MODERN DOUBLE DECK ELEVATOR APPLICATIONS AND THEORY

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ABSTRACT

Since their introduction in the 1930's, Double Deck Elevators have been applied in over 30 buildings throughout the world. The majority of the projects have been "pure double deck applications" where all of the local lifts are double deck units. Some very high rise office towers utilize double deck elevators for sky lobby shuttles that then feed tenants and visitors to the single deck, local lifts. With the advent of new microprocessor based, Artificial Intelligence equipped dispatch controls, double deck elevator applications are enjoying a renaissance, particularly in Asia, where very dense building populations, relatively small floor plates, and high land costs make them a logical choice.

This paper will explore the reasons for applying double deck elevators in new high rise office buildings and then review the design theory and dispatching algorithms that make these units attractive. A definition of elevator design terms, with particular emphasis on double deck applications, and a listing of the world's current double deck installations will be included in the paper appendix.

1.0 INTRODUCTION

In 1931, the first double deck (D.D.) elevators (two tandem cars stacked one above the other and fixed in the same car frame) were installed in the 66 story Cities Service Building constructed at 60 Wall Street in New York City. This "pure" double deck scheme was an attempt to increase the group handling capacity of the high rise zone lifts by having each car only stop at alternate levels during peak traffic periods. The cars then would simultaneously load and unload while serving two adjacent floors at each stop. The building was located above a subway stop and it was envisioned that tenants desiring to go to odd numbered upper floors would board the lower deck while even floor tenants would load onto the upper, even deck. This boarding characteristic created dual loading lobbies at the basement and ground floors (Figure 1) that were interconnected by escalators so that during the morning up-peak, building tenants could sort themselves out by odd or even destination floors before they entered the elevators. The system was designed so that the elevators would operate as double deck enabled, odd/even units during the morning up peak and evening down peak traffic periods and then be switched to single deck units, with only the top car operative, during the remainder of the day. The elevators were operated by attendants, had automatic signal control and were dispatched by starters from the main lobbies. A year after the building opened the great depression hit and the masses of tenants needed to fill the upper floor rental areas never materialized. The double deck operation was scrapped in order to save the employee cost for the excess elevator operators. Thereafter, the bottom car was counterbalanced with sandbags, sealed off, and operated as single deck elevators till the 1980's when the cars were modernized to permanent single deck operation.

By designing a building with double deck elevators, it was expected that each double deck lift could provide service to more upper zone floors while reducing the required number of lifts (and shafts) compared to conventional, single deck (S.D.) elevatoring required to provide a similar level of service in a given size building. To date, about 30 large office buildings have been constructed throughout the world utilizing double deck solutions and they seem to work quite well. The D.D. to S.D. ratio works out to about 70% or an approximate 30% savings in the number of hoistways required. Surprisingly, the cost of the elevators D.D. vs S.D. is about the same even though there are fewer double deck units. However, the tremendous core savings for the D.D. solution makes the building more efficient by creating more rentable area. If this additional revenue is projected over the economic life of the project, it usually results in a tremendous advantage in favor of the double deck approach for certain, selected projects.

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2.0 ANALYSIS

The old criteria for double deck elevator applications in high rise office buildings was to start looking at the viability of applying them when the building:

1. Containing over 93,000 gross square meters of office space.
2. Had typical floor sizes in excess of 23,000 gross square meters each.
3. Was to contain over 40 office floors with populations of at least 200 persons/floor.
4. Contained very dense, single zone tenants with intense arrival queues and lots of interfloor traffic.
5. The building was located proximate to a rapid transit station.

Utilizing these design requirements meant that double deck installations were primarily reserved for monumental, headquarters type, single tenant buildings. The double deck equipment required to satisfy these design parameters, generally consisted of very large 1800/1800 KG cars, was very expensive to purchase and maintain, and the operation was confusing to the building tenants and visitors. The dispatching logic was relatively unsophisticated and was based almost exclusively upon the functioning of a mechanical selector, with a morning up peak, odd/even restricted floors service algorithm and a trailing deck response strategy during non peak times. With masses of zone tenants constantly requiring one way and two way interfloor transport, it was almost a given that every time an elevator stopped, there would be simultaneous loading/unloading at each two floor stop. These heavy zone populations also assured that almost every interfloor stop involved cancelling coincidental and/or congruent registered car and hall calls. In short, it was basically a people response dispatching strategy with little computing logic required.

If the tenant densities decrease or the arrival/departure queue intensities degrade due to tenant changes or more use of flex time, the double deck systems equipped with the old dispatching controls tend to break down because there is no longer enough people to push the buttons and heavily load the cars. Under these conditions, the waiting times for service at upper floors increase along with the number of "other deck loading" activations. These changes often lead to tenant frustrations with accompanying complaints to building management about poor service and can generally only be alleviated by a modernization to new microprocessor based controls.

Modern, pure double deck applications generally involve very tall, slender office towers with relatively small floor plates of about 1,400 to 1,850 gross square meters each. The high land costs and relatively dense zone tenancies (10 to 12 sq. m/person are not uncommon) associated with many Asian developments makes these types of projects a logical double deck choice. These projects generally require much smaller car sizes, 1360/1360 KG or 1600/1600 KG and are equipped with sophisticated graphics and signage directing the tenants and visitors to the appropriate deck. The elevator motion, motor control and dispatching logic are generally microprocessor based systems employing the latest double deck application algorithms and advanced dispatching strategies that speed up the elevator trip. These applications are more efficient than the older people based dispatch systems because they continually scan the car and individual deck status, the number of car and hall calls registered and then assign the best deck to service the call.

The following chart indicates the maximum car loads and zone populations that can be handled by a given size S.D. or D.D. lift.

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FIGURE 1

ELEVATOR CAPACITIES/MAXIMUM ZONE POPULATIONS

ELEVATOR CAPACITY (KG)	FULL CAR LOAD (PERSONS)	NOMINAL CAR LOAD (PERSONS)	MAXIMUM ZONE POPULATION (PERSONS)	
			AVERAGE INTERVAL ≤30 SECONDS AND 12% HANDLING CAPACITY	AVERAGE INTERVAL ≤30 SECONDS AND 14% HANDLING CAPACITY
SINGLE DECKS				
1360	20	16	1,333	1,143
1600	23	19	1.583	1,357
1800	27	22	1,833	1,571
2260	33	25	2,083	1,786
4530	66	50	4,166	3,571
DOUBLE DECKS				
1360/1360	20/20	16/16	2,666	2,286
1600/1600	23/23	19/19	3,166	2,714
1800/1800	27/27	22/22	3,666	3,143
2260/2260	33/33	25/25	4,166	3,571

2.1 DOUBLE DECK DESIGN ADVANTAGES:

Double lift designs are unique and some of their design advantages are listed below:

1. Fewer passenger elevators and groups of elevators are required when compared to a similar single deck design.
2. Smaller capacity size elevators are required, when compared to single decks, because each car frame has two cabs.
3. Double deck elevators generally do not require contract speeds as fast as single deck units because they serve more stops and generally do not have to express as far to reach their first local stop. Speed is used to partially overcome express travel distances.
4. Each elevator carries more people (two cabs/unit) with fewer typical stops, due to two floor jumps, enroute to a rider's destination.
5. Each double deck elevator zone typically contains 18-20 upper floor stops compared to no more than 15-16 stops for a single deck zone arrangement.
6. During the up-peak condition, passengers generally reach their destination floor quicker, than on comparable single deck units, because the number of typical stops is halved.
7. Double deck arrangements result in tremendous building elevator core savings (about 30%) when compared to a similar single deck service scheme.
8. Taller buildings are possible for the same size building site because the core area is reduced, each double deck zone serves more floors, and the amount of rentable area is increased. A typical 60 story office tower would require 3 zones of double deck lifts (6-8 elevators per zone) or 4 zones of single deck lifts. If we figure 6 elevators per zone, this works out to 18 double decks vs 24 single deck elevators (a 75% ratio) or 36 D.D. cabs vs 24 S.D. cabs.
9. They require smaller first floor elevator loading lobbies and upper corridor widths because each car is normally smaller, and during peaks, the cars always stop at two floor jumps.
10. Double deck elevators require fewer entrances.

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11. Double deck elevators generally take less time to install because there are fewer of them.
12. Double deck elevator continuing maintenance costs are less than comparable single deck units because there are fewer of them.

2.2 DOUBLE DECK LOBBY DESIGNS:

Typical double deck loading lobby arrangements are shown on attached Figure 2:

1. Because of their simultaneous loading characteristics, double deck elevators create a dual loading lobby situation where one loading lobby must be located on top of the other.
2. Most morning up-peak, double deck applications require that the upper odd floor level tenants load on the bottom deck and that even upper floor tenants load on the top deck.
3. There are 4 possible dual loading lobby variations: a) a split level lobby, b) a main lobby at the lower level, c) a main lobby at the upper level, or d) a dual entry/exit lobby at each level.
4. Up and down escalators are generally provided between each loading lobby in order to speed up required elevator passenger entry/exiting level changes.
5. The split level lobby is preferred from a visual and efficiency standpoint but this arrangement requires the installation of more escalators than for the single entry lobby schemes.
6. The space adjacent to the main, dual loading lobbies or dual sky lobbies, created when using a double deck shuttle scheme, are normally devoted to retail tenants. This commercial space can be utilized to create double floor height atriums, food courts, retail stores, or mini malls and lends itself to innovative architectural treatment.
7. During down travel, a departing double deck elevator passenger has no control over which elevator deck picks him up after he registers a down hall call on an upper floor. Upon arrival at the bottom terminal, he will exit at the bottom or upper lobby landing and then sort out his building exiting choice by use of the adjacent escalators.

2.3 DOUBLE DECK, SPECIAL BUILDING DESIGN REQUIREMENTS:

Double deck elevator installations do require some unique building requirements:

1. Dual loading lobbies with up and down escalator interconnections are required.
2. Generally, all building levels served by the elevators must have the same floor-to-floor heights.
3. Special graphics and signage should be strategically placed at the building entry points to direct people to the appropriate zone floors and the proper odd/even loading lobby.
4. Double deck elevators require slightly larger hoistway widths and depths due to the larger car frames, heavy duty rails and bigger counterweights.
5. Normal elevator overtravel requires the addition of one extra floor height if a) the lower deck is to be capable of serving the top floor in the zone or b) the zone has an odd number of floors requiring the bottom deck to serve the top floor.
6. Machine room and pit reactions are slightly increased due to the larger hoist machine sizes and heavier suspended car loads (car frame and counterweights) and car capacities (two cars in each frame).
7. Lock down type rope compensation is required for all lifts.
8. If the building parking shuttles do not serve both building loading lobbies, a separate handicapped person shuttle elevator may be required to serve between these floors. Alternately, special handicapped controls can be provided inside each car to permit a wheelchair bound person to momentarily override the odd/even stopping pattern.
9. The size of the main building lobby exits might have to be increased to avoid congestion created by the heavy down peak traffic that can be discharged by the double deck elevators at the main lobbies.

TYPICAL DOUBLE DECK DUAL LOADING LOBBY ARRANGEMENTS

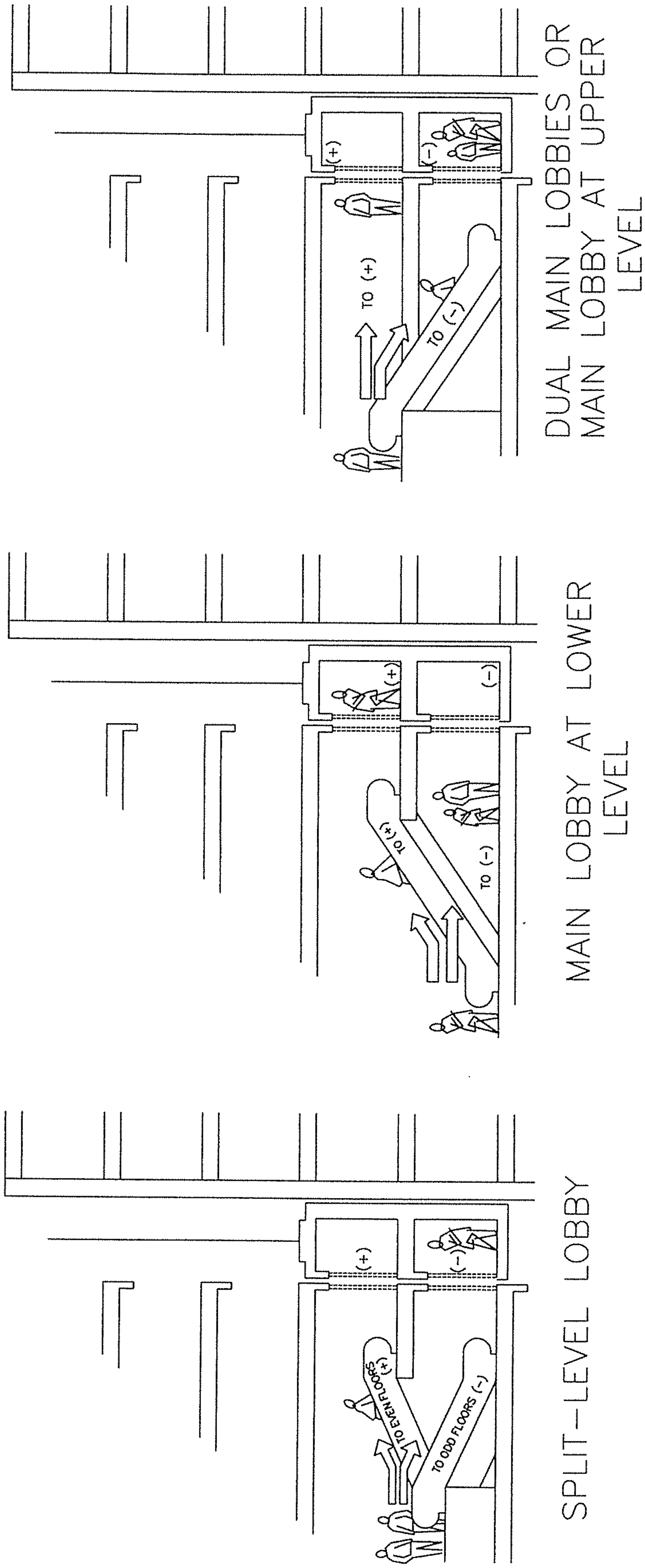

FIGURE 2

LOBYARG

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2.4 DOUBLE DECK PROBLEMS:

Double deck elevators do present some problems in bidding, operation and applications:

1. Most of the double deck installations have been installed by the Otis Elevator Company so in the past there has only been one viable bidder. The most recent double deck projects have been bid by Otis, Schindler, Fujitec, Mitsubishi and Kone. Otis still claims they have a valid patent on the "trailing deck response" non peak operation algorithm.

2. Building tenants can cheat the morning up-peak odd/even dispatching strategy by boarding the wrong deck and then a) wait for the restricted odd/even car calls to become unbridled after either deck stops in response to a hall call, b) wait for the car to make its first stop, momentarily jump out and quickly register an up hall call and then reboard the elevator, or c) ride on the wrong deck until the car reverses. After any of these 3 scenarios occurs, the car calls become unbridled and the inscrutable elevator rider can then immediately register his real destination car call.

3. In order for the double deck strategy to be effective, there must be an adequate number of zone tenants and visitors present. A minimum number of people are required to register calls and load both decks in order to take advantage of the system's ability to provide: a) simultaneous loading/unloading characteristics at each 2 floor jump, b) adjacent or congruent hall call stop cancellations, and 3) coincidental stop car and hall call cancellations.

3.0 DOUBLE DECK OPERATION

3.1 GENERAL

With a double-deck elevator system, two elevator cabs are connected in tandem, one on top of another, to the same car frame and share the same hoistway. Each elevator then can serve two adjacent floors simultaneously.

At the lower loading building lobbies, zone tenants and visitors board the elevators from two different levels, depending upon whether their upper-level destination is an odd or even-numbered floor. When first entering the building, they must identify whether they should board a lower level(-) deck or the upper level(+) deck. The two loading lobbies are interconnected by adjacent escalators and elevator passengers are directed by prominent signage to the appropriate loading lobby.

3.2 THE RESTRICTED UP-PEAK CONDITION

During the morning up-peak condition, when incoming tenants and visitors arrive at the building, they board the appropriate odd or even elevator deck. When selected for dispatch, both decks of a single unit have their doors open simultaneously for loading and elevator riders select their in-cab destination floor by registering car calls as they enter the cab. During this condition the odd or even cab will only accept the appropriate floor registrations even though all cabs are equipped with all-zone floor buttons.

If an elevator rider tries to register a call for an even floor in the odd deck or vice versa, the car call will simply not register. Thus, the car calls are restricted at the loading lobbies during this condition. Once the elevator is dispatched the doors close and the car expresses to the first typical floor stop, where both car doors open and the passengers discharge simultaneously, two floors at a time. If a car call is not registered for one deck, while the other deck is unloading, the doors for the nonresponding deck remain closed and a back-lighted sign that displays SERVING OTHER DECK illuminates inside the cab.

3.3 UNRESTRICTED UP-PEAK TRAVEL

As soon as an up hall call is registered, the bottom, trailing deck of the selected elevator ascending in the up direction will normally stop in response to this call. The car call buttons for both decks then become "unbridled", passengers entering either deck can now enter car calls for any floors above them, and either deck can stop at any upper floor it serves. This trailing deck response strategy is designed to promote two-floor runs and permit simultaneous loading of the upper deck if it picks up a congruent hall call.

3.4 TWO WAY, INTERFLOOR SERVICE

During non peak times (the majority of the day), the elevators are a) parked where they answered their last call, b) are placed into zones or, c) are moved to strategic positions within the zone. In order to answer a down hall call, the upper, trailing deck normally responds forcing the lower, lead deck to respond to any adjacent hall calls. Similarly, a response to a registered up hall call is normally answered by the lower trailing deck which leaves the upper, lead deck available to answer other calls. If the group supervisory control determines that a trailing deck is full or that the lead deck has registered coincidental car and hall calls for a particular floor, it may instead select that deck to respond. The important point to remember with non peak, two way traffic is that the efficiency of the double deck interfloor service depends upon the frequency of adjacent (congruent) hall stops and coincident car and hall call responses, i.e., heavy interfloor traffic volume creates more coincident and congruent stops thus increasing the system efficiency.

3.5 DOWN TRAVEL

If no passenger boards either deck during the local stop up travel, the in-cab car call odd-even restriction is removed upon car reversal and both decks become "unbridled" during down direction travel. An elevator traveling down will normally answer a registered corridor call with it trailing (now the top) deck. Again, the lower, leading deck is free to pick up congruent hall calls. During down travel, the cars do not follow the restricted odd/even pattern but search for "congruent"[1] and "coincident"[2] calls at adjacent landings. By searching for congruent hall calls and coincident car and hall calls, the supervisory control system is attempting to minimize the number of required stops, maximizing the number of passengers served, and reducing the typical elevator round-trip times, all while increasing the group handling capacity. A down traveling passenger has no control over which deck will pick him up, has no clue as to whether the upper or lower deck picked him up (since all cabs look the same), and doesn't know which loading lobby he will exit at until the car arrives at the lower loading lobbies and the cab doors open.

3.6 CAR LOAD WEIGHTING OPERATIONS

Each deck is equipped with an electronic device for determining the number of people loaded in each car. The group supervisory control system utilizes this information to a) initiate selected dispatching patterns, b) to dispatch a car in advance of its normal rotation, c) to bypass registered hall calls if either deck becomes full, d) to select the alternate deck if the normally selected trailing deck is too full to respond to registered hall calls and, e) to pretorque a hoist motor to prevent "rollback" if the car loads exceed the weight of the counterweight.

3.7 MODERN DISPATCHING IMPROVEMENTS

Newer forms of microprocessor-based group dispatching for double-deck lifts such as Otis Elevonic 411 or Schindler Miconic VM are more efficient in assigning calls to decks, particularly during nonpeak times. With their increased scanning speed, large computer storage memories, and advanced dispatching or

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[1] congruence means registered hall calls at two adjacent landings that can be served by a single stop

[2] coincidental means that the car/deck stops in response to registered car and hall calls for the same level

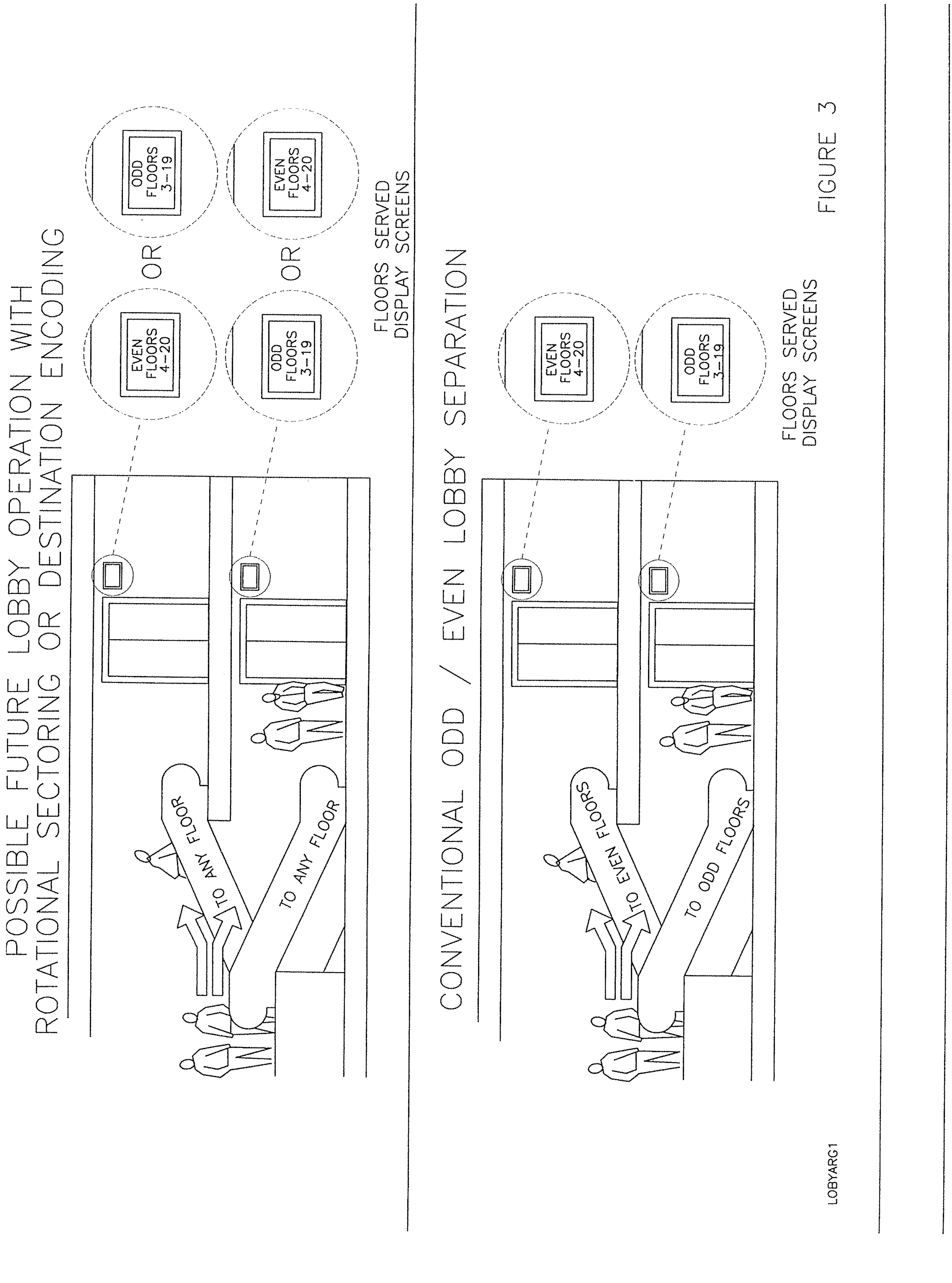
POSSIBLE FUTURE LOBBY OPERATION WITH
ROTATIONAL SECTORING OR DESTINATION ENCODING
TO ANY FLOOR
TO ANY FLOOR
EVEN FLOORS 4-20
OR
ODD FLOORS 3-19
ODD FLOORS 3-19
OR
EVEN FLOORS 4-20
FLOORS SERVED
DISPLAY SCREENS
CONVENTIONAL ODD / EVEN LOBBY SEPARATION
TO EVEN FLOORS
TO ODD FLOORS
EVEN FLOORS 4-20
ODD FLOORS 3-19
FLOORS SERVED
DISPLAY SCREENS
LOBYARG1

FIGURE 3

artificial intelligence capabilities, these microprocessor controls are capable of more closely matching the available elevator service (decks) to the traffic demands while significantly reducing the system response times. These systems continually update the status of each car and scan all registered car and hall calls to select the most efficient deck to respond to the demands.

4.0 CONCLUSIONS:

The introduction of microprocessor based controls with advanced dispatching capabilities has expanded the market for pure double deck applications in high rise office buildings. This increased computing power has made the double deck lifts more efficient during non peak times as the "trailing deck response" to registered hall calls is no longer required. Instead, modern dispatch systems make it possible to assign the best deck to answer a particular call.

With the introduction of electroluminescent or active dot matrix display screens located at the dual loading lobby floors (Figure 3), coupled to rotational sectoring (channeling) or destination encoding operations, it may even be possible to eliminate the odd/even restrictive dispatching that causes so much consternation among conventional double deck riders. Under this scenario, an elevator rider could enter either elevator loading lobby and wait till the dispatching system selected the appropriate odd/even car or deck that will stop at his selected floor.

Double deck installations are no longer just confined to monumental, high rise buildings and are being considered in many modern 30-50 story office building applications. Is there a double deck installation in your future?