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(19) **United States**(12) **Patent Application Publication**
Zou(10) **Pub. No.: US 2007/0107621 A1**(43) **Pub. Date: May 17, 2007**(54) **STRUCTURE AND OPERATION OF A
THREE DIMENSIONAL TRANSPORTATION
SYSTEM****Publication Classification**(51) **Int. Cl.**
E01B 25/00 (2006.01)(52) **U.S. Cl.** **104/130.01**(57) **ABSTRACT**

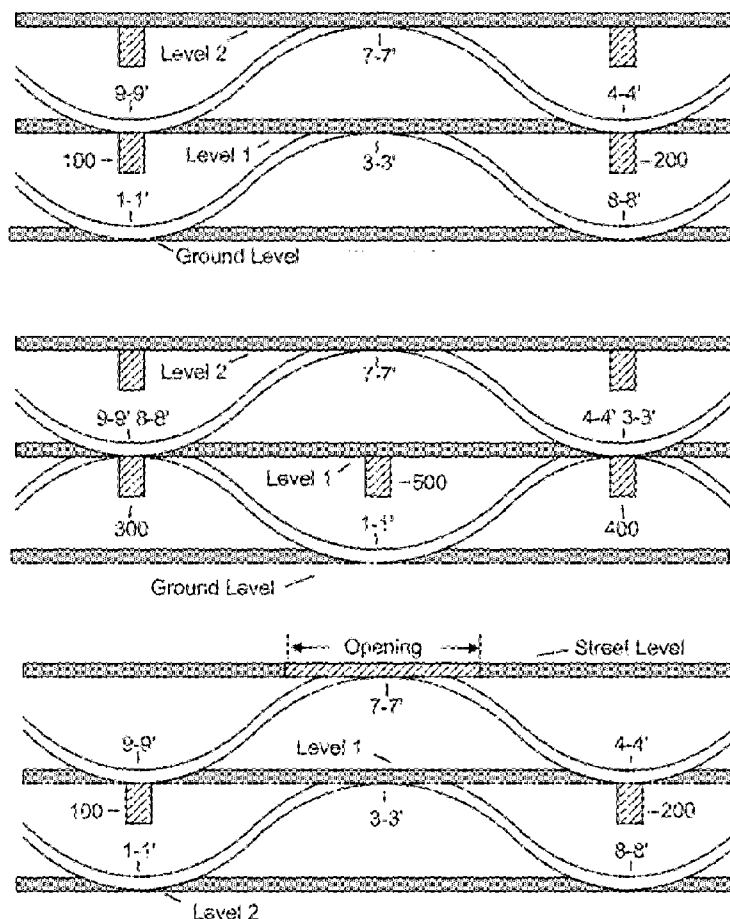
This invention provides methods of guideway construction and vehicle operation for a three-dimensional transportation system, in which a vehicle changes lane or direction by widening or narrowing the width between its left wheels and its corresponding right wheels. In such a transportation system, vehicles diverge from a source lane and merge into a target lane aerially either above or below the tracks, through the empty space between the left guideway and the right guideway. A transportation system in which traffic lanes could be stacked vertically one above another, and additional lanes could be added later without additional land usage. In such a transportation system, a vehicle could raise or lower its center of gravity in the vertical direction to offer the advantages of safe operation and easy loading/unloading. Such a transportation system could accommodate dual-mode vehicles. Such a transportation system is suitable for automatically moving people and goods.

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(60) Provisional application No. 60/767,058, filed on Feb. 28, 2006. Provisional application No. 60/597,188, filed on Nov. 15, 2005.

**Alignment of Guideways**

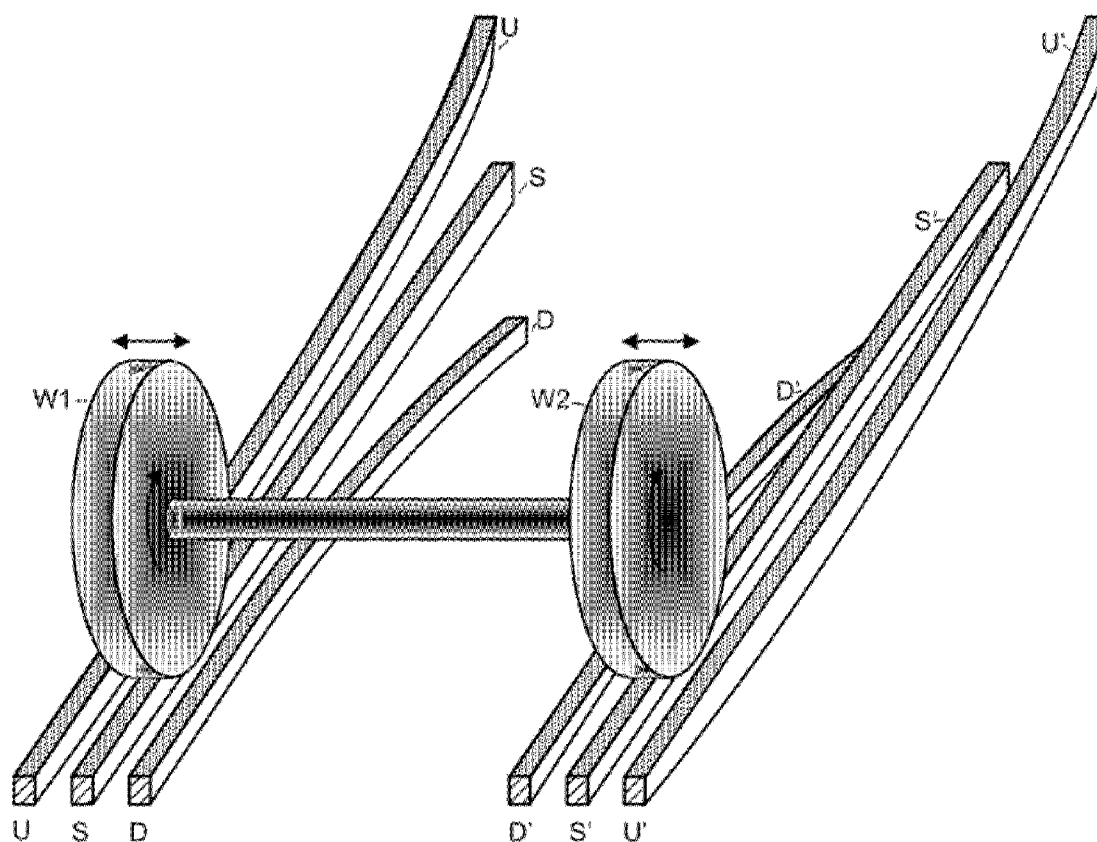


Fig. 1 Three Dimensional Guideway Switching Mechanism

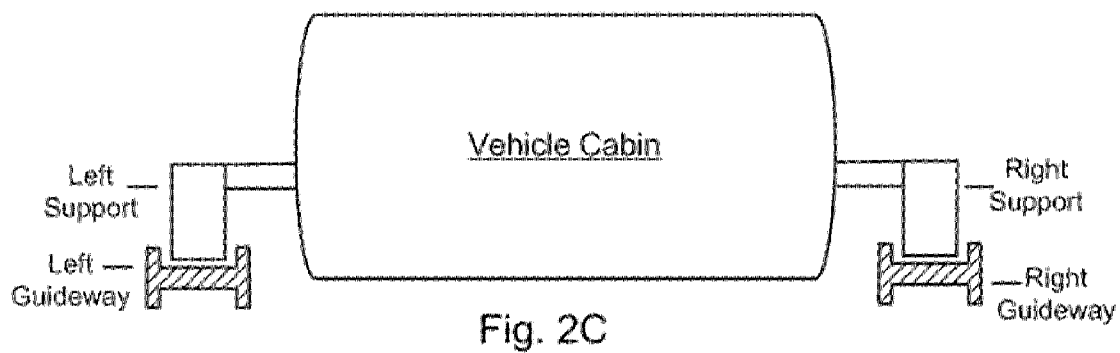
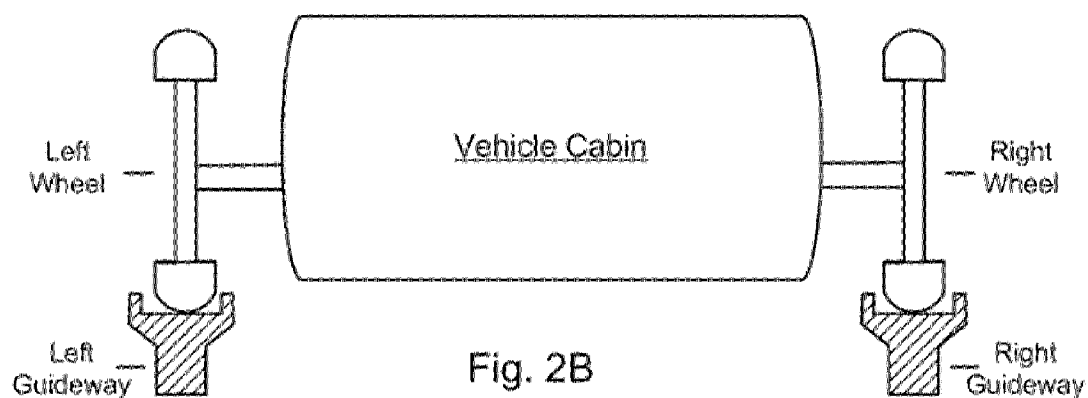
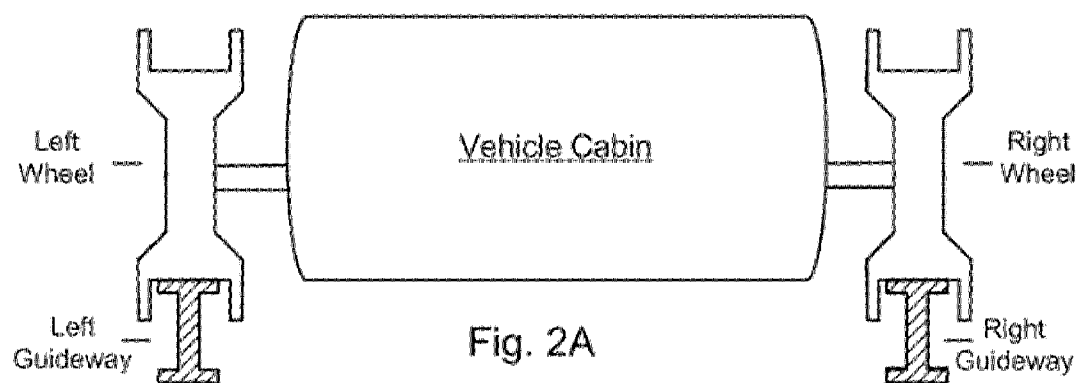


Fig. 2 Examples of Guideways

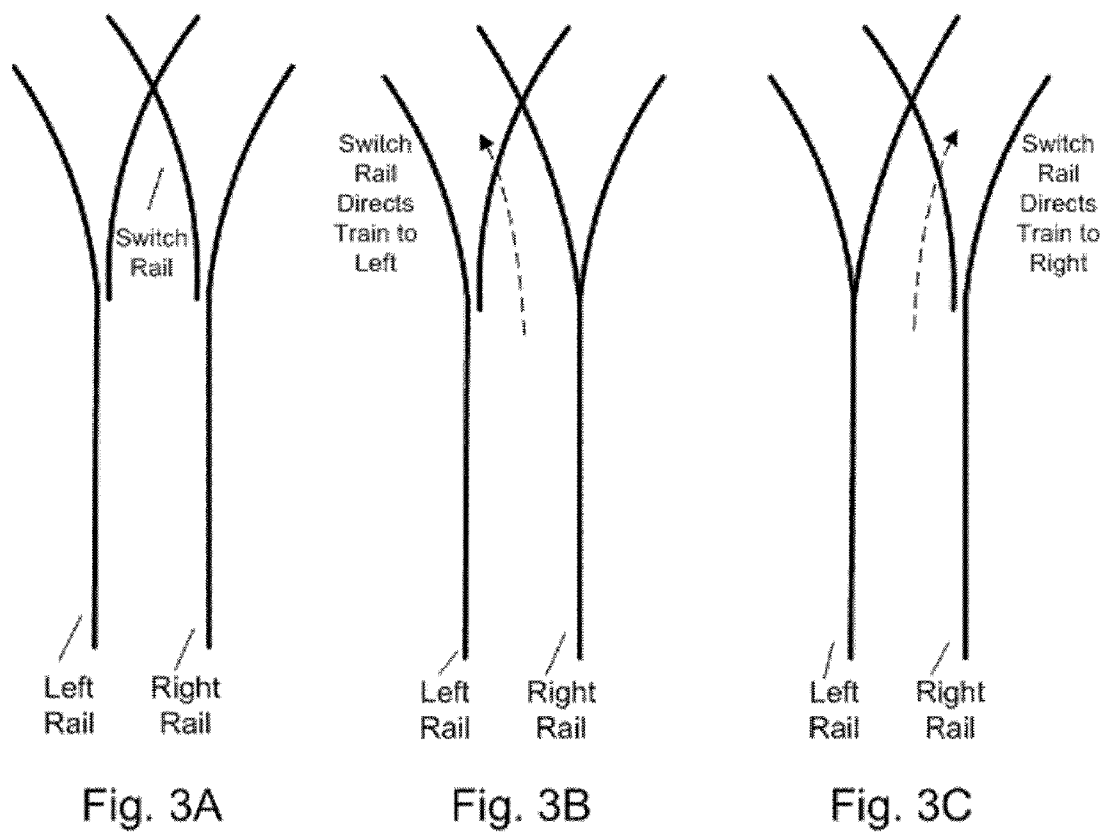


Fig. 3 Conventional Rail Switching Mechanism

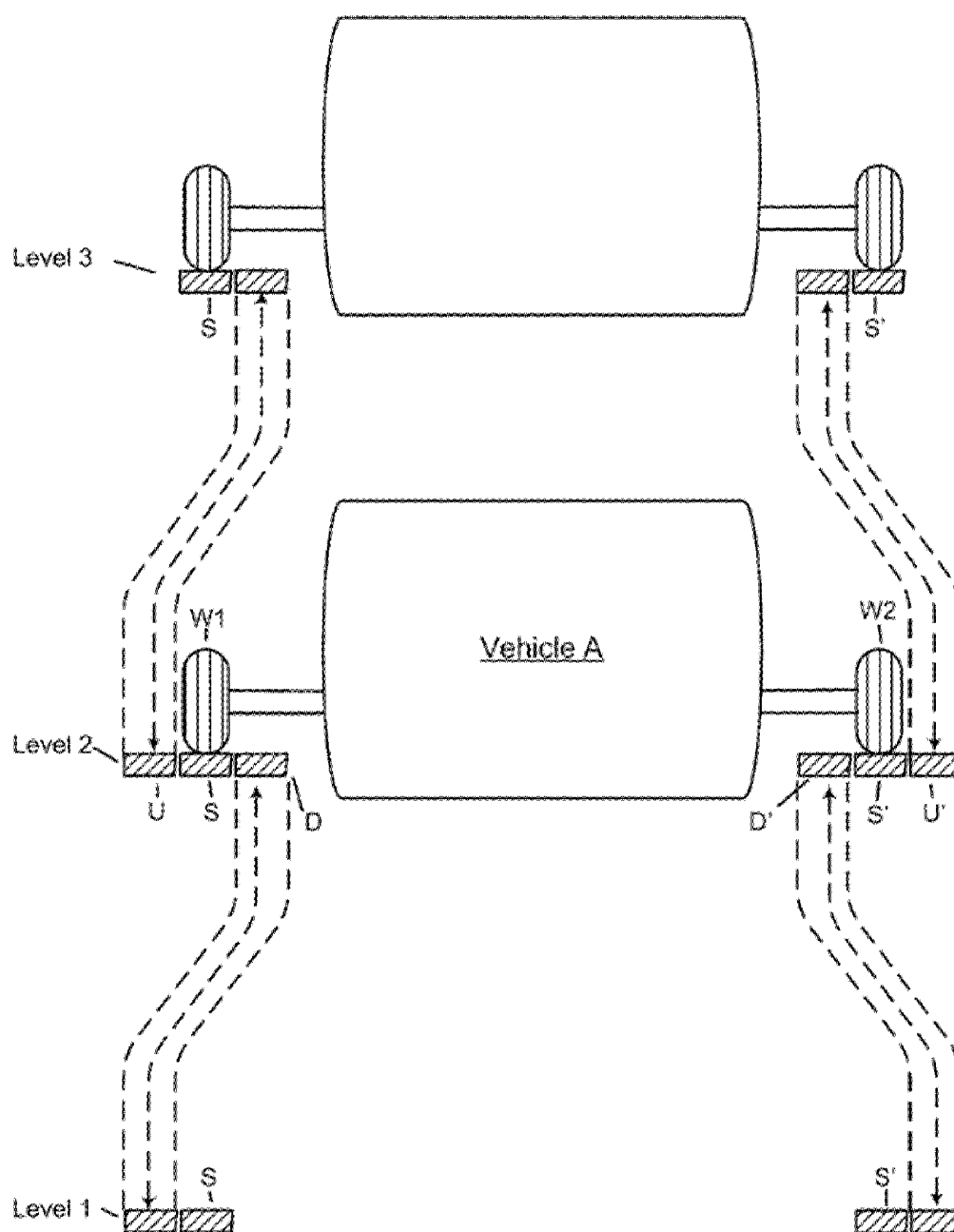


Fig. 4 An Example of Three-Level Guideways

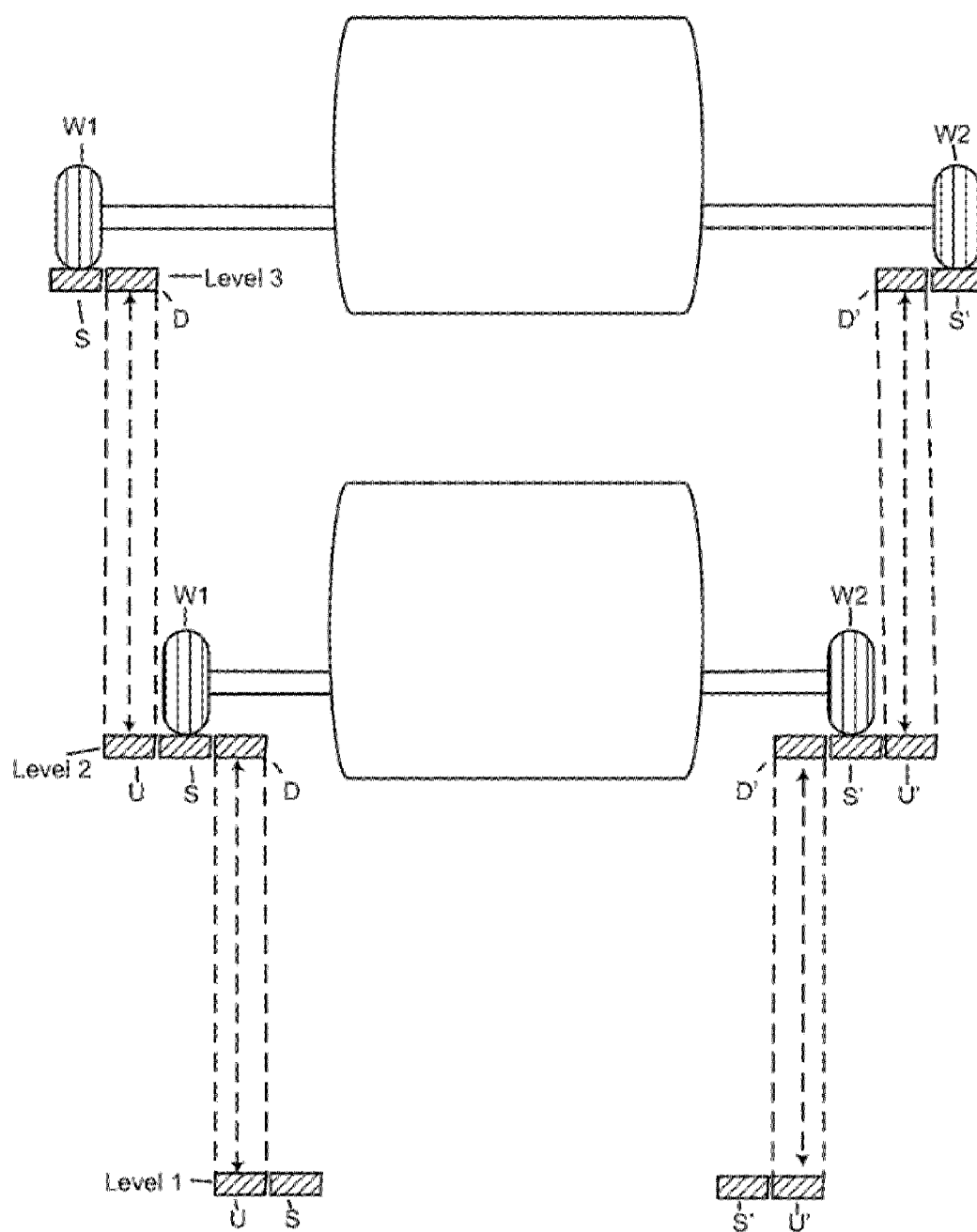


Fig. 5 Another Configuration of Three-Level Guideways

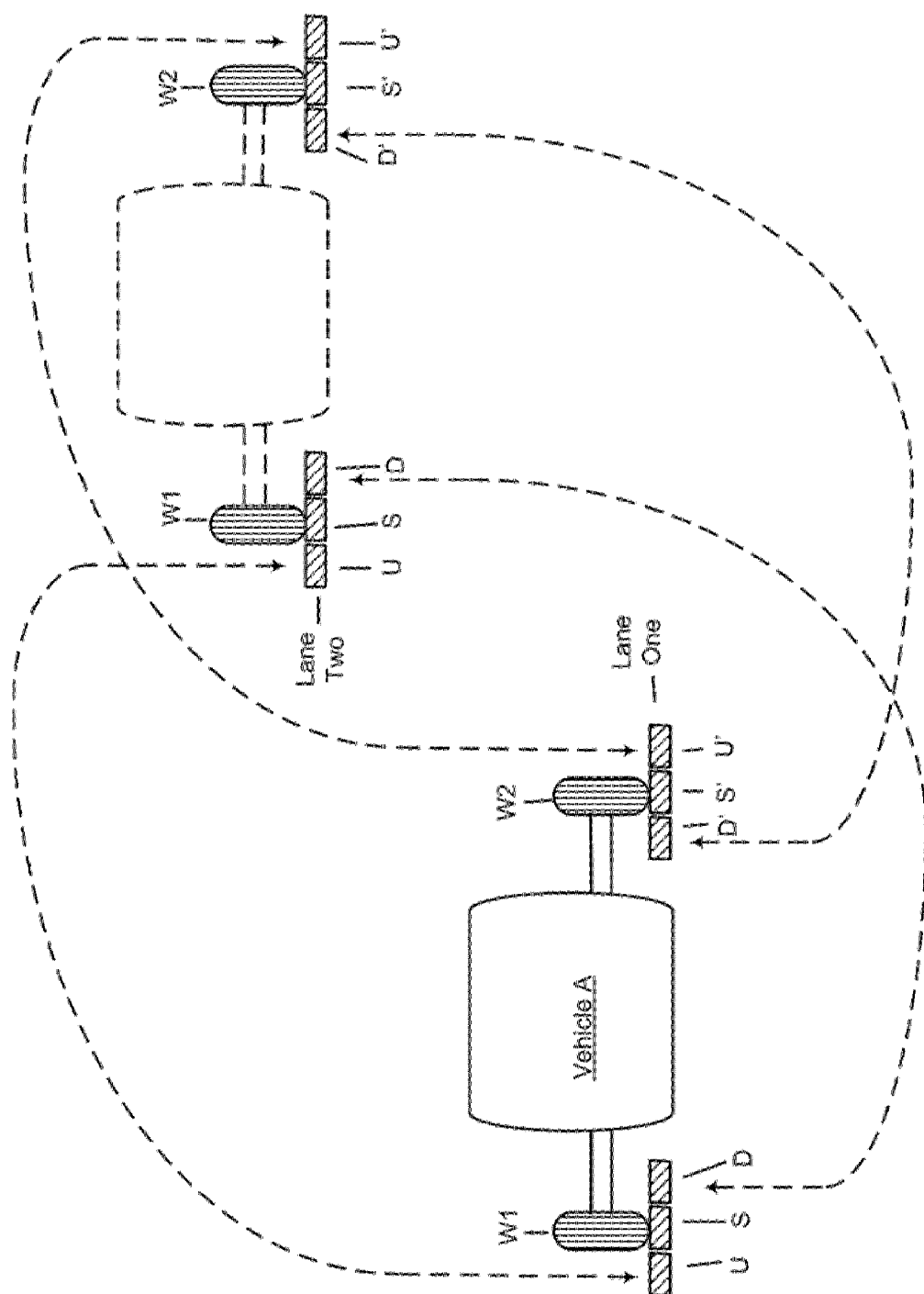


Fig. 6 Two-Level Guideways Not Vertically Aligned

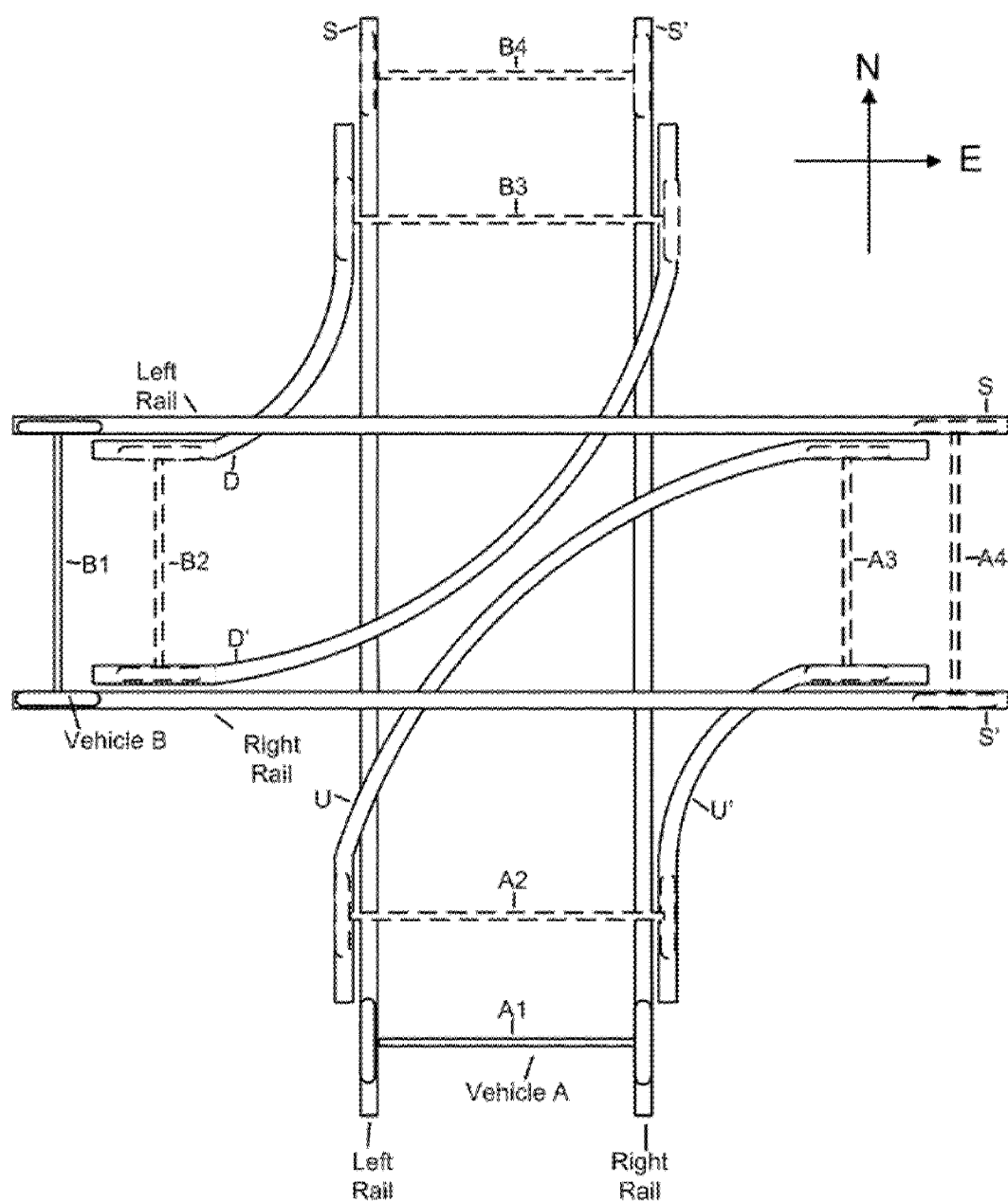


Fig. 7 Switching at an Intersection

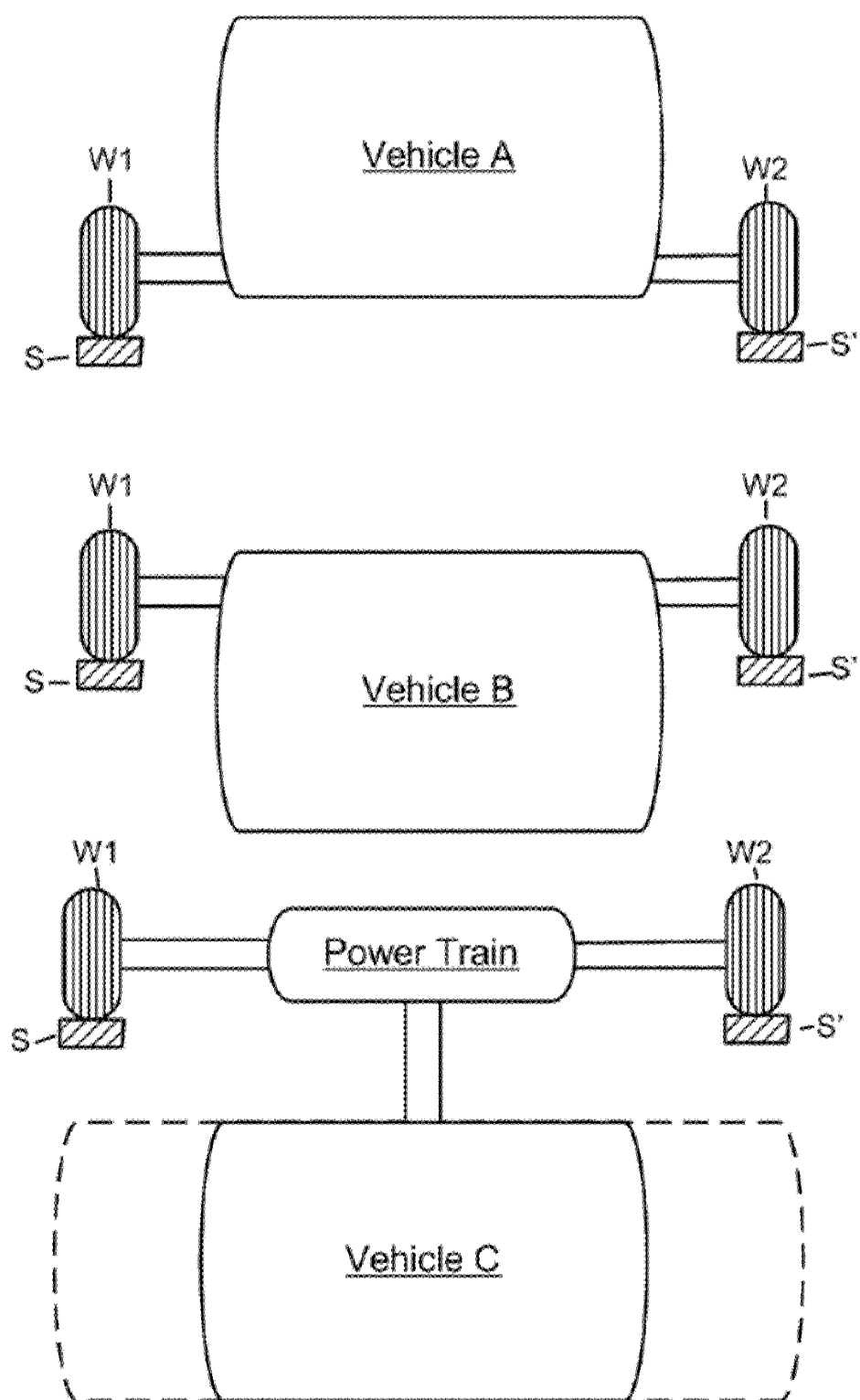


Fig. 8 Possible Vehicle Vertical Positions

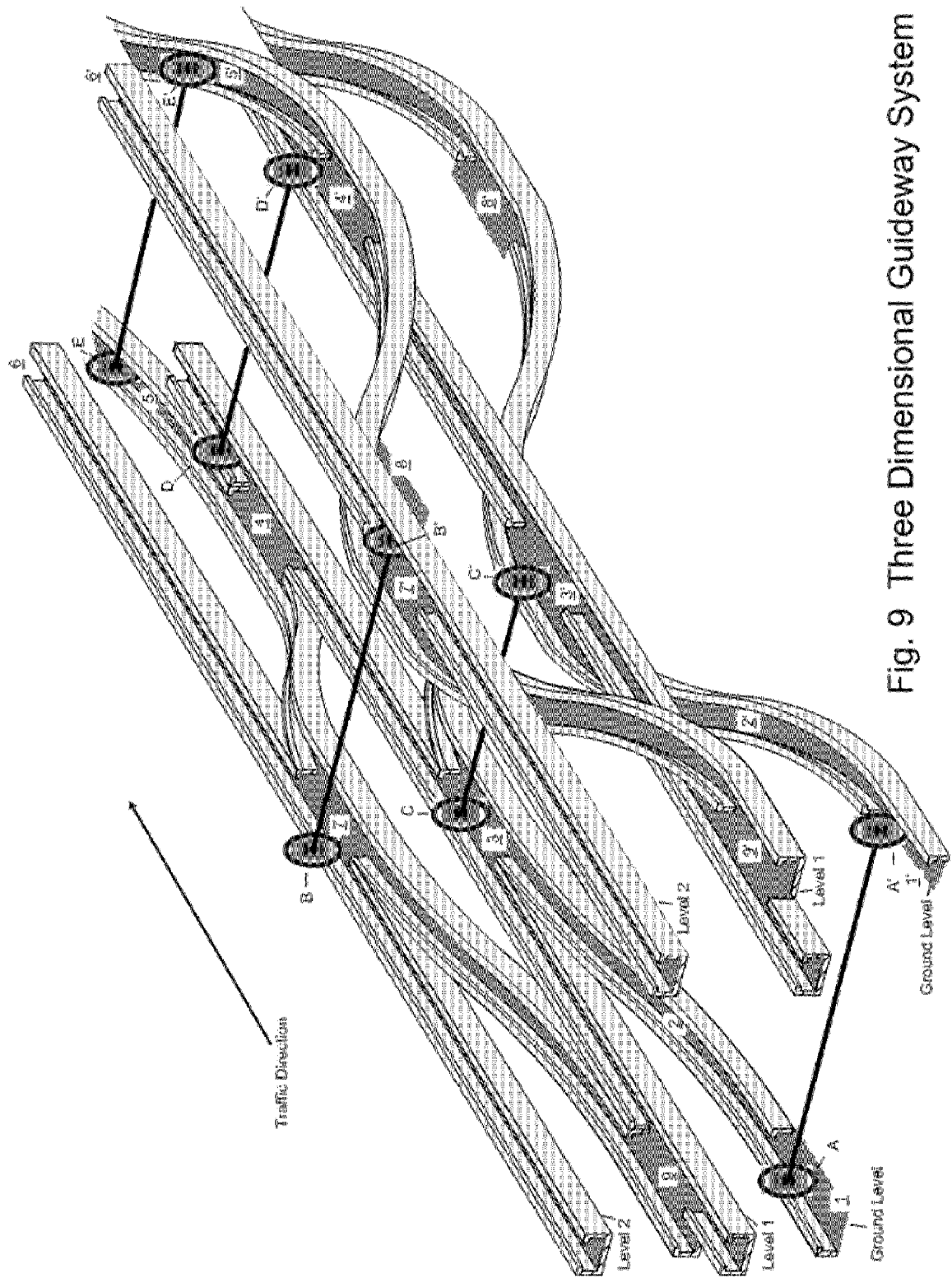


Fig. 9 Three Dimensional Guideway System

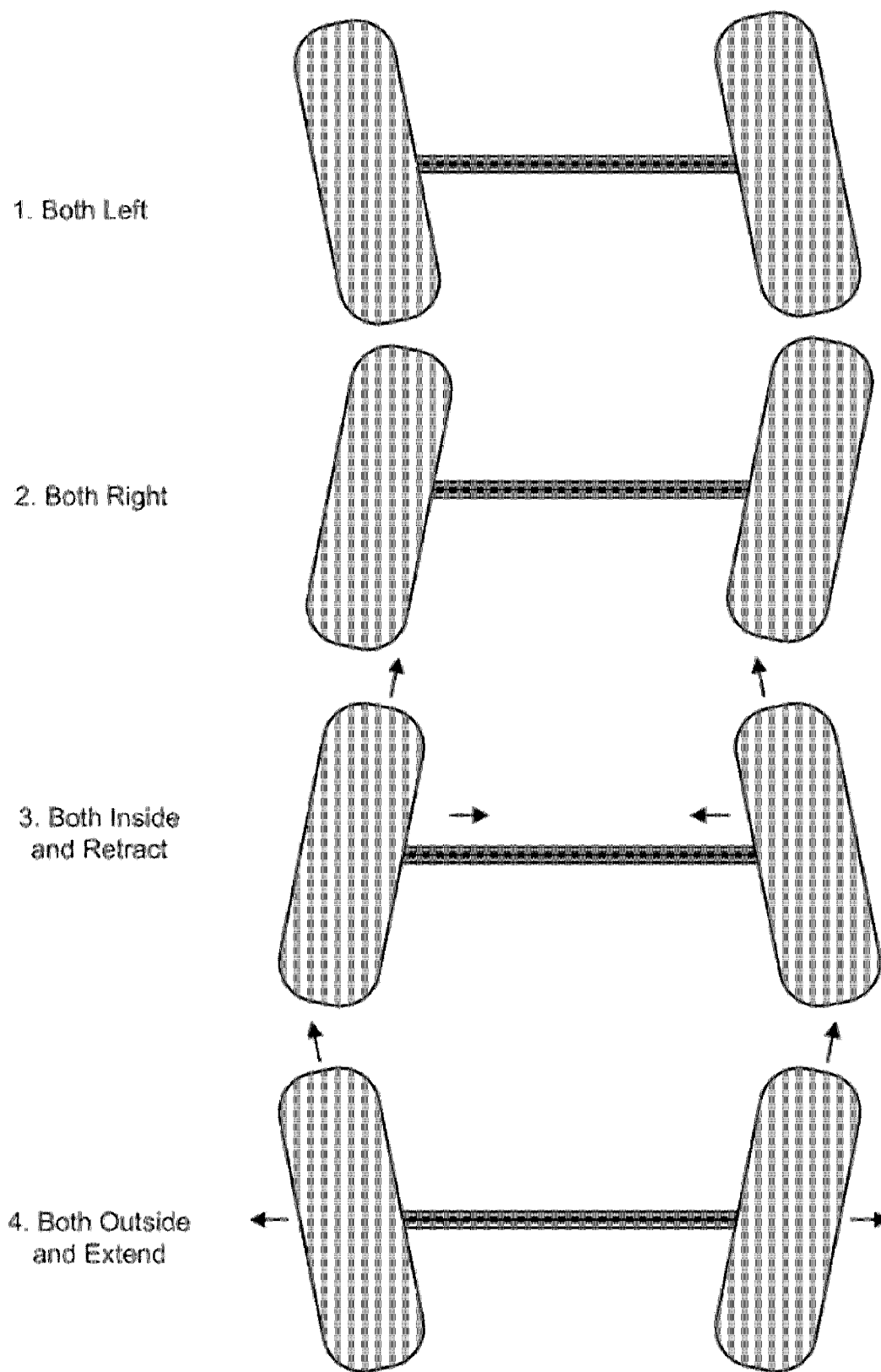


Fig. 10 Wheel-Moving Methods

Fig. 11A

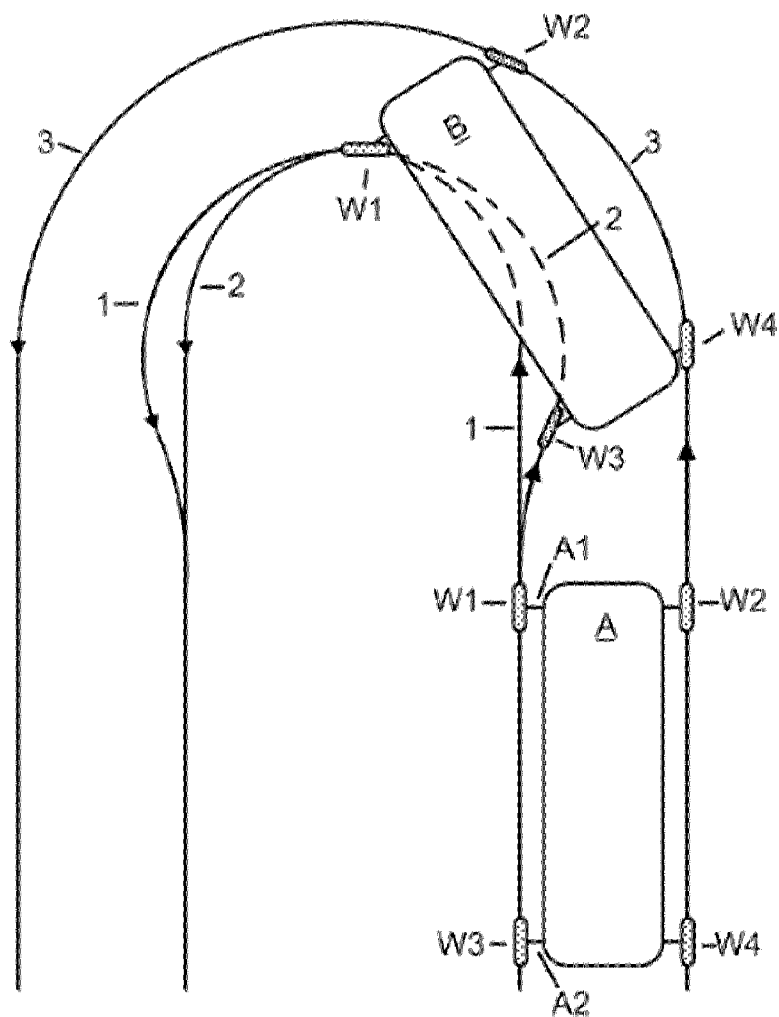


Fig. 11B

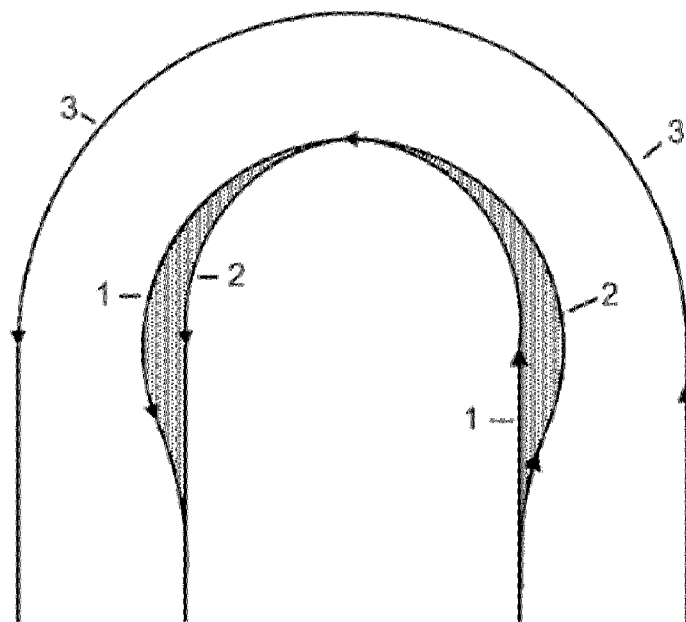


Fig. 11 Guideways at U-Turn

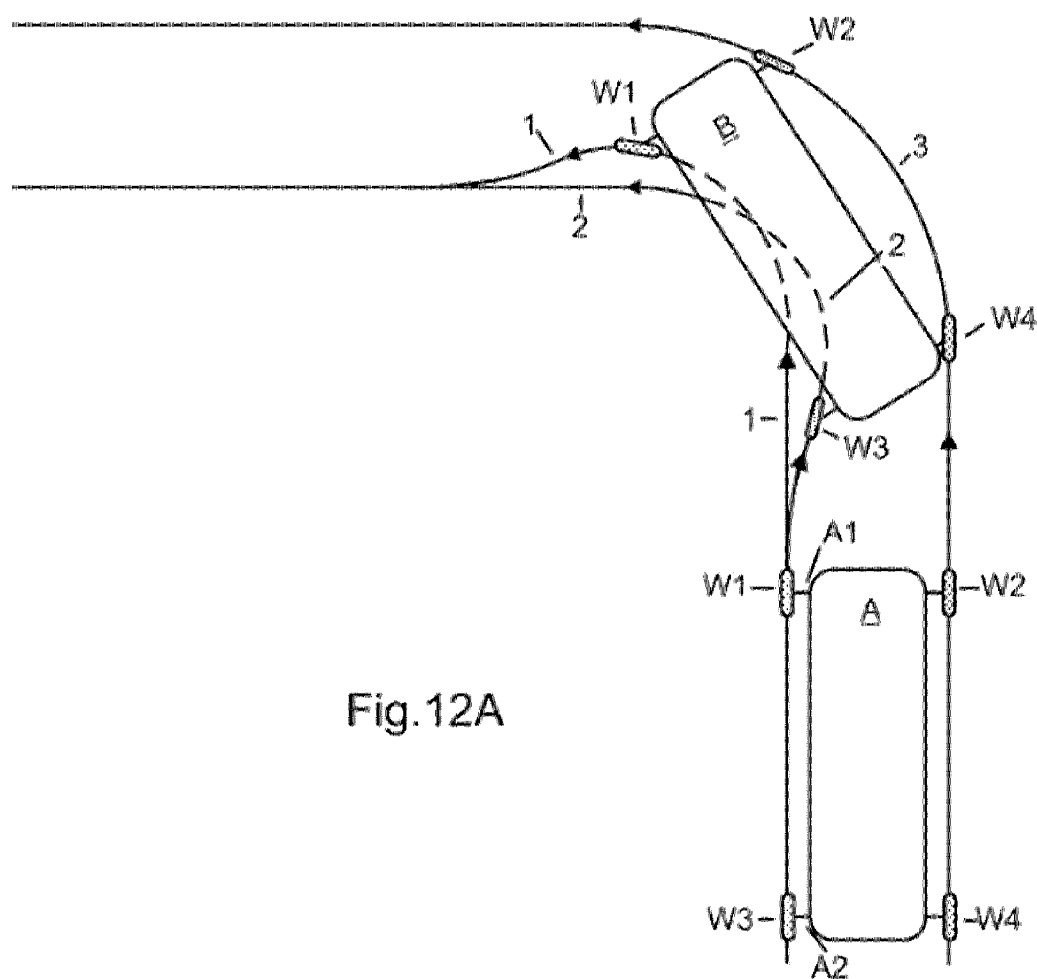


Fig. 12A

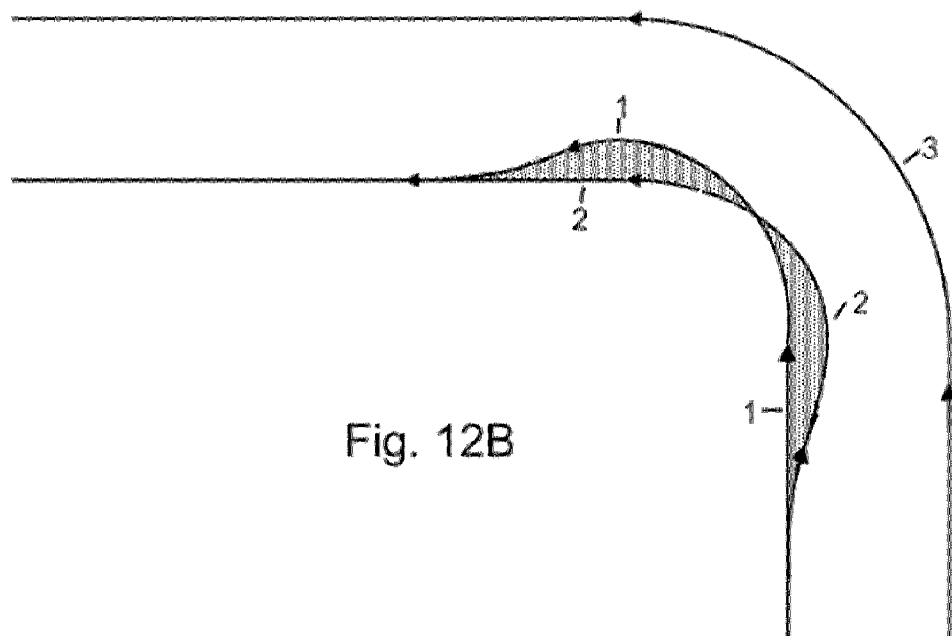


Fig. 12B

Fig. 12 Guideways at Left-Turn

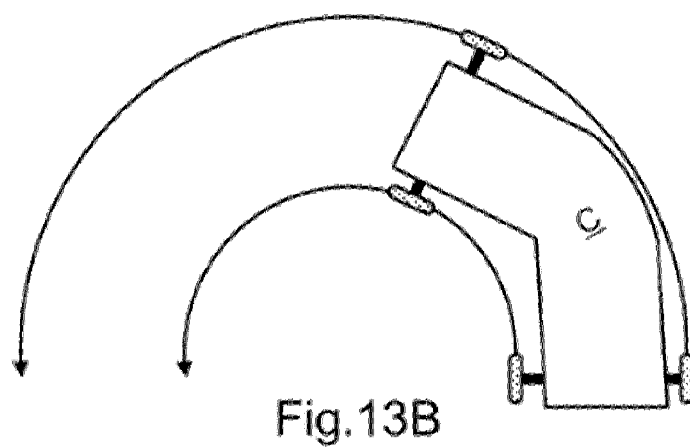
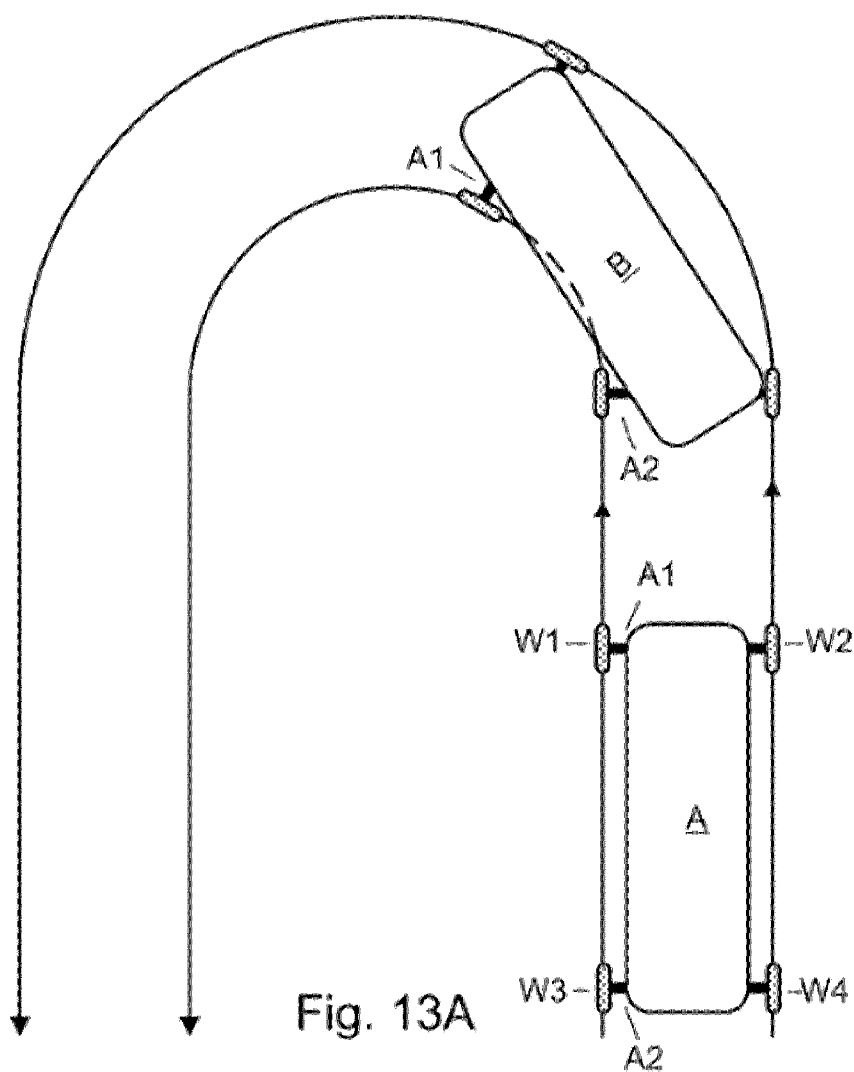


Fig. 13 U-Turn with Two Concentric Half Circles

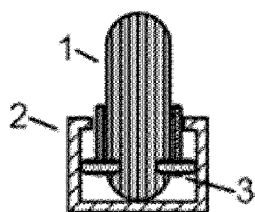


Fig. 14A. Frontal View

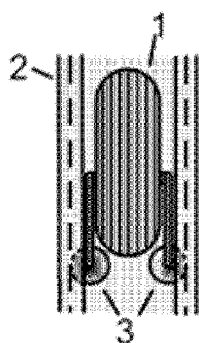


Fig. 14B. Top View

Fig. 14 Examples of Wheels and Guideway

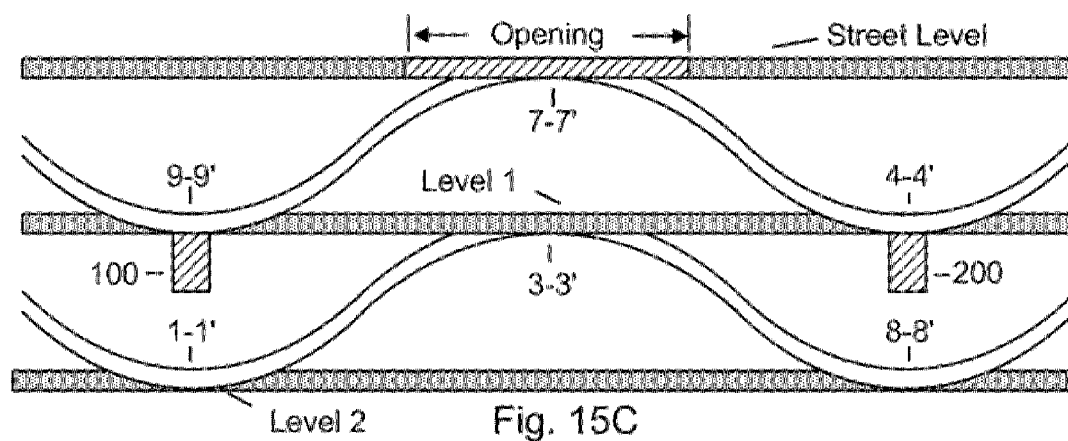
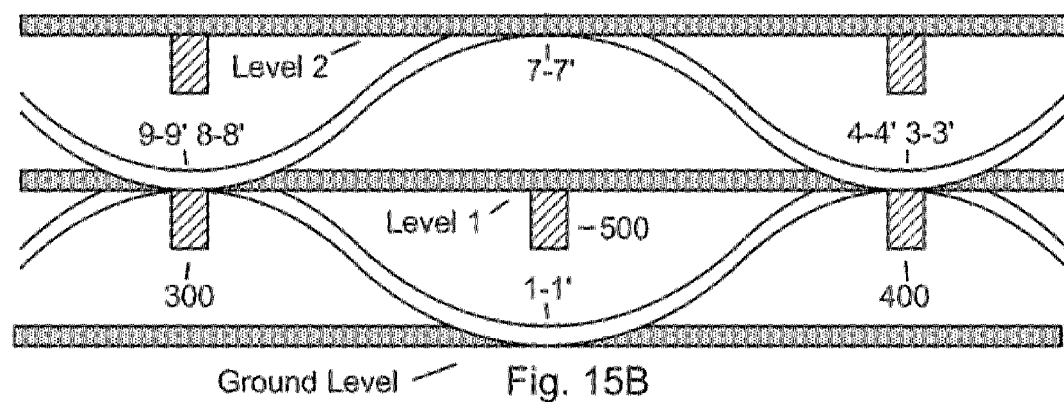
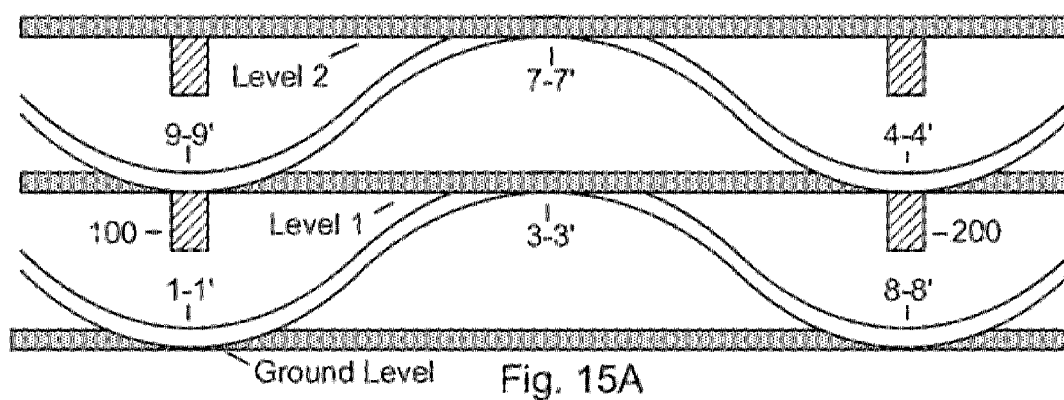


Fig. 15 Alignment of Guideways

STRUCTURE AND OPERATION OF A THREE DIMENSIONAL TRANSPORTATION SYSTEM

[0001] The present application claims the benefits under 35 U.S.C. § 119(e) of U.S. Provisional Application Ser. Nos. 60/597,188, filed Nov. 15, 2005 and 60/767,058, filed Feb. 28, 2006, both of them are incorporated herein by this reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of Invention

[0003] This invention relates to improvements to efficiency and safety of transportation infrastructure, as well as improvements to speed and convenience of transportation vehicles.

[0004] With ever increasing gasoline price and urban traffic congestion, alternative transportation methods are eventually going to supplement the current automobile based personal transportation system and the existing mass transit system, especially in urban areas. Individual driven automobiles cause air pollution, traffic congestion and huge consumption of gasoline. The public mass transit systems currently in use worldwide are not preferred method of transportation for many individuals because a person often has to stop and switch vehicles many times, sometimes carrying luggage, before reaching his final destination.

[0005] With the advancements made in computer and telecommunication technologies in the last few decades, the time has matured for automated people or cargo moving technologies. Many systems have been proposed and tested. Some of these systems have been operational. The common features of all those systems are:

[0006] (1) Electric driven;

[0007] (2) Automatic operation;

[0008] (3) Travel on guideways;

[0009] Some systems offer dual mode operation. A dual mode vehicle could travel on guideways either automatically or manually and could also travel on regular road with human control.

[0010] 2. Prior Art

[0011] One automated transportation system currently under development is Taxi 2000 system (now called Skyweb Express). Taxi 2000 vehicles run on smooth rubber tires in an U-shaped trough as the guideway. Propulsion is electric with linear induction motor (LIM) and direct current from a power rail. Switching is mechanic with a switch arm in the vehicle following guide rails in the guideway. Stations are offline so that stopped vehicles will not interfere with the moving vehicles.

[0012] Another innovative transportation system is the FlyWay system from SwedeTrack, which consists of vehicles of different sizes suspended under beams. The cabin is connected through a slot to a drive engine running inside the beam. Running surfaces inside the beam are effectively protected from snow, leaves and vandalism. A unique feature for FlyWay is the ability to lower the cabin from the beam at stations. Stations can be placed at grade and travelers need not go up and down to enter and exit.

[0013] A dual mode transit system with the acronym of "RUF" is being developed in Denmark. The RUFs are battery-operated cars designed to be able to run driverless in platoons on a monorail. The center of the car is guided and supported by the monorail. When the car is not on the guideway, it can be driven just like a regular electric car on the road.

[0014] U.S. Pat. No. 6,742,458 describes a guideway construction method and vehicle operation mechanism for a dual mode transportation system. A vehicle travels on two parallel longitudinally extending guideways. The wheels of the vehicle could extend axially so that it could ride on the guideways. When the wheels are in the retracted position, the vehicle could be driven on regular road, allowing dual mode operation. Wheel extension and retraction are also one of requirements of the current invention. However, the construction method of the guideways, the operation method of the vehicles, and the purposes of the wheel extension and retraction as defined by U.S. Pat. No. 6,742,458 are all different from current invention as we could see from the following descriptions.

[0015] Many more alternative transit systems are envisioned, proposed, and tested. Overviews of alternative transportation methods are given by [1] and by [2]. A list of patented transportation methods based on guideways is given in the reference section.

SUMMARY OF THE INVENTION

[0016] One objective of this invention is to develop a cost effective way of guideway construction, especially in highly populated areas, and to eliminate many obstacles of road travel, such as traffic lights, road congestion and traffic accidents.

[0017] Another objective of the invention is to improve the switching mechanisms as well as loading/unloading mechanisms of a guided transport system, so that vehicles in such a system, either public owned or private owned, offers the same conveniences as that of individual driven automobiles, capable of moving people or cargo from the starting point to the ending point without stopping, vehicle changing or extended walking.

[0018] A further objective of the invention is to develop a guideway system that is suitable for automated people and cargo moving, and in the mean time allows dual mode vehicles to use the guideway system, so that a vehicle could travel in areas both with and without guideway network.

[0019] The overall objective of this invention is to have a transportation system with most of the advantages of automobiles, and without the associated disadvantages, by utilizing a novel guideway switching mechanism and a novel vehicle operation method.

[0020] This invention provides the methods of guideway construction and vehicle operation for a three-dimensional transportation system, in which a vehicle changes lane or direction by widening or narrowing the width between its left wheels and its corresponding right wheels. As shown by FIG. 1, without any maneuvering, a vehicle (only two wheels are shown for simplicity) traveling on straight guideways S, S' would continue to move in its original direction. If the vehicle needs to move up, it could move out of the straight guideways by widening the space between left

wheel W1 and right wheel W2 and moving to guideways U, U'. The distance between wheel W1 and wheel W2 must be able to change from the distance between S and S', to distance between U and U'. If a vehicle needs to move downward, the width of its wheel spacing needs to be narrowed to match the width of D and D', so that the wheels could ride on the down-moving guideways. In such a transportation system, vehicles diverge from a source lane and merge into a target lane aerially either above or below the tracks. Left guideways never touch or cross right guideways in such a transportation system. Vehicles could move between levels by going through the empty space between left guideways and the corresponding right guideways. Such a lane and direction change method offers many advantages as compared to traditional two dimensional rail switching methods. It is more efficient, uses less land, and is easier for future guideway expansion.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] FIG. 1 shows how a vehicle could depart a pair of guideways, either by widening the distance between its left wheel and its right wheel to move up, or by narrowing this distance to move down.

[0022] FIG. 2 shows that guideways of different constructions could be used to carry out the methods of this invention.

[0023] FIG. 3 shows the conventional railroad switching method, for the purpose of comparison.

[0024] FIG. 4 shows a three level guideway system and the method of switching among three different levels. The up and down moving guideways have varying width from left to right so that vehicles will not collide with the guideways.

[0025] FIG. 5 shows another embodiment of the guideway switching method, in which the ascending and descending guideways have fixed widths.

[0026] FIG. 6 shows the guideway switching methods of two non-vertically aligned guideways.

[0027] FIG. 7 shows how vehicles change directions at an intersection with this method.

[0028] FIG. 8 shows that a vehicle's passenger and cargo compartments could be located above the track, even with the track or below the track.

[0029] FIG. 9 shows a preferred embodiment of the proposed dual mode guideway system. The guideways are made of open channels and the wheels are made of rubber tires.

[0030] FIG. 10 shows that a vehicle's wheels need to turn to various directions and move axially to follow the guideways.

[0031] FIG. 11A and FIG. 11B show how to construct guideways at a U-turn for a vehicle with non-rotating axles, by keeping outer wheels to follow the outer guideway and tracing the trajectories of the inner wheels.

[0032] FIG. 12A and FIG. 12B show how to construct guideways at a right-turn.

[0033] FIG. 13A and FIG. 13B show the alternative ways of making a U-turn. FIG. 13A shows that the axles of the wheels need to rotate to allow a U-turn. FIG. 13B shows that a vehicle with flexible body could allow a U-turn.

[0034] FIG. 14A and FIG. 14B show a detailed embodiment of a wheel assembly and the corresponding guideway.

[0035] FIG. 15A and FIG. 15B show two preferred embodiments of guideway vertical alignment. FIG. 15C shows loading/unloading location of an underground guideway system.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0036] This invention provides structural designs and operational methods of a three-dimensional transportation system. Vehicles in this system are guided and supported by guideways.

[0037] The term "guideway" is defined as a mechanical member that supports and guides moving vehicles. The principle of the invention could be applied for different methods of construction for the guideways. As shown in FIG. 2A, the top guideways are guiding and supporting rails, as we would normally expect for a railroad system. The middle guideways (FIG. 2B) are guiding and supporting channels for tires. The bottom drawing (FIG. 2C) illustrates a mag-lev vehicle guideways. All of these, and other methods with which the principles of this invention could apply, are included in the definition of guideways. A vehicle in such a system would be supported on two groups of guideways, a left guideway group and a right guideway group, with each group consisting of up-moving, down-moving and straight moving guideways. A left guideway group and a right guideway group in parallel supporting vehicles traveling at the same direction together are defined as a "lane" or a "track". A highway is defined as multiple lanes grouped together with vehicles traveling at the same direction for one-way traffic, or two directions, forward and backward, for two-way traffic. This invention concerns with the very basic construction and operation methods of a three-dimensional transportation system consisting of networks of highways. In the following descriptions and drawings, we will use flat supporting surfaces as examples of guideways, with the understanding that the supporting surfaces could be any suitable guideways. "Vehicle" is used here as the transportation vessel containing people or goods. To simplify the description, we will use two wheels, a left wheel and a right wheel connected by an axle, to represent a vehicle. However, a vehicle could have many wheels in this system, and the methods are not limited to a single vehicle such as a car, but should also include multiple vehicles coupled together either mechanically or electronically in a platoon, as an example, a train. The principles could also apply to mag-lev vehicles, or vehicles supported and moved by other means, that do not have rotating wheels.

[0038] Here an axle is defined as a real or an imaginary member that connects the center points of two corresponding left and right wheels. "Imaginary member" applies to, but is not limited to, cases when the centers of a pair of wheels are not physically connected by a single piece of material, rather by the body of the vehicle.

[0039] The key features of this three-dimensional transportation system are the novel methods of lane change and direction change as compared to that of the two dimensional system. FIG. 3 shows the switching mechanism of a section of conventional railroad system. FIG. 3A shows that conventional railroad shunts a train by using two switching rails.

When the switching rails swing to the right, they direct the train to the left, as shown by FIG. 3B. When the switching rails swing to the left, they direct the train to the right, as shown by FIG. 3C. The shunting and switching on conventional railroad are controlled by the rails. A train could not directly change its direction, without the prior movements of the switching rails. Rails must cut across each other for implementing two dimensional switching. In a three-dimensional transportation system, multiple lanes in a highway are no longer required to stay in a two dimensional surface. Multiple lanes could be stacked together as multi-level lanes in a vertical direction. Multiple lanes in fact could be placed in any spatial locations relative to each other. In our three-dimensional guideway system, lane switching could be accomplished aurally without guideways cutting across each other, and the vehicles control lane switching, without any guideway movement.

[0040] As shown by FIG. 1, without any maneuvering, a vehicle traveling on guideways S, S' would continue to move in its original direction. If the vehicle needs to move up, it could move out of the straight guideways by widening the space between left wheel W1 and right wheel W2 and moving to guideways U, U'. The width from guideway U to guideway U' must be larger than the width from guideway S to guideway S'. If it is not, the vehicle could hit the guideways U and U' when it intends to travel straight forward. A vehicle with fixed width between left wheel W1 and right wheel W2 obviously could not move to guideways U and U', because if the width between W1 to W2 equals to width between S to S', as this is required for straight line travel, the vehicle would continue to move forward along S and S' in a straight line fashion, and not able to move up along guideways U and U'. The distance between wheel W1 and wheel W2 must be able to change from the distance between S and S', to distance between U and U'.

[0041] Therefore, in our three dimensional guideway system, a vehicle could move up if the up-moving guideways are wider from left to right than the straight-moving guideways, and the distance between the left and the right wheels of a vehicle is widened accordingly during the vehicle's switching and ascending so that the wheels are riding on the up-moving guideways.

[0042] The down-moving guideways need to be narrower than the straight moving guideways, for an example, as guideways D and D' shown in FIG. 1. If a vehicle needs to move downward, the width of its wheel spacing needs to be narrowed to match the width of D and D', so that the wheels could ride on the down-moving guideways.

[0043] With the adjustment of wheel width and track width, a vehicle in our three-dimensional system could move out of a track freely without guideways crossing each other. A vehicle could move up or move down to depart a track. By the same manner, a vehicle could arrive at a track either from above or from below. To prevent vehicle/guideway collisions, guideways leading to above or coming from above must have guideway spacing wider than the horizontal straight moving guideways. Guideways leading to below or coming from below must have guideway spacing narrower than the horizontal straight moving guideways. And the wheel width of the vehicle should be widened or narrowed to match the guideway spacing so that the wheels are riding on guideways.

[0044] We will now illustrate how multiple lanes could be constructed. As an example we could consider a three-lane highway as shown on FIG. 4. For simplicity, rear view of a three-lane section is shown with guideway supporting structures omitted. There are three levels of guideways stacked on each other, with level one as the lowest level and level three as the highest level. There are three types of guideways. Type "S" stands for straight-moving guideway, type "U" stands for up-moving guideway and type "D" stands for down-moving guideway. Vehicle A as shown in FIG. 4 is initially traveling along straight guideways S and S' on level two. If it needs to move up a level to level-three, the wheels of the vehicle, W1 and W2, first need to move outward. W1 needs to move to guideway U and W2 need to move to guideway U'. There should be adequate horizontal traveling distance in which at least two of the straight-moving guideways, up-moving guideways and down-moving guideways are at the same level. This distance should allow wheels to move outward from guideways S and S' to guideways U and U', or inward from guideways S and S' to guideways D and D'. The vehicle should be designed in such a way that not only can the wheels be turned to left or right as required by the curvature of the track, but also can they be moved inward and outward axially to and from the vehicle, as well as turned to the center or the outer side of the track, so that the wheels could ride on guideways of varying width from left to right. After certain horizontal guideway switching distance, guideways U-U' are directed upward. While moving up, the distance between guideway U and guideway U' is kept a constant at first until the guideways are at least above the height of the wheel of the straight moving vehicle, then this distance narrows. Guideways U and U' eventually would become the inner guideways of level three, after ascending from level two. The contact mechanism of the wheels and the guideways should be that the wheels would automatically follow the guideways as their width changes. By such guideway/wheel configuration, a vehicle could move upward, through the empty space in the middle, without hitting guideways or guideway supporting structures. Once the vehicle is at level three, the wheel distance between W1 and W2 needs to be widened again so that they move to the S and S' guideways of level three to continue travel at the upper level.

[0045] Similarly, if vehicle A needs to move down to level one, the wheel distance needs to be reduced while moving forward, so that at the point of descending from the horizontal position, the wheels are riding on D and D'. As the vehicle is descending along guideways D and D', the distance between wheel W1 and wheel W2 need to be widened to match the gradually widened guideway width. The descending guideways D and D' need to be widened as they approach level one and become its outer guideways. By such arrangements, vehicles traveling on guideways S and S' at level one will not hit the descending guideway D and D'.

[0046] Therefore, in our three-dimensional vertically aligned guideway system in which lane and direction changes are accomplished by changing the width between right and left wheels and between right and left guideways, the ascending guideways should leave the current level as the outer guideways and arrive at the higher level as the inner guideways; the descending guideways should leave the current level as the inner guideways and arrive at the lower

level as the outer guideways. The straight-moving guideways should stay at the middle between the ascending and descending guideways.

[0047] The intention and operational method of the wheel extension and retraction of this invention are different from what is described by U.S. Pat. No. 6,742,458. The main purpose of wheel extension and retraction here is to allow three dimensional aerial lane-switching for a vehicle. The main purpose of wheel extension and retraction as described by U.S. Pat. No. 6,742,458 is for vehicle support. Construction methods of U.S. Pat. No. 6,742,458 would not allow multiple levels of traffic lanes to be stacked together vertically.

[0048] Either two or three of the ascending, descending and straight-moving guideways are at the same switching locations, for a short horizontal distance of lane or direction changes. When not switching, only a single middle straight-moving guideway on each side is needed for each lane to carry the straight-moving traffic on that lane. The term "straight-moving", i.e., the middle guideways, is only relative to "ascending" or "descending". The middle guideways could be curved according to geographical characteristics of the landscape on which the guideways are built.

[0049] The reference characters U, U', S, S', D, D', W1, W2 have the same meanings in all the drawings of this patent application, and we are not going to define them again.

[0050] In the above guideway configuration, the ascending and descending guideways are widened or narrowed as the guideways are connected from one level to another, and wheel widths are adjusted accordingly to match the guideway widths. Another way of construction is that ascending and descending guideway widths do not change from one level to another. As shown in FIG. 5, the inner guideways (D and D') of a higher level could be connected to the outer guideways (U and U') of a lower level. If the widths of the ascending and descending guideways do not change, then an pair of upper level guideways (U-U', S-S', D-D') should be two sizes wider than the corresponding guideways of the next lower level in order for vehicles to accomplish such three dimensional lane changes. Although wheel control is easier, such a guideway system becomes top heavy and is more difficult for future expansion. The same operating principles as before should be held for this construction method. That is, guideways coming from a lower level or leading to a lower level must be the inner guideways of the current level; guideways coming from a higher level or leading to a higher level must be the outer guideways of the current level. As long as this operating principle is held, vehicles could travel upward and downward without hitting guideways and guideway supporting structures.

[0051] Traffic lanes, with two guideway groups each, in fact could also be located relative to each other in any spatial positions. FIG. 6 shows two traffic lanes that are not aligned vertically. In such a case, a vehicle in lane one could move up through outer guideways U and U' and descending to lane two from above, riding on outer guideways of lane two; or it could also move down through inner guideways D and D' and ascending to lane two from below, riding on inner guideways of lane two. In such cases, both D,D' and U,U' guideways have constant width from left to right. Connecting outer guideways of lane one to inner guideways of lane

two is also possible, and decision on how to construct the connection should be determined by economics.

[0052] Such lane change method could also be applied to lanes that are not going at the same direction. In fact, this method could be applied to multiple lanes with lane directions changing from 0° to 180° relative to each other; an example of such lane change is a 90° directional change at an intersection. For simplicity, we illustrate two one-way lanes that are 90° to each other.

[0053] As shown in FIG. 7, one-way eastbound guideways are at upper level; one-way northbound guideways are at lower level. Vehicle A, riding on lower level (northbound), is initially heading north on straight (middle) guideways S and S', at the location of A₁. In order to turn east, its wheel width must first increase, so that its wheels have switched from the middle guideways to outer guideways at A₂ position. Riding on outer guideways U and U', vehicle A goes up and separates from lower level traffic. As the guideways U and U' are going up and turning, the distance between U and U' is gradually narrowed so that upon reaching the upper eastbound level, guideways U and U' become the inner guideways of the eastbound track. The wheel width of vehicle A is narrowed as well by forcing them to follow guideways U and U'. Vehicle A is riding on the inner guideways of the upper eastbound track when it first reaches the upper level at A₃ position from below. In order to travel eastbound on the upper level, the wheel width of vehicle A need to increase again so that the wheels are on the middle guideways (S and S') at A₄ position. Similarly, initially eastbound vehicle B on upper level need to follow position B₁, B₂, B₃ and B₄ in order to turn northbound at the lower level. Its wheels need to be narrowed to move to the inner guideways (D and D') of upper level first and arrive at the lower level riding on the outer guideways with gradually increased guideway and wheel width. Then its wheel width needs to be reduced in order to switch to the middle guideways (S and S') to travel northbound.

[0054] It is also possible for vehicle A to reach upper level from above, and for vehicle B to reach lower level from below. The rules of the road are that inner guideways are for sending vehicles to below and for receiving vehicles from below and outer guideways are for sending vehicles to above and for receiving vehicles from above. Many possibilities exist as long as the above rules are followed. Any complex traffic patterns could be constructed based on the basic operational methods described above.

[0055] Since guideways no longer cut across each other anywhere in the system by this construction method, the cargo or passenger compartment of a vehicle could be located above (vehicle A), even with (vehicle B), and below the guideway elevation (vehicle C) as shown by FIG. 8. The "even with" option would require a wider track width and less sharp curvature at turns, to allow the vehicle to go through without being caught by the guideways at the turning point. One embodiment of the below the guideway elevation option (vehicle C) has the vehicle cabin width wider than the guideway width, as the dashed line shown in FIG. 8. Vehicle C with the solid line could go through the gap between S and S' when it intends to move from one level to another level vertically. Vehicle C with the dashed line could not go through the gap between S and S' during vertical movements. In such a case, up-moving and down-

moving guideways need to turn to the either sides of the straight-moving guideways to allow continuous traffic.

[0056] Another advantage of such construction methods is that a vehicle could be equipped with an in-vehicle lift system so that the passenger or the cargo compartment could be raised or lowered to facilitate the loading and unloading of human or cargo. Such guideway and vehicle construction methods would also allow the adjustment of the center of the gravity of a vehicle so that the vehicle could travel at the safest mode.

[0057] Passengers could enter or exit a vehicle anywhere along the track, without waiting for a station to stop, either by utilizing the in-vehicle lift system, or by using the ground level exits. In a preferred embodiment, multilane elevated highways with the bottom lane as the stop lane, and with upper lanes as nonstop lanes would allow traffic to continue, without being affected by stopped vehicles.

[0058] Individual owned vehicles and public or transit company owned vehicles should both be allowed to travel on the guideways. An individual owned vehicle should be allowed to leave the guideways and travel to its destination with a human driver in control on existing regular road. Public or transit company owned vehicles are preferred to be driverless and controlled by computers.

[0059] FIG. 9 shows an embodiment of such a dual mode guideway system. Here A-A', B-B', C-C', D-D', E-E' are two wheels of vehicles, for simplicity, other wheels are not shown. Guideways at different functional locations are labeled as 1-1', 2-2', 3-3', 4-4', 5-5', 6-6', 7-7', 8-8' and 9-9'. A dual mode vehicle with wheels (A-A') on the ground level needs to align its wheels with the guideways 2-2' at the entrances 1-1'. The up-moving guideways 2-2' must first rise to an elevation at least higher than the top of the wheels on the ground level, then the guideways narrow its distance between 2 and 2' while going up, and becomes the inner guideways of the first elevated level at 3-3'. The vehicle travels up along the guideways 2-2', adjusting its wheel width along the way, to reach level one at position C-C'. At this position, the vehicle wheel width must be either widened so that it could travel at level one, or if it does not widen, the vehicle would be forced to travel downward to the ground level along the down-moving guideways to position 8 and 8'. If the vehicle traveling at level one reaches position 4-4', it has the option of widening its wheel width so that it could move upward along guideways 5-5', and reaches the upper level at position 6 and 6'. Or it could continue traveling at level one, by keeping the wheel width constant. Guideways 5-5' start at the outside of level one, and curve into the inside of the level two. For an up-moving vehicle, its wheel width must be first widened to fit into the up-moving guideways, and then narrowed along the way to reach the upper level with its wheels at the retracted position. Similarly, a vehicle at position B-B' could continue to travel at level two by keeping its wheel width constant, or to move downward by narrowing its wheel width at position 7-7'. While moving downward, the wheel width must be widened to match the guideways, which would become the outer guideways of level one at position 4-4'. The guideway structure at position 9-9' is the same as that at position 4-4', but 9-9' is one section ahead of 4-4'.

[0060] FIG. 9 could be used to illustrate possible loading and unloading strategies. A private vehicle should be

allowed to drive on the guideways and on the ground. A dual mode private vehicle could load and unload on the ground level, with a human driver in control while on the ground. A dual mode vehicle could enter the guideway system through 1 and 1' and could leave the guideway system through 8 and 8'. A public or transit company owned vehicle should not be allowed to travel to the ground level, unless a human driver, rather than a computer, is in control. For a vehicle that is not allowed to travel on the ground level, an in vehicle lift system could then be used for loading and unloading while the vehicle is stopped on level one. Another option is to allow a public/transit vehicle to reach the ground level guideways at 8-8', and then send it back to level one after loading/unloading. Such a vehicle is not allowed to leave the guideway system, and this rule shall be enforced either by software control or by mechanical restraint. Level two should be a nonstop lane to allow continuous traffic. With such strategies, offline station is no longer needed, and loading and unloading could be done conveniently anywhere along a highway.

[0061] FIG. 10 shows the motion of wheels for riding on guideways. The wheels must be able to turn left (1) and right (2), turn inside and retract to the center (3), and turn outside and extend axially (4). All those types of wheel maneuvers should be allowed by a vehicle designer in order to force the wheels to follow the guideways.

[0062] For a vehicle making a turn, each of its wheels would turn to different directions at a particular moment, as this is required by the trajectories of the tracks as shown by FIG. 11. It is inadequate to describe a vehicle by two wheels anymore when the vehicle is making a turn. As an example we would use four wheels of a vehicle to demonstrate a vehicle making a sharp U-turn. Vehicle A in FIG. 11 is designed in such a way that its axle A1 of two front wheels W1 and W2 is in parallel to its axle A2 of two back wheels W3 and W4, and both axles (A1, A2) are perpendicular to the vehicle's longitude direction, and further more the axles are fixed to the vehicle, not able to move or rotate. With such a vehicle design, the wheels of a vehicle at a U-turn would not follow two concentric half-circle guideways. As shown by FIG. 11A, the outer guideway (3) at the turn is a half circle, but the inner guideways (1, 2) are not half circles. Guideways 1 and 2 are constructed by forcing outer wheels W2 and W4 to follow outer guideway 3, and then by tracing the wheel movements of W1 and W3, respectively. W1 and W2 use different guideways. During the U-turn, inner front wheel W1 will follow guideway 1 and inner back wheel W3 will follow guideway 2. Guideways 1 and 2 have different trajectories, and one is the mirror image of the other. We could see that at the position of vehicle B, four wheels of the vehicle are pointing at four different directions. We could also see that the gap between guideway 3 to guideways 1, 2 at a U-turn is narrower than the gap between them at a straight section. FIG. 11B shows that guideways 1 and 2 could be combined to form a wide single guideway, by putting supporting road surface between them. Such a construction method implies that all vehicles in the system must have the same size and the same wheel locations.

[0063] FIG. 12 shows how right turn guideways are constructed using the similar method. The reference characters in FIG. 12 and the following FIG. 13 have the same meanings as that in FIG. 11.

[0064] FIG. 13 shows that vehicles need to be designed differently in order to have two concentric half-circles as U-turn guideways. If the axles of the wheels (A1, A2) are able to rotate as shown in FIG. 13A, so that the axles are always perpendicular to the traveling direction, then the wheels are able to follow U-turn guideways made of two concentric half-circles. FIG. 13B shows that a flexible vehicle (C) is able to follow such guideways.

[0065] FIG. 11A and FIG. 13A give two extremes of wheel and axle design. FIG. 13A method is used for conventional train design, and FIG. 11A method is used for conventional automobile design, but with a slight difference. A conventional automobile travels on two-dimensional road surface, and there is no need to force its wheels to turn to various directions as shown in FIG. 11A for guided vehicle movement. Many road vehicles and toy cars are designed between those two extremes, with various degrees and methods of axle rotation.

[0066] There are many methods of forcing wheels to follow guideways. One of such methods is shown on FIG. 14. FIG. 14A shows the frontal view of a guideway (2) and a wheel assembly (1, 3). FIG. 14B shows the top view of the same. The guideway is a channel opened on top (2). Large supporting wheel 1 is guided by small guiding wheels 3. The supporting wheel is used for vehicle support. The guiding wheels are held in place by two struts that are attached to the center of the supporting wheel. The guiding wheels are restrained by two edges of the guideway so that the vehicle could not be derailed. The number of guiding wheels for each supporting wheel could be varied from one to four. The guiding wheel locations relative to the supporting wheel and relative to each other could also be varied.

[0067] FIG. 9 shows a preferred embodiment of guideways that align different levels of straight moving, up-moving and down-moving guideways. Each location of lane switching (3-3', 4-4', 7-7' etc.) has only two guideways, one straight, and one up-moving or down-moving. Having only two choices at each switching location would be simpler for a vehicle to switch, especially for a vehicle driven by a computer. Two-dimensional side view of FIG. 9 is shown in FIG. 15A, where the arch shaped guideways (1-3-8, 9-7-4, 1'-3'-8', 9'-7'-4') provide additional structural supports for the straight moving guideways. Guideway support posts would be installed at locations 100, 200. Another construction method is that 9-7-4 and 9'-7'-4' are kept the same as that of FIG. 15A, but 1-3-8 and 1'-3'-8' are moved so that 1-1' are below 7-7' as shown in FIG. 15B. A vehicle in guideways of FIG. 15B has a choice among three possible directions in a switching location. Guideway support posts would be installed at locations 300, 400, and 500 in FIG. 15B to provide equivalent structural support for the guideways.

[0068] While it is more economical and easier to build elevated guideways, underground guideways could also be built with the same principles as outlined above, especially in city areas where space is limited. For a system of underground guideways, the topmost level becomes the stopping and loading level, and it is best at the street level. Vehicles load and unload, as well as enter and exit underground guideways at ground openings, which would be at location 7-7' as shown by FIG. 15C. Stairways and escalators are not needed for passengers to access the underground guideway networks. Such an underground transportation

system is more convenient for public to use, and cost much less than subway systems currently used worldwide.

[0069] Those guideway construction and vehicle operation methods offer many advantages for a transit system by providing the following possibilities:

[0070] (1) Multiple traffic lanes could be stacked together vertically. Future addition of extra lanes could be easily implemented without additional land use.

[0071] (2) Lane switching could be accomplished in a shorter travel distance, and is controlled by the vehicle, not the guideways. Such a switching mechanism would be more reliable than methods that require guideway movements.

[0072] (3) Land and space requirements for highway construction are much less than the conventional two-dimensional highway system. They allow construction of such a transit system in an existing city area in which a two-dimensional highway is impossible to build due to space limitation. They eliminate traffic lights altogether. A vehicle would not be required to stop until it reaches its destination. A multi-lane elevated highway with upper lanes as non-stop lanes and the lowest lane as stop lane would prevent stopped vehicles from affecting the non-stopping vehicles. For an underground guideway system, the topmost level becomes the loading/unloading level, and the lower levels carry continuous traffic flow.

[0073] (4) Automated transit system is possible with these construction methods. Vehicles are guided by guideways and there is less chance of accident. Implementation of computer control is easier.

[0074] (5) Without any obstruction in-between the left guideway group and the right guideway group, passenger or cargo compartment could move up and down with an in-vehicle lift system. This would allow a vehicle to stop at an elevated level above ground and pick up passengers or cargo from ground level. No designated station is needed for loading and unloading. Vehicles could stop anywhere along an elevated highway at the lowest level, or along an underground highway at the topmost level. The cargo or the passenger compartment could stay above the track, even with the track, or below the track during travel.

[0075] (6) A vehicle travels at elevated or underground levels could avoid traffic accidents of vehicle-human collision on the ground or street level.

[0076] (7) These construction and operation methods would allow vehicles to be operated as dual-mode vehicles. A vehicle could travel at the ground level on guideways or on regular road. When a vehicle is on guideways, it could be computer-controlled. When a vehicle is on regular road, it is preferred that a human driver controls the vehicle.

[0077] (8) Since the weight of the guideways constructed with such methods is much less than regular roadway, each section of guideways could be modular and could be fabricated in shops, lowering manufacturing and field installation cost of guideways. Underground guideways system could be constructed with much less space requirements than that of a subway system of similar traffic load.

REFERENCES CITED

[0078] The following references are used to support the application:

[0079] (1) "Innovative Transit Systems-Survey of current developments", Ingmar Andréasson, VINNOVA Report VR 2001:3, (Swedish version KFB-rapport 2000:69), ISBN 91-89588-03-7, ISSN 1650-3104, UTGIVARE/PUBLISHER: VINNOVA-Verket för Innovationssystem/The Swedish Agency of Innovation Systems, Stockholm.

[0080] (2) <http://faculty.washington.edu/~jbs/itrans/>. A website devoted to innovative transportation technologies, developed by Jerry B. Schneider, Professor of University of Washington, Seattle, Wash. 98195. This website is more comprehensive and up to date than any review articles and books, and should be referenced although referencing a website is unconventional.

[0081] (3) <http://www.swedetrack.com>. This is the webpage of Swedetrack.

[0082] (4) U.S. Pat. No. 6,857,374, Feb. 22, 2005, Novacek. It describes a transportation system for guiding and switching vehicles with complex wheel arrangements on a dedicated guideway.

[0083] (5) U.S. Pat. No. 6,679,181, Jan. 20, 2004, Fox. A dual mode transportation system in which a vehicle could be coupled and decoupled with a leading vehicle during traveling. The leading vehicle could provide power and guidance to the following vehicles. A decoupled vehicle could travel on normal road.

[0084] (6) U.S. Pat. No. 5,657,699, Aug. 19, 1997, Bishop. A vehicle and guideway system in which a vehicle could grip on the guideway to prevent slippage during braking, acceleration, and grade climbing.

[0085] (7) U.S. Pat. No. 6,202,566, Mar. 20, 2001, Hutchinson. A transportation system that uses a carrier to move payloads. The carrier hangs on a motive units that travels on a guideway.

[0086] (8) U.S. Pat. No. 6,651,566, Nov. 25, 2003, Stephan, et al. A guideway system and method of power transfer from the guideway to a vehicle.

[0087] (9) U.S. Pat. No. 6,393,993, May 28, 2002, Reese. A monorail switching system for guided vehicles.

[0088] (10) U.S. Pat. No. 6,314,890, Nov. 13, 2001, Geldbaugh. A dual usage transportation system in which a vehicle runs on roadway surface and is attached to an adjacent guide rail system. The vehicle could be detached and run as a free vehicle.

[0089] (11) U.S. Pat. No. 6,363,857, Apr. 2, 2002, Kauffman. A transportation system in which a transporter could move people or vehicle to different destination on the network.

[0090] (12) U.S. Pat. No. 6,742,458, Jun. 1, 2004, Henderson. A dual mode transportation system and vehicle.

[0091] (13) WO 2004/098971, Nov. 18, 2004, Wu. An automated personal transportation system for moving passengers and light freights is constructed with a track network and small vehicles on the track network.

[0092] (14) WO 99/65749, Dec. 23, 1999, Jensen. A transport system of the dual-mode type which comprises dual-mode vehicles and a monorail, whereby said dual-mode vehicles can run both on an ordinary roadway and as rail vehicles on the monorail. The patent for the RUF system.

What is claimed is:

1. A system of guideway construction and vehicle design methods as described in FIG. 1-2, and FIG. 4 to 10, in which vehicles ride on the guideways groups supporting left and right wheels, with empty space between the left and the right guideways. Lane and direction switching are accomplished by guideway switching among inner, middle and outer guideways. A vehicle initiates the guideway switching by widening or narrowing its wheel width, at a horizontal section that contains at least two of the inner, middle and outer guideways. After guideway switching, upper-moving guideways (outer) could guide the vehicle up and down-moving guideways (inner) could guide the vehicle down, and straight-moving guideways (middle) could guide the vehicle forward. In this system, outer guideways are for sending vehicles to above and receiving vehicles from above; inner guideways are for sending vehicles to below and receiving vehicles from below; and middle guideways are for carrying vehicles traveling at the current level. If a vehicle at one level needs to move up, it could move out of the straight guideways by widening the space between its left wheel and the corresponding right wheel and moving to the outer guideways. If a vehicle needs to move downward, the width of its wheel spacing needs to be narrowed to match the width of inner guideways, so that the wheels could ride on the down-moving guideways. In such a transportation system, vehicles diverge from a source lane and merge into a target lane aerially either above or below the tracks. Vehicles could move between levels by going through the empty space between left guideways and the corresponding right guideways.

2. A guideway construction method of claim 1, in which outer guideways of a level could guide a vehicle up to another level and inner guideways of a level could guide a vehicle down to another level. If the later level receives the vehicle from its underside, then the guideways would curve into inner guideways of the later level, with varying left to right track width along the way. If the later level receives the vehicle from above, then the guideways would curve into outer guideways of the later level, with varying left to right track width along the way. It is convenient for multiple levels aligned vertically; however, the principle could be applied to any relative spatial location of the lanes.

3. A guideway construction method of claim 1, in which up-moving guideways and down-moving guideways have fixed width. However, the upper level guideway width is wider than that of the lower level, so that lower level outer guideways could connect to upper level inner guideways without narrowing or widening.

4. A guideway construction and vehicle design method of claim 1, by which a vehicle's passenger or cargo compartment could be located above the guideway level, even with the guideway level and below the guideway level. Such construction method would allow the passenger or the cargo compartment of a vehicle to be lowered or raised for loading and unloading, and for safer operation due to lowered center of gravity.

5. A guideway construction and vehicle design method for directional changes of a rigid vehicle with non-rotating axles, as shown by FIG. 11 and FIG. 12. In a directional change, all outer wheels will follow a single outer guideway and the inner wheels will follow multiple tracks, one for each inner wheel. The track trajectories are determined by tracing the movements of each inner wheel. All the inner tracks could be combined to form a wide single inner guideway to accommodate all the inner wheels. This implies that all vehicles in the system must have the same size and the same wheel locations.

6. A guideway construction method and a wheel restraining method as shown in FIG. 14, in which the guideway is a channel and the wheel assembly includes supporting wheel and guiding wheels. The edges of the channel restrain the guiding wheels and prevent a vehicle from derailing.

7. A guideway construction and vehicle design method of claim 1, with each section of the guideways as an open

channel as defined by FIG. 9 and FIG. 14. The ascending and descending guideways form continuous arches that could also provide structural support for the straight moving guideways as shown by FIG. 15A. This guideway construction method could accommodate dual mode vehicles that could travel both on guideways and on regular road. A dual mode vehicle could enter an elevated guideway system by aligning its wheels with a pair of up-moving guideways and exits the guideway system by aligning its wheels with a pair of down-moving guideways that lead to the ground. A dual mode vehicle could enter an underground guideway system by aligning its wheels with a pair of down-moving guideways and exits the guideway system by aligning its wheels with a pair of up-moving guideways that lead to ground openings on the street.

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