ELEVATOR SYSTEMS AND METHODS FOR OPERATING SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit under 35 U.S.C. 119(e) of U.S. provisional application number 60/993,588, filed September 13, 2007, the contents of which are incorporated by reference herein in their entirety.

TECHNICAL FIELD

The present application relates to elevator systems for transporting passengers and freight within buildings and other structures.

BACKGROUND

There is an ongoing need for improved elevator service in large buildings. Today, the prevailing trend is towards taller and thinner buildings. Taller buildings generally have more occupants and thus have more elevator passengers. Each elevator car in the building is slower because there are more floors to service and thus more stops. Therefore, as buildings get taller, the need for more cars increases rapidly. At the same time, thinner buildings have less available space for elevator shafts. These shafts use up valuable space on each floor, regardless of whether or not they service that floor. It is estimated that more than thirty percent of the floor space in a one-hundred story building is dedicated to the elevator system. Thus, conventional elevator systems may be inadequate for some modern buildings.

Figure **1** shows the main components of a conventional elevator system. A car **10,** also commonly referred to as a cab or cage, is the compartment used to transport passengers between floors. A shaft **12,** also commonly referred to as a well, hoistway or hatchway, is the vertical passageway in the building through which the car travels. A bank, also commonly referred to as a group, is a set of adjacent shafts enclosed by a shaft wall **13**. A counterweight **14** is a weight that serves to counterbalance the car. A cable **16,** also commonly referred to as a hoist or rope, supports the car by connecting it to the counterweight **14**. A pulley **18,** also commonly referred to as a sheave, is a wheel or sprocket that guides the cable at the top of the shaft. The pulley **18** is usually driven by a motor. The counterweight **14** serves to reduce the effort required by the motor to move the car up and down, since power would be needed to lift only the difference between the weights of the counterweight and of the car. The elevator systems include a control system comprising hardware and software that control the movement of cars. Today, most elevators operate by dedicating one car per shaft. This basic engineering design has survived decades of technical improvements.

Because the cable **16** stretches from the elevator car to the top of the elevator shaft **12**, and usually occupies the center of the elevator shaft **12**, it would interfere with any other elevator car that was operating above the car in the same shaft **12**. While it is possible to move the cables 16 to the side of the elevator shaft **12**, the cables **16** and counterweights **14** would likely become tangled during operation. Eliminating the use of the cable **16**, however, would in turn necessitate elimination of the counterweight **14**. Eliminating counterweights in most conventional systems would necessitate the use of powerful driving motors, which in turn would substantially increase the power consumption and space requirements of the elevator system.

Another problem is that the weight of the cable **16** can become significant in tall buildings with long shafts **12**. This affects the balance between the car and the counterweight **14** as the car moves from the top to the bottom of the elevator shaft **12**. When the car is at the top of the elevator shaft **12**, the weight of the cable 16 is on the side of the counterweight **14**. This weight shifts to the other side as the car moves to the bottom of the elevator shaft **12**. Thus, counterweights **14** can potentially be unsuitable for elevator systems in very tall buildings.

The most common configuration in use today in tall buildings comprises multiple banks of elevators, with each bank serving a range of floors. For example, one bank would serve floors one through twenty, another would serve floors twenty-one through forty, and yet another would serve floors forty-one through sixty, and so on. This arrangement usually reduces service times for passengers. The problem with this idea is that the shafts for banks extend through all floors below the service range, regardless of whether or not the car stops at that floor. This consumes valuable floor space on floors that are not serviced by the elevator bank.

Moreover, with some modern architectural designs, there is a need for elevators that move in slanted or curved paths. Buildings are no longer simple cuboids (shaped like a box). Elevators may need to follow complex paths, with some vertical segments, some horizontal segments, and other slanted or curved segments. There are situations, for example, in large ships, where a straight vertical shaft is not feasible because of structural components or critical functional areas that block a straight run. There is also a need for elevator cars that move horizontally from one bank of elevators to another. Workers in buildings that cover large areas of ground often need to ride an elevator to a crossover floor, walk to a different elevator bank and take that to their destination.

Prior inventions have tried to address above problems in different ways. One idea, as exemplified by U.S. Patent No. 5,419,414 to Sakita, has multiple independent cars in a shaft. In this design, however, the cars use counterweights and cannot pass each other. Another group of inventions, as exampled by U.S. Patent No. 5,861,586 to McCarthy et al., have cars that fit inside carriages or frames. The carriages are attached to counterweights and move up and down elevator shafts. Cars can be loaded on or unloaded from these carriages by moving the cars horizontally into or out of the carriages. These systems do not permit multiple cars simultaneously plying in a shaft. Although self propelled cars that operate without counterweights can address some of the above problems, such systems are inherently inefficient and will not be commercially economical in the foreseeable future. For example, U.S. Patent No. 6,955,245 to Dünser et al. describes a scheme where self propelled cars can switch between shafts, but requires a dedicated shaft for parking purposes.

SUMMARY

The systems and methods disclosed herein can facilitate the simultaneous operation of multiple elevator cars in a single elevator shaft, and can facilitate the switching of elevator cars between elevator shafts. This can potentially increase the utilization of the elevator systems, and can potentially improve the service provided to the passengers and cargo being transported by the elevator systems.

The elevator cars can switch shafts in embodiments disclosed herein. When the paths of two cars threaten to intersect, one of the elevator cars switches to an adjoining shaft and proceeds to its destination floor. If there is a lot of traffic, the car may have to switch several times before it reaches its destination. Switching is also necessary when a car moving upwards or downwards comes across a stationary car that is loading or unloading passengers at a floor. A computer-based control system can be configured to route all of the cars so that collisions are prevented and switching is minimized. The switching system needs to allow cars to smoothly move between shafts while being as safe and efficient as today’s systems.

Embodiments disclosed herein can include more than one elevator shaft, the shafts can be located in ‘banks’ so that they are located adjacent to each other, and openings can be present between the shafts so that the elevator cars can move from one shaft to another. This is usually not a problem, both for existing buildings and in new architecture.

Embodiments disclosed herein do not require a counterweight and hoist cable. Rather, the downwardly and upwardly-moving cars are mechanically linked so that downwardly-moving cars serve to balance the upwardly-moving cars. The control system can be programmed to cause the number of downwardly-moving cars to be about equal to the number of downwardly-moving cars at any given time. Multiple cars can be operated in each shaft on a simultaneous basis.

Embodiments disclosed herein facilitate free movement of elevator cars between elevator shafts through the use of a slide arm or other mechanism that the cars to switch to adjoining shafts. The switch can be made while the cars are moving or stationary. The switching operation can be repeated on a particular car so that the car can move to any shaft in the elevator bank. The paths of all cars are managed by the control system that plans and monitors all the operations.

DRAWINGS

The foregoing summary, as well as, the following detailed description of preferred embodiments, are better understood when read in conjunction with the appended diagrammatic drawings. The drawings are presented for illustrative purposes only, and the scope of the appended claims is not limited to the specific embodiments shown in the drawings. In the drawings:

Figure 1 is a side view of a conventional elevator located within an elevator shaft;

Figure 2 is a side view of an embodiment of a drive assembly of an elevator system;

Figure 3A is a plan view of the positioning of twelve of the drive assemblies shown in Figure 2 in elevator bank with three shafts;

Figure 3B is a cross-sectional view of the elevator bank depicted in Figure 3A, taken along the line B3 of Figure 3A;

Figure 4A is a plan view of the elevator bank shown in Figures 3A and 3B, depicting an elevator car in each of the left and right shafts of the elevator bank;

Figure 4B is a cross-sectional view of the elevator bank depicted in Figures 3A-4A, taken along the line B4 of Figure 4A;

Figure 4C is a perspective view showing the elevator cars depicted in Figure 4A traveling within the elevator bank shown in Figures 3A-4B;

Figure 5 magnified side view of the area designated A5 in Figure 4C;

Figure 6 is magnified perspective view of the area designated A6 in Figure 5;

Figure 7 is a perspective view of a pair of clamp runners associated of the elevator system shown in Figure 2-6, depicting one of the clamp runners in a retracted, or nearly retracted state;

Figure 7a is a magnified perspective view of the area designated A7 in Figure 7;

Figure 8 is a perspective view of the clamp runners shown in Figure 7, showing one of the clamp runners in the process of extending;

Figure 9 is a perspective view of the clamp runners shown in Figures 7 and 8, showing one of the clamp runners approaching a fully-extended condition;

Figure 10A is a magnified cross-sectional view of a clamp and guide roller of the elevator system shown in Figures 2-9, taken along the line section A10 of Figure 10B;

Figure 10B is a magnified cross-sectional view of two clamps of the elevator system shown in Figures 2-10A, taken along the line section B10 of Figure 10A, depicting the lower clamp in an engaged position and the upper clamp in a disengaged position.

Figure 10C is a magnified cross-sectional view of the guide rollers shown in Figure 10A, taken along the line section C10 of Figure 10A, depicting a lower guide roller in an engaged position and an upper guide roller in a disengaged position.

Figure 11 is a side view depicting one of the elevator cars shown in Figures 4A-4C preparing to switch between elevator shafts, showing lower clamp runners in the process of extending;

Figure 12 is a side view depicting the elevator car shown Figure 11 switching between elevator shafts, showing upper and lower clamp runners attached to drive assemblies in the originating and destination shafts;

Figure 13 is a perspective view of elevator car shown in Figures 11 and 12 switching between elevator shafts;

Figure 14A is a plan view showing an alternative embodiment in which elevator cars can switch between elevators shafts in the front to back and left to right directions;

Figure 14B is a magnified view of the area designated B14 in Figure 14A;

Figure 15A is a side view of an alternative embodiment having two overlapping sets of drive assemblies located in the same elevator shaft to extend the run of an elevator within the shaft;

Figure 15B depicts an elevator car switching between the two overlapping sets of drive assemblies shown in Figure 15A;

Figure 16 is a side view of an alternative embodiment having slanted drive assemblies to facilitate operating in a slanted elevator shaft;

Figure 17A is a side view of an alternative embodiment of the drive loop of the drive assembly shown in Figure 2;

Figure 17B is a side view of the drive loop shown in Figure 17A, from a perspective rotated approximately ninety degrees from the perspective of Figure 17A;

Figure 18A is a side view of another alternative embodiment of the drive loop of the drive assembly shown in Figure 2;

Figure 18B is a cross-sectional view taken along the line B18 of Figure 18A;

Figure 19A depicts the drive assembly shown in Figure 2 balancing two elevators cars;

Figure 19B shows two linked drive assemblies balancing two elevator cars;

Figure 19C shows three linked assemblies balancing four elevator cars;

Figure 20A is a side view of two elevator cars being joined;

Figure 20B is a plan view of the elevator cars shown in Figure 20A, depicting side walls between the two elevator cars swinging open;

Figure 21A is a side view of an alternative embodiment of the elevator cars shown in Figures 4A-4C;

Figure 21B depicts the elevator car shown in Figure 21A in a tilted state; and

Figure 22 is a block diagram of a computer control system and various electrical components of the elevator system shown in Figures 1-13.

DETAILED DESCRIPTION

Embodiments of elevator systems that can facilitate simultaneous operation of multiple elevator cars in one elevator shaft, and that can facilitate movement of elevators cars between shafts, are disclosed herein. The embodiments can comprise a propulsion or drive mechanism referred to herein as a drive assembly **20**, and a computer control system. The drive assembly **20** and the computer control system can facilitate the independent and simultaneous movement of multiple elevator cars **10** in one or more elevator shafts **12**. The elevator cars **10** can be detachably connected to one or more drive assemblies **20** using, for example, clamping devices in the form of sliding clamp runners **40** on which clamps **42, 44** are mounted.

Drive Assembly

The drive assembly **20** is a mechanism that guides, propels, and stabilizes the elevator cars **10** within their corresponding elevator shafts **12**. Figure **2** is a diagrammatic view of a drive assembly **20** spanning a twenty-floor building having floors denoted sequentially by the reference characters **21a-21s**. The drive assembly **20** comprises a frame **27,** an upper pulley or sprocket **28a**, a lower pulley or sprocket **28b**, and a drive member in the form of an endless flexible loop **23** stretched over the upper and lower sprockets **28a**, **28b**.

The upper and lower sprockets **28a**, **28b** are mounted for rotation on the drive assembly frame **27.** The upper and lower sprockets **28a**, **28b** rotate as denoted by the arrows **28c** in Figure **2**, to drive the loop **23** at a substantially constant speed. One segment **22** of the loop **23** is constantly moving upward, and the other segment **26** is constantly moving downward during operation of the elevator system, as denoted by the arrows **22a, 26a** in Figure **2**.

The drive assembly **20** also includes a stationary segment **24**. The stationary segment **24** is securely mounted on the frame **27** of the drive assembly **20**. The stationary segment **24** is located between, and is substantially parallel to the segments **22**, **26** of the loop **23**, as shown in Figure **2**. The stationary segment **24** can be a rigid plate having a width and thickness that are substantially the same as the respective width and thickness of the loop **23**. The stationary segment **24** can function as a guide rail for the elevator cars **10**, and can help to stabilize the elevator cars **10** during movement thereof.

At least one drive assembly **20** is located in each elevator shaft **12**. The frame **27** of each drive assembly **20** is securely mounted on a wall of the corresponding elevator shaft **12**. In the embodiments described herein, four drive assemblies **20** are installed within each elevator shaft **12**. One drive assembly **20** can be located at or proximate each corner, i.e. left-front, right-front, left-rear, right-rear, of the elevator shaft **12**, so that the front wall of the elevator shaft **12** supports two of the drive assemblies **20** and the rear wall of the elevator shaft **12** supports the other two drive assemblies **20**. The set of four drive assemblies **20** located in each elevator shaft **12** is referred to herein as a drive assembly set **31**. The use of four drive assemblies **20** in each elevator shaft **12** is disclosed for exemplary purposes only. More or less than four drive assemblies **20** can be used in each shaft **12** in alternative embodiments.

The lower sprocket **28b** of each drive assembly **20** can be disposed in a shaft well that extends below the lowest serviced floor **21a** of the corresponding elevator bank, as shown diagrammatically in Figure **2**. The upper sprocket **28a** of each drive assembly **20** can be disposed in a space above the highest serviced floor **21s** of the corresponding elevator bank. The upper and lower sprockets **28a**, **28b** can be driven by on one more motors **25** connected by a belt **29** or other suitable means to the lower sprocket **28b**. The motors **25** can be connected to the upper sprocket **28a**, or to both the upper and lower sprockets **28a**, **28b** in alternative embodiments.

The system described herein can be used in banks of elevators having multiple adjacent shafts, with at least one drive assembly set **31** being installed within each shaft. The horizontal spacing between the drive assemblies **20** located on the left and right sides of each elevator shaft is substantially the same for all shafts in a bank. The horizontal spacing between the drive assemblies **20** located at the front and rear of each elevator shaft likewise is substantially the same for all shafts in a bank. Also, the spacing between the upward moving segment **22**, the downwardly moving segment **26**, and the stationary segment **24** within each drive assembly **20** is substantially the same among all of the drive assemblies **20** in the bank. The drive assemblies **20** in the bank can be mechanically coupled and synchronized so that all of the drive assemblies **20** move at substantially the same speed.

Figures **3A** and **3B** are plan and elevation views, respectively, depicting the positioning of twelve drive assemblies **20** in an elevator bank having three shafts **12a**, **12b,** and **12c**. In addition, Figure **3B** depicts landing areas associated with the floors **21a, 21b,** and elevator shaft doors **32** in their respective closed positions. No elevators cars are shown in Figures **3A** and **3B**, for clarity of illustration. Only the front drive assemblies **20** are shown in the elevation views; the rear drive assemblies **20** are located directly behind the front drive assemblies **20** in these views.

Figures **4A, 4B,** and **4C** are plan, elevation, and perspective views, respectively, for the bank of three elevator shafts **12a**, **12b**, **12c**, depicting an elevator car **10** in the elevator shaft **12a** and another elevator car **10** in the elevator shaft **12c**. The sides of the elevator shafts **12a**, **12b**, **12c** are unobstructed so that the elevator cars **10** can move sideways between adjoining shafts **12a**, **12b**, **12c**. The use of an elevator bank having three shafts **12a**, **12b**, **12c** is disclosed for exemplary purposes only. Alternative embodiments can be used in elevator banks having more, or less than three shafts.

The loop **23** can be a flexible belt or band. The loop **23** can be formed, for example, from a synthetic rubber material reinforced with KEVLAR to provide the loop **23** with sufficient tensile strength. The loop **23** engages teeth **52** on the upper and lower sprockets **28**, as shown in Figure **5**. The teeth **52** can extend through holes **64** in the formed in the loop **23**, as shown in Figure 6**,** to discourage slippage of the loop **23**.

Each drive assembly **20** also comprises a plurality of rollers **58**. The rollers **58** are mounted on brackets **56**, which in turn are mounted on the drive assembly frame **27**. The rollers **58** are arranged in pairs, as shown in Figure **5**, so that the loop **23** travels between the two rollers **58** in each pair. The rollers **58** help to guide the loop **23**. The rollers **58** also help to stabilize the loop **23** so that the loop **23** does not experience substantial horizontal vibration or twisting. The rollers **58** also allow the drive assembly **20** to be curved or slanted.

The rollers **58** can engage the loop **23** in channels **62** formed in the inwardly and outwardly-facing surfaces of the loop **23**, as shown in Figure **6**. Cladding **66** formed from an abrasion-resistant material can be fastened to the inwardly and outwardly-facing surfaces of loop **23** by a suitable means such as rivets **67**, to help protect the surfaces from wear.

Clamp Runner

The elevator cars **10** are connected to the loop **23** of one or more associated drive assemblies **20** on a selective basis by the clamps **42, 44**, and extension devices in the form of clamp runners **72**. The elevator cars **10** move upward by clamping onto the upward moving segment **22** of the loops **23** of the associated drive assemblies **20**, using the clamps **42, 44**. The elevator cars **10** move downward by clamping onto the downwardly moving segment **26** of the loops **23**, using the clamps **42, 44**. The elevator cars **10** clamp onto the stationary segments **24** of the associated drive assemblies **20** using the clamps **42, 44** when the elevator cars **10** are not moving.

Each clamp runner **72, 74** comprises three horizontally-oriented sliding bars **73** formed from a rigid material such as steel. The bars **73** of each clamp runner **72, 74** can slide lengthwise along each other, so that the clamp runner **72, 74** can extend in opposite directions. Figures **8-9** depict the upper clamp runner **72** extending sideways.

The bars **73** of each clamp runner **72, 74** can be coupled to and aligned with each other by, for example, roller bearings disposed within slots formed in the bars. The clamp runners **72, 74** are depicted herein with three bars for exemplary purposes only. Each clamp runner **72, 74** can include more, or less than three bars in alternative embodiments.

The innermost bar **73** of each clamp runner **72, 74** is securely attached to a wall **71** of a corresponding elevator car **10** as shown in Figures **7-9**, using fasteners or other suitable means. In alternative embodiments, the clamp runners **72, 74** can be attached to the elevators car **10** by way of springs and dampers, to help attenuate bumps that passengers may feel during transitions in the operating state of the elevator cars **10**.

The outermost bar of each clamp runner **72, 74** has at least two clamps **42, 44** mounted thereon, with at least one clamp **42**, **44** located at or near each end of the bar. More than one clamp **42**, **44** can be mounted at or near the ends of the outermost bar in the alternative, to provide redundancy and to potentially facilitate faster transitions in the operating state of the elevator car **10**.

Electric stepper motors **75** can be mechanically coupled to each of the clamp runners **72, 74** to move the bars of each clamp runner **72, 74** in relation to each other, thereby causing the clamp runner **72, 74** to extend and retract. In one embodiment, the motor **75** is mechanically attached to each movable bar **73** and can turn a pinion **78** which engages a rack **77** through a slot **79** in the bar **73**. The rack **77** is mounted on an inner bar **73**. Turning the pinion **78** will cause the two bars **73** to slide relative to each other. Other means, such as hydraulically actuated pistons, can be used to extend and retract the clamp runners **72, 74** in alternative embodiments.

The motor **75** of each clamp runner **72, 74** can be communicatively coupled to an on-board car manager system **222** of the elevator car **10** (described below), so that the car manager system **222** can control the extension and retraction of the clamp runners **72, 74**. Each clamp runner **72, 74** can include a position sensor **76** communicatively coupled to the car manager system **222**, to provide the car manager system **222** with an indication of the extent to which the clamp runner **72, 74** is extended or retracted.

The car manager system **222** can issue control inputs to the motor **75** of each clamp runner **72, 74** to cause the clamp runner **72, 74** to extend so as to position the associated clamps **42, 44** over the upwardly or downwardly moving segments **22**, **26** of the loop **23**, to facilitate engagement of the clamps **42, 44** and the loop **23**. The horizontal spacing between the clamps of each clamp runner **72, 74** is substantially the same as the spacing between the upwardly or downwardly moving segments **22**, **26** in the left and right drive assemblies **20** in a shaft. Thus, the left and right clamps **42, 44** can simultaneously engage corresponding drive segments **22**, **26** on the left and right drive assemblies **20**.

In the embodiments disclosed herein, the clamp runners **72, 74** are arranged in pairs **40**, with one clamp runner **74** being located directly below the other **72** within each pair as shown in Figures **7-9**. The upper and lower clamp runners **72, 74** of each clamp runner pair **40** are identical, and operate independently of each other. For example, Figures **8** and **9** depict the upper clamp runner **72** of the pair extending toward the right, while the lower clamp runner **74** remains in its retracted position. The clamp runners **72, 74** in alternative embodiments can be arranged in groupings having more than two clamp runners **72, 74**, to provide greater redundancy and smoother operation.

In the embodiments disclosed herein, each elevator car **10** has four pairs **40** of clamp runners **72, 74** mounted thereon. More or less than this number of clamp runners **72, 74** can be mounted on each elevator car **10** in alternative embodiments. The pairs **40** of clamp runners **72, 74** can be located along the upper-front, lower-front, upper-rear, and lower-rear edges of the elevator car **10** as shown in Figures **4A-4C.** Figure **4B** shows the pairs **40** of clamp runners **72, 74** located on the front of each elevator car **10**, and their respective positions in relation the associated drive assembles **20**. As shown in Figure **4A**, two additional pairs **40** of clamp runners **72, 74** are mounted on the rear of each elevators car **10**, behind the front-mounted clamp runners **72, 74**.

Figure **10A** depicts one of the clamps **44** engaging the downward moving segment **26** of a corresponding loop **23**. The clamps **42**, **44** comprise pads **108** that grip the segment **26**, and pistons **107** that move the pads **108** into and out of contact with the segment **26**. The pistons **107** can be actuated by pressurized hydraulic fluid **107a** or other suitable means. The hydraulic fluid **107a** can be supplied from a reservoir (not shown). The flow and pressure of the hydraulic fluid **107a** supplied to each clamp can be by regulated by valves **106** that respond to inputs from the car manager system **222**.

The clamp **42**, **44** also comprises a caliper **105** on which the pistons **107** are mounted. The caliper **105** is mounted on a pin **102**, which acts as a hinge for the caliper **105**. The pin **102** and the caliper **105** are mounted on a swivel housing **101**, so that the pin **102** and the caliper **105** can swivel away from the downward moving segment **26** when the clamp **42**, **44** is not engaged. The swiveling motion of the swivel housing **101** can be effectuated using hydraulic fluid, one or more electric motors, or other suitable means. The calipers **105** can be configured to slide linearly, instead of swiveling, in alternative embodiments. Figure **10B** is a sectional view taken along the line **B10** in Figure **10A**, showing the caliper **105** of the lower clamp **42** in its engaged position, and the caliper **105** of the upper clamp **44** (on the associated upper clamp runner **72**) in its disengaged position.

Each clamp **42, 44** also has guide rollers **104** mounted on either side thereof, as shown in Figures **10A** and **10C**. When the clamp **42** is engaged on one of the moving segments **22**, **26** of the loop **23**, one of the guide rollers **104** is engaged against the stationary segment **24** of the associated drive assembly **20**; the guide rollers **104** do not engage the loop **23**. The guide rollers **104** stabilize the associated elevator car **10**. Moreover, the engagement of the guide rollers **104** and the stationary segment **24** causes the stationary segment **24** to act as a guide for the elevator car **10**.

The guide rollers **104** are disposed in the swivel housing **103**, and swivel away from the loop **23** when not engaging the stationary segment **24**. Each clamp **42** and guide roller **104** can swivel independently of each other, and engage the loop **23** and stationary segment **24** only as needed. The swiveling motion can be effectuated using hydraulic fluid, electric motors, or other suitable means. Figure **10C** is a sectional view taken along the line **C10** of Figure **10A**, and shows the lower guide roller **104** mounted on a clamp runner **72** and engaging the stationary segment **24**. The guide rollers **104** can swivel away around the pin **102,** as shown by the arrow **104a** in Figure **10C**. The upper guide roller **104** is shown in a disengaged state in Figure **10C**. The guide rollers **104** can be configured to slide linearly, instead of swiveling, in alternative embodiments.

Alternate embodiments of the clamp runners **72** can be configured to extend uni-directionally instead of bi-directionally. The two clamp runners **72, 74** in each clamp runner pair **40** can be configured to extend in opposite directions. If a clamp runner in the set **40** needs to be extended in a particular direction and the appropriate runner is already engaged, then that runner has to be freed before it can be used. The engaged runner can be freed by first engaging the other runner in the pair **40**. For example, say the clamp runner **72** is configured to extend only to the right and the clamp runner **74** is configured to extend only to the left. Say that clamp runner **74** is currently engaged and clamp runner **72** is currently free. If the car is to switch shafts to the left, it needs to extend a clamp runner to the left. Since, only clamp runner **74** is configured to move left, it needs to be freed before it can be used. Clamp runner **74** can be freed by first engaging clamp runner **72** on the same drive segments as clamp runner **74**.

Starting and Stopping

The clamp runners **72**, **74** of each pair **40** of clamp runners are mounted so that one of the clamp runners **72** is located above the other clamp runner **74**, from the perspective of Figures **4A**, **4B**, and **7-9**. The car manager system **222** operates the upper clamp runners **72** of the four clamp runner pairs **40** on each elevator car **10** simultaneously as a set, referred to hereinafter as "the upper set." The car manager system **222** operates the lower clamp runners **74** of the four clamp runner pairs **40** on each elevator car **10** simultaneously as a separate set, referred to hereinafter as "the lower set." Hence, in the embodiments disclosed herein, the upper set of clamp runners **72** includes four clamp runners **72**, one from each of the four pairs **40** of clamp runners **72**. The lower set of clamp runners **74** includes the remaining four clamp runners **74** on the elevator car **10**. All eight clamps **42** associated with the upper set of clamp runners **72** engage or disengage simultaneously on the four drive assemblies **20** in the corresponding elevator shaft. All eight clamps **44** associated with the lower set of clamp runners **74** likewise engage or disengage simultaneously on the four drive assemblies **20** in the corresponding elevator shaft.

Under most operating conditions, only one of the two sets of clamp runners **72**, **74** is engaged on the associated drive assemblies **20** at one time. The other set of clamp runners **72**, **74** is free, i.e., disengaged, waiting to be used for the next transition in the operating state of the elevator car **10**. The upper and lower sets of clamp runners **72**, **74** thus alternate with each other between an engaged and disengaged (free) state. A transition occurs when, for example, an elevator car **10** accelerates from a stationary and to a moving state; decelerates from a moving to a stationary state; or switches its position from one elevator shaft to another.

In the figures, clamps **42, 44** that are in an engaged state with the loops **23** or stationary segments **24** are depicted as darkened, i.e., filled, circles. Clamps **42, 44** that are in a free, i.e., disengaged, state are depicted as unfilled circles. Thus, in Figure **4B**, the upper set of clamp runners **72** on the left elevator car **10** are engaging the upwardly-moving segments **22** of the associated drive assemblies **20**, and the lower set of clamp runners **74** are disengaged so that the left elevator car **10** is moving upward. The lower set of clamp runners **74** on the right elevator car **10** in Figure **4B** are engaging the downwardly-moving segments **26** associated drive assemblies **20**; and the upper set of clamp runners **72** are shown in a disengaged state so that the right elevator car **10** is moving downward.

In the embodiments disclosed herein, each elevator car **10** has eight clamps **42, 44** engaged onto the loops **23** or the stationary segments **24** of the corresponding drive assemblies **20** at any time, four at the upper corners and four at the lower corners of the elevator car **10**. Each elevator car **10** also has eight more clamps **42, 44** that are disengaged. For example, the left elevator car **10** depicted in Figures **4A-4C** is attached to the upwardly-moving segments **22** of the associated drive assemblies **20** using eight clamps **42**. Four of the engaged clamps **42** are visible as the darkened circles at the corners of the elevators car **10** in Figure **4B**; the other four engaged clamps **42** are located directly behind the engaged clamp **42**, and therefore are not visible in Figure **4B**. The right elevator car **10** is similarly clamped to the downwardly-moving segments **26** of its associated drive assemblies **20**.

The upper or lower sets of clamps **42, 44** engage the stationary segments **24** of their associated drive assemblies **20** when the elevator cars **10** are stationary. Moreover, as shown in Figures **4A-4B,** the free, i.e., disengaged, clamps **42, 44** can be positioned over the stationary segments **24** of the associated drive assemblies **20** so that the clamps **42, 44** are available for the next transition in the state of the elevator car **10**.

In addition to being able to firmly clamp on to the moving segments **22**, **26** of the loops **23** and the stationary segments **24**, the clamps **42, 44** are capable of smoothly and gradually accelerating and decelerating the elevator car **10** when it is starting or stopping its vertical motion. To accomplish this, the clamps **42, 44** do not abruptly lock on to the moving segments **22**, **26** or the stationary segments **24**; rather, the clamps **42, 44** undergo a smooth and gradual increase in traction over a few seconds, acting like a clutch, until the elevator car **10** is moving at the same speed as the moving segments **22**, **26**, or comes to a stop in relation to the stationary segments **24**. The car manager system **222** can effectuate the application of force by the clamps **42, 44** in this manner by sending a control input to the valves **106** on each clamp **42, 44** so as to cause the valves **106** to direct pressurized hydraulic fluid into or out of the clamp **42, 44**. The clamping force exerted by the various clamps **42, 44** associated with a particular elevator car **10** may vary among the clamps **42, 44**. For example, the clamps **42, 44** on one corner of the elevator car **10** may grip more, i.e., achieve more traction, than the others, thereby causing the elevator car **10** to tilt. The tilt may be left to right, front to back, or both. Position sensors **109b** mounted on the guide rollers **104** and communicatively coupled to car manager system **222** can detect the onset of the tilt. The position sensors **109b** can be a laser based device that reads position markings off the guide rails.

The car manager system **222** causes one of more of the engaged clamps **42, 44** to reduce traction and slip as required to cause the elevator car **10** to remain substantially horizontal. Load sensors **109a** on each clamp **42, 44** can measure the load borne by each clamp **42, 44**, and can provide this measurement to the car manager system **222**. The car manager system **222** can individually modulate the clamping force generated by each clamp **42, 44** to avoid exceeding load limits, to effectuate smooth transitions between various states of motion, to keep the elevator cars **10** substantially level, and to align the elevator cars **10** with the landings of the destination floors as the elevator cars **10** decelerate and stop.

When an elevator car **10** is stationary, the upper or the lower set of clamp runners **72**, **74** engage the stationary segments **24** of the associated drive assemblies **20**. When an elevator car **10** needs to transition to a state of upward motion from a stationary condition, the car manager system **222** of the elevator car **10** (discussed below) effectuates the following actions. In the descriptive example below, the lower set of clamp runners **74** engages the corresponding drive assemblies **20** and the upper set of clamp runners **72** is disengaged. In the alternative, the upper and lower clamp runners **72**, **74** can exchange roles.

1. The set of clamp runners **72** that is not engaged, i.e., that is not attached to the drive assemblies **20** by its associated clamps **42**, is actuated in unison so as to align the eight associated disengaged, i.e., free, clamps **42** with the upwardly moving segments **22** of the loops **23** of the corresponding drive assemblies **20**.

2. The free clamps **42** simultaneously begin to engage the corresponding upwardly moving segment **22** so that the upwardly moving segments **22** begin slipping upward through the free clamps **42**. The strain gauge load sensors **109a** on the clamps **42** monitor the load bourn by each clamp **42** so that the car manager system **222** can gradually increase the traction exerted by each clamp **42**.

3. When the clamps **42** which are in the process of engaging the upwardly moving segments **22** are able to bear the weight of the elevator car **10** and its contents, the other eight clamps **44** that have been clamped to the stationary segments **24** disengage. The car manager system **222** is configured to ensure that the elevator car **10** is not simultaneously clamped to both the stationary segments **24** and the upwardly moving segments **22**.

4. The clamping force of the clamps **42** that are in the process of engaging the segments **22** continues to gradually increase, so that the slippage between the clamps **42** and the segments **22** continues to decrease, and the elevator car continues to accelerate smoothly in the upward direction. The clamps **44** that were previously clamped to the stationary

segments **24** swivel away or retract so that they will not interfere with the loops **23** when the clamp runner **72** is extended for the next transition. The newly disengaged clamps **44**, which are ready for the next transition in the operating condition of the elevator car **10**, can remain aligned with the stationary segments **24**, or can be moved.

When an elevator car **10** needs to transition to a state of downward motion from a stationary condition, the car manager system **222** effectuates the following actions:

1. The set of clamp runners **72** that is not engaged is actuated in unison so as to align the eight associated free clamps **42** with the downwardly-moving segments **26** of the loops **23** of the associated drive assemblies **20**.
2. The clamps **44** that have been engaging the stationary segments **24** simultaneously begin to disengage from the stationary segments **24** so that the stationary segments **24** start slipping through the clamps **44**. The position sensors **109b** on the guide rollers **104** are used to measure the downward acceleration so that the car manager system **222** can cause the clamps **44** to gradually release the stationary segments **24** and the elevator car **10** accelerates downward at a rate comfortable to the passengers therein.
3. The clamps **42** that have not been engaged begin to gradually engage the associated downwardly-moving segments **26** as the other clamps **44** release the stationary segments **24**.
4. The engaging clamps **42** fully engage the downwardly-moving segments **26** when the elevator car **10** reaches a downward speed approximately equal to that of the downwardly-moving segments **26**.
5. The clamps **44** that were previously clamped to the stationary segments **24** fully disengage, and are ready for the next transition.

When an elevator car **10** needs to transition to a stationary condition from a state of upward motion, the car manager system **222** effectuates the following actions:

1. The set of clamp runners **72** that is not engaged is actuated in unison so as to align the eight associated free clamps **42** with the stationary segments **24** of the associated drive assemblies **20**.
2. The eight clamps **44** that have been engaging the upwardly-moving drive segments **22** simultaneously begin to release the drive segments **22** so that the drive segments **22** begin slipping through the clamps **44**. The position sensors **109b** on the guide rollers **104** are used to measure the deceleration so that the car manager system **222** can gradually decrease the traction exerted by each clamp **44**, thereby causing the drive segments **22** to slip

in relation to the corresponding clamps **44**. The gradual onset of slippage causes the elevator car **10** to decelerate at a rate comfortable to the passengers therein, due to the effects of gravity on the elevator car **10**.

3. The free clamps **42** begin to engage the corresponding stationary segments **24** as the vertical speed of the elevator decreases, and fully engage the stationary segments **24** when the vertical speed reaches zero.

4. The clamps **44** that were previously clamped to the upwardly-moving drive segments **22** fully disengage, and are ready for the next transition.

When an elevator car **10** needs to transition to a stationary condition from a state of downward motion, the car manager system **222** effectuates the following actions:

1. The set of clamp runners **72** that is not engaged is actuated in unison so as to align the eight associated free clamps **42** with the stationary segments **24** of the associated drive assemblies **20**.

2. The free eight clamps **42** simultaneously engage the stationary segments **24** so that the stationary segments **24** begin slipping through the clamps **42**. The strain gauges **190a** on the clamps **42** monitor the load bourn by each clamp **42** so that the car manager system **222** can gradually increase the traction exerted by each clamp **42**. The gradual onset of traction causes the elevator car **10** to decelerate at a rate comfortable to the passengers therein.

3. The clamps **44** that have been engaging the downwardly-moving drive segments **26** begin to disengage from the drive segments **26** as the other clamps **42** engage the stationary segments **24**.

4. The clamps **44** that were previously clamped to the downwardly-moving drive segments **22** fully disengage from the drive segments **26** when the other clamps **42** are able to bear the weight of the elevator car **10** and its contents. The disengaged clamps **44** are ready for the next transition at this point.

Switching shafts

Moving elevator cars **10** from one shaft to an adjoining shaft can be effectuated by sliding the free, i.e., disengaged, clamp runners **72, 74** all the way to the adjoining shaft so that the associated clamps **44** engage the drive assemblies **20** in the adjoining shaft. Although the clamp runners **72**, **74** can be made strong enough to resist bending even when fully extended, each clamp runner **72**, **74** will not have to bear the full weight of the elevator car **10** and its contents when extended.

Figures **7** and **9** depict a pair **40** of clamp runners **72**, **74**. The upper clamp runner **72** of the pair **40** depicted in Figure **7** is shown in its fully retracted position, with its associated clamps **42** in a free, i.e., disengaged state. The clamps **44** of the lower clamp runner **74** are depicted in Figures **7-9** in an engaged state. Figure **8** shows the upper clamp runner **72** extending to the right, so as to clamp on to a drive assembly **20** in an adjoining elevator shaft. Figure **9** shows the clamp runner **72** in an almost fully extended position, so the disengaged clamps **42** thereon can engage a moving drive segment **22**, **26** or a stationary drive segment **24** of the drive assembly **20** in the adjacent elevator shaft.

Figures **11**, **12,** and **13** depict an upwardly-moving elevator car **10** moving from a first, or originating elevator shaft to a second, or destination elevator shaft. The upper clamp runners **72** of the each clamp runner set **40** are clamped to the upward moving segment **26** of the drive assemblies **20** in the originating elevator shaft at the start of the transition between elevator shafts. In the descriptive example below, the upper set of clamp runners **72** is engages the corresponding drive assemblies 20 and the lower set of clamp runners **74** is disengaged. In the alternative, the upper and lower clamp runners **72**, **74** can exchange roles. The transition process can proceed as follows:

1. As shown in Figure **11**, the lower clamp runners **74**, which are disengaged at the start of the transition process, extend in a direction denoted by the arrows **111** until the clamps **44** of each lower clamp runner **74** are aligned with upwardly-moving drive segments **22** of a drive assembly **20** in the destination elevator shaft.

2. The clamps **44** that have been aligned with the upwardly-moving drive segments **22** in the destination elevator shaft engage the upwardly-moving drive segments **22**. The engagement can be done rapidly if the drive segments **22** in the destination elevator shaft are moving at substantially the same speed as the elevator car **10** in the originating elevator shaft. At this point, the elevator car **10** is attached to four drive assemblies **20** in the originating elevator shaft, and the four drive assemblies **20** in the destination elevator shaft, using all sixteen of the clamps **42**, **44** associated with elevator car **10**.

3. The lower clamp runners **74**, i.e., the clamp runners **74** that have been clamped to the drive segments **22** in the destination elevator shaft, are retracted. At the same time, the upper clamp runners **72**, which are still clamped to the drive segments **22** in the originating elevator shaft, are extended. The retraction and extension of the clamp runners **72**, **74** causes the elevator car **10** to move from the originating elevator shaft to the destination elevator shaft, in the direction denoted by the arrow **121** in Figure **12**. Moreover, the elevator car **10**

is still moving upwards because it is clamped to the upwardly-moving drive segments **22** of the various drive assemblies **20**. Hence, the elevator car **10** moves in an upward-right diagonal direction.

4. When the elevator car **10** has fully translated into the destination elevator shaft, the clamps **42** attached to the drive segments **22** in the originating shaft disengage, thereby freeing the upper clamp runners **72**.

5. The upper clamp runners **72** are retracted into the destination elevator shaft with the elevator car **10**.

After the elevator car **10** has moved to the destination shaft and the clamp runners **72** have been retracted, the elevator car **10** can immediately initiate a move to another elevator shaft. The clamp runners **74**, as discuss above, can extend in either direction, i.e., toward the right or left. Hence, the clamp runner **72** that just retracted into the destination elevator shaft can extend the other way to initiate movement into the next elevator shaft. In alternative embodiments in which the clamp runners **72** are arranged in groups of three, or in which clamp runners **72** can be extended past the adjoining shaft, the elevator car **10** can smoothly switch past multiple shafts without having to wait until the clamp runners **72** have been retracted from the originating shaft.

The movement and actuation of the clamp runners **72, 74** and clamps **42, 44** during the transition process can be effectuated based on inputs for the car manager system **222**.

The transition from the originating to the destination elevator shafts can be made while the elevator car **10** is stationary, or while the elevator car **10** moving upwards or downwards. The central control system **220** is configured to verify that the destination shaft is clear of another elevator car **10** before initiating the transition. For the most part, there are no structural barriers between elevator shafts in modern buildings. Occasionally, however, structural beams or other obstacles that block access between elevators shafts may be present. In such cases, the locations of the beams or obstacles can be programmed into the central control system **220**, and the central control system **220** can be programmed to cause the elevator cars **10** to navigate around the beams or obstacles.

Extending drive segments

A drive assembly **20** may not extend the entire length of the elevator shaft in which it is installed, especially in very tall buildings, because the drive assemblies **20** have a maximum practical length. Figures **15A** and **15B** depict an alternative embodiment that addresses this potential issue.

Figure **15A** shows two adjacent elevator shafts, and three sets of drive assemblies **20** installed in each elevator shaft. The sets of drive assemblies **20** are vertically stacked in relation to each other, and partially overlap. The middle set of drive assemblies **20** is disposed at a slight horizontal offset in relation to the lower and upper sets of drive assemblies **20**. The upper portion of the lowermost set of drive assemblies **20** overlaps the lower portion of the middle set of drive assemblies **20** in an overlap zone designated by the reference character **152**. The upper portion of the middle set of drive assemblies **20** likewise overlaps the lower portion of the uppermost set of drive assemblies **20** in an overlap zone designated by the reference character **153**. The drive assemblies **20** of the lower, middle, and upper sets are substantially parallel.

An elevator car **10** can transition from a first, or originating set of drive assemblies **20** to a second, or destination set of drive assemblies **20** as shown in Figure **15B**. In particular, Figure **15B** depicts an elevator car **10** moving through the transition zone **152**, and transitioning from the lower to the middle sets lower of drive assemblies **20**.

As the upwardly moving elevator car **10** enters the transition zone **152**, its upper set of clamp runners **72** are attached to the drive segments **22** of the lower set of drive assemblies **20**, and its lower set of clamp runners **74** is free, i.e., disengaged (the lower set of clamp runners **74** can be attached, and the upper set can be free in the alternative). As the elevator car **10** moves through the overlap zone **152**, the clamps **42** on the lower (free) set of clamp runners **74** are aligned with, and engage the upwardly moving segments **22** on the middle set of drive assemblies **20**. For a brief period of time, the elevator car **10** is attached to both the lower and middle sets of drive assemblies **20**, as shown in Figure **15B**. The clamps **44** of the upper set of clamp runners **72** disengage before the elevator car **10** exits the overlap zone **152**, and the elevator car **10** continues upward, driven by the middle set of drive assemblies **20**. The movement and actuation of the clamp runners **72**, **74** and clamps **42**, **44** during the transition process can be effectuated based on inputs for the car manager system **222**. The transition between the lower and middle sets of drive assemblies **20** can be smooth if the drive segments **22** in the lower and middle sets are moving at substantially the same speed.

The elevator car **10** can subsequently transition between the middle and upper sets of drive assemblies **20** in substantially the same manner. Moreover, transitions between the various drive assemblies **10** while the elevator car 10 is moving downward can be made in substantially the same manner.

Elevator shafts can be equipped with more, or less than three sets of drive assemblies in alternative embodiments, depending on the height of the elevator shaft. An elevator car **10** can start at the bottom (or top) floor and switch drive assemblies **20** as many times as necessary to reach the top (or bottom) of the elevator shaft.

The example above described an elevator car **10** going through the overlap zone while staying in the same shaft. However, as depicted in Figure **15A** elevator cars **10** can also move from one elevator shaft to another while moving through an overlap zone.

Express Zones

In an alternative embodiment, some of the sets of drive assemblies **20** can be configured to run at faster speeds that the other drive assemblies **20**. With this configuration, elevator cars **10** that clamp on to the faster drive assemblies **20** move faster than the elevator cars clamped onto the slower drive assemblies **20**. The faster drive assemblies 20 can be disposed in elevator shafts dedicated to express travel. Alternatively, the faster drive assemblies can be disposed adjacent to slower drive assemblies **20** located in the same or an adjacent elevator shaft, to facilitate the use of both local and express speeds in the same elevator shaft.

The elevator cars **10** can transition from a stationary condition to an intermediate speed before going to the relatively fast express speed. Alternatively, the elevator cars **10** can transition directly to express speed from a stationary condition.

In embodiments in which the elevator cars **10** transition through an intermediate speed, a set of relatively slow intermediate drive assemblies **20** can be used in combination with a set of relatively fast express drive assemblies **20**. The express drive assemblies **20** can be disposed in the same shaft as the intermediate drive assemblies **20** or, alternatively, in an adjoining shaft.

The intermediate drive assemblies can accelerate the elevator car **10** from a stationary condition to an intermediate speed. The express drive assemblies accelerate the elevator car 10 from the intermediate speed to the express speed. Transition zones similar to the transition zones **152**, **153** described above can provided between the intermediate and express drive assemblies **20**.

To transition to the express speed from the intermediate speed, the free, i.e., disengaged, set of clamp-runners **72** on the elevator car **10** can be positioned so as to align the associated clamps **44** over the drive segments **22** of the express drive assemblies **20**, in response to inputs generated by the car manager system **222**.

The free clamps **44** begin to engage the drive segments **22** of the express drive assemblies **20**, and gradually increase their traction until the express drive assemblies **20** are able to bear the weight of the elevator car **10** and its contents. At this point, the previously engaged set of clamps **42**, i.e., the clamps **42** associated with the intermediate drive assemblies **20**, disengage.

The intermediate drive assemblies **20** can be used to transition the elevator cars **10** from express speed to a stationary condition, in a manner substantially similar to the above-described acceleration process.

Sections of one or more elevator shafts can be dedicated as express zones, one for upward and one for downward movement, so that upwardly moving and downwardly moving cars do not interfere with each other. The elevator cars **10** do not stop to load or unload passengers while in the express zones. Elevators shafts that accommodate express zones can be located adjacent to each other to allow smooth switching from one express shaft to another.

Switching shafts front to back

Figures **14A** and **14B** depict an alternative embodiment that facilitates front-back switching of elevator cars **200** in the front to back direction, as well as the left to right direction. The spacing between drive assemblies **20** in this embodiment is sufficient to permit the elevator cars **10** to switch shafts positioned in the noted directions **147**, **149**. In particular, Figure **14A** shows four elevator shafts **12p**, **12q**, **12r**, **12s** arranged in a bank. The elevator car **10** in shaft **12p** is small enough to fit between the drive assemblies **20** in both the front-back and left-right directions.

Four drive assemblies **20** are disposed in each of the elevator shafts **12p**, **12q**, **12r**, **12s** to facilitate left-right motion. These drive assemblies **20** are positioned at or near the four corners of the shaft and are referred to as the left-right set **146** of drive assemblies **20**.

Four additional drive assemblies **20** are disposed in each shaft **12p**, **12q**, **12r**, **12s** to facilitate front-back motion. These drive assemblies **20** are positioned at or near the four corners of the shaft, are substantially perpendicular to the other set of drive assemblies **20**, and are referred to as the front-back set **148** of drive assemblies.

Arrows **147**, **149** in Figure **14A** indicate the possible directions in which movements between the elevator shafts **12p**, **12q**, **12r**, **12s** can occur.

The elevator cars **10** have clamp runners **144** mounted on the front and back thereof, as in the embodiments described above. The elevator cars **10** also have clamp runners **142** mounted on the left and right sides thereof. The clamp runners **142**, **144** can be substantially identical to the clamp runners **74**.

In this embodiment, the runner pairs **142**, **144** are wider than the car and the spacing between the drive assemblies, since the drive assemblies are further apart than the width of the car and clamp runners need to simultaneously engage the two drive assemblies on either side of the car. The clamp runners **142**, **144** need to be stowed in their retracted positions when the clamp runners **142**, **144** are not engaged, so that the elevator car **10** can move between the drive assemblies **20**. Moreover, the clamp runners **142**, **144** are mounted on the elevator car **10** so that the clamp runners **142** and the clamp runners **144** do not interfere with each other when both sets of clamp runners **142**, **144** are extended.

Figure **14B** is a magnified view showing a clamp runner **144** positioned to facilitate switching between elevator shafts in the left-right directions. A clamp **105** mounted on the clamp runner **144** is engaged on the downwardly-moving segment **26** of a corresponding drive assembly **20** in the left-right set **146** of drive assemblies **20**. A guide roller **104** is shown engaging the stationary segment **24** of the drive assembly **20**. The associated clamp runner **142** used for front-back movement is free, i.e., disengaged, and is in its retracted state.

Facilitating movement of the elevator cars **10** in the front-back and left-right directions allows a bank of elevators to encompass several planes, with the elevator cars **10** freely switching shafts in both the left-right and front-back directions while the elevator cars **10** are moving up and down. Having an elevator bank encompass multiple planes, stacked front to back, can potentially provide better utilization of space than would otherwise be possible, and can potentially enhance the overall efficiency of the system.

The elevator cars **10** can transition from left-right to front-back movement using sequences that are conceptually similar to those described earlier. For example, if the elevator car **10** is configured for left-right movement, the clamp runners **144** mounted on the front and back of the elevator car **10** can be engaged. To change configurations to accommodate front-back movement, the clamp runners **142** mounted on the sides of the elevator car **10** can extend and engage on the appropriate drive segments **20** in the front-back set **148** of drive assemblies **72**. At this point, all of the clamp runners **142**, **144** are engaged. The **144** can subsequently disengage and retract. At this point, clamp runners **142** are engaged, and the elevator car **10** is configured to move in the front-back direction. The transition can happen while the elevator car **10** is moving up or down, or is stationary.

As a further embodiment, extending drive assemblies in tall buildings can be accomplished as follows. Each shaft already has two sets of drive assemblies. The two sets can be installed so that they are staggered vertically. For example, the lower left-right set can extend between floors 1 through 20 and the next higher set can extend from 21 through 40. A front-back set can extend between floors 1 through 10 and the next higher set can extend between floors 11 through 30. A car that needs to go up the shaft from floor 1 to floor 40 can start with the lower left-right drive set, and then switch to the front-back set anywhere between floors 11 through 20, and then switch back to the upper left-right set between floors 21 through 30.

Slanted and Curved Shafts

Alternative embodiments can be constructed for applications where the elevator shaft is curved or slanted. In these embodiments, the drive assembly **20** can be customized for the shaft. The frame **54** and the stationary segments **24**, which function as guide rails, are curved or slanted, which in turn causes the rollers **58** and the elevator car **10** to follow the curved or slanted path defined by the stationary segments **24**. The horizontal spacing between the drive assemblies **20** remains constant along the length of the elevator shaft.

In addition, the car manager system **222** can provide inputs that cause the clamp runners **72**, **74** on the elevator cars **10** to extend and retract as required to maintain the elevator car **10** in a substantially vertical orientation, so that the passengers are not aware that they are moving along a curved or slanted path. For example, Figure **16** shows two elevator cars **10** with their clamp runners **72** extended so as maintain the associated elevator cars **10** is substantially horizontal orientations. Unlike in the previously-described embodiments, the engaged clamp runners **72** in the upper and lower clamp runners sets **40** set extend to unequal lengths, and may extend in different directions. The free clamp runners **74** are fully retracted, and are ready to be used for a subsequent transition in speed, drive segments, or elevator shafts in accordance with the techniques discussed above.

If the elevator car **10** is to move along a curved path, then the inclination of the drive segments **22**, **26** varies from point to point, and the extension of the clamp runners **72** will be continually adjusted during movement of the elevator car **10**, to keep the elevator car **10** in a substantially vertical orientation. Position sensors **109b** can give the car manager system **222** a substantially accurate reading of the car's position in the shaft. The car manager system **222** can be configured with the inclination of the shaft at each shaft position and can extend the clamp runners **72** as necessary.

If the curved or slanted drive assemblies **20** obstruct the normal location of the doors of the elevator car **10**, as in the embodiment shown in Figure **16**, the floor landing doors **32** can be placed on the left or right side of the elevator car, instead of the front or rear. The landing doors **32** would be offset away from the inclined shaft **12b**. Passengers can enter and exit the elevator cars **10** through the side walls of the leftmost or rightmost shaft of the elevator bank. When the elevator car has stopped at a landing, the car manager system **222** can extend the clamp runners **72, 74** as necessary so that the car moves horizontally and is positioned conveniently adjacent to the doorway **32**. Figure **16** shows the car on the right stopped and aligned with a landing doorway **32**.

In an alternate embodiment, the elevator car **10** can be switched to a drive assembly **20** that bends so as to assume a vertical orientation at the landing. This can facilitate the conventional placement of elevator doors at the front of the elevator car **10**.

Horizontal travel between non-adjacent banks

In an alternative embodiment, provisions are provided to transfer elevators cars **10** between non-adjacent elevator banks located in the same or different buildings. In these embodiments, transfer points can be provided at specific locations along the edges of the elevator banks, and horizontal or sloped causeways can be provided between the transfer points. Wheeled trolleys that can carry one of more of the elevator cars **10** transit along the causeways to transport the elevator cars **10** between the elevator banks.

If the drive assemblies **20** in the elevator banks are positioned as shown in Figures **4**, **11**, and **12**, i.e., if the drive assemblies are positioned in front and in back of the elevator cars **10**, the transfer points will be located at the extreme left or extreme right shafts. Since the drive assemblies **20** configured in this manner obstruct front to back movement, the elevator cars **10** first move sideways out of the elevator banks before moving forward or backward. Alternatively, if the drive assemblies **20** are positioned as shown in Figure **14**, i.e., if the drive assemblies are positioned wide enough to allow a car **10** to pass through, then the transfer points can be at any point along the periphery of the elevator bank.

Transfer of an elevator car **10** between two non-adjacent elevator banks can be effectuated as follows. The clamp runners **72** on the elevator car **10** are unclamped from the associated drive assemblies **20** at a transfer point in the first elevator bank, while the elevator car **10** is stationary. The elevator car **10** is placed on a wheeled trolley, which transports the elevator car **10** to a transfer point at the second elevator bank via a causeway. The clamp runners **72** on the elevator car **10** are clamped to drive assemblies **20** located within an elevator shaft in second elevator bank. The elevator car **10** can subsequently continue its vertical translation in the second elevator bank.

Alternate drive assembly and clamp runner

Figures **17A** and **17B** depict an alternative embodiment of the drive assemblies **20**. The alternative drive assembly shown in Figures **17A** and **17B** comprises a toothed belt **170** in lieu of the loop **23** of the drive assemblies **20**. The belt **170** can be formed, for example, from a synthetic rubber material reinforced with KEVLAR to provide the belt with sufficient tensile strength. The belt **170** can have reinforcing pins embedded in the teeth thereof. One segment **22** of the belt **170** moves upwardly, in the direction denoted by the arrow **179**; the other segment of the belt **170** (not shown) moves downwardly. A stationary segment (not shown) is located between the moving segments. The stationary segment has the same toothed profile of the belt **170**, but is rigid and also functions as a guide rail.

The corresponding clamp mechanism comprises of a pair of clamp sprockets **171** that move in to engage the belt **170** from both sides thereof. The clamp mechanism is mounted on a swivel or sliding housing (not shown.) During the engagement process, the clamp sprockets **171** initially straddle the belt **170**, and then move toward the belt **170** so that teeth **172** of the clamp sprockets **171** mesh with the teeth on the belt **170**. If the belt **170** is moving at a different speed than the elevator car **10** (and the attached clamp sprockets **171**), the clamp sprockets **171** will spin as the clamp sprockets **171** engage the belt **170**. A motor (not shown) can be used to spin the clamp sprockets **171** to a desired speed prior to engagement with the belt **170**, to help minimize shocks to the clamp sprockets **171** and the belt **170** during the engagement process.

The clamp sprockets **171** can have an integrated disk brake that stops the clamp sprockets **171** from rotating in relation to the belt **170**, so that the clamp sprockets **171** and the attached elevator car **10** move upwardly or downwardly with the belt **170**. The disk brake includes calipers **173**, electrically or hydraulically driven pistons **177** mounted on the calipers **173**, and brake pads **175** mounted on the pistons **177**. The brake pads **175** are positioned so that the brake pads **175** can engage a smoothened area **174** on the side of each clamp sprocket **171**. The calipers **173** and the pistons **177** press the brake pads **175** on to the spinning clamp sprockets **171** to slow the rotation of the clamp sprockets **171**. This causes the weight of the elevator car **10** to be slowly and smoothly transferred to the belt **170**. When the calipers **173** are fully engaged, the clamp sprockets **171** stop spinning, and the motion of the elevator car

10 is synchronized with that of the upwardly or downwardly segment of the belt **170** to which the clamp sprockets **171** are engaged.

Figures **18A** and **18B** depict another alternative embodiment of the drive assemblies **20**. The alternative drive assembly of Figures **18A** and **18B** comprises a double-stranded chain **180** in lieu of the toothed belt **170**. The chain **180** comprises outer link plates **182**, inner link plates **184**, and cylindrical rollers **186**. The outer link plates **182**, inner link plates **184**, and cylindrical rollers **186** are connected using pins **188** and clips **189**. Guide sprockets (not shown) mounted on the drive assembly frame **27** function as guide rollers by engaging one strand of the chain **180** to dampen vibration. Toothed sprockets mounted on the clamp mechanism of the elevator car **10** engage the other strand of the chain **180**, and operate in substantially the same manner as the clamp sprockets **171** described above.

In other alternative embodiments of the drive assemblies **20**, the loop **23** can be replaced by long screws or worm drives that extend along the length of the drive assemblies **20**. The drives may be flexible to accommodate curved shafts. The alternative embodiments include three screws or worm drives: one each for upward and downward movement of the elevator car **10**, and one for when the elevator car **10** is the stationary condition.

The upward and downward screws or worm drives turn in opposite directions; the stationary screw or worm drive does not turn. The clamping devices of these embodiments comprise a worm or spur gear that engages the moving screw or worm drive. The worm or spur gear spins upon engaging the corresponding screw or worm drive, if the elevator car **10** is not moving at the same speed as the drive assembly. An integrated disk brake on the worm or spur gear engages to gently stop the spinning thereof. When the brake has fully locked the worm or spur gear, the elevator car **10** is moving in the direction and at the speed dictated by the screw or worm drive to which the elevator car **10** is clamped.

Computer control system

The computer control system manages the overall operation of this elevator system. The computer control system comprises the central control system **220**, a car manager system **222** associated with each individual elevator car **10**, and various sensors on each car.

Various components and sub-components of the control system are depicted in the form of a block diagram in Figure **22**. The central control system **220** comprises a computer processor. The processor can be, for example, a microprocessor. The central control system **220** also comprises a memory device communicatively coupled to the processor. The central control system **220** further comprises a set of computer-executable instructions stored on the memory device. The algorithms for path computation for the elevator cars can be incorporated into the computer-executable instructions.

The central control system **220** also comprises a transceiver **221** or other suitable device communicatively coupled to the processor **220**, for facilitating communications between the central control system **220**, the car managers **222**, and other components.

Each elevator car **10** includes a car manager system **222**. The car manager systems **222** are depicted in the Figure **22**. Each car manager system **222** comprises a processor such as a microprocessor. Each car manager system **222** also comprises a memory device communicatively coupled to the processor **222**, and a set of computer-executable instructions stored on the memory device. In addition, the car managers **222** each comprise a transceiver **221** or other suitable device communicatively coupled to the processor **222**, to facilitate communications with the central control system **220** and other components.

Each car manager system **222** receives inputs from multiple points, including the load sensors **109a**, shaft position sensors **109b**, clamp runner position sensors, door sensors **225**, and the hydraulic system of the corresponding elevator car **10**. The hydraulic lines **229** connect the hydraulic pumps **228** to the clamp valves **106**, the clamp swivel control valves **226**, and the clamp runner slide control mechanism **227**.

The central control system **220** manages the overall operation of the bank of elevators by handling calls and requests from elevator passengers, planning car movements to optimize utilization and to prevent collisions, timing the shaft switching of cars to avoid obstructions, and balancing the loads so as to not exceed system limits.

The central control system **220** is configured to prevent collisions by planning, tracking, and coordinating the movements of all of the elevator cars **10**. The central control system **220** reserves specific segments within the elevator shafts for specific periods of time to facilitate the passage of an elevator car **10** through the segment. For safety, an additional buffer space is reserved above and below the actual reserved space. When an elevator car **10** transitions between elevators shafts, segments in both elevators shafts are reserved during the transition period. When an elevator car **10** is stationary at a landing, the shaft segment around the elevator car **10** is reserved for as long as the elevator car **10** is there. Collisions are prevented because the central control system **220** does not permit any other elevators cars **10** to enter the reserved segments.

The central control system **220** also balances the elevator system by tracking the difference in upward and downward forces for each period of time, as discussed below.

The central control system **220** determines the optimal paths for the elevators cars **10** by minimizing the total cost of the paths. The total cost of a path is the sum of the costs of the transitions that make up the path. The transitions include ‘starting’, ‘stopping’, ‘moving” up or down the shaft, ‘switching shafts’, and ‘pausing’. Each type of transition may have a different cost.

In the preferred embodiment, the path computation is done whenever a car is ready to move. A suitable path is computed based on the car’s starting and destination floors, so that the car does not move through any shaft segment that is already reserved, and so that the system balance is maintained within limits, and so that the total path cost is minimized. The computed path is sent to the car manager **222** on the elevator car **10** as a sequence of commands for the transitions required to follow the path.

The car manager system **222** of each elevator car **10** controls operation of the onboard electronic subcomponents on each car. The car manager system **222** also manages the clamps **42**, the clamp runners **72**, load sensors, and tilting mechanism, and monitors the onboard call buttons.

Elevator cars such as the elevator cars **10** need a constant supply of electricity to operate lights, fans, on-control systems, etc. Moreover, on-board control systems and emergency communications systems need reliable data signal connections with associated systems located outside of the elevator shafts. Both of these requirements can be addressed by power distribution using the drive assemblies **20**. In particular, a low voltage (potential difference) can be applied across the stationary segments **24** of the drive assemblies **20** located at the front and rear of each elevator shaft. The voltage can be adequate to drive the lights, air conditioning, hydraulics and other electronic systems. A battery can be located on board each elevator car **10** for emergency use.

Control data, digitized voice channels and music are multiplexed on a carrier and transmitted bi-directionally over the power supply using existing technology.

Balancing without counterweights

All the drive assemblies **20** associated with a bank of elevators can be mechanically linked so that the drive assemblies **20** are driven by one set of motors. This configuration permits the elevator cars **10** to act as counterweights to each other. In particular, a load on an upwardly-moving segment **22** can be balanced by a substantially equal load on a downwardly-moving segment **26**, even if the drive segments **22**, **26** are associated with different drive assemblies **20** located in different elevator shafts.

Figure **19A** depicts two identical weights denoted by the reference characters **192** and **194**. The weight **192** is associated with an upwardly-moving elevator car **10**, and the weight **194** is associated with a downwardly-moving elevator car **10**. The two equal weights **192**, **194** balance each other in the single drive assembly **20** in shaft **12a**.

In Figure **19B**, the weight **192** is carried by a first drive assembly **20** located in a first elevator shaft **12a**, and the weight **194** is carried by a second drive assembly **20** located in a second elevator shaft **12b**. The first and second drive assemblies **20** are mechanically linked by a horizontal belt **196** which transfers loads between the two drive assemblies **20**, thereby allowing the two weights, i.e., the upwardly and downwardly-moving elevator cars **10**, to balance each other even though the weights **192**, **194** are located on different drive assemblies **20** in different elevator shafts.

In Figure **19C**, two weights **192**, representing two upwardly-moving elevator cars **10**, are being carried by a first drive assembly **10** in shaft **12a**. Two weights **194**, representing two downwardly-moving elevator cars **10**, are being carried by a second and a third drive assembly **20**. The first, second, and third drive assemblies **20** are located in different elevator shafts. The first, second, and third drive assemblies **20** are mechanically linked by a horizontal belt **197** which transfers loads between the three assemblies **20**, thereby allowing the four weights to balance each other even though the weights are located on different drive assemblies **20** in different elevator shafts, and are distributed in an uneven manner common three drive assemblies **20**.

The central control system **220** is configured to ensure that, at any given time, the total load associated with the upwardly-moving elevator cars **10** is approximately counterbalanced by the total load associated with the downwardly-moving elevator cars **10**. The balancing equation programmed into the central control system **220** considers the vertical forces associated with by the weight, acceleration, deceleration and friction for each elevator car **10**. Stationary elevator cars are not relevant to the balancing equation. The central control system **220** also ensures that the total unbalanced load on the drive motors remains within acceptable limits.

The central control system **220** schedules the movement of the elevator cars **10** to achieve the above-noted counterbalancing and load-limiting functions. In particular, the central control system **220** may move empty elevator cars **10** up or down, and/or delay the movement of loaded elevator cars **10**, to maintain an acceptable balance between upwardly-moving and downwardly-moving loads, and to avoid exceeding the maximum acceptable load on the drive motors. The overall system should be configured to operate in a satisfactory manner with an imbalance equal to at least the weight of one empty elevator car **10**, to ease the scheduling process and to avoid scheduling deadlocks. If necessary, an elevator car **10** may be halted in the middle of its transit until another elevator car **10** is available to balance the load. Whenever possible, such halts are made at a location so that the car doors can be opened if the expected delay is long.

In elevator banks or systems that incorporate express zones, the drive assemblies **20** associated with in the express zones can be mechanically coupled to the drive assemblies **20** associated with the non-express zones by reduction gears. This feature can facilitate load balancing among drive assemblies **20** operating at different speeds. In particular, elevator cars **10** operating at relatively high vertical speeds in express zones exert a proportionally higher vertical load on the drive motors than elevators cars **10** operating at slower vertical speeds in non-express zones. For example, if the elevator cars **10** operating in the express zones are moving at twice the speed of the elevator cars **10** operating in the non-express zones, the load exerted on the drive motors by the elevators cars **10** operating in the express zones is double that of the elevators cars **10** operating in the non-express zones.

The above-described counterbalancing methodology eliminates the need for each individual elevator car to be equipped with its own counterweight. Eliminating the need for individual counterweights **14** can potentially improve the overall efficiency of the elevator system by reducing the amount of energy need to operate the system. Moreover, eliminating the need for individual counterweights can make it feasible to operate two or more elevator cars **10** in one elevator shaft on a simultaneous basis.

Linking the various drive assemblies **20** together can help ensure that all the drive assemblies **20** operate at substantially the same speed. Speed synchronization is needed, for example, to facilitate the smooth switching of elevator cars **10** between shafts.

The mechanical linkage between drive assemblies **20** can incorporate chain loops, drive shafts, hydraulics, a combination thereof, or other suitable means in alternative embodiments. Moreover, the drive motors can be connected to different drive assemblies **20**, and the operation of the drive motors can be coordinated by other suitable means so that so that the drive assemblies **20** move at substantially the same speed.

Joining elevator cars

The use of relatively small elevator cars is desirable because smaller elevator cars, in general, can facilitate faster transit times. A need for relatively large elevator cars may occasionally exist, however, in some applications. For example, larger elevator cars may be needed to carry stretchers bearing injured people. To satisfy this need while facilitating the using small elevator cars, two or more elevator cars can be joined together temporarily so as to move in tandem in adjoining elevator shafts, and a side wall on each of the elevator cars can open to provide a relatively large adjoining space defined by the two elevator cars.

Figure **20A** is an elevation view of an embodiment in which two elevator cars **200** located in adjoining shafts **12a** and **12b** are being temporarily joined to form a larger car. The elevator cars **200** are aligned horizontally, and are rigidly connected to each other using multiple sliding bars (not shown) positioned under the floors and above the ceilings of each elevator car **200**.

Each elevator car **200** has a sub-floor panel **204**. The sub-floor panel **204** of each elevator car **200** is slid towards the sub-floor panel **204** of the other car **200**, in the direction denoted by the arrows **207**, and is latched to the other sub-floor panel **204**. The sub-floor panels **204** form an extended floor that bridges the gap between the cars **200**. Each elevator car **200** has a ceiling panel **205** that likewise slides toward and is latched to the ceiling panel **205** of the other elevator car **10**, to form an extended ceiling.

As shown in Figure **20B**, each elevator car **200** has a side wall **206** that can separate and swing open like a bi-fold doors in the directions denoted by the arrows **209**. The side walls **206**, when opened, form new side walls between the two cars **200**. Moreover, folding the side walls **206** creates a relatively large, unified space within the two elevator cars **200**.

The central control system **220** can coordinate the movement of cars so that the joined cars move together in tandem without interference from other cars. The car manager systems **222** in the joined elevator cars **200** can control the operation of the clamp runners **72**, **74** so that they do not interfere with each other. The elevator cars **200** can be operated in a joined state only if there are no obstructions between their associated shafts within the range of travel in which the joined elevators cars 200 are to operate. The combined car can even switch shafts if necessary.

Smaller cars can take passengers directly to their specific destinations and are less likely to stop at intermediate floors to load or unload other passengers. They reduce passenger transit times and improve utilization. Newer buildings with many offices or apartments can be designed so that these small cars go directly to the inside of a specific office or apartment, without stopping at any intermediate floors. Security features can be provided to ensure that the car does not unload unauthorized passengers at private stops.

With proper design, it may be possible to completely eliminate the shared elevator lobby area on each floor, thus further improving the utilization of floor space in the building. In apartment buildings, passengers can authenticate themselves at the ground floor lobby and elevator can take them directly to their homes.

Tilting cars during horizontal acceleration

Elevator passengers are accustomed to vertical accelerations and forces induced when an elevator car **10** starts or stops moving vertically upward or downward. When elevator cars **10** move sideways to transition between different elevator shafts, passengers are subjected to horizontal accelerations and forces as well. The passengers may be caught unaware and may lose their balance due to these forces. Also, luggage or freight in the car may tip over when horizontal forces are applied.

To mitigate this potential issue, the entire elevator car **10** can be tilted slightly toward the direction of horizontal acceleration. The elevator car **10** can be tilted in the opposite direction during deceleration. In one possible embodiment shown in Figure **21A**, the tilting mechanism comprises hydraulically actuated cylinder **214**. The clamp runners **72** are mounted on a mounting plate **212**. The body of the elevator car **10** is mechanically coupled to the mounting plate **212** using multiple hydraulic cylinders **214**. The hydraulic cylinders **214** can extend or contract in a substantially synchronized manner to tilt the elevator car **10** in relation to the mounting plate and the clamp runners **72**, in the direction denoted by the arrow **216**. In this embodiment, there are eight hydraulic cylinders **214**, of which the four mounted on the front wall are shown. More or less than eight hydraulic cylinders **214** can be used in alternative embodiments. The elevator car **10** can be tilted using other suitable means, such as pneumatic cylinders, screw jacks, or electric motors, in alternative embodiments.

The central control system **220** can be configured to calculate the degree and timing of the tilt so that the passengers do not feel any substantial horizontal forces. The optimal angle of tilt is a function of the vertical force and the horizontal acceleration acting on the elevator car **10**. Load sensors **109a** used to measure the weight of the elevator car **10** can provide a measurement of the vertical force at a given instant. The vertical force is primarily the weight of the elevator car **10**, but can vary slightly depending on whether the elevator car **10** is accelerating or decelerating in the vertical direction. The horizontal acceleration of the car **10** can be predicted based on the movement of the clamp runners which are in turn controlled by the car manager system **222**.

The desired angle of tilt can be calculated by the car manager system **222** using, for example, an algorithm that calculates the angle of tilt as the trigonometric tan inverse function of the ratio of the horizontal and vertical forces. The central control system **220** can send a control input to the jacks **214** to effectuate the desired tilt. With the elevator car **10** tilted, passengers should experience little if any change in the perceived horizontal force acting on them as the elevator car **10** accelerates horizontally. Rather, the passengers may feel a slight change in the vertical force acting on them, which is generally considered acceptable.

The foregoing description is provided for the purpose of explanation and is not to be construed as limiting the invention. Although the invention has been described with reference to preferred embodiments or preferred methods, it is understood that the words which have been used herein are words of description and illustration, rather than words of limitation. Furthermore, although the invention has been described herein with reference to particular structure, methods, and embodiments, the invention is not intended to be limited to the particulars disclosed herein, as the invention extends to all structures, methods and uses that are within the scope of the appended claims. Those skilled in the relevant art, having the benefit of the teachings of this specification, can make numerous modifications to the invention as described herein, and changes may be made without departing from the scope and spirit of the invention as defined by the appended claims.

Parts List	**Description**
10	Elevator car
12	Elevator shaft. 12*n* refers to shaft *n*
13	Shaft wall
14	Counterweight
16	Cable
18	Conventional pulley
20	Drive assembly
21	Floor at a level. 21*n* is the n^{th} level.
22	Upward moving segment
22a	Direction of upward moving segment
23	Belt loop
24	Stationary segment
25	Drive motor
26	Downward moving segment
26a	Direction of downward moving segment
27	Drive assembly frame
28a	Upper pulley
28b	Lower pulley
28c	Direction of rotation of pulley
29	Drive propulsion belt
31	Drive assembly set
32	Door to shaft on landing
40	Clamp runner pair
42	Upper Clamp
44	Lower Clamp
46	Direction of motion of car
52	Tooth on sprocket
56	Roller support bracket
58	Rollers on loop
62	Channel for guide rollers
64	Hole in loop belt

66	Abrasion resistant cladding
67	Rivet to fasten cladding
68	Direction of motion of belt
71	Car wall
72	Upper clamp runner
73	Clamp runner bars
74	Lower clamp runner
75	Clamp runner stepper motor
76	Clamp runner position sensor
77	Rack
78	Pinion
79	Slot in bar
101	Swivel housing
102	Swivel pin
103	Roller swivel
104	Guide roller
104a	Direction of swiveling of guide rollers
105	Swiveling caliper
106	Hydraulic valve
107	Piston
107a	Hydraulic fluid
108	Brake pad
109a	Strain gauge load sensor
109b	Shaft position sensor
111	Direction of motion of clamp runner
121	Direction of motion of car
142	Retracted clamp runner
144	Extended clamp runner
146	Left-right set of drive assembly
147	Left-right direction arrow
148	Front-back set of drive assembly
149	Front-back direction arrow
152	Transition zone

153	Transition zone
170	Toothed belt
171	Clamping sprocket
172	Sprocket tooth
173	Caliper
174	Braking surface on sprocket
175	Brake pad
177	Piston
180	Flexible chain
182	Outer link
184	Inner link
186	Roller
188	Pin
189	Clip
192	Upward moving car
194	Downward moving car
196	Linkage belt for two drive segments
197	Linkage belt for three drive segments
200	Joinable elevator car
204	Sliding floor panels
205	Sliding ceiling panels
206	Side walls opening
207	Direction of floor movement
209	Direction of side wall swinging open
212	Clamp runner mounting plate
214	Tilting hydraulic cylinders
216	Direction of tilt
220	Central control system computer
221	Communications device
222	Car manager computer
223	Clamp mechanism controller
225	Door control mechanism and sensor
226	Swivel control valves

227	Clamp runner slide control mechanism
228	Hydraulic pumps
229	Hydraulics supply line

What is claimed is:

1. An elevator system for use in an elevator shaft, comprising:

an elevator car;

a drive assembly capable of being mounted on a wall of the elevator shaft and comprising a movable drive member; and

a clamping device mechanically coupled to the elevator car and movable in relation to the elevator car so that the clamping device can engage the movable drive member of the drive assembly on a selective basis.

2. The elevator system of claim 1, further comprising an extension device mounted on the elevator car, wherein the clamping device is mounted on the extension device and the extension device can extend in relation to the elevator car to position the clamping device proximate the drive member.

3. The elevator system of claim 1, further comprising a plurality of the drive assemblies and one or more drive motors, wherein the one or more drive motors are mechanically coupled to the plurality of drive assemblies so that the one or more drive motors collectively drive the plurality of drive members at substantially the same speed.

4. The elevator system of claim 3, further comprising a plurality of the elevator cars, and a controller, wherein the controller schedules the transit of the elevator cars on the drive assemblies so that a total downward force exerted by the elevator cars and the contents thereof on the drive assemblies is approximately counterbalanced by a total upward force exerted by the elevator cars and the contents thereof on the drive assemblies.

5. The elevator system of claim 4, wherein the controller counterbalances the total upward and downward forces by moving empty elevator cars up or down and/or delaying the movement of loaded elevator cars.

6. The elevator system of claim 2, wherein the extension device is a clamp runner comprising a first bar, and a second bar mechanically coupled to the first bar so that the second bar can slide in relation to the first bar.

7. The elevator system of claim 6, wherein the clamp runner further comprises a third bar mechanically coupled to the second bar so that the third bar can slide in relation to the second bar, the clamping device is attached to the third bar, and the first bar is attached to the elevator car.

8. The elevator system of claim 1, wherein:

the drive member is a flexible loop;

the drive assembly further comprises a frame capable of being attached to the wall of the elevator shaft, and a first and a second pulley mounted for rotation on the frame; and

the flexible loop is mounted on the first and second pulleys.

9. The elevator system of claim 2, wherein:

the drive assembly is a first drive assembly capable of being mounted on a wall of a first elevator shaft;

the system further comprises a second drive assembly capable of being mounted on a wall of a second elevator shaft, a second extension device mounted on the elevator car, and a second clamping device mounted on the second extension device;

the second extension device is capable of extending into the second shaft so that the second clamping device can engage the second drive assembly while the elevator car is positioned in the first shaft; and

the second extension device can retract while the second clamping device engages the second drive assembly, and the first extension device can extend while the first clamping device engages the first drive assembly to transfer the elevator car from the first to the second elevator shaft.

10. The elevator system of claim 10, wherein:

the second elevator shaft is located to one side of the first elevator shaft;

the elevator system further comprises:

a third drive assembly capable of being mounted in the first elevator shaft in an orientation substantially perpendicular to an orientation of the first drive assembly;

a fourth drive assembly capable of being mounted in a third elevator shaft located in front or in back of the first elevator shaft, in an orientation substantially perpendicular to the orientation of the first drive assembly;

a third extension device mounted on the elevator car;

a third clamping device mounted on the third extension device;

a fourth extension device mounted on the elevator car;

a fourth clamping device mounted on the fourth extension device;

the fourth extension device is capable of extending into the third shaft so that the fourth clamping device can engage the fourth drive assembly while the elevator car is positioned in the first shaft;

the fourth extension device can retract while the fourth clamping device engages the fourth drive assembly, and the third extension device can extend while the third clamping device engages the third drive assembly to transfer the elevator car from the first to the third elevator shaft.

11. The elevator system of claim 1, wherein the drive member is a flexible loop, and the clamping device is a clamp comprising a caliper, a piston mounted on the caliper, and a pad mounted on the piston so that the pad can securely grasp the flexible loop in response to movement of the piston and the caliper.

12. The elevator system of claim 11, wherein: the drive assembly further comprises a frame capable of being attached to the wall of the elevator shaft, and a stationary segment fixedly mounted on the frame; and the clamp further comprises a guide roller that engages the stationary member to guide the elevator car.

13. The elevator system of claim 1, further comprising a controller for controlling a clamping force exerted on the drive member by the clamping device.

14. The elevator system of claim 13, further comprising a sensor communicatively coupled to the controller for detecting tilting of the elevator car, wherein the controller can adjust the clamping force exerted by the clamping device to minimize tilting of the elevator car.

15. The elevator system of claim 1, wherein a first segment of the drive member travels in a first direction, a second segment of the drive member travels in a second direction opposite the first direction, the clamping device can engage the first segment to move the elevator car in the first direction, and the clamping device can engage the second segment to move the elevator car in second direction.

16. The elevator system of claim 1, wherein the drive member is one of a flexible loop; a screw; a worm drive; a toothed belt, and a chain.

17. The elevator system of claim 1, wherein the drive member is one of a screw and a worm gear and the clamping device comprises a worm or a spur gear that engages the screw of the worm gear.

18. The elevator system of claim 2, further comprising one or more of a hydraulic cylinder, a pneumatic cylinder, a screw jack, or an electric motor mechanically coupled to the elevator car and the extension device so that the hydraulic cylinder, pneumatic cylinder, screw jack, or electric motor can tilt the elevator car in relation to the extension device.

19. The elevator system of claim 18, further comprising a controller that calculates a desired angle of tilt of the elevator car in relation to the extension device as a trigonometric tan inverse function of a ratio of horizontal and vertical forces acting on the elevator car.

20. The elevator system of claim 2, wherein:

the extension device is a first extension device and the clamping device is a first clamping device;

the system further comprises: a second drive assembly capable of being mounted in the elevator shaft so that a lower portion of the second drive assembly is adjacent to an upper portion of the first drive assembly; a second extension device mounted on the elevator car; and a second clamping device mounted on the second extension device; and

the first clamping device can engage the first drive assembly and the second clamping device can engage the second drive assembly as the elevator car transitions between being driven by the first and second drive assemblies.

21. The elevator system of claim 20, wherein the movable drive member of the first drive assembly operates at a first speed and the movable drive member of the second drive assembly operates at a second speed different than the first speed.

22. The elevator system of claim 2, wherein:

the drive assembly is a first drive assembly, the extension device is a first extension device, and the clamping device is a first clamping device;

the system further comprises a second drive assembly capable of being mounted on another wall of the elevator shaft, a second extension device mounted on the elevator car, and a second clamping device mounted on the second extension device;

the elevator shaft is slanted or curved in relation the vertical direction;

the first and second drive assemblies can be positioned within that shaft to follow the slant or curve of the shaft; and

the first and second extension devices can extend in opposite directions and/or to different lengths so that the elevator car remains substantially horizontal while travelling within the shaft.

23. The elevator system of claim 1, further comprising means for transferring the elevator car between non-adjacent elevator banks.

24. The elevator system of claim 1, further comprising two of the elevator cars, wherein:

each of the elevator cars has a sub-floor panel capable of sliding toward and engaging the sub-floor panel of the other elevator car when the elevator cars are positioned side by side in adjacent elevator shafts;

each of the elevator cars has a ceiling panel capable of sliding toward and engaging the ceiling panel of the other elevator car when the elevator cars are positioned side by side in the adjacent elevator shafts; and

each of the elevators cars has a side wall that can separate and swing open to form a portion of a new side wall between the elevator cars when the elevator cars are positioned side by side in the adjacent elevator shafts.

25. A method, comprising:

providing an elevator car having a first and a second extension device mounted thereon, and a first and a second clamping device mounted on the respective first and second clamping devices;

engaging a first drive assembly with the first clamping device, the first drive assembly being located in a first elevator shaft;

extending the second extension device to align the second clamping device with a second drive assembly located in a second elevator shaft;

engaging the second drive assembly with the second clamping device; and

retracting the second extension device and extending the first extension device to transfer the elevator car from the first to the second elevator shaft.

26. A method, comprising:

providing one or more drive assemblies located in one or more elevator shafts;

providing at least two elevator cars capable of engaging the one or more drive assemblies on a selective basis so that the one or more drive assemblies can lift and lower the elevator cars; and

coordinating operation of the elevator cars so that a total force exerted on the one or more drive assemblies by the elevator cars and the contents thereof being lifted is approximately counterbalanced by a total force exerted on the one or more drive assemblies by the elevator cars and the contents thereof being lowered.

27. The method of claim 26, wherein coordinating operation of the at least two elevator cars so that a total force exerted on the one or more drive assemblies by the elevator cars being lifted is approximately counterbalanced by a total force exerted on the one or more drive assemblies by the elevator cars being lowered comprises lift and/or lowering one or more of the elevator cars in an empty condition, and/or delay movement of one or more of the elevator cars in a loaded condition.

28. The method of claim 26, further comprising providing one or more motors mechanically coupled to the one or more drive assemblies so that the one or more motors drive the one or more drive assemblies at substantially the same speed.

29. A method, comprising:

providing a first and a second elevator car;

clamping the first elevator car to an upwardly-moving segment of a drive member mounted within an elevator shaft so that the first elevator car moves upwardly within the elevator shaft; and

clamping the second elevator car to a downwardly-moving segment of the drive member so that the second elevator car moves downwardly within the elevator shaft while the first elevator car moves upwardly within the elevator shaft.

ABSTRACT

The systems and methods disclosed herein can facilitate the simultaneous operation of multiple elevator cars in a single elevator shaft, and can facilitate the switching of elevator cars between elevator shafts. This can potentially increase the utilization of the elevator systems, and can potentially improve the service provided to the passengers and cargo being transported by the elevator systems.