elevators). Compared system-wide, the ODYSSEY system would have reduced total core space by ~70,000 m². The straight returns on rents

on this space in just 10 years of \$200,000,000 to \$300,000,000 US could help convince interested parties that the building was economically viable.

Also note that, in the conventional scheme, traffic would somehow have to circulate to essentially one "group" of 56 double-deck shuttles all going to just the first skylobby, compared to the manageable-size groups of five shuttles per zone in the ODYSSEY case.

Sometimes we are asked, "How long would it take a person to get to the top floor in such a building?" In this case, it would take a passenger ~6 to 8 minutes to reach the top office floor, but ~30 to 60 seconds less in the ODYSSEY case — considering the time to wait for and enter-exit an additional shuttle cab, walk around a larger core once more, and the longer trip on the top zone locals in the conventional case. Also, visitors to tall buildings may require more time to locate connecting local elevators at skylobbies, depending upon layout and signage. With the ODYSSEY system, passengers are provided with scheduled transportation that keeps moving.

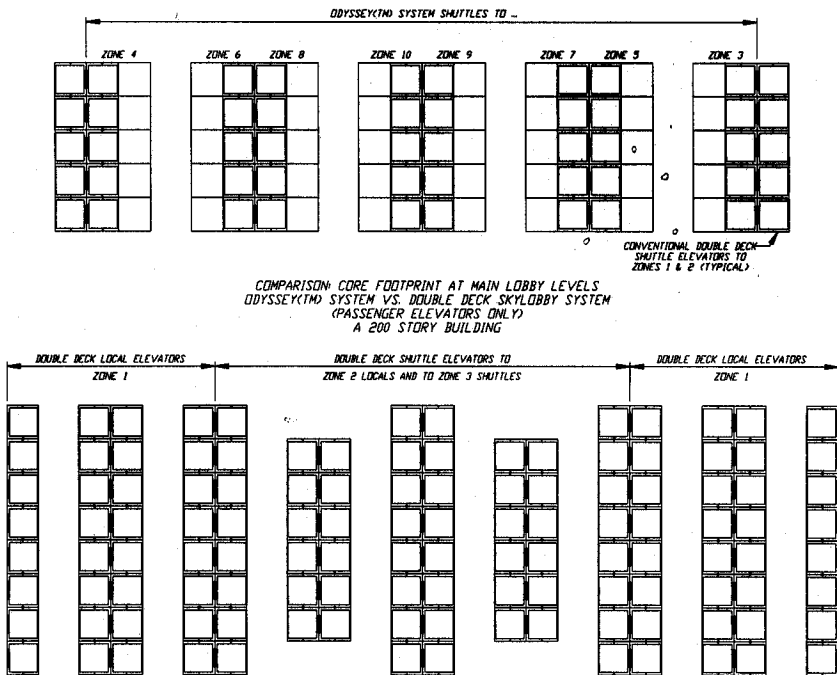


Figure 6

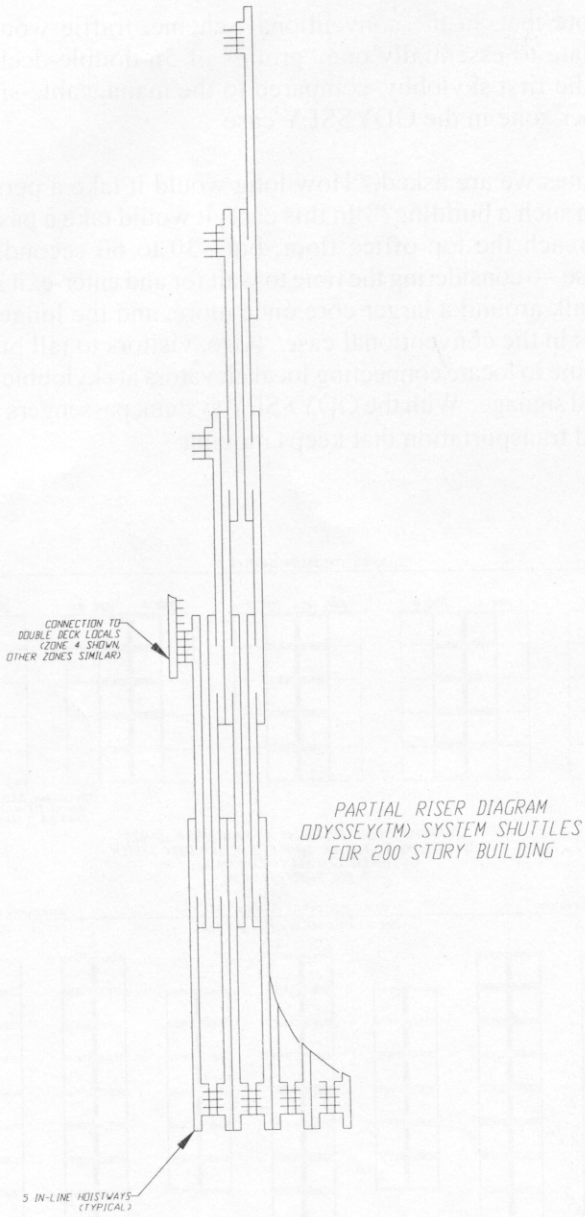


Figure 7

A 50- or 60-Story Building

Figure 8 shows the more "everyday" tall building under discussion in almost every part of the world. Here, a double-cab ODYSSEY "shuffle" is applied to a 60-story building, in comparison to conventional groups of double-deck local elevators rising low-mid-high from one main lobby. Machine rooms have been omitted for clarity.

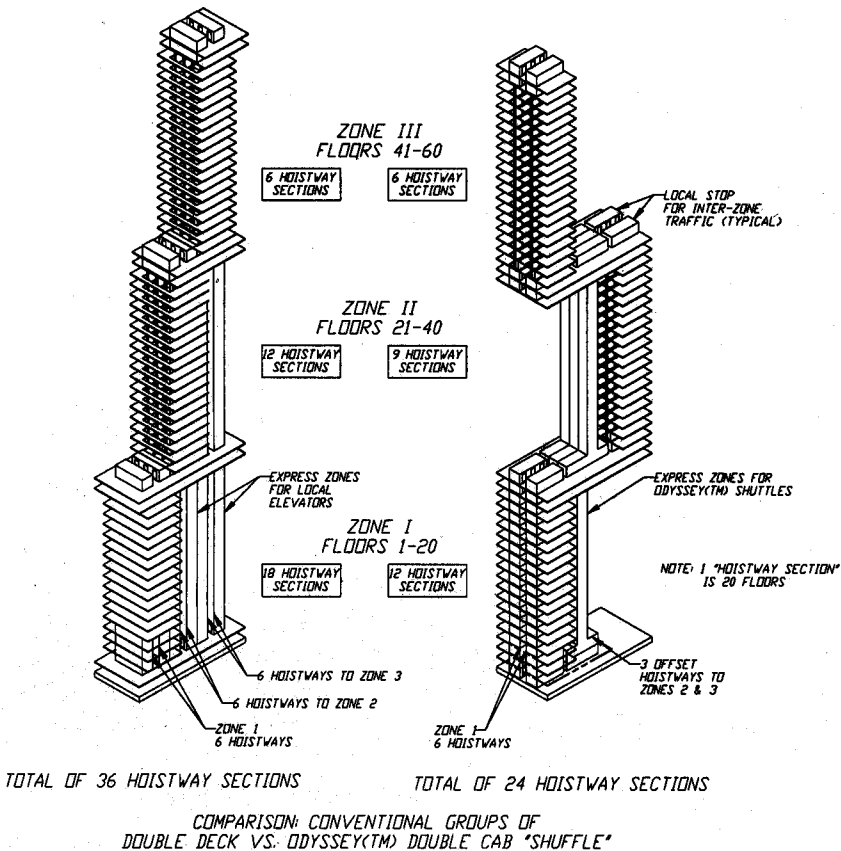


Figure 8

With the “shuffle,” cabs leave the main lobby in alternating fashion bound for each of two skylobbies, using both ends of the hoistway. At the same time traffic is moved between the two skylobbies. For separate tenants, separate boarding lobbies are used for destinations in separate zones. However, buildings with a single tenant or purpose, or buildings in which people both live and work could also benefit from the ability of the “shuffle” to handle inter-skylobby traffic equally as well as the system handles main lobby traffic.

For those interested, the operation of the “shuffle” can be viewed in the simulation shown in the original CD-ROM that was included in our public announcement packages. A still shot from the CD-ROM is shown as Figure 3. To the passenger, the operation is transparent — the ODYSSEY system looks like and is used like any other elevator, including its entrance doors. (Author’s note: In proofreading Figure 3, the off-line loading areas should have been shown as part of the hoistway.)

Skyscraper on Its Side

Many indications are that the more common mega-projects are airports, very long or wide multi-use complexes, campus layouts of office buildings, medical complexes, etc. From another perspective, urban centers or central city business districts have similar circulation problems — long walking distances, travel that is up and down and gradient, and weather challenges. The applications for the ODYSSEY system in these cases seem limitless.

For example, automobile parking often involves long walks. Long distances and multi-levels also pose circulation challenges for retailers in upper or remote areas of large retail complexes, which can influence revenue generation and the success of the project. Let’s assume a super-wide project is proposed, that parking is at the remote ends of the project on a large lower level, and that several floors of retail are provided above. Figure 9 depicts one ODYSSEY system solution. A “mini” people mover is provided at the upper level of parking at each end, which connects via shuttle elevators to a main artery people mover above. After parking their automobile or bicycle, passengers board a TRANSITOR cab on the “mini” people mover. The cab moves onto a shuttle elevator and then onto the main artery system, where passengers can get off at any stop along the way. The main artery can be located in a grand atrium for passengers to view available retail, and also to add to the attraction of the complex.

Just as important as circulation, the system can also be expanded without sacrificing traffic performance. For example, the single leg main artery shown in Figure 9 could take people to one of the ends shown, stop and unload people, and then switch cabs with a people mover in a connecting leg (not shown). Compared to having one "train" taking people from one end to the other of this expanded-length system, for the same interval or "headway" between departures (which is essential for handling capacity), travel could be extended indefinitely using multiple legs. The transfers could also occur at connections to key transportation nodes, which could be to other modes of transport and/or locations for high-rise buildings. Such features hint of a new future in transportation.

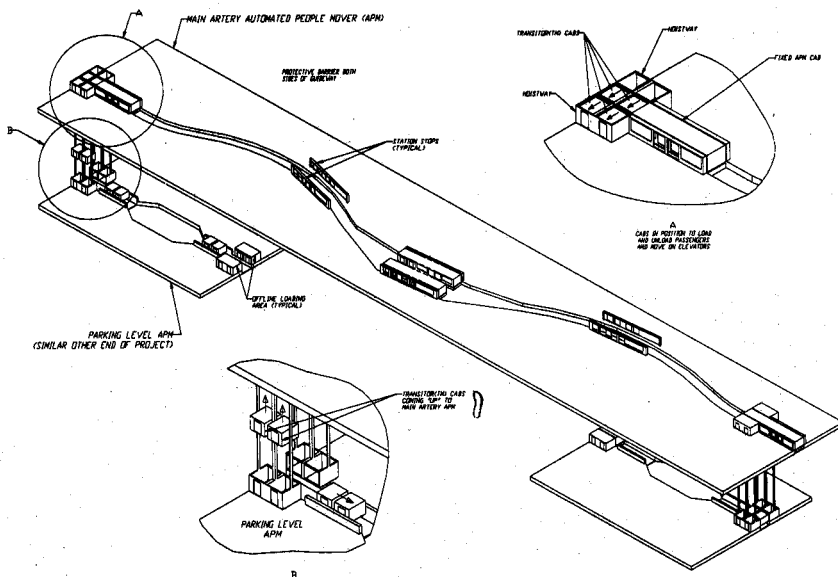


Figure 9

Unfamiliar airports can be intimidating places, even for experienced travelers. With the ODYSSEY system, arriving passengers could board a people mover with different entrance doors labeled, "connecting flights", "ground transportation", "restaurants and retail", etc. Behind these doors would be a series of TRANSITOR cabs that would take people quickly and directly where they want to go. Similar circulation conveniences could be

provided upon arriving at an airport - a person could simply enter a call for the desired airline in a parking garage. Of course, one day soon a person's electronic ticket may be used to place the call.

Equipment in the Odyssey System

Describing most of the equipment of the ODYSSEY system is like describing our elevators or people movers. For example, referring to Figure 5(a), our latest ACVF traction powertrain that can handle the loads of 2250+2250 kg capacity double deck shuttle elevators traveling at 10 m/s for a travel of 400 meters, can easily handle the lifting requirements of the ODYSSEY system — considering the system's shorter legs of travel and traffic performance that enables smaller duties.

For lower rise buildings, hydraulic or even winding drum elevator equipment could be used. We might even consider moving a TRANSITOR on one of our Tubular Linear Induction Motor (TLIM) elevators, about a 1000 of which have been sold so far, mostly in Japan. With the TLIM, the elevator is roped and counterweighted (for energy advantage), but the overhead sheaves are not used for traction nor are they connected to a motor. A cylindrical LIM primary or "stator" is made part of the counterweight, which "climbs" a stationary piston that is the LIM secondary or "rotor". The tubular shape naturally equalizes the attractive force in LIM motors. The end results are — no machine room and a comfortable ride.

For long horizontal distances, we also use wire ropes to propel most of our present automated people movers (APM's), while the car is suspended on a thin cushion of air called HOVAIR* suspension. We believe this provides the most reliable and comfortable ride in the APM industry. Those who have traveled between the airside and landside portions of Terminal 2 at Tokyo's Narita Airport, for example, have experienced the system's ride quality and dependability — car "up-time" in 1997 has been in excess of 99.9%, with passengers having service 100% of the time due to the dual arrangement. Recently, we added the option of detachable rope grips that actuate when cars stop to load/unload. These can extend travel without limit, handle "pinch loop" arrangements at APM terminals more easily, and enable multiple rope loops that allow more cars on a guideway. For economy, we also provide systems with small wheeled cabs. Our latest people mover is linear induction motor (LIM)-propelled and HOVAIR suspended.

Now to the unique parts. For cab transfer components, the timing for the ODYSSEY system was excellent considering the servoed kinematics,

precision, and robustness available in today's robotic and motion control devices. For ride comfort, a LIM will propel the TRANSITOR cab off/on the car frame or bogie. The motor has an inaudible frequency and is servoed for position and velocity, adding to the LIM's non-contact nature. TRANSITOR cab wheels are lined with special resilient materials, and the rails they ride upon engage each other seamlessly. We also move the cabs slowly during transfer, considering the direction passengers standing feel the acceleration with any horizontal transportation.

In moving a cab off a car frame at the same time another cab moves on, the same degree of traction is maintained at the elevator machine, considering the counterweight. However, even if simultaneous transfer of cabs does not occur, the car is held level at the floor or hoistway offset.

Figure 10 is a diagram of an overall full-scale model we just completed at our Test Tower and Quality Assurance Center in Bristol, Connecticut. Reduced to its broadest functional components — the cab is put on wheels, moved off the car frame with a LIM, mechanical connections bridge the gap, power rails maintain cab power in this case, and the rest relies on standard elevator and APM equipment.

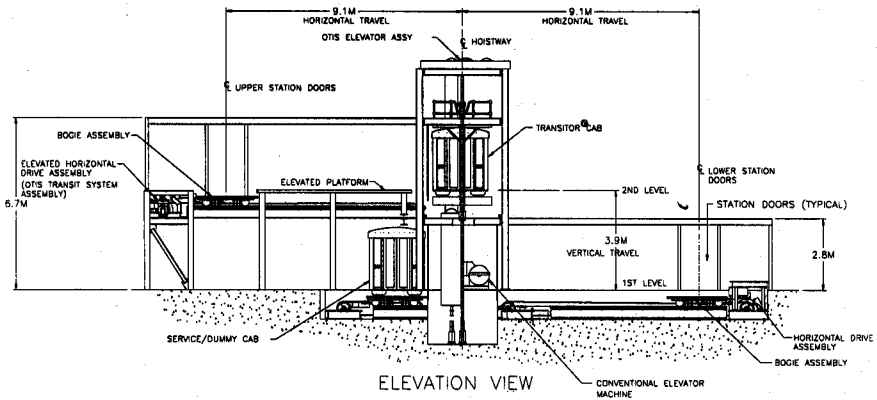


Figure 10

We think the sophisticated simplicity of this transfer is essential for reliability. Proven non-contact parts and robust static components have also added reliability, as have our worldwide quality processes and test centers, which include test-to-failure methodology before product release.

Dispatching and Car Control

When a TRANSITOR cab is operating with a group of local elevators serving many floors, Otis' latest dispatching technology can be called upon. Dispatching is the process of assigning calls to elevators in a group based on the large number of decision combinations involved and system status that changes constantly. Our state-of-the-art ELEVONIC* 411, RSR PLUS* dispatcher computes a figure of merit called Relative System Response based on bonus and penalties determined using crisp logic. In addition, we have introduced Fuzzy Logic for the dispatcher where we might, for example, say a car is "0.4 crowded" or "0.9 — close" in lieu of the crisp 0 or 1. Soon we will be introducing Artificial Neural Networks with continuous batch learning of the elevator group's actual traffic.

In the case of skylobby shuttle elevators, ODYSSEY car control is focused generally on synchronization. For example, for unequal hoistway legs of 75 m. and 150 m., individual elevator powertrains are sized initially for car speeds of 3.2 and 8.0 m/s, respectively. Elevator controllers then manage individual velocity profiles to ensure that simultaneous arrival occurs. In the case of a passenger holding the doors open an extra long time — despite an advance signal that the doors will be closing — passengers in cabs in connecting hoistway legs will be advised of the delay before "take-off". ODYSSEY dispatching in tall buildings is focused on managing system-wide traffic movements between shuttle and local elevators. This is one of the reasons why we say, "the integrated building transportation system."

For a super-wide building, Figure 9 shows a relatively simple (but effective) ODYSSEY scheme. Taking this further, passengers could have been transported from the parking level to a skylobby above the main artery without changing cabs. As systems grow more and more complex, with multiple stops and destinations and origins both vertically and horizontally, with different pedestrian flow volumes and arrival processes, we will use computer modeling to examine traffic performance and ensure TRANSITOR cabs have available "slots". The software involved will reflect our long tradition and passion for dispatching automatic elevators.

Human Engineering

We know people expect more from elevators than the delays, discomforts and risks they may tolerate in commuting via ground transportation to their office or residential building in many urban areas. Based on our

contribution to vertical transportation and the skyscraper, we believe that with the ODYSSEY system people will soon begin to expect more from other modes of transportation. Still, in introducing the first major "vertizontal" mode of ground transport — where passengers are moved vertically, then horizontally, then vertically again — we know special attention must be paid to human comfort and convenience.

First and foremost, each ODYSSEY system is tailored to the particular project, so the input of the architect and other experts can be captured early in the design. Some handrails, stanchions, and/or fold-down seats will be provided in most cases. People will also be informed of cab movements naturally with windows when outside the hoistway, and position and direction displays and voice announcements when not. For travel outside and then inside a hoistway, electrochromatic windows can be provided that change from transparent to opaque, perhaps with displays in the windows themselves when in the opaque mode. The technology available in today's human interfaces for machines will be applied in a way to make a ride on the ODYSSEY system a very pleasant experience.

Closing

At the first Conference on High Technology Buildings in São Paulo, we compared super speed single deck elevators to double deck elevators, intelligent dispatching, etc. We indicated that with the assistance of technology we could reach much taller from the experienced shoulders of our past. We knew then the ODYSSEY system was coming. Accordingly, this second such conference in São Paulo seemed a fitting place to present this technical primer on our ODYSSEY system.

Vertical transportation has been removed as an economic and technological barrier from building taller buildings. The rest will be up to other disciplines, like the structural community that founded CTBUH and, of course, the urban planners. In the meantime, while decisions are being made on tall buildings, we also feel a revolution in horizontal transportation is about to begin more on the ground with this vertizontal mode of transport becoming more and more a part of airports and other mega-wide complexes. Perhaps one driver will be the individual's desire to regain the "human connection" which we are each losing as we communicate more and more via electronic means. In any event, the goal of ODYSSEY is to move people conveniently and comfortably wherever mankind wants to build.

References

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- 3 Barker, F.H., 1995 "IS 2000 FEET PER MINUTE ENOUGH?" (IS 10 METERS PER SECOND ENOUGH"?), Proceedings of the First International Conference on High Technology Buildings, Council on Tall Buildings and Urban Habitat, São Paulo, Brazil
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- 5 Contact: Otis Elevator Company, World Headquarters, Communications Department, 10 Farm Springs Rd., Farmington, Connecticut 06032, USA; FAX (860) 676-6973 or E-Mail: masotti@whq.otis.com
- 6 Elevator World, 1991 THE LIM ELEVATOR DRIVE, Elevator World, Mobile, Alabama, USA, March 1991, pp. 34-40.
- 7 At the time of writing, the ODYSSEY system demo was moving horizontally and vertically including transfer of the TRANSITOR cab.
- 8 Powell, B. and Sirag, D., 1993 FUZZY LOGIC: A NEW WAY OF THINKING ABOUT THE COMPLEXITIES OF DISPATCHING ELEVATORS, Elevator World, September 93, pp.78-84

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