

Proposal for 3D Taxi Connecting High-rise Buildings

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In this paper, a “3D taxi that connects high-rise buildings” is proposed. It is an advanced idea that can effectively utilize the 3D space of a city and increase the efficiency of the movement of people and goods. This proposal has the potential to contribute to reducing urban congestion, saving travel time, and improving energy efficiency. The following items are possible examples of applications: (1) a transportation network connecting high-rise buildings within the megacity (for example, Shinjuku Subcenter, Marunouchi, and Roppongi Hills can be connected in three dimensions) and (2) linking buildings such as hospitals, research institutes, and pharmaceutical companies (connecting adjacent buildings will create an evacuation route in case of an emergency). The basic technology is a 3D elevator, which can move not only up and down (vertically), but also left and right and forward and backward. If such elevators are connected among multiple high-rise buildings, people and things can move three-dimensionally and efficiently, without relying on conventional ground or underground transportation. In the future, the introduction of image sensors will be essential. In this study, a model of this 3D elevator is proposed as a “3D taxi”, and an example of how this concept can be used to move people and things to their destinations is indicated.

1. Introduction

The following idea is proposed in this study: a 3D taxi connecting high-rise buildings. This concept is a very futuristic and interesting idea for the evolution of urban infrastructure and the mobility revolution. A 3D elevator model is proposed in the next section, and an example of guidance to the destination is explained in Sect. 3.

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Overviews of some of Japan's famous skyscrapers are indicated below.

- (1) Toranomon Hills (Tokyo): 255.5 m, 52 floors, 53 elevators⁽¹⁾
- (2) Yokohama Landmark Tower (Yokohama City): 296.33 m, 70 floors, 74 elevators⁽²⁾
- (3) Abeno Harukas (Osaka Prefecture): 300 m, 60 floors, 56 elevators⁽³⁾
- (4) Azabudai Hills Mori JP Tower (Tokyo): 325 m, 64 floors, 71 elevators⁽⁴⁾

To quickly transport a large number of passengers (users) to their desired floors, many elevators are required. The more elevators there are, the more space is required for their installation and the higher the cost of equipment. Currently, there are two main methods for efficiently operating elevators for super-high-rise buildings, namely, the sky lobby system and the double-deck elevator system. The sky lobby method is used at Abeno Harukas, where it reduces the number of elevators installed while still maintaining transport capacity. In this system, passengers take a shuttle elevator from the ground level to a certain floor (sky lobby), then transfer to another elevator to travel to their destination floor. The shuttle elevator is an elevator that goes directly to a specific floor. For example, if the elevator travels directly between the first and tenth floors, it travels nonstop between the first and tenth floors.

There are two reasons why the sky lobby system is adopted for elevators in skyscrapers: (a) transport capacity is ensured in a small area and (b) passengers can reach higher floors comfortably. Usually, the taller a building is, the more elevators need to be installed to ensure sufficient transport capacity. The more elevators installed, the larger the installation area, which has the disadvantage of reducing the "sales area" in the case of a commercial facility. The taller the building, the longer it takes for passengers to reach the higher floors. For instance, consider moving from the first floor to an office on the 35th floor. When it is crowded and the passenger uses an ordinary elevator, it may stop at the first floor, second floor, and so forth up to 34 times. In the sky lobby system, passengers can travel from the first floor to the sky lobby on the 30th floor by a shuttle elevator, then transfer to an ordinary elevator. It takes a maximum of only six stops to reach the destination (35th floor), and thus, the travel time can be significantly reduced.⁽⁵⁾ The number of sky lobbies must be increased to reduce the number of elevator transfers and significantly shorten travel times. More sky lobbies mean less available space and more costs.

First, we explain the history of the sky lobby system. The first sky lobby elevator was installed at the John Hancock Center,⁽⁶⁾ which was completed in 1969 in Chicago, USA, and is approximately 344 meters above the ground (100 stories). Next, we explain the double-deck elevator system. The double-deck elevator is an elevator with two passenger boxes (cars, *kago* in Japanese) connected one above the other, and it is possible to transport many people at once. In other words, it is a "two-story elevator". This type of elevator was first manufactured in 1931 by Otis Elevator Co., which is the world's largest elevator manufacturer, and the distance between the upper and lower cars (*kago*) can be changed. This function is called the "floor adjustment function". This function can be implemented in buildings where the ceiling height varies from floor to floor, making it suitable for high-rise buildings.

The advantage of introducing a double-deck elevator is that passengers can ride in two cars, one above the other, at the same time. This can increase the transportation capacity by 1.5 to 1.9 times and can reduce the long wait times during the following times when the elevators are crowded: every morning before 9:00 (before work starts) and around 12 o'clock (lunch time).

More space can be created for offices and other purposes by reducing the number of installed elevators and the proportion of elevators in the building area.

However, the double-deck elevator system has both advantages and disadvantages. The main disadvantage of the double-deck elevator is that the lower car can only stop at odd-numbered floors (e.g., 1st, 3rd, and 5th), and the upper car can only stop at even-numbered floors (e.g., 2nd, 4th, and 6th). Therefore, the first and second floors are basically connected by an escalator, with passengers heading to odd-numbered floors getting on from the first floor and passengers heading to even-numbered floors getting on from the second floor. Also, when the upper car stops, for example, on the 32nd floor where passengers are getting on or off, an announcement is made in the lower car saying, “The upper car is currently being used for passengers to get on and off. Please wait a moment (The other car is now in service).” All passengers must wait until the upper car has finished loading and unloading.⁽⁷⁾ Furthermore, even if there are only a few passengers, two cars must be operated, resulting in waste.

As an example of its introduction in Japan, 16 double-deck elevators are in operation at Azabudai Hills Mori JP Tower, which is the tallest building in Japan.⁽⁴⁾ However, the sky lobby system and double-deck elevators alone are not enough to operate the elevators for skyscrapers efficiently. Kimura *et al.* proposed a 3D elevator system that efficiently operates a single elevator for skyscrapers.^(8,9) Vehicles that connect skyscrapers and travel between them have not yet been realized. Such vehicles can be considered as taxis moving around interconnected buildings. The elevators have been considered as a kind of shared bus up until now. A 3D elevator model corresponding to a taxi is proposed in this study, and an example of guidance to a destination is also indicated. The implementation of this model requires the introduction of various sensors along with AI technology.

2. 3D Taxi Moving between Skyscrapers

A 3D taxi that can move vertically and horizontally (left and right, forward and back, up and down) in a cluster of skyscrapers is proposed in this section. First, the functions of the 3D taxi are described. There are two 3D taxi corridors (for going up and down, etc.) set up everywhere in the cluster of skyscrapers. The 3D taxis can turn left and right and move forward, back, up, and down on the corridors just like regular roads, making use of a sensor that operates as a traffic light. The taxi stand is located within the skyscrapers, such as the main places where people gather and paid spots that can be set up as needed. Two methods are considered to call a 3D taxi, namely, summoning it via a mobile phone and calling out at a stop to hail the 3D taxi. The instructions for the destination are given via voice, and the payment is made using a dedicated IC card.

The method of realizing this system is described below. The 3D taxi has a square shape, as shown in Fig. 1. There are four entrances and exits, and only the side for pedestrian passage is designed to open. There are several sofas installed in the taxi. The movement of the taxi is controlled by multiple electric gears installed on the sides for lateral movement, as well as at the front and back for longitudinal movement, and at the four corners in a diagonal arrangement. Specifically, when it moves in the left and right directions, only the taxi’s electric gears on the left and right sides are extended, while the other gears are retracted into the 3D taxi body. The

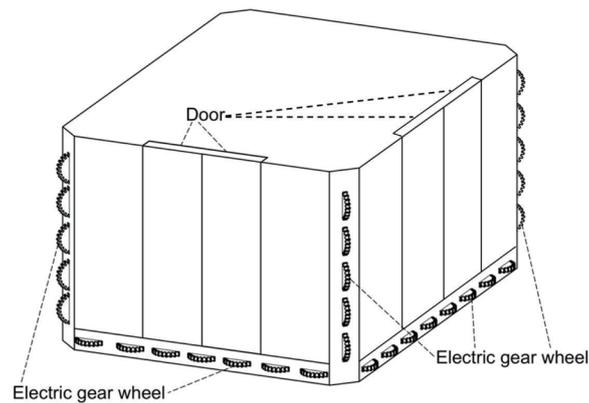


Fig. 1. Image of 3D taxi.

same actions apply when moving in other directions. To be able to extend the electric gears from the four corners of the taxi, the corners are flat in shape.

Funase *et al.* proposed a 3D parking lot that maximally utilizes 3D space.⁽¹⁰⁾ Kimura *et al.* applied that research to propose a 3D elevator.^(8,9) The 3D elevator system presented in this paper is composed of a skeleton of poles resembling a jungle gym. The overview is shown in Fig. 2. The electric box can move left and right, up and down, and back and forth within this skeleton. The electric box in the 3D elevator system is shown in Fig. 3.

The electric box must be on an odd-numbered floor when it moves horizontally. Only the electric gears on the left and right sides of the electric box are extended, while the other electric gears are retracted inside the electric box. The state in which the electric gear is fitted into the groove of the side pole is shown in Fig. 4. This diagram is a cross-sectional view from above. In Fig. 4, when the electric gear passes through the vertical pole, they are pushed up, and once they pass, they are returned to their original position by a spring, allowing the gear and the protrusions of the horizontal pole to fit together. When passing through the vertical pole, the electric gear is pushed up by the propulsion force of the other electric gears that are fitted into the horizontal poles.

When the electric box moves up and down, the box is moved so that its four corners are directly in front of the vertical pole. The electric gears on the left and right sides as well as those on the front and back sides are retracted at this time. After that, the electric gears are extended from the four corners of the electric box and fitted into the grooves of each vertical pole. These actions allow for vertical movement. Additionally, the way the electric gears extend from the four corners and fit with the vertical pole is the same as the movement in the left and right directions caused by the horizontal pole and the electric gear. There are no obstructing poles during movement.

When the electric box moves in the forward and backward directions, it must be on an even-numbered floor. The electric gears on the left and right sides as well as those from the four corners are retracted, and only those on the front and back sides are extended and fit into the grooves of the front and back poles. When the box is passing by a vertical pole, it is similar to the movement in the left and right directions, and the electric gear is pushed up by the spring. This action enables the box to move in the forward and backward directions.

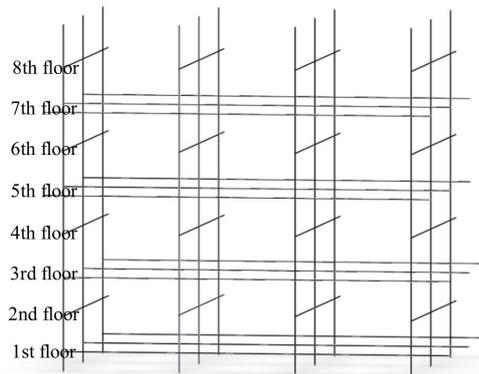


Fig. 2. Skeleton of 3D elevator (3 places left and right, 8 places up and down, and 2 places front and back).⁽¹⁰⁾

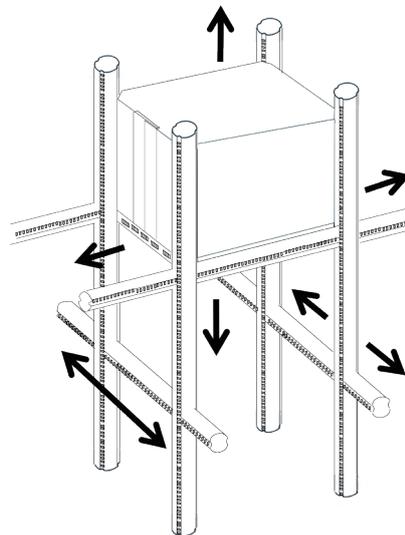


Fig. 3. Electric box in 3D elevator.

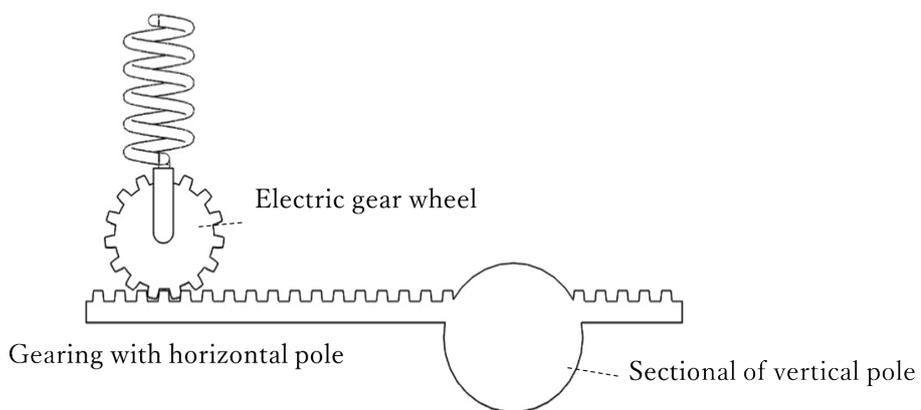


Fig. 4. State where electric gear fits into groove of horizontal pole.

We next consider the switching movement from other directions. The 3D elevator shown in Fig. 2 can move left and right as well as up and down on the first floor, but it cannot move forward and backward. It is possible to move in the forward–backward and up–down directions on the second floor, but the movement in the left and right directions cannot be executed directly. It is necessary to first move up or down by an odd number of floors in the vertical direction to execute the movement that cannot be performed directly. The 3D elevator in Fig. 2 is in the odd-numbered-floor state, which is the same as the first floor, and the even-numbered-floor state is the same as the second floor. The inability to move back and forth on the first floor is due to the front and back horizontal poles obstructing the movement of the electric box. Additionally, there is no pair of horizontal poles in the front and back directions to serve as rails for movement. Similarly, the inability to move horizontally on the second floor is due to the horizontal poles on the left and right obstructing the horizontal movement of the electric box and the lack of a pair of horizontal poles in the left and right directions, which serve as rails for movement. The described actions allow the electric box to move freely left and right, up and down, and forward and back in the 3D elevator. The 3D taxi is a paid electric box for personal use that moves within a skyscraper district.

3. Example of Guidance to the Destination

An example of the realization of a 3D taxi is explained below. A 3D taxi is a vehicle that travels through a network in 3D space. The intersections on a 2D plane are controlled by traffic signals in the typical vehicle traffic network. The movement of a 3D taxi in three dimensions is similarly implemented. A passenger can call a 3D taxi only at the designated points that correspond to registered bus stops. To call a 3D taxi, the passenger can either call using the microphone installed at each stop or summon the 3D taxi via the passenger’s mobile phone. The summoned 3D taxi will be the nearest waiting 3D taxi. The destination is understood through

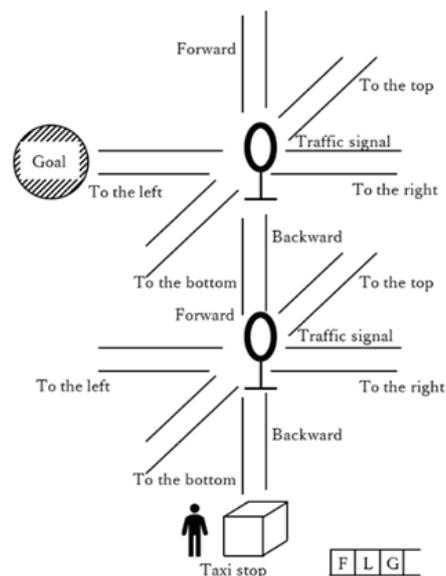


Fig. 5. Mechanism of guidance to destination (forward, left, and goal in order).

voice recognition. A series of branch point information is derived from the information of starting and destination points. This guidance is shown in Fig. 5. The taxi is guided to the destination on the basis of this information. When the corridors become crowded, the estimated time required to travel along each corridor to the destination is predicted, and the corridor that allows for the shortest arrival time is chosen.

4. Conclusions

In this study, we proposed a 3D elevator (taxi) that connects a group of high-rise buildings (skyscraper district). This research can be divided into the following two areas: (a) a 3D elevator that efficiently operates within a skyscraper and (b) a vehicle that moves between the main locations of the group of connected high-rise buildings. There are references^(8,9) regarding the former (a), and basic proposals were made regarding the latter (b) in this paper.

The expected advantages of this research are considered to be the following: (1) relief of urban traffic congestion (reducing surface traffic volume), (2) advanced barrier-free transportation (allowing elderly and disabled individuals to move between cities without stress), (3) compatibility with the smart city concept (easier to control the entire urban space in an integrated manner), and (4) improvement of the building's aggregation and sharing functions (making it easier to link facilities and services across multiple buildings, such as hospitals, commercial facilities, and public services).

The following items are issues that should be resolved: (1) compliance with the Building Standards Act, (2) urban planning development (assurance of legal consistency in connecting buildings), (3) cost and maintenance (high initial investment and complex infrastructure development), (4) consensus building among owners (with the agreement of each building owner as a prerequisite), and (5) security and privacy (there is a need for access control due to movement between buildings).

Each intersection is equipped with sensing systems such as cameras, but there is a need to understand the situation of the proposed taxis and people in more detail. Establishing various sensing systems will be the key.

Acknowledgments

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