Evaluation of the ThyssenKrupp (TKE) MULTI System.

The TKE/CTBUH Research Paper introduces MULTI as "A Next Generation Vertical Transportation System", with a reference to historic Paternosters as if there is a similarity. *Quote "the general idea (of the Paternoster) is still considered as the prototype for the ideal system" Unquote.* However, these systems are not at all similar. Paternosters featured an endless chain of *slow moving open cars*, which never stopped. On each floor, one or two passengers could jump IN or OUT of the cars. MULTI cars move at high speed and must stop to open doors, load/unload passengers, close doors and accelerate to a next stop. Very much, like traditional elevators.

The MULTI Research Paper does not mention a control system! Are MULTI cars equipped with destination buttons in the cars? The Research Paper refers to different traffic options and simplified traffic concepts; however, traffic is spontaneous, i.e. not subject to options or concepts. In view of these controversies, the writer made a few performance calculations for the MULTI system to check its potential as a vertical transportation system for tall buildings.

MULTI systems for express service to Sky Lobbies.

A conventional elevator with a contract speed 10 m/s will have a door-to-door flight time (DDFT), which includes door opening and closing) of approximately 36 seconds for a direct trip over a distance of 200 meter. The maximum speed of the MULTI system is 6 m/s. For this speed, the DDFT over a distance of 200 m. is approximately 45 seconds. With these data, we can calculate and compare the transport capacities of conventional express elevators with single loop MULTI systems to a Sky Lobby at, for example, level 200 meter. We assume that, from the Sky Lobby, local groups serve zones totaling 50 floors. The average population of floors served is 100 persons, i.e. the total population served from the Sky Lobby is 5000 persons. Transport capacities to Sky Lobbies are determined by minimum evacuation times, which take into account floor populations, restaurant capacities, tourists etc. This paper assumes the evacuation capacity should be approximately 1000 persons per 5 minutes, i.e. the time to evacuate 5000 persons from the Sky Lobby is 25 minutes.

Evacuation capacity of MULTI systems

The round trip time of a MULTI car engaged in the *evacuation* of a Sky Lobby, starts when an empty car has completed its horizontal move to the starting position on level zero. The doors remain closed because loading is not required. The up Flight Time of 31.5 s (36-4.5 for door operation) defines the time of arrival in the arrival position at level 200. Door opening for unloading is not required, the car moves horizontally to its loading position (6 s), doors open (2.0 s) and car loading starts (8 s). After loading the DDFT (36 s) *to floor zero* defines the moment unloading starts at level zero. After unloading (8 s) doors close (2.5 s) and the car starts its horizontal move (6 s) to the starting position. The 6 seconds for the horizontal move is probably too short, because in the departure position the linear drive and guide rails must return to vertical positions for the next up trip. This may take a few seconds. The total round trip time (rtt) for evacuation is 31.5 + 6 + 2 + 8 + 36 + 8 + 2.5 + 6 = 100 seconds.

During door opening (2.0 s), unloading (8 s), door closing (2.5 s) and the horizontal move to its starting position (6 s) the arrival position at floor zero is blocked for further arrivals. The sum of these times is 18.5 seconds and defines the minimum evacuation departure interval of MULTI cars from the Sky Lobby and floor zero.

During evacuation the maximum number of cars which can depart from the Sky Lobby during a period of five minutes is 300/18.5 = 16.2. Consequently, the maximum evacuation capacity of ONE MULTI loop is 16.2 * 8 = 130 persons per five minutes. The rtt of 100 seconds divided by 18.5 = 5.4, i.e. the minimum number of cars required for evacuation.

An evacuation capacity of 1000 passengers per 5 minutes would require 1000/130 = 7.7, i.e. EIGHT single loop MULTI systems with 16 hoist ways. The number of cars required for evacuation services would be 6 cars in each loop, a total of 48 cars.

Maximal transport capacities of MULTI express groups for heaviest simultaneous traffic

For heaviest up and down traffic the minimum departure interval of 18.5 seconds for evacuation is not correct, because after the horizontal move of a car to its departure position doors must open (2 s) for car loading (8 s) and door closing (2.5). This implies the minimum departure interval at each lobby increases by 12.5 seconds to 31 seconds and the average rtt to 125 seconds. The optimal number of cars for this traffic is 125/31 = 4 cars. Each loop enables 4 cars to make 300/125 = 2.4 X 4 = 9.6 trips per 5 minutes and transport 77 persons up and down. An 8-loop system can transport 614 persons in both directions per 5 minutes.

Departure intervals determine the transport capacities of MULTI groups

A single loop MULTI system to a Sky Lobby at level 200 can operate with 4 to 6 self-propelled cars. Six cars assure maximum evacuation capacity; however, for busiest simultaneous traffic the optimal number of cars is four. If the loop operates with six cars these must, during heaviest simultaneous up and down traffic, reduce their average travel speed to delay arrival in lobbies, i.e. tolerate longer travel times in the cars. To solve this problem, i.e. optimizing of travel times and transport capacities for normal operations the two extra cars for evacuation should park outside the loop.

Evacuation capacity conventional Express elevators

The table below calculates the round trip time and transport capacities of single-, double- and triple-deck express elevators, with contact loads of 1600 KG per deck, for evacuation of a Sky Lobby.

Loading 16 passengers	16	seconds
Door to door flight time (down trip)	36	seconds
Unloading 16 passengers	16	seconds
Door to door flight time (up trip without passengers)	36	seconds
Total round trip time	104	seconds
Number of roundtrips per 5 minutes	2.88	trips
Transport capacity single deck car	46.15	persons
Transport capacity double deck car	92.31	persons
Transport capacity triple deck car	138.46	persons

The evacuation capacity of EIGHT triple-deck express elevators is 1108 persons per 5 minutes, i.e. approximately the same as eight single loop MULTI systems! The average waiting time for the T-D cars will be approximately 7 seconds and zero s for the MULTI cars.

Conclusions for Express MULTI systems

It seems unlikely that MULTI systems will reduce space- and energy requirements in comparison with triple-deck express groups. The capital cost of EIGHT MULTI systems and the large number of cars will be high. These systems will require perfect maintenance because a car failure will be a big problem. Passenger evacuation and access of technicians will be difficult. Parking of cars not required for evacuation may be problematic.

The energy consumption for the up trip of a full car and the rate of energy recovery during the down trip of a full car are of great interest. This aspect of the MULTI system is not mentioned anywhere. To maintain strict silence in respect of performance and efficiency data is typical for the elevator industry.

For passenger transportation to Sky Lobbies, the MULTI “back-pack” drive system is not an optimal solution. The distance between the small roller guide wheels of the drive system is short. In addition, these wheels are always under pressure because carloads are ex-centric. This combination of mechanical details implies the ride quality of MULTI cars depends on guide rails being perfectly straight. This problem probably defined the maximum speed of 6 m/s for the MULTI system.

A further drawback of the “back-pack” drive system: it does not facilitate through-opening car doors for simultaneous loading and unloading. A twin-linear drive system in the car center might be an option for express elevators, particularly because horizontal moves are a useless feature for vertical transportation systems.

MULTI system for service to Local Zones of adjacent floors.

A local zone of *adjacent* floors is a major problem for MULTI systems. Each stop of a MULTI car blocks a hoist way for approximately 12 seconds, door opening and closing (4.5 s), dwell time (minimum 1 s) plus the *time cost for deceleration and re-acceleration*. The horizontal move of a car to an adjacent hoist way blocks two hoist ways for approximately 18 seconds. The biggest problem of MULTI systems will be the **“bunching”** of cars, because stops of previously departed cars block hoist ways. For info about the problem of bunching refer to Chapter 6: “Average Waiting Time, the misleading parameter”, of the book "The planning and performance of groups of elevators" on website elevatorgroupcontrols.com.

The TKE/CTBUH MULTI Research Paper does not mention a MULTI control system, although each car must know the destinations of its passengers, i.e. on which floors it has to stop and open doors! Historic paternosters did not require a control system. Passengers jumped in and out of the slow moving cars.

Technically the writer admires the ingenuity of the MULTI system; however, it is most unlikely that MULTI systems can satisfy the vertical transportation requirements of tall buildings.